THE EFFECTS OF FILM FORMING ANTITRANSPIRANTS ON NURSERY PRACTICES

By

GORDON CLARKE HALL

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Oklahoma State University

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THE EFFECTS OF FILM FORMING
ANTITRANSPIRANTS ON
NURSERY PRACTICES

Thesis Approved:

Carl E. Whitcomb
Thesis Adviser

R. N. Payne

Wayne W. Huffine

W. R. Kays

N. N. Durham
Dean of the Graduate College

PREFACE

The original purpose of this study was to further test the feasibility of using antitranspirants as a replacement for intermittent mist in the propagation of vegatative cuttings. A number of problems soon became apparent about the use of antitranspirants and serious doubt was raised about the usefulness of these coatings under any circumstances. Therefore various other experiments were attempted to study the possible use of antitranspirants in nursery practices other than propagation.

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CHAPTER I

INTRODUCTION

The propagation of plants asexually in some cases antedates recorded history. Some of the oldest fruit crops such as olive, grape, and fig were propagated in this manner (12). The invention of glass houses in the nineteenth century made the rooting of leafy cuttings easier. The development of intermittent mist and discovery of rooting hormones has brought vegetative propagation in the modern day nursery industry to a highly developed science. Many factors are understood about rooting of cuttings, however, many questions remain and many theories have been postulated.

Rooting of cuttings is the simplest and least expensive method of propagation for many species. Many highly desirable and useful ornamental plants, however, cannot be reproduced in this manner. It would be particularly useful if propagation from cuttings could be extended to a wider range of plants for economic and plant breeding purposes. If cuttings could be rooted directly in the containers instead of being rooted or grafted and then transferred to containers, a substantial savings might result.

The rooting of cuttings at the present time is most often achieved by the use of an intermittent mist system with variable on - off cycles. This has been the preferred way of rooting most materials grown in the nursery since the development of mist systems in the early 1950's (15). However, almost since the beginning, serious questions have been raised as to whether mist is the optimum system for rooting.

One possible area for research that has had little attention is the use of antitranspirants as a replacement for mist. This is the main area of research in this study. In the literature review, past research in the area of antitranspirants as well as other closely related areas such as nutrient leaching, nutrients in the propagation media, nutrients in the mist and other possible answers to the leaching versus rooting problems are discussed.

CHAPTER II

REVIEW OF LITERATURE

The ideal intermittent mist system would turn on when the film of water covering the foliage begins to break due to evaporation. When the film of water again covers the leaves and stem, the system would turn off. This prevents desiccation until the cutting can develop roots and take up water. Any additional mist increases leaching of nutrients from foliage and excessively wets the rooting medium.

With the discovery of growth regulators and hormones many significant advances were made in plant propagation (15). All of the problems dealing with rooting, however, were far from being solved. Leaching of nutrients from the foliage remains a serious problem, at least for some species. Since the application of any water to cuttings may cause leaching this has been accepted as a valid assumption (15).

Rooting of cuttings can be aided by basal treatment with synthetic auxins. Hartmann and Kester (14) point out that auxins in general are involved in a number of physiological processes including stem growth, root formation, lateral bud inhibition, abscission of leaves and fruit, fruit development and activation of cambial cells. They go on to state that auxins seem to be universally present in plants and are apparently non-specific in their action, that is, response to auxin in one species usually shows up the same in others (14). Leopold points out that the term "growth hormone" has become synonymous with auxin and studies of the mechanism of auxin action have been mainly studies of the effects of auxin on cell enlargement (17). Synthetic auxins appeared first in the form of indoleacetic acid (IAA) and later indolebutyric acid (IBA) and napthaleneacetic acid (NAA) were used. These have been used separately or many times in combination (15). Synthetic auxin is usually applied to the base of cuttings. The auxin concentration and length of the dip (when liquid concentrations are used) can be critical to root initiation (25).

In addition to the use of mist and auxin there have been many studies on the physiology of rooting in an effort to determine why some cuttings are difficult to root. Through various studies it has become rather widely accepted that substances essential for root initiation are synthesized in the buds and leaves of cuttings and are translocated to the base of cuttings through the phloem (14,15). This has been substantiated by both leaf removal and girdling which drastically reduced rooting of cuttings (12,14,22). Substances besides auxins are translocated from the top of the cutting to the base. These include a group of compounds called rooting cofactors (3,6,7). These substances have been theorized for quite some time. They were referred to by Went as early as 1938 and he called them rhizocalines (35).

Hess (15) found that these cofactors acted synergistically with IAA to promote the rooting process. The degree of variation in quantity or total absence of these cofactors is thought to have a direct bearing on the rooting ability of certain cuttings. He also found that easily rooted forms of plants have a larger number of these cofactors (15). It is, however, essential to point out that exactly what these chemical cofactors are or what their mode of action is, remains vague. Hartmann and Kester (14) states the following general formula for what he believes could take place during root initiation.

```
Phenolic       Auxin           Auxin    Cell          Adventitious
Co-Factor  +  (endogenous  →  phenol → division  →   root
(from buds)    or applied)    complex ↑               initials
                                       |
                                    enzyme
```

Besides the physiological factors there have also been certain environmental questions raised concerning root initiation. For instance, chilling the tops of 'Bartlett' pear cuttings while warming the bottoms increased rooting. It is believed in this case that the rooting cofactors actually inhibited root initiation and that cooling the tops slowed translocation of these substances from the leaves and buds, thus aiding root initiation (13). Light also plays an extensive part in rooting. The most obvious reason is the fact that light is the source of energy for photosynthesis which is important for root initiation and growth (14). Hartmann and Kester (14) point out that both the intensity and duration of the light must be great enough so that carbohydrates will accumulate in excess of those used in respiration. This is especially true in the case of leafy cuttings, while leafless cuttings depend on stored carbohydrates. They further postulate that light is necessary for the manufacture of auxin, which promotes root initiation. But the presence of light seems inhibitory to rooting dormant deciduous cuttings if the auxin requirement is supplied externally. For instance, deciduous hardwood cuttings, which probably store previously manufactured auxin, initiate roots best in darkness (14). Smaller leafy cuttings without the capability of storing as much auxin or carbohydrates need light for food and auxin production (14).

Many other factors which may influence rooting have also been studied. Sherwood (25) stated in his study of the rooting of blue spruce from cuttings that one of their main concerns was locating stock plants which showed good shape and blue color. He went on to state, that he felt a stock plant with a high percentage of rooting is necessary. This idea of a genetic relationship to rooting needs to be approached experimentally with other species. Some work has been done on juvenility and its effects on root initiation, with the general conclusion being that young actively growing tissue is more apt to root than older more mature tissue (20). It has also been shown that etiolation of stem tissue can aid the rooting ability on certain plants such as pecans (21). In addition there is a growing concern that even if some of these hard to root plants could be induced to develop roots, would they be sufficient to support the plant in its future development. Dickey (7) found that the degree of rooting did not influence subsequent growth of viburnum and thryallis but did have a significant effect on subsequent growth of podocarpus. This would indicate a species response that can only be determined once the root initiation problem is solved.

One of the major problems is the application of water to the foliage of the cutting which can lead to leaching. The hypothesis that nutrients were leached from foliage under mist was first based on the observed nutrient deficiencies on cuttings under a mist system (11,15). From this, researchers used tissue analysis to determine what nutrients were being leached and when during the rooting process this problem was most prevalent. Tukey, Tukey, and Wittwer (34) used radioisotopes and found that the above ground parts of plants should be considered as organs of both uptake and loss of nutrients. In addition Sorenson and Coorts (27) found less nitrogen, phosphorus and potassium when cuttings were under mist, both at the time of rooting and callus, than had been present initially. This held true for a number of species tested which included Buxus sempervirens, Ilex crenata 'Microphylla', Juniperus horizontalis 'Plumosa'. and Taxus media. Tukey and Morgan (33) state that every plant studied had been found capable of nutrient loss by leaching to some degree. They go on to state that losses by leaching in 24 hours might be as high as 80% to 90% of the potassium content and 50% to 60% of the calcium content of mature leaves. In addition to mineral elements, they found that large amounts of organic materials are leached, principally carbohydrates. Tamm (28) stated that losses of Ca, K, and Na from foliage of coniferous and hardwood forest trees occurred during rainfall.

Joiner and Gruis (16) showed that after initial losses of nitrogen, phosphorus and potassium there was no significant change in nutrient levels. This is supported in part by Evans (8) who found that nitrogen and phosphorus were leached from cacao cuttings primarily during the first two weeks under mist but, that nitrogen continued to be leached for the duration of propagation time.

In addition to the question of what is leached and when, Good and Tukey (11) have shown that leaching depends on whether cuttings are softwood or hardwood and the species of plant being rooted. They found that leaching is less severe from cuttings which are young and actively growing, than from older cuttings.

Besides the problem of nutrients being leached from foliage it has also been postulated that rooting cofactors may be leached and are therefore not translocated to the base of the cuttings as would normally occur. This is supported by Tukey and Tukey (32) who summarized that rooting is associated with leaching of nutrients, inhibitors and promotors of rooting. Tukey and Lee (31) went on to state that many substances in plants play a key role in root initiation and development. These include auxins and rooting cofactors and possibly phenolic and flavanoid substances. It seems logical that rooting inhibitors and promotors could be leached. This particularly emphasized the need for a substitution or modification of the mist system as it presently exists.

Three possible solutions to the problem of leaching have received some consideration: first is nutrient mist, either in the normal mist system or applied intermittently to restore nutrients lost during misting; second is adding nutrients to the propagation medium; third is the use of antitranspirants as a replacement for mist.

The use of nutrient mist to partially replace nutrients lost during the misting process has received considerable attention. Good and Tukey (11) summarized by stating that nutrients added to cuttings through the mist would be of benefit to both herbaceous and softwood cuttings as well as hardwood cuttings. This is further supported by Sorenson and Coorts (27) who found some benefit in both rooting percent and number of roots per cutting. However, the benefit derived seemed to vary according to species of plant tested and amount of nutrients applied. Rooting performances was also affected by what time of year the cuttings were taken, with no consistent benefit evident.

Hess (15) states that while in some cases nutrient mist has accelerated rooting, the greatest benefits appear to be realized in the subsequent growth of the cuttings once they are rooted. Also, incomplete results by Perry (18) showed that cuttings maintained under nutrient mist have a deep green color while cuttings under water mist become chlorotic. Joiner and Gruis (16) found increased Nitrogen content of tissue under nutrient mist with no increase in rooting percent or root quality of any plants tested. With foliar application of potassium they did find increased rooting percent and increased root quality of viburnum. However, this again was not consistent throughout all of the species tested (16).

The addition of fertilizers to the propagation medium is generally done in the form of slow release fertilizers such as Osmocote.* Hess (15) stated that while in some cases there were beneficial effects on root initiation, the greatest effect is realized once the cutting is rooted. This is supported by Self and Pounders (24) who used Osmocote 18-9-13 on Ardisia japonica, Viburnum tinus, Hedera helix, Pittosporum spp., Cornus florida, Ilex crenata 'Compacta'. Euonymus pulchellus, Gardenia radicans, 'Pink Giant' Hidodegiri Azalea, and Juniperus conferta. Euonymous spp. 'Gold Spot', and Osmanthus spp. They found no increase in rooting percentage, with the only consistent benefit being to hasten rooting and initial growth (24). Whitcomb and

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*A plastic encapsulated slow release fertilizer manufactured by Sierra Chemical Company, Newark, California.

Schulte (37) found similar results with Juniper chinensis 'Pfitzer' using Osmocote 18-6-12. They did, however, get an increased rooting percentage of Ilex cornuta 'Burford' which suggests the possibilities of a species response to this type of treatment. In no case did they find any benefit from micronutrients added to the medium.

Another possibility is the use of antitranspirants as a replacement for mist to aid rooting. Transpiration is the evaporation of water from plant tissue. In woody plants this principally occurs from the leaves, but may also occur through lenticels (26). Stomata are generally on the lower surface only and are bordered on either side by cresent shaped guard cells, which when full of water, as in the turgid condition, become distended causing the stomata to open. When these guard cells are low in water they collapse and the stomata close (22,26,6). Even though these stomata are very small (12.5 - 6.5 microns) they are quite numerous 72,000/sq. in. for black poplar and 625,000/sq. in. for scarlet oak) and while only comprising 1% of the total leaf surface even when open, 95% of the water given off by the leaf is through this opening while only 5% is lost by the epidermis (26). In addition to their function as an exit for water vapor they also facilitate the intake of carbon dioxide (3). Covering or closing these openings could have dramatic physiological effects on plant growth, rooting and subsequent survival.

Antitranspirants are defined as chemicals capable of reducing the transpiration rate when applied to foliage. They are usually applied in the form of a spray, but may also be applied as a dip to above ground plant parts (3). Types of chemicals used become an important factor in the determination of their use.

Basically three types of chemical antitranspirants have been used as foliar sprays. The first are reflecting materials, which theoretically reduce the absorption of radiant energy and thereby reduce leaf temperatures and thus transpiration rates. The second types are emulsions of wax, latex or plastics which dry on the foliage to form a thin transparent film that reduces the loss of water from foliage. Third are chemicals which when sprayed on the foliage to prevent stomata from opening fully thereby decreasing water loss (26,3,4,5). Some of the commercially available antitranspirants are listed in Table I (1).

There has been a considerable information generated on the physiological effects of antitranspirants on plants. The predominance of this research has been in using antitranspirants in various capacities on growing plants. Very little research has been done of the use of antitranspirants in propagation.

One of the major problems with antitranspirant effectiveness is the completeness and duration of coverage attainable on the leaf surface. A major part of the incompleteness of some antitranspirant coverage is due to degradation of the film. Gale and Hagan (9) state that factors such

TABLE I

COMMERCIALLY AVAILABLE ANTITRANSPIRANTS
PRESENTLY AVAILABLE

TRADE NAME	ANTITRANSPIRANT INGREDIENT	TYPE
All-Safe	latex	Film-forming
Clear Spray	latex	Film-forming
Foli-Gard	acrylic copolymer	Film-forming
Keynote	plastic-wax	Film-forming
Mobileaf	wax	Film-forming
Protecto	wax	Film-forming
Sunco Folicote	wax	Film-forming
Vapor Guard	polyterpene	Film-forming
Wilt Pruf	polyvinyl	Film-forming
Needle Fast	latex and phenylmercuric acetate	Film-forming and stomata-closing
Spruce Seal	phenylmercuric	Stomata-closing
Stoma Seal	phenylmercuric acetate	Stomata-closing
Sun Guard*	hydrated lime	reflecting
Tre-Co-White*	hydrated lime	reflecting

*Marketed as sunburn preventive.

as solar ultra-violet radiation, temperature extremes, oxidation and micro-organisms cause degradation of some antitranspirant films. This is further emphasized by Snyder (26), in New Jersey, who stated that there was a marked decrease in effectiveness of the antitranspirant used until after the fifth week, during which time only moderate reduction in water loss occurred. He stated however, that retreatment showed more effectiveness in the 5 weeks following than in the initial 5 week period. Davenport, Hagan and Martin (3) found that duration of antitranspirant effectiveness determines when respraying is required and thus the economic usefulness. Duration depends on efficiency and durability of the material, effectiveness of the spraying operation, environmental conditions, and the amount of new foliar growth produced by the plant since spraying. They concluded the benefit, therefore, could last from a few days to several weeks. Gale, et al. (10), in Israel, found that under cool humid conditions, reduction of transpiration was much less and growth was slightly reduced. They concluded that antitranspirants would only be advantageous under conditions of moist soil and high evaporative demand. Finally, Davies and Kozlowski (5) found that both environment and species influence the efficiency of antitranspirants. They state that both factors should be evaluated prior to recommending the use of any film type antitranspirant.

Another problem that needs explanation is the plant response to incomplete coverage by an antitranspirant film.

This incomplete coverage could be due to any of a number of reasons, including, improper spraying, degradation, and foliar growth. Davenport, Fisher and Hagan (2) observed that stomates under an antitranspirant film are actually opened further due to an increase in guard cell turgidity, which in turn is caused by increased water potential in the leaf. However, they also noted that when the film coverage was incomplete the stomates in the uncovered portion were open wider than those on an untreated leaf, though not as wide as those actually under the antitranspirant film.

Reish, Smith and Chadwick (19), Ohio, found in testing Foli-Gard and Wiltpruf that neither of these film type antitranspirants caused the stomates to close, nor did they prevent them from closing. They also noted, using microscopes and silicone rubber impressions of the stomates, that there were definite openings in the many stomatal aperatures by the third day with Foli-Gard. Pronounced cracking of stomatal aperatures were observed after one day with Wiltpruf!

The problem of CO_2 uptake retardation is dealt with by Davenport et al. (3,4) who state that currently available antitranspirant films reduce carbon dioxide intake. Further, if growth increases are desired the antitranspirant should be applied at a stage of plant development when growth is more dependent on cell expansion than on photosynthesis and cell division. They went on to say that leaves may be "suffocated" by a strong concentration of antitranspirant material which is relatively impermeable to carbon dioxide and oxygen. In another paper, Davenport, Fisher and Hagan (2) found that since antitranspirants increase plant water potential, cell expansion could increase in spite of decreased photosynthesis. Davenport, Hagan and Martin (3), California, felt that with stomate-closing antitranspirants (not film-forming) transpiration ratios should be reduced, i.e., less water transpired per unit of growth, providing the applied chemicals do not damage the plants internal photosynthetic mechanism. However, with film-forming antitranspirants they found that there were large reductions in transpiration rates, but since the $H_2O:CO_2$ permeability ratios tend to exceed unity for currently available materials, the transpiration ratios may not be reduced. With one film-forming antitranspirant (CS6432: Chevron chemical company) used on *Nerium oleander* leaves the transpiration ratio was temporarily increased because of a greater reduction in photosynthesis than in transpiration. After two days this trend was reversed, possibly due to decreasing continuity of the film on the leaf surface (3). They go on to say that this could be advantageous by preventing large reductions in photosynthesis while still achieving a retardation of transpiration.

Another possible physiological problem with antitranspirants is temperature buildup. Davenport, Hagan and Martin (3) stated that leaves dissipate heat chiefly by thermal emission so there is no danger of heat buildup due to the use of antitranspirants. Gale and Hagan (9) also stated that only under extreme conditions of high incident radiation and very low wind velocity would leaf temperature be significantly raised by reduction of transpiration.

However, this is in contrast to Thames (29) who attributed the failure of wax emulsions on loblolly pine to heat being trapped inside the coatings by the greenhouse effect.

There has also been a limited amount of study done on species response to different antitranspirants. One particular article by Gale, et al. (10) in Israel, stated that xeromorphic plants such as pines are so efficient in reducing transpiration when the soil is dry that antitranspirants treatments can be of little or no use. However, most research in this area is summarized by stating that none of the antitranspirants tested were superior for all species of plants (26,30).

Whitcomb and Davies (36), Florida, studied the use of antitranspirants for the rooting of Juniperus chinensis 'Hetzi' and Podocarpus macrophylla cuttings. Cuttings were placed directly in one gallon containers after being dipped in antitranspirant concentrations of 5% or 25% and placed in full sun or in 50% shade with all of the cuttings being coated with antitranspirant except the basal end. Cutting bases were either untreated or treated with 3,000 p.p.m. IBA. Their results indicate that shade is needed for best rooting of both species. The antitranspirant, Foli-gard, at 5% in shade showed best results for Junipers. In most cases, with either species, the rooting was actually better than under the conventional intermittent mist check. Podocarpus rooting occurred about 2 weeks sooner than controls and the Junipers two weeks later than the mist check. The question remains as to the effectiveness of this technique with different species, shade treatments, antitranspirants and perhaps most importantly, environmental conditions (23).

All of the areas mentioned in this review cannot be explored in one series of experiments. They are only pointed out in an effort to show the extent and complexity of research in the vegetative propagation of hard to root plant materials and in locating more efficient ways of rooting. This study was set up primarily to determine the usefulness of further developments along the lines of the research done by Whitcomb and Davis (36), in Florida, while taking into consideration improvements that could be contributed by other research done in this area.

CHAPTER III

MATERIALS AND METHODS

Experiment I was designed to determine the effects of various combinations of antitranspirants, auxin levels and light on the rooting of *Juniperus chinensis* 'Hetzi' and *Juniperus scopulorum* 'Blue Heaven' cuttings without mist. The following set of factorial treatment combinations were used:

5 antitranspirants (10 percent concentration):

1. Foli-Gard (acrylic copolymer)
2. Folicoat (emulsifiable wax)
3. Wiltpruf (a polyvinyl chloride)
4. Dry Check (no antitranspirant)
5. Mist check (2 seconds/minute of daylight hours)

5 levels of auxin (Hormex,* talc preparation of IBA):

1. None
2. 8,000 ppm
3. 16,000 ppm
4. 30,000 ppm
5. 45,000 ppm

3 levels of shading:

1. No shade
2. 33 percent shade from saran
3. 62 percent shade from saran

All treatments were replicated 10 times. *Juniperus*

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*A Commercial Talc Preparation Containing IBA, Manufactured by Brooker Chemical Company, Hollywood, California.

scopulorus 'Blue Heaven' (hereafter referred to as 'Blue Heaven' juniper) cuttings were stuck on December 1 and 2. Juniperus chinensis 'Hetzi' (hereafter referred to as 'Hetzi' juniper) were stuck December 8. Six inch terminal cuttings of each of the two species were taken and placed on per 3.5 inch square plastic container. The rooting medium was a 1-1 by volume mix of peat and perlite. All antitranspirant treated cuttings and the dry check were placed on wire benches in a clear plastic greenhouse where humidity was maintained between 65 and 80 percent by wetting walls and floors several times daily. Relative humidity was monitored mid-morning and mid-afternoon daily. The rooting medium was watered directly as needed. Control cuttings in the mist were stuck at the same time and received the same auxin and light intensity treatment. The mist cycle was 2 seconds on every minute during the daylight hours.

Experiment II was designed to determine the effects of antitranspirant coatings on nutrient leaching under mist. This phase of the research was done with 'Hetzi' juniper and initiated at the same time as experiment I. It consisted of the following factorial set of treatment combinations:

5 sampling dates:

1. Before misting
2. 2 weeks in mist
3. 4 weeks in mist
4. 6 weeks in mist
5. 8 weeks in mist

7 antitranspirant treatments:

1. None

2. Folicoat 10 percent
3. Foli-Gard 10 percent
4. Wiltpruf 10 percent
5. Folicoat 20 percent
6. Foli-Gard 20 percent
7. Wiltpruf 20 percent

All treatments were replicated 10 times. The mist cycle, container size, and rooting medium was the same as in experiment I. All cuttings were treated with 16,000 p p m auxin as a talc preparation.

Experiment III was based on the results of experiments I and II. It was designed to determine the effectiveness of antitranspirants in reducing water loss from plant tissue. The experiment consisted of the following factorial treatment combinations:

3 antitranspirants:

1. Foli-Gard
2. Folicoat
3. Wiltpruf

3 concentrations of each antitranspirant:

1. 0 percent
2. 10 percent
3. 20 percent

All of the treatments were replicated 6 times. 'Hetzi' juniper and <u>Ligustrum japonicum</u> (hereafter referred to as ligustrum) cuttings were taken, weighed, dipped entirely in the appropriate treatment, allowed to dry and then weighed again. Cuttings were placed on an open laboratory table with no direct sunlight. Every 48 hours thereafter all samples were weighed. This continued until water loss was negligible. Relative humidity in the laboratory ranged from 60 to 65 percent and was monitored daily with a sling psychrometer.

Experiment IV was based on the results of the previous experiment. It was designed to determine the stability of antitranspirant films on foliage of 2 plant species at 2 relative humidities and the relative water loss from plant tissue. The following factorial set of treatment combinations was used with 'Hetzi' juniper and ligustrum:

3 antitranspirants:

1. Foli-Gard
2. Folicoat
3. Wiltpruf

2 concentrations of each antitranspirant:

1. 0 percent
2. 10 percent
3. 20 percent

2 levels of humidity:

1. Low (60-65 percent)
2. High (90-95 percent)

All treatments were replicated 3 times. Methods of taking cuttings and applying treatments were the same as in experiment III. Cuttings to receive low humidity conditions were placed on an open laboratory table. Cuttings to receive high humidity conditions were placed on wire racks in large boxes lined with wet paper towels. Relative humidity was monitored daily in both areas with a sling psychrometer. All cuttings were observed under a binocular microscope twice daily to determine the stability of the antitranspirant films. At the end of four days all cuttings were weighed, oven dried and weighed again to determine the moisture content of the tissue.

CHAPTER IV

RESULTS AND DISCUSSION

Experiment I

There were no significant differences in the rooting of any of the antitranspirant treated cuttings, of either species, at any light intensity or auxin level. The 'Hetzi' juniper cuttings did root sporadically using the antitranspirant treatments with 142 out of 600 cuttings initiating root systems of varying quality. However, there was no consistent relationship with treatments. The 'Blue Heaven' juniper cuttings rooted even less frequently under the antitranspirant treatments with only 9 out of 600 initiating roots.

On the other hand, the control cuttings under intermittent mist and receiving the same light and auxin treatments rooted well (Table II). There were no significant differences between any of the mist controls. However, the 'Hetzi' juniper cuttings rooted 100 percent in all light intensities except where 45,000 ppm auxin was used under 33 and 62 percent shade. Auxin level did not appear to be critical, but, root grade was highest with 16,000 ppm in most cases. Mean root grade of cuttings decreased with increasing shade.

'Blue Heaven' juniper cuttings rooted better in mist

TABLE II

ROOTING OF 'HETZI' JUNIPER CUTTINGS UNDER MIST AT VARIOUS AUXIN LEVELS AND LIGHT INTENSITIES AFTER 14 WEEKS

	NO SHADE		33% SHADE		62% SHADE	
Auxin Levels (ppm IBA)	Mean Root Grade	%3's or better*	Mean Root Grade	%3's or better*	Mean Root Grade	%3's or better*
0	8.6	100	7.6	100	6.6	100
8,000	9.2	100	7.8	100	5.7	100
16,000	9.2	100	8.9	100	7.3	100
30,000	9.0	100	8.7	100	6.8	100
45,000	9.5	100	8.3	90	6.1	90

*Based on a scale of 1 to 10 with 1 = no roots developed, 3 = minimum roots for plant survival, 10 = a heavily rooted cutting.

than with antitranspirants (Table III). With no shade, cuttings generally rooted better with increasing auxin levels. Cuttings under 33 percent shade rooted equally well as those with no shade, but better than those with 62% shade.

No benefit was derived from antitranspirants in the rooting of cuttings of either species. 'Hetzi' juniper cuttings rooted well with nearly all treatments under mist. 'Blue Heaven' juniper, although not rooting sufficiently well to be commercially feasible, did show promise with mist and 16,000 ppm auxin.

This experiment constitutes the original thrust of this research which was to further develop and test procedures used to root cuttings by the use of antitranspirants as a replacement for mist. Even though different researchers have come up with a variety of results using antitranspirants, there was still room for considerable optimism. Based on the success of Whitcomb and Davis (36), in Florida it seemed a relatively straight forward task to develop a similar system in Oklahoma. This did not prove to be the case and further research was done to locate a possible solution for the failure in experiment I. It was felt that additional tests of the antitranspirants ability to control water loss under more controlled conditions was needed therefore experiment III was done.

Experiment II

There were no significant differences between

TABLE III

ROOTING OF 'BLUE HEAVEN' JUNIPER CUTTINGS UNDER MIST
AT VARIOUS AUXIN LEVELS AND LIGHT
INTENSITIES AFTER 15 WEEKS

	NO SHADE		33% SHADE		62% SHADE	
Auxin Levels (ppm IBA)	Mean Root Grade	%3's or better*	Mean Root Grade	%3's or better*	Mean Root Grade	%3's or better*
0	2.5	40	1.6	30	1.2	10
8,000	1.4	10	4.4	60	1.7	20
16,000	3.6	50	2.8	50	1.3	10
30,000	2.8	50	3.9	50	2.1	20
45,000	4.3	50	2.4	50	2.2	30

*Based on a scale of 1 to 10 with 1 = no roots developed, 3 = minimum roots for plant survival, 10 = a heavily rooted cutting.

antitranspirant treatments in preventing leaching loss of nitrogen, potassium, calcium or magnesium from cuttings under mist (Table IV). However, potassium levels decreased with increasing time under mist (Table V). This is in contrast to work by Joiner and Gruis (16) who reported that potassium lost to leaching occurred primarily in the first 4 weeks, which was their first sampling date. Based on these results no more research in this area seemed fruitful and the search proceeded to experiment III.

Experiment III

It was felt that by taking weight measurements at intervals a closer approximation of when the antitranspirant failed could be made. The weight of antitranspirant treated 'Hetzi' juniper and ligustrum cuttings decreased 23-24 percent in 48 hours (Tables VI and VII). The controls decreased in weight 25-26 percent during the same period. At the termination of the experiment (10 days), all cuttings had decreased in weight by 44-46 percent.

These results and results from experiment I conflict with the research done in Florida. In considering the possible differences between the two studies (Florida and Oklahoma) it was felt that the relative humidity of the two areas could have played a major role. Therefore, the identical treatments were used as in experiment III with low humidity normal to this area and high humidity chambers.

TABLE IV

EFFECTS OF ANTITRANSPIRANT TREATMENTS ON MEAN NUTRIENT LOSS FROM *JUNIPERUS CHINENSIS* 'HETZI' CUTTINGS UNDER MIST

COATINGS	RATE	PPM POTASSIUM	PPM CALCIUM	PPM MAGNESIUM	PPM NITROGEN
Control	0	6367 a[z]	2784 a[z]	1406 a[z]	125
Folicoat	10%	7133 a	2690 a	1407 a	125
Folicoat	20%	6283 a	2629 a	1442 a	125
Foli-Gard	10%	7283 a	2494 a	1343 a	125
Foli-Gard	20%	7200 a	2640 a	1442 a	125
Wiltpruf	10%	7183 a	2610 a	1431 a	125
Wiltpruf	20%	6633 a	2691 a	1410 a	125

[z]All means followed by the same letter are not significantly different at the 5 percent level.

TABLE V

PPM POTASSIUM IN 'HETZI' JUNIPER CUTTINGS DURING THE MISTING PERIOD

TIME

	BEFORE MISTING	2 WEEKS	4 WEEKS	6 WEEKS	8 WEEKS
POTASSIUM PPM	7381	7179	7167	6441	6149

TABLE VI

PERCENT WEIGHT LOSS FROM 'HETZI' JUNIPER CUTTINGS MEASURED AT VARIOUS TIME INTERVALS AFTER TREATMENT WITH ANTITRANSPIRANTS

Coating	Rate	0-2 Days	2-4 Days	4-6 Days	6-8 Days	8-10 Days
Folicoat	10%	23.0_{a}^{z}	13.2_{a}^{z}	8.1_{a}^{z}	3.7	1.5
Folicoat	20%	22.8_{a}	13.5_{a}	8.0_{a}	3.9	1.5
Wiltpruf	10%	24.5_{abc}	13.6_{a}	7.9_{a}	3.4	1.3
Wiltpruf	20%	24.2_{ab}	13.7_{a}	7.7_{a}	3.6	1.4
Foli-Gard	10%	27.8_{c}	14.0_{a}	6.8_{a}	2.8	1.1
Foli-Gard	20%	24.9_{abc}	13.9_{a}	6.9_{a}	2.7	1.1
Control	0	26.4_{bc}	13.5_{a}	6.2_{a}	2.5	1.9

[z]All means followed by the same letter are not signifiantly different at 5 percent level.

TABLE VII

PERCENT WEIGHT LOSS FROM LIGUSTRUM CUTTINGS MEASURED
AT VARIOUS INTERVALS AFTER TREATMENT
WITH ANTITRANSPIRANTS

Coating	Rate	0-2 Days	2-4 Days	4-6 Days	6-8 Days	8-10 Days
Folicoat	10%	25.6_{b}^{z}	17.8_{c}^{z}	12.7_{a}^{z}	4.8	1.7
Folicoat	20%	23.7_{ab}	15.2_{a}	12.5_{a}	7.2	1.9
Wiltpruf	10%	24.4_{ab}	16.0_{ab}	11.6_{a}	6.5	2.1
Wiltpruf	20%	24.0_{ab}	16.3_{ab}	11.9_{a}	7.1	2.1
Foli-Gard	10%	22.6_{a}	16.1_{ab}	12.9_{a}	8.3	1.9
Foli-Gard	20%	24.6_{ab}	15.9_{ab}	12.0_{a}	6.5	1.8
Control	0	25.6_{b}	16.9_{bc}	12.1_{a}	6.0	1.1

^{z}All means followed by the same letter are not significantly different at the 5 percent level.

Experiment IV

Visual observations of the antitranspirant coatings using a binocular microscope showed good coverage from all antitranspirants initially, however, by the end of the fourth day all coatings in the low humidity were cracking and showing obvious signs of stress. This is in agreement with Gale and Hagan (9) who believed that a number of environmental factors could cause degradation of antitranspirant films. This is further supported by Davenport, Hagan and Martin (3), who stated that the film could last from a few days to several weeks and attributed environmental conditions as one of the major problems. No signs of coating deterioration were visible in the high humidity chambers. At the end of the fourth day, ligustrum cuttings in the high humidity retained from 7 percent (20 percent, Folicoat) to 18 percent (20 percent, Foli-Gard) more moisture than untreated controls (Table VIII). Ligustrum cuttings in the low humidity, however, retained 8 percent more moisture than the control when treated with 10 percent Folicoat but lost 23 percent more moisture than the control when treated with 10 percent Wiltpruf. Antitranspirant treatments had no effect on 'Hetzi' juniper cuttings in high humidity (Table IX), but there was a 3 to 16 percent decrease in water loss in low humidity with the use of antitranspirants. It is interesting to note here that Davies and Kozlowski (5) felt that both environment and species influenced antitranspirant performance.

TABLE VIII

EFFECTS OF ANTITRANSPIRANTS ON PERCENT WATER RETAINED IN LIGUSTRUM CUTTINGS AT LOW OR HIGH HUMIDITY AFTER 4 DAYS

COATING	RATE	LOW HUMIDITY	HIGH HUMIDITY
Folicoat	10%	48.2_a^z	62.6_b^z
Folicoat	20%	41.4_a	58.2_b
Wiltpruf	10%	34.0_a	60.0_b
Wiltpruf	20%	34.0_a	62.9_b
Foli-Gard	10%	46.0_a	62.1_b
Foli-Gard	20%	45.5_a	65.8_b
Control	0	44.2_a	54.2_b

[z] All means followed by the same letter are not significantly different at 5% levels.

TABLE IX

EFFECTS OF ANTITRANSPIRANTS ON PERCENT WATER RETAINED IN 'HETZI' JUNIPER CUTTINGS AT LOW OR HIGH HUMIDITY AFTER 4 DAYS

COATING	RATE	LOW HUMIDITY	HIGH HUMIDITY
Folicoat	10%	25.7_a^z	59.4_a^z
Folicoat	20%	33.8_a	55.9_b
Wiltpruf	10%	28.4_a	59.0_b
Wiltpruf	20%	34.2_a	58.8_b
Foli-Gard	10%	32.2_a	55.7_b
Foli-Gard	20%	29.3_a	57.1_b
Control	0	24.9_a	55.6_b

[z]All means followed by the same letter are not significantly different at 5% level.

These data show that the use of antitranspirants as a replacement for mist is not practical under low humidity conditions. The primary cause of failure is the breaking of the antitranspirant coating. These data also suggest that the use of antitranspirants on any landscape plants in areas of low humidity is of doubtful benefit. Because of the stability of the antitranspirant coating under high humidity, the basic technique of using antitranspirants as a substitute for mist and to aid in transplanting and other landscape uses appears to hold promise. There is, however, the possibility that more durable chemicals may be developed which would retard transpiration for a longer period of time under low humidity conditions. It must be pointed out that an ever present problem with any future coating, as with present ones, would be carbon dioxide permeability and other possible interference with the photosynthetic process.

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VITA

Gordon Clarke Hall

Candidate for the Degree of

Master of Science

Thesis: THE EFFECTS OF FILM FORMING ANTITRANSPIRANTS ON NURSERY PRACTICES

Major Field: Horticulture

Biographical:

Personal Data: Born in Tulsa, Oklahoma, March 21, 1950 and is the son of E.A. and Mary E. Hall.

Education: Graduated from Thomas A. Edison High School, Tulsa, Oklahoma, in May, 1968; received Bachelor of Science degree in Agriculture with a major in Forestry, May, 1973.

Professional Experience: Currently employed by Oklahoma State University Extension Service as an Extension Agent for 4-H and youth; Comanche County, Oklahoma.