

THE EFFECTIVENESS OF WILT PRUF, VAPOR GARD, EXALT 4-10
AND MULCHING FOR REDUCING WINTER DESICCATION
OF THREE TAXA OF BROADLEAF EVERGREENS

by

KEITH MICHAEL FUNK

B. S., Kansas State University, 1977

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Horticulture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1979

Approved by:


Major Professor

Document
LD
2668
.T4
1979
F85
c.2

TABLE OF CONTENTS

	Page
INTRODUCTION.....	1
LITERATURE REVIEW.....	2
A. Antitranspirants.....	3
B. Water Potential Measurement.....	6
C. General.....	7
MATERIALS AND METHODS.....	8
A. First Year.....	9
B. Second Year.....	10
C. Data Analysis.....	11
RESULTS AND DISCUSSION.....	11
A. First Year 1977-1978.....	11
Leaf water potential evaluation.....	11
Visual evaluation.....	13
B. Second Year 1978-1979.....	14
Leaf water potential evaluation.....	14
Visual evaluation.....	15
Scanning electron microscope observation.....	17
SUMMARY AND CONCLUSIONS.....	35
LITERATURE CITED.....	37

LIST OF TABLES

Table	Page
1. Leaf water potential and visual injury rating of <u>Buxus sempervirens</u> , <u>Euonymus fortunei</u> 'Golden Prince' and <u>Ilex cornuta</u> 'Lydia Morris', as affected by four anti-transpirant treatments, when computed as a mean of all species.....	20
2. The effect of Vapor Gard, Exalt 4-10, Wilt Prus and a water spray on leaf water potential and visual injury rating, of three species of broadleaf evergreens, when computed as a mean of all treatments.....	21
3. Leaf water potential of boxwood, euonymus and holly at each treatment level on November 23, 1978.....	22
4. Visual injury rating for boxwood, euonymus and holly at each treatment level on March 21, 1979.....	23
5. Effect of Vapor Gard, Exalt 4-10, Wilt Pruf and a water spray on visual injury ratings of 'Fosters No. 2' holly for 1976.....	24

LIST OF FIGURES

Figure	Page
1. Research planting and treatment design.....	26
2. Lower leaf surface of <u>Euonymus fortunei</u> 'Golden Prince' control plant showing stomata.....	28
3. Lower leaf surface of euonymus showing covered stomata, one week after treatment with Exalt 4-10.....	28
4. Lower leaf surface of euonymus one month after Exalt 4-10 application.....	30
5. Lower leaf surface of euonymus showing increased cracking of Exalt 4-10 antitranspirant.....	30
6. Lower leaf surface of euonymus showing a section of Exalt 4-10 separated from the leaf.....	32
7. Upper leaf surface of euonymus showing extent of cracking of Exalt 4-10.....	32
8. Soil temperature, as affected by the presence or absence of a six-inch sawdust mulch, determined daily from December 1, 1978, to March 1, 1979, at a depth of two inches using thermalcouples.....	34

INTRODUCTION

Broadleaf evergreens are a valuable group of plant materials both in the nursery trade and for the home landscape. The use of certain species of broadleaf evergreens is limited in some areas of the country where winter injury due to desiccation, low temperatures, or both occurs.

Desiccation of plant tissues during winter months is a result of water loss, through transpiration, in excess of water absorbed by the roots. If the water deficit in the plant becomes too great, tissue damage occurs which is manifested in many ways depending on the plant species and extent of desiccation. This type of damage is most prevalent when warm temperatures and/or high winds accompany frozen or dried-out soils (10, 20, 23).

Low temperature injury is caused by the freezing of the cell structures in the plant. Ice formation in the form of extracellular freezing does not usually damage tissue of hardy plants. It is when the freezing is intracellular that the cell is invariably killed (10, 19, 23, 24).

To reduce the damage caused by desiccation and low temperatures, film forming antitranspirants have been tested with some degree of success (10, 17, 21, 23). Film-forming antitranspirants are not insulators and therefore cannot prevent injury caused by low temperatures (10). In fact, the increase in water potential caused by antitranspirants may even increase freezing injury (16, 19, 24).

Antitranspirants are, however, routinely applied to plant foliage to reduce water loss by transpiration (1, 2, 3, 4, 5, 8, 9, 10, 11, 13, 14, 17, 20, 21, 22, 24, 25). The literature reveals varying degrees of effectiveness and durability based on the plant taxa, antitranspirant used, and environmental factors. If leaf water loss could be curtailed during the winter months, damage due to desiccation could be reduced significantly.

Antitranspirants are not 100 percent effective in preventing water loss, which means some degree of water stress will occur. This stress could be alleviated if the soil temperature remained high enough for water to be available to the roots for replacement of water lost from transpiration. It may be possible to reduce the depth to which the soil freezes by applying a sufficiently thick mulch. Research has demonstrated that during winter months, soil temperatures under a mulch are not as severe as soil temperatures in an unmulched area (7, 13, 15, 25).

This research studied the effectiveness of mulching and the application of three antitranspirants on three species of broadleaf evergreens as a possible means of controlling desiccation during winter months.

LITERATURE REVIEW

Between 95 percent and 99 percent of the water lost by leaves occurs through the stomata which may be located only on the lower leaf surface, only on the upper leaf surface, or on both surfaces (1, 11, 13, 22, 25). There is also a very small percentage of water lost through

the non-stomatious portion of the leaf (11, 13, 25). Stomata are very small and in the case of holly they average 12.5 by 6.5 microns (one micron equals 1/25,000 of an inch) (22). Stomata are also exceedingly numerous, 625,000 per square inch of leaf surface in the case of scarlet oak, yet the stomatal area frequently comprises only one percent of the total leaf surface (22). Since roughly 95 percent of the water lost by leaves occurs through these small, numerous stomata, the logical way to control leaf water loss is through the stomata.

A. Antitranspirants

Film-forming antitranspirants, sprayed on the foliage of a plant, will slow transpiration by forming a physical barrier over some, if not all, the stomata (4, 5, 10, 13, 22, 23). Studies show, however, that the durability and effectiveness of a particular antitranspirant varies with the plant taxa, nature of leaf surface, coverage, number of applications, and environmental factors (1, 2, 3, 4, 5, 9, 10, 11, 13, 14, 17, 20, 21, 22, 23, 25).

In a study conducted by Hall and Whitcomb (11), juniper and ligustrum leaves were coated with antitranspirants, placed in low humidity chambers, and observed under a microscope at intervals following treatment. Wilt-Pruf, Foli-Gard and Vapor Gard at all rates tested began to break and peel from the leaf surface after 2-3 days. However, the same plant materials with the same antitranspirant treatments were placed in high humidity chambers and the films remained intact for several weeks.

Using the scanning electron microscope, Davies and Kozlowski (5) found that antitranspirants which form a hard film over the leaf surface

will crack directly over the stomata, perhaps as a result of guard cell movement. They also found the incidence of film cracking increased with time. Such cracking should cause a decrease in the effect of the antitranspirants.

Other studies report chipping and cracking of antitranspirant films, specifically vinyl latexes such as Wilt Pruf (10, 20, 21, 23). Upon drying the vinyl latex became brittle and cracked, possibly due to leaf movement in the wind. Those films which remain flexible, such as Foli-Gard which is an acrylic copolymer, remain intact and effective for a longer period of time.

Transpiration reductions of up to 90 percent on potted plants in the lab were reported by Davenport (1). In the field, however, where coverage is not so thorough, a wax base antitranspirant can reduce transpiration by about 35 percent initially with effectiveness declining to about ten percent by the third week. In another paper by Davenport (3), he reported CS-6432 reduced water loss in oleander by 30-35 percent during the first week, 20-25 percent during the second week and ten percent the third week.

Snyder (22) found Ilex opaca 'Hedge Holly', Ilex crenata convexa, and Ilex crenata rotundifolia lost appreciably less water following treatment with Foli-Gard, Plant Shield, Rhoplex, Vapor Gard and Wilt Pruf. However, Buxus sempervirens was not affected by the antitranspirants and no reason was given to explain this. An examination of the results showed that the antitranspirants all varied in effectiveness of reducing water loss with no single material superior for all species. The antitranspirants in this experiment were most effective during the

first week after application with a marked decrease in effectiveness until the fifth week. After this time there was only a slight reduction in water loss.

Davies and Kozlowski (5) found Improved Wilt Pruf on Fraxinus americana seedlings decreased transpiration for 32 days after treatment with no apparent decrease in effect. Improved Wilt Pruf definitely showed an increase in effectiveness as compared to Wilt Pruf.

Clear Spray, Dow Silicone, CS-6432 and Improved Wilt Pruf reduced transpiration of Pinus resinosa seedlings within the first 24 hours after application (5). Folicote did not influence water loss during the first 24 hours but subsequently reduced transpiration by more than half. No decrease in effectiveness was observed on P. resinosa during the 32-day experimental period. Thirty-two days after treatment, all compounds significantly reduced water loss.

Scanning electron microscopy studies of the distribution of anti-transpirants on F. americana showed the films to be discontinuous (5). In many cases the film exhibited cracking directly over the stomatal pore. In contrast, electron micrographs of the stomata of untreated P. resinosa seedlings showed them filled with an amorphous wax. Micrographs of antitranspirant treated P. resinosa needles suggested the compounds combine with the wax to form an impermeable plug, which helps to explain the increased effectiveness of antitranspirants on P. resinosa as compared to F. americana. This study emphasized that the species influences the effect and usefulness of antitranspirants.

Symmes (23) did not find any reliable information based on controlled experiments with boxwood that would prove that antitranspirants

are at all beneficial in preventing boxwood winter injury or that supposed benefits from its use are more effective than burlap or other screening protection. He also reports that experimentation designed to weigh the theoretical benefits of antitranspirants against the probable countervailing metabolic side effects, discussed in the following paragraph, have been conducted.

Antitranspirants also have some interesting side effects. The main function of an antitranspirant is to reduce water loss from the leaf and thereby increase leaf water potential. As leaf water potential increases, so does the turgidity of stomatal guard cells causing an increase in stomatal apertures and a proposed decrease in stomatal resistance to water vapor loss (2, 4, 11). Aside from restricting water vapor from escaping, antitranspirants also prevent or reduce the permeability of certain gases such as carbon dioxide (1, 2, 3, 4, 5, 9, 10, 11, 13, 22, 23, 25). As a result of reduced CO₂ concentrations in the leaf, photosynthesis is also slowed (1, 2, 4, 5, 9, 10, 13, 22, 23, 25).

B. Water Potential Measurement

Plant growth and internal processes are related more directly to plant water stress than soil water deficit; however, field evaluation of water stress in plants can be time-consuming and cumbersome. Generally, the techniques employed for the most accurate measurements of plant water stress are restricted to the laboratory. The pressure chamber (pressure bomb) technique as described by Kozlowski (13) and Winters (25) has been widely recognized by researchers as a suitable measure of leaf water potential and is readily adapted for use in the field as well as the

greenhouse or laboratory. Kaufmann (12) reports it is important to standardize the pressure chamber technique as much as possible with respect to sample size, time required to place sample in the chamber, and the rate of pressure increase. Other factors such as time of day, ambient temperature, maturity of sample and sample location on the plant have been shown to affect pressure chamber values (24).

C. General

Cold acclimation of Juniperus chinensis 'Hetzi' may be a result of a higher bound water/free water ratio as postulated by Pellett (19). It has been shown that hardy plants lose moisture during the fall and winter (16). Pellett's goal was to compare seasonal changes in shoot and root tissues of J. chinensis 'Hetzi' which differ in acquired cold acclimation. Decreases in shoot moisture percentages and increases in sucrose/glucose percentages during the fall and winter paralleled the increase in cold acclimation. Work done by White and Weiser (24) serves to support Pellett's research. With less moisture in the foliage, an increase in metabolite concentration would function to increase cold resistance. It then follows that 'Hetzi' juniper shoots having a low moisture content would and did develop the greatest hardiness.

White and Weiser (24) studying desiccation in the field found that reducing desiccation did not reduce winter burn of arborvitae. Rapid changes in temperature, rather than drying, were found to be the principal cause of winter burn. However, low temperature alone is not the problem. There must be ice formation in the leaf tissue for injury to occur. Ice formation in the form of extracellular freezing does not usually harm tissues of hardy plants. It is when the freezing is intra-

cellular that the cell is invariably killed. Research has shown that adding certain kinds of sugars, such as raffinose, may reduce the temperature at which ice will form in a plant. This work also agrees with conclusions made by Pellett (19).

Soils under a sawdust mulch had a higher moisture content and were less variable in temperature than unmulched soils (7). Percent soil moisture was determined at weekly intervals for one year and showed a consistently higher soil moisture content under the sawdust mulch than under clean cultivated plots. At no point did the percent soil moisture, under the mulch, approach the permanent wilting point. Temperature under the mulch was recorded at 8 a.m. and 4 p.m. daily for one year and in the fall-winter months the soil temperature of the unmulched plots was as much as 10°F colder than the mulched plots. There was also a much greater daily temperature fluctuation in the unmulched plots throughout the year. This report is indicative of a number of reports dealing with soil moisture and soil temperature (11, 13, 15, 16, 25).

MATERIALS AND METHODS

This two-year research project began on September 30, 1977, at the Kansas State University Horticulture Experiment Field, two and one-half miles southwest of Derby, Kansas. Planted on this date were 48 plants each of Buxus sempervirens L. (boxwood), Ilex cornuta 'Lydia Morris' (holly), and Euonymus fortunei 'Golden Prince' (euonymus). The holly and euonymus were two-gallon, container grown plants; and the boxwood was 12"-16", balled and burlapped. Following a one-month

establishment period, the plants were treated with Vapor Gard, Wilt Pruf, Exalt 4-10, and a water control spray.

The (statistically approved) planting and treatment design consisted of 144 plants, divided into 12 treatment replications, each completely randomized. The 12 replications were then split into three blocks of four replications each. Each block was three plants wide with 16 plants in a row for a total of 48 plants per block (Figure 1).

A. First Year

On October 28, 1977, each treatment was applied at the recommended rate (Table 1). The antitranspirants were applied with a canister-type pressure sprayer at 55 pounds per square inch. All efforts were made to cover both the upper and lower leaf surfaces. Since the plants and treatments were randomized, it was necessary to shield the plant being sprayed to prevent drift onto surrounding plants.

On November 14, 1977, six replications were chosen at random to be mulched with a six-inch layer of sawdust. It was hoped that the soil temperature under the mulch would remain higher than the unmulched replications, thereby keeping the soil from freezing as deeply. This would allow the plants in the mulched plots to replace at least some of the water lost through desiccation.

Samples were collected on November 14 and December 11, 1977, and March 17, 1978 for scanning electron microscope observation of the anti-transpiration film at 200x and 400x. Micrographs were taken of the films especially where cracking occurred (Figures 3-7). Each of the 144 plants was sampled by cutting a 4-6 inch twig, inserting the cut end into moist

oasis block to keep them fresh until leaf samples could be mounted for observation in the SEM laboratory.

To ascertain the effect of film-forming antitranspirants on desiccation, a technique was used which determined water potential in the leaves. A representative sample of every plant was prepared and placed in a pressure bomb on January 9, 1977, as described by Kaufmann (12) and Winter (25). In a pressure bomb, an intact shoot may be measured by enclosing the shoot in a chamber with the cut end protruding. The cut end is observed through a hand lens as the gas pressure in the pressure chamber is raised by admitting nitrogen under pressure. As the gas pressure on the outsides of the leaf cells counterbalances their water potential and reverses the transpiration stream, water appears as exudate from the cut end of the stem. The water potential of the shoot is the negative of the pressure needed to accomplish this.

A visual rating of desiccation damage was made on March 17, 1978, using a scale of 1-9 where 1 = 100 percent brown tissue and 9 = no damage. The visual rating should correspond with treatment effectiveness.

After the visual ratings were made, the mulch was removed from the plots to equalize conditions during the growing season. All plants were fertilized and irrigated to keep them healthy. As the summer progressed, the plants were pruned to maintain uniformity of size.

B. Second Year

Plants, treatments, replications, mulch placement, method of treatment application and method of sampling were exactly the same as the previous testing period. The spray treatments were applied November 17, 1978, and the mulch December 1, 1978.

The first pressure bomb sampling date was November 23, 1978, following the same procedure as described for the first year. The purpose of sampling so early in 1978 was to compare the antitranspirant effectiveness in November to the effectiveness at the second sampling on February 8, 1979, after colder temperatures and the passage of six weeks. Plants were visually rated on March 21, 1979, using the same scale as the previous year.

C. Data Analysis

Data collected for both years was analyzed by means of a Duncan's Multiple Range Test at the five percent level of significance. An analysis of variance of leaf water potential and injury rating was determined for each treatment, species, mulch, and block. Interactions of treatments x species, treatments x mulch, species x mulch, and treatments x species x mulch were also analyzed.

RESULTS AND DISCUSSION

A. First Year 1977-1978

Leaf water potential evaluation. Leaf water potential of *B. sempervirens*, *I. cornuta* 'Lydia Morris', and *E. fortunei* 'Golden Prince', which were sprayed with Vapor Gard, Exalt 4-10, and Wilt Pruf, was not significantly greater or less than the control plants when tested, during desiccating conditions, ten weeks after treatment (Table 1). This result is comparable to work done by Davenport (1) and others (2, 3, 4, 5, 9, 10, 11, 13, 14, 20, 21, 22) who have shown that antitranspirant films are most effective during the first week after application and decline rapidly thereafter.

There was a significant difference among species with respect to leaf water potential (Table 2). Boxwood consistently had the lowest leaf water potential regardless of treatment. Euonymus and holly, however, repeatedly had the highest leaf water potentials. Kozlowski (13) reported that there are differences among species with respect to their leaf water potentials. Pellett (19) suggested that the reason for these differences is a difference in the bound water to free water ratios. Those species with the highest bound water to free water ratio would have the lowest leaf water potential, causing pressure bomb readings to be high. Conversely, species with a low bound water to free water ratio would have a higher leaf water potential and therefore a low pressure bomb reading.

Mulching had no significant effect on leaf water potential when analyzed as a mean of all treatments and species. There was also no difference in the interactions of treatment x mulch, species x mulch, or treatment x species x mulch. These results had not been anticipated.

It was assumed, based on work done by Fry (7) and others (11, 13, 15, 16, 25), that mulching would maintain a higher soil temperature. This would prevent the soil from freezing as deeply and thereby permitting plant roots to replace water lost through transpiration, providing that plant roots were sufficiently deep to be below the frost line. Even though soil temperatures under the mulch were consistently higher than the unmulched areas (Figure 8), mulching had no appreciable effect on leaf water potential or visual injury. Insufficient root depth may have been the cause but root depth measurements were not made.

The theoretically beneficial effects of mulching, in combination with a reduced transpiration rate caused by an antitranspirant, should have increased leaf water potential significantly. However, since mulching had no effect, as previously discussed, and the antitranspirants had lost their effectiveness (1, 2, 3, 4, 5, 9, 10, 11, 13, 14, 20, 21, 22), it follows that there was no difference in the effect of this interaction.

Visual evaluation. At the time of pressure bomb measurement, the boxwoods were the only species showing leaf injury. The last flush of growth (which was very soft and succulent at the time of planting) had turned brown but the older, more mature leaves were still a dark, glossy green. Since damage occurred on all boxwood regardless of treatment, damage was probably due to low temperature injury because the succulent tissues had insufficient time to harden for winter. Some of the damaged leaves exhibited a peculiar separation of epidermal layers or "ballooning." Epidermal separation is an indication of low temperature damage, according to Kozlowski (13), and further supports the conclusion of low temperature damage.

From mid-January to late February the plants were almost completely covered with snow. Only the taller stems of the hollies and euonymus were visible. The snow, acting as a mulch, protected the plants from the low temperatures and desiccating conditions which were optimal during that time. Therefore, data collected on March 10, 1978, may not be applicable to desiccation research.

Visual ratings of the plants, based on a scale of 1 to 9, were made on March 10, 1978. At this time, none of the antitranspirants

were superior to the control in reducing leaf damage on any of the three species of plants (Table 1). This was expected since leaf water potential measurements in January showed no differences among treatments.

All three species sustained some degree of damage; however, there was no one species with significantly more damage than the rest (Table 2). As pointed out earlier in this section, boxwood was the only species showing leaf damage at the time of pressure bomb sampling, soon after which, the plants were protected from low temperature and desiccating conditions by snow. The damage which occurred to the holly and euonymus may have already happened before the sampling date, the visible signs not appearing until later when warmer temperatures increased physiological activity in the plant (13, 25).

Plants in mulched replications were no less damaged than plants in unmulched replications, the ramifications of which have already been discussed in section A. The snow cover, acting as a mulch, may have served to nullify any differences between mulched and unmulched replications also.

B. Second Year 1978-1979

Leaf water potential evaluation. The first pressure bomb sampling date was November 23, six days after antitranspirant application. At this time, all three antitranspirants increased leaf water potential significantly for each of the three species as compared to the control (Table 3). When computed as a mean of all species combined, Vapor Gard and Exalt 4-10 increased leaf water potential by 31 percent and 28 percent respectively. Wilt Pruf also proved to be a superior treatment to

the control, increasing leaf water potential by 20 percent (Table 1). Since measurements were made within the first week after treatment application, these results were expected. Work done by Davenport (1) and others (2, 3, 4, 5, 9, 10, 11, 13, 14, 20, 21, 22) has shown anti-transpirants to be most effective during the first week.

Species, again, were significantly different with respect to leaf water potential, when computed as a mean of all treatments (Table 2).

On the February 8 pressure bomb sampling date, eleven weeks after treatment application, none of the three antitranspirants yielded a superior leaf water potential reading in comparison with the control (Table 1). These results coincide with the results of 1977-1978.

There was a significant difference between species with respect to leaf water potential (Table 2). Regardless of treatment, boxwood consistently had the lowest leaf water potential while euonymus and holly had the highest leaf water potential. This again coincides with the results from 1977-1978 and work done by Kozlowski (13) and Pellett (19).

Mulching had no significant effect on leaf water potential when analyzed as a mean of all treatments and species. There was also no difference in the interaction of treatment x mulch, species x mulch, or treatment x species x mulch.

Visual evaluation. Although there was a heavy snow cover on the ground during mid-January through February, the snow was shoveled off the experimental plots, exposing the plants to the low temperatures and desiccating conditions that the plants were protected from the previous year. By February 8, 1979, when pressure bomb readings were taken, all plants were damaged regardless of treatment.

As in the previous year, the boxwoods exhibited the browning of the last flush of growth as well as the "ballooning" of the leaves indicating low temperature damage. The stems of the damaged growth also displayed peeling bark, another indication of low temperature damage.

All holly, regardless of treatment, were brown. When samples were tested in the pressure bomb, many of the readings were extremely low, indicating a high leaf water potential which would typify a slightly or undamaged plant. However, I do not feel these were valid readings. If the plants were damaged from desiccation, leaf water potentials would have been very low. It follows then, the high leaf water potentials were caused by dead, water-soaked tissue resulting from low temperature injury and may cause a misrepresentation of the data.

On March 21, 1979, a visual rating of the plants was made using the same scale as the previous year. All species tested differed significantly from each other with euonymus showing the least damage and holly the most (Table 2). According to Levitt (16), *E. fortunei* and *B. sempervirens* are somewhat hardier than *I. cornuta* which explains the above results.

The better treatments were Wilt Pruf and the control spray when computed as a mean of all three species combined (Table 1). However, even the superior rated plants were 54 percent damaged. When individual treatments were compared separately with each species, Wilt Pruf and the control spray were found to be superior on euonymus and holly whereas none of the three treatments had any effect on boxwood at the time of rating (Table 4).

The superior visual ratings received by the control spray are supported by Levitt (15, 16), Pellett (19) and others (13, 25) who point out that plants normally lose moisture during the fall and winter months in preparation for the winter. As the moisture content of the leaves decreases, there is an increase in the bound water to free water ratio, due to an actual increase in water binding substances, as well as the increased concentration due to the moisture loss. The increase in bound water and cell metabolite concentration effectively lowers the point at which the plant tissues will freeze. But, by applying film-forming anti-transpirants, leaf water potential is increased which decreases the bound water to free water ratio and thereby makes the plant more susceptible to low temperature injury.

Wilt Pruf also received a higher visual rating than Vapor Gard or Exalt 4-10. Davies and Kozlowski (5) found that even though Wilt Pruf is good for reducing transpiration, the reduction is short term. Vinyl latexes such as Wilt Pruf become brittle upon drying and will crack due to leaf movement in the wind. After eight days its effectiveness is greatly reduced and soon is comparable to a control water spray which would permit the natural loss of moisture accompanying cold temperature acclimation.

Scanning electron microscope observation. Electron micrographs, taken one week after antitranspirant application, revealed each anti-transpirant had effectively covered or blocked the stomata of all three species when compared to the control (Figures 2 and 3). Pressure bomb measurements made at this time revealed that leaf water potentials of all three species were higher than leaf water potential readings taken

ten weeks later on February 8, 1979 (Table 2) and that all species sprayed with an antitranspirant had significantly higher leaf water potentials than their respective control sprays (Table 3). Therefore, antitranspirants were responsible for increasing leaf water potential at this time.

Micrographs taken one month after treatment application showed definite cracking over the stomata (Figure 2c). Even though pressure bomb measurements were not made at this time, the effectiveness of the antitranspirants in controlling water loss, through transpiration, can be assumed to have declined dramatically due to an increased number of uncovered stomata. Davenport (1) and others (2, 3, 4, 5, 9, 10, 11, 13, 14, 20, 21, 22) have shown the effectiveness of antitranspirant films to be greatest during the first week after application but declines rapidly thereafter. Fisher (6) also reported cracking of antitranspirant films and subsequent loss of effect over time as observed under the scanning electron microscope.

In February the antitranspirants were cracked and peeling (Figure 2d), indicating the effect of the antitranspirant films had become comparable to the control. This was confirmed by leaf water potential data (Table 1). As increasing numbers of stomata are uncovered, water loss through transpiration increases causing high pressure bomb readings which indicate a low leaf water potential. If the films had not cracked, the pressure bomb readings would have revealed higher leaf water potentials.

At the time of the March visual injury rating, all the films were nearly gone. Figures 2e and 2f show a section of Exalt 4-10 lifted off

the lower and upper leaf surface of euonymus respectively.

Pair and Still (17) showed some success testing several film forming antitranspirants for winter desiccation reduction, including Vapor Gard, Exalt 4-10 and Wilt Pruf, on 'Fosters No. 2' holly in 1976 (Table 5). Temperatures during the critical desiccation period (January through February) were such that low temperature damage did not interfere with desiccation damage measurements on 'Fosters No. 2' holly. The results showed Exalt 4-10 and Vapor Gard to reduce winter desiccation damage better than Wilt Pruf or the control.

Other work has shown acrylic copolymers such as Exalt 4-10 and Vapor Gard to resist cracking (and subsequent loss of effect) longer than a vinyl latex such as Wilt Pruf. The longer lasting Exalt 4-10 and Vapor Gard allowed the plant to maintain a leaf water potential high enough to escape the degree of desiccation damage exhibited by the plants treated with Wilt Pruf or a control water spray.

Table 1. Leaf water potential and visual injury rating of Buxus sempervirens, Euonymus fortunei 'Golden Prince' and Ilex cornuta 'Lydia Morris', as affected by four antitranspirant treatments, when computed as a mean of all species.

Treatment	Dilution ratio	Leaf Water Potential (ATM)			Injury Rating	
		1/9/78	11/23/78	2/8/79	3/10/78	3/21/79
Vapor Gard	1:20	-19.2a	-12.3c	-26.2a	6.3a	3.6b
Exalt 4-10	1:4	- 9.7a	-12.9c	-21.2a	6.3a	3.8ab
Wilt Pruf	1:5	- 9.9a	-14.5b	-24.6a	6.6a	4.2a
Control	water	-10.4a	-17.8a	-25.8a	6.1a	4.2a

Means followed by the same letter are not significantly different at the 5% level.

Table 2. The effect of Vapor Gard, Exalt 4-10, Wilt Pruf and a water spray on leaf water potential and visual injury rating, of three species of broadleaf evergreens, when computed as a mean of all treatments.

Species	Leaf Water Potential (ATM)			Injury Rating	
	1/9/78	11/23/78	2/8/79	3/10/78	3/21/79
<u>Buxus sempervirens</u>	-26.0a	-24.9a	-39.6a	6.3a	3.9a
<u>Euonymus fortunei</u> 'Golden Prince'	- 5.4b	-10.4b	-19.2b	6.5a	4.6a
<u>Ilex cornuta</u> 'Lydia Morris'	- 5.4b	- 7.7c	-14.9c	6.3a	3.3c

Means followed by the same letter are not significantly different at the 5% level.

Table 3. Leaf water potential of boxwood, euonymus and holly at each treatment level on November 23, 1978.

Treatment	Leaf Water Potential (ATM)		
	Boxwood	Euonymus	Holly
Vapor Gard	-20.4a	- 9.5a	-6.8a
Exalt 4-10	-22.6a	- 9.6a	-6.4a
Wilt Pruf	-26.4a	- 9.5a	-7.6a
Control	-30.1b	-13.0b	-9.9b

Means followed by the same letter are not significantly different at the 5% level.

Table 4. Visual injury rating for boxwood, euonymus and holly at each treatment level on March 21, 1979.

Treatment	Visual Injury Rating		
	Boxwood	Euonymus	Holly
Vapor Gard	4.1a	3.9b	2.7b
Exalt 4-10	4.2a	4.1ab	2.9ab
Wilt Pruf	3.9a	5.1a	3.4ab
Control	3.2a	5.2a	4.1a

Means followed by the same letter are not significantly different at the 5% level.

Table 5. Effect of Vapor Gard, Exalt 4-10, Wilt Pruf and a water spray on visual injury ratings of 'Fosters No. 2' holly for 1976.

Cultivar	Vapor Gard	Exalt 4-10	Wilt Pruf	Control
'Fosters No. 2'	6.5a	7.4a	4.8b	3.0b

Means followed by the same letter are not significantly different at the 5% level.

Figure 1: Research planting and treatment design.

I = Ilex cornuta 'Lydia Morris'

E = Euonymus fortunei 'Golden Prince'

B = Buxus sempervirens

1 = Vapor Gard

2 = Exalt 4-10

3 = Wilt Pruf

4 = Control

 = mulch

I2	E2	B2
B3	E3	I3
E1	B4	I4
I1	B1	E4
E1	B4	I4
E2	I3	B2
B3	I1	E3
B1	I2	E4
I2	E3	B1
B2	E4	I3
E1	I1	B3
I4	E2	B4
B1	E4	I4
I3	B4	E3
I2	B2	E1
B3	E2	I1

B4	I1	E3
B3	E1	I3
I4	E2	B2
I2	E4	B1
E3	B1	I4
I1	B4	E1
E4	I2	B3
B2	I3	E2
E3	I2	B4
B1	E2	I1
I4	B3	E1
E4	B2	I3
I2	B2	E3
E4	I4	B4
B1	E1	I3
I1	E2	B3

E1	B3	I2
I1	B1	E3
E2	B4	I4
I3	E4	B2
B4	E2	I1
B3	E1	I4
I3	B2	E3
E4	I2	B1
B1	E4	I1
B3	E2	I3
I2	E3	B4
B2	I4	E1
B4	I4	E3
E1	B2	I2
I3	B3	E2
E4	I1	B1

Figure 2: Lower leaf surface of Euonymus fortunei 'Golden Prince' control plant showing stomata.

Figure 3: Lower leaf surface of euonymus showing covered stomata, one week after treatment with Exalt 4-10.



Figure 4: Lower leaf surface of euonymus one month after Exalt 4-10 application. Note the beginning of some cracking.

Figure 5: Lower leaf surface of euonymus showing increased cracking of Exalt 4-10 antitranspirant.

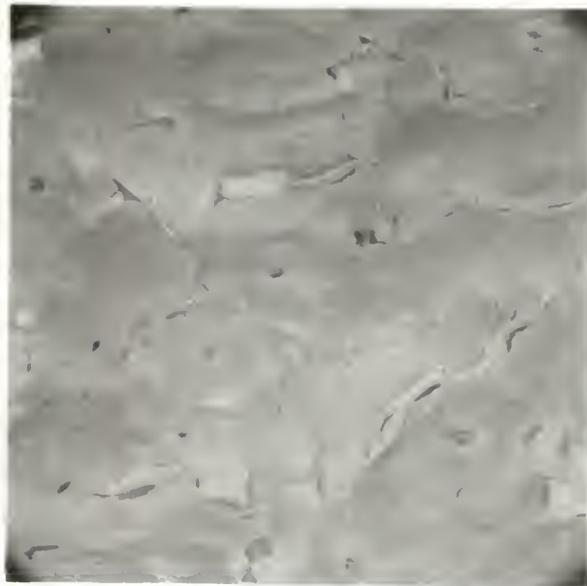


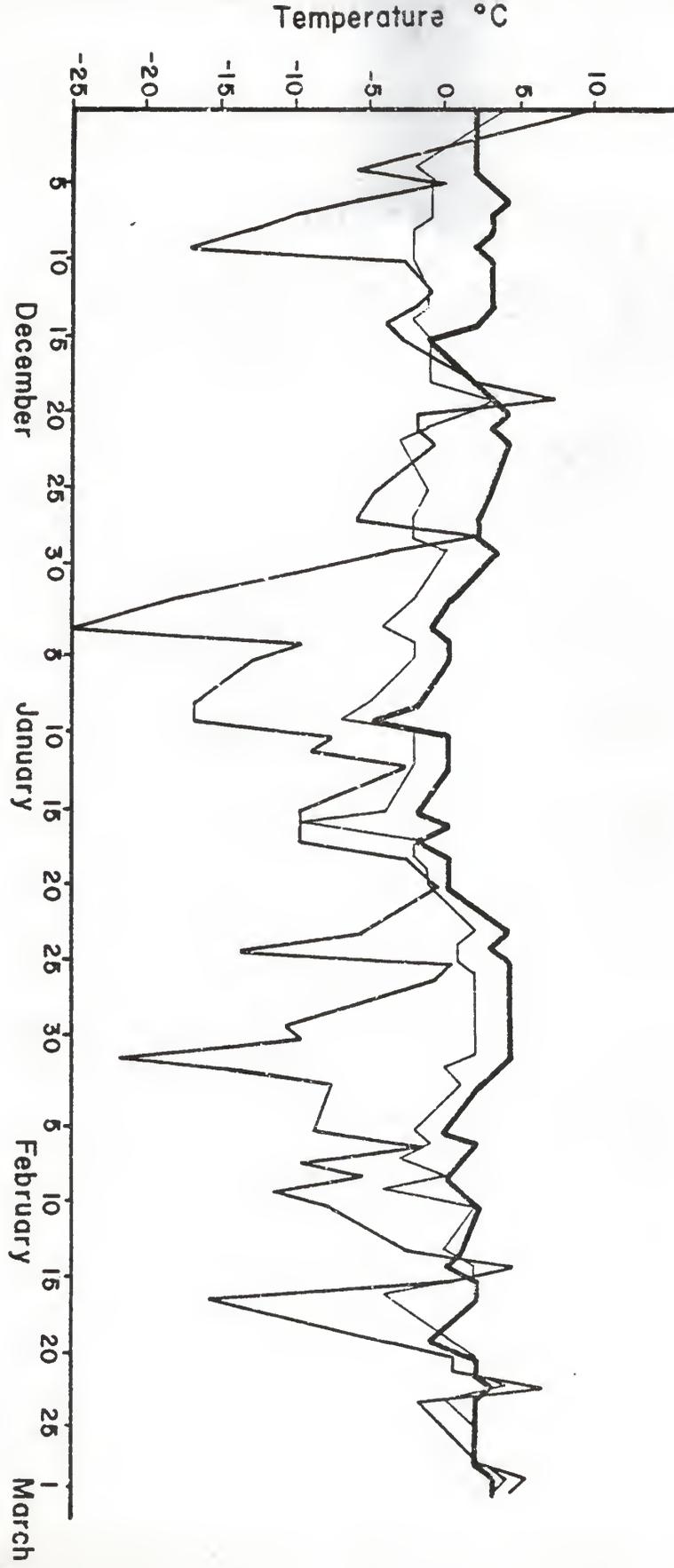
Figure 6: Lower leaf surface of euonymus showing a section of Exalt 4-10 separated from the leaf.

Figure 7: Upper leaf surface of euonymus showing extent of cracking of Exalt 4-10.



Figure 8: Soil temperature, as affected by the presence or absence of a six-inch sawdust mulch, determined daily from December 1, 1978, to March 1, 1979, at a depth of two inches using thermalcouples.

———— mulched soil temperature
———— unmulched soil temperature
———— ambient air temperature



SUMMARY AND CONCLUSIONS

Some studies have shown limited success using film forming anti-transpirants to reduce damage due to winter desiccation (10, 15, 17, 20, 21). This study, however, has shown that Vapor Gard, Exalt 4-10 and Wilt Pruf applied in late fall as a foliar spray to Buxus sempervirens, Euonymus fortunei 'Golden Prince' and Ilex cornuta 'Lydia Morris' planted in mulched and unmulched replications, failed to reduce winter damage. Since the antitranspirants offered no protection against minimum temperature injury, which prevailed both years, any measurable response caused by the antitranspirants in preventing desiccation was eliminated.

Scanning electron micrographs taken of boxwood, euonymus and holly leaves revealed cracking of all three antitranspirant films and the reduction of leaf water potential from November 23, 1978, to February 8, 1979, could be attributed to the cracking of the films. As the films crack, passages for water vapor loss are created, resulting in increased transpiration and reduced leaf water potential.

Plants in mulched replications did not have significantly higher leaf water potentials than plants in unmulched replications even though soil temperatures under the mulched replications were consistently highest. It was assumed that a mulch, while maintaining a higher soil temperature, would prevent the soil from freezing as deeply and thereby permitting plant roots to replace water lost through transpiration. However, plant root depths were not measured to determine if roots were sufficiently deep to escape the frost line. Root depth measurements

and possibly percent soil moisture should be incorporated into future research.

Since low temperatures play such a critical role in the successful use of film forming antitranspirants to reduce winter desiccation damage, future research on this subject should either be restricted to areas where low temperatures are not a problem or plant taxa should be used which can tolerate the low temperatures encountered here.

LITERATURE CITED

1. Davenport, D. C. 1976. Antitranspirants and plant cultivation. *American Nurseryman*. 144(2):14,22.
2. Davenport, D. C., M. S. Fisher, and R. M. Hagan. 1972. Some counteractive effects of antitranspirants. *Plant Physiology*. 49:722-724.
3. Davenport, D. C., P. E. Martin, and R. M. Hagan. 1973. Effects of antitranspirants on water use by highway oleander plantings. *J. Am. Soc. Hort. Sci.* 98(5):421-425.
4. Davenport, D. C., K. Uriu, and P. E. Martin. 1974. Effects of film antitranspirants on growth. *J. Exp. Botany*. 25(85):410-419.
5. Davies, W. J., T. T. Kozlowski. 1974. Short and long-term effects of antitranspirants on water relations and photosynthesis of woody plants. *J. Am. Soc. Hort. Sci.* 99(4):297-304.
6. Fisher, M. W., and T. L. Lyon. 1972. Antitranspirant film detection by scanning electron microscopy of cathodoluminescence. *Hort. Sci.* 7(3):245-246.
7. Fry, B. O., and E. F. Savage. 1968. Evaluation of sawdust as a mulch for young blueberry plants. *Proc. Am. Soc. Hort. Sci.* 93:273-279.
8. Gale, J. 1967. Plastic films on plants as antitranspirants. *Science*. 156:650-655.
9. Gale, J. 1961. Studies on plant antitranspirants. *Physiol. Plant.* 14:777-785.
10. Gouin, F. R. 1978. Anti-transpirants or anti-desiccants and winter survival. *Nurserymen's News Cooperative Extension Service*. September-October, pp. 3-5.
11. Hall, G. C., and C. E. Whitcomb. 1976. Antitranspirants: an investment or an unnecessary expense? *American Nurseryman*. 144(2):114-122.
12. Kaufmann, M. R. 1968. Evaluation of the pressure chamber method for measurement of water stress in citrus. *Proc. Am. Soc. Hort. Sci.* 93:186-189.
13. Kozlowski, T. T. 1968. *Water deficits and plant growth*. Vols. I, II and III. Academic Press, New York and London.

14. Kreith, F., A. Taori, and J. E. Anderson. 1975. Persistence of selected antitranspirants. *Water Resources Research*. 11(2): 281-286.
15. Levitt, J. 1941. Frost killing and hardiness of plants. Burgess Publishing Co., Minneapolis, Minn.
16. Levitt, J. 1956. The hardiness of plants. Academic Press, Inc., New York, New York.
17. Pair, J. C., and S. M. Still. 1976. Unpublished data.
18. Pease, R. W., and T. L. Hayes. 1966. Scanning electron microscopy of biological materials. *Nature*. 210:1049.
19. Pellett, N. E., and D. B. White. 1968. Relationship of seasonal tissue changes to cold acclimation of Juniperus chinensis 'Hetzi'. *J. Am. Soc. Hort. Sci.* 94:460-462.
20. Smith, E. M. 1971. Some aspects of the use of anti-desiccants to prevent winter injury. *Arborist's News*. 36(4):37-38.
21. Smith, E. M., L. C. Chadwick, and K. W. Reisch. 1966. The use of anti-desiccants in reducing transpiration and protecting ornamental plants against winter injury. *Proc. Am. Soc. Hort. Sci.* 88:703-705.
22. Snyder, W. E. 1964. The effect of several antitranspirant materials on apparent transpiration of selected ornamental plants. *Comb. Proc. Int. Plant Prop. Soc.* 14:227-233.
23. Symmes, H. M. 1978. Are antitranspirants the panacea for boxwood winter injury? *The Boxwood Bulletin*. 18(2):21-26.
24. White, W. D., and C. J. Weiser. 1965. Find key factor in winter burn of arborvitae. *American Nurseryman*. 121(9):28-30.
25. Winter, E. J. 1974. *Water, soil and the plant*. Macmillan Press, Ltd., London and Basingstoke.

THE EFFECTIVENESS OF WILT PRUF, VAPOR GARD, EXALT 4-10
AND MULCHING FOR REDUCING WINTER DESICCATION
OF THREE TAXA OF BROADLEAF EVERGREENS

by

KEITH MICHAEL FUNK

B. S., Kansas State University, 1977

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Horticulture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1979

Vapor Gard, Exalt 4-10 and Wilt Pruf were applied to the foliage of Buxus sempervirens, Euonymus fortunei 'Golden Prince' and Ilex cornuta 'Lydia Morris', planted in mulched and unmulched replications, to determine the effect on leaf water potential and desiccation injury. Pressure bomb measurements made one week after antitranspirant application showed all three spray materials had significantly increased the leaf water potential of each species when compared to the control. Measurements made six weeks after treatment application revealed leaf water potentials, regardless of treatment, were not significantly different than the control, indicating a loss of antitranspirant effect. Electron micrographs taken of the films at regular intervals after application showed cracking of the films.

A six-inch sawdust mulch, applied to half of the treatment replications, did not significantly affect leaf water potentials even though soil temperatures of the mulched replications were consistently higher than soil temperatures of the unmulched replications.

Plants were assigned visual injury ratings in early spring. Since the antitranspirants offered no protection against minimum temperature injury, which prevailed both years, any measurable responses caused by the antitranspirants in preventing desiccation were eliminated.