Reduction of Salt Buildup and Twig Injury in Roadside Peach Trees with Film-Forming Sprays

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Peach trees located along a major highway were sprayed in November 1987 with five film-forming products (Folicote, RD 1725, RD 1726, Rhodorsil, and Joncryl 1938). There were also two control (unsprayed and burlap-covered) treatments. By spring 1988, burlapped twigs accumulated the least chloride (0.29 percent by dry weight of twig tissue) and twigs were least injured (5.3 cm dieback). In contrast, unsprayed twigs accumulated the most chloride (1.79 percent) and were the most injured (139 cm dieback). Corresponding data for spray-treated twigs were intermediate, indicating small-to-moderate beneficial influence of most products, especially RD 1726 (1.39 percent chloride ion; 8.7 cm dieback) and Joncryl 1938 (1.24 percent chloride ion; 7.4 cm dieback). Burlapped and unsprayed twigs contained 0.08 and 0.31 percent sodium, respectively, and all spray-treated twigs between 0.30 and 0.36 percent sodium. In another study, peach trees were sprayed with Folicote, RD 1725, and four other emulsion-based formulations (RD 2033, RD 2034, RD 2035, and RD 2036); half of each tree was sprayed several times during the winter with a 2 percent rock salt solution. Twigs treated with RD 2034 showed the least injury and accumulated moderately less salt than the control twigs from both salted and nonsalted sides of trees. All other treatments were ineffective, and in fact twigs treated with RD 2034 accumulated more salt than the control and had the greatest injury. Scanning electron and light microscopy revealed progressive deterioration in the surface integrity of Folicote, RD 1725, RD 2033, RD 2034, RD 2035, and RD 2036 during the winter. RD 2033 deteriorated the least and RD 2034 the most.

Application of salt to major highways during the winter is a common practice in northern areas of the United States and Canada. Numerous studies have established that roadside salt sprays cause significant damage to roadside vegetation (*1,2*). Expression of salt injury symptoms results from physiological drought or desiccation (*3,4*).

Film-forming antitranspirants or antidesiccants have been used experimentally to prevent winter injury (*4–6*). These products form a thin vapor barrier that limits water loss (*7*).

Reisch (*8*) reported that the antidesiccants Vapor Gard and Foli-Gard reduced needle browning on white pine and Norway spruce sprayed with sodium chloride (NaCl). Emmons et al. (*9*) reported that, as in Germany, antidesiccants were ineffective in reducing salt damage under Minnesota highway conditions. In fact, both Vapor Gard and Wilt Pruf increased damage on Austrian pine; Wilt Pruf caused heavy needle mortality of Pfitzer juniper (*9*). In view of the limited research, inconsistent results, and renewed interest in the potential of film-forming products as aids to protecting trees against roadside salt, Piedrahita (*10*) screened 18 different antidesiccants and related film-forming products during a 3-year period and identified five superior products for further testing.

The objectives of this study were to reevaluate under field conditions these five previously selected products, to test four other formulations, and to assess the durability or integrity of these new products during the winter using microscopy.

MATERIALS AND METHODS

Plant Material and Film Treatments

Location 1

Twenty 8-year-old trees of Garnet Beauty peach [*Prunus persica* (L.) Batsch.] planted in two 10-tree rows bordering the southern side of a major highway near Grimsby, Ontario, were used. Row 2 was located 36 m away and furthest from the highway; Row 1 was located 31 m away from the highway and separated from Row 2 by a row of pear trees. There was a buffer row of pear trees in front of Row 1 (26 m from the highway).

On November 9, 1987, selected branches on each tree were sprayed with Folicote, RD 1725, RD 1726, Rhodorsil, and Joncryl 1938, prepared according to the manufacturers' recommended dilution rates (Table 1). There were also two control (unsprayed and burlap-covered) treatments. During spraying, the prevailing weather was clear and sunny, and air temperature was 10°C. Each formulation was applied to the point of runoff with a 20-L compressed-air sprayer to which was added Triton XR surfactant (Rohm and Haas, Ontario) at a rate of 2.5 ml per liter of product. Overspray onto adjacent branches was prevented by a large polyethylene sheet covering. The experimental design was split plot with treatments as main plots and rows as subplots.

Twig Samples

On April 11, 1988, two 30-cm twigs per treatment branch were sampled for chemical analysis. On May 12 (budbreak), dieback was determined on two similar twigs and expressed as the distance in centimeters from the terminal to the first

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TABLE 1 RATES AND DESCRIPTION OF FILM-FORMING PRODUCTS

Product	Type of Product	Major Use	Dilution (v/v)[z]	% Solids at dilution	Low temperature threshold (o°C)	Colour after application	Source
Folicote	Wax emulsion	Antidesiccant	1:10	5.0	6-8	Translucent	Aquatrols Corp., N.J.
Joncryl 1938	Acrylic polymer	Water-proof	1:5	10.0	4-5	"	Johnson and Sons, Ontario
Rhodorsil (Siliconate 51T)	Silicon	Treatment of tile and brick	1:50	8.0	0	"	May and Baker, Ontario
RD 1725	Wax emulsion	Tree protectant[y]	1:5	10.0	4-5	"	International Waxes, Ontario
RD 1726	" "	"	1:3	10.0	4-5	"	" "
RD 2033	" "	"	1:3	10.6	4-5	White	" "
RD 2034	" "	"	1:3	12.0	4-5	"	" "
RD 2035	" "	"	1:3	11.7	4-5	"	" "
RD 2036	" "	"	1:5	10.0	4-5	Translucent	" "

[y] New product formulated for this research project.

[z] Volume of water to volume of product.

TABLE 2 DIEBACK AND SALT CONTENT IN TWIGS OF GARNET BEAUTY PEACH TREES SPRAYED WITH VARIOUS FILM-FORMING PRODUCTS

Treatments	Twig dieback (cm)[y]	Na^+	Cl^-
		(% dry weight)	
	Film effects		
Untreated	13.6 a[x]	0.31 b	1.79 a
Folicote	10.0 abc	0.31 b	1.45 b
RD 1725	11.8 ab	0.32 ab	1.35 b
Rd 1726	8.7 bed	0.34 ab	1.39 b
Rhodorsil	12.3 a	0.36 a	1.43 b
Joncryl	7.4 cd	0.30 b	1.24 b
Burlap	5.3 d	0.08 c	0.29 c
	Row effects		
Row 1[v]	13.2 a	0.32 a	1.48 a
Row 2[v]	7.5 b	0.25 b	1.08 b

Background levels: 0.035 ppm Na^+; 0.14 ppm Cl^-.

[y] Analysis of variance conducted on values transformed to log (x+1).

[x] Values in columns followed by the same letters are not significantly different from each other at the 5% level by Duncan's multiple range test.

[v] 31 and 36 m from the highway, respectively.

istic hollows formed by other films (Figures 2a–2f). Whereas RD 2035 tended to be smooth and less rippled (Figure 2d), RD 2033 (Figure 2e) and Folicote (Figure 2f) appeared more textured, especially at higher magnifications. Lenticels occluded by RD 2033 (Figure 2e) and occluded to a lesser degree by RD 2036 (Figure 2b) were typically less hollowed and more difficult to discern, indicating thorough coverage of these films.

Unprotected lenticels of nonsalted control twigs appeared wart-like at lower magnifications (Figure 3a). Corresponding salted control twigs appeared pitted (Figure 3c) and, at higher magnifications, the contour in the vicinity of these lenticels tended to appear somewhat softer or less textured (Figure 3d) than that of nonsalted counterparts (Figure 3b).

By the end of December, the surfaces of RD 2034 and RD 2035 (both nonsalted and salted twigs) under light microscope appeared glossier and thinner than in early December. Under SEM, about 25 and 10 percent of lenticels on the surfaces of RD 2034 and RD 2035, respectively, were unplugged. Salted surfaces of twigs treated with RD 2034 (Figures 4a and 4b) and RD 2035 (Figures 4c and 4d) were characterized by sunken and darkened, blotched, or watermarked areas in the vicinity of the lenticels, although most lenticels remained blocked. This appearance provides evidence of early deterioration in the surfaces of RD 2034 and RD 2035.

By late January, progressive deterioration occurring most rapidly in RD 2034 was observed in all films except RD 2033. By late March, all films, including RD 2033, appeared markedly different (Figures 5 and 6) than in December (Figure 2). Both nonsalted (Figure 5) and salted (Figure 6) films appeared thinner, etched, or weathered, with bare patches or uneven coverage. Except for RD 2033 (nonsalted, Figure 5E; salted, Figure 6E), 50 to 75 percent of lenticels were unplugged in most of the other treatments.

For apple trees, in similar SEM studies conducted by Piedrahita (*10*), Folicote, RD 1725, RD 1726, and Joncryl 1938 covered twigs evenly in all areas except the lenticels, which remained only partially plugged. By February or March, most of the lenticels were exposed. Longitudinal fissures, observed living flower bud subtended by living stem. Data for twig dieback were transformed to log $(x + 1)$ before analysis of variance.

Location 2

Twenty-eight 12-year-old Madison peach trees, situated 45 to 50 m from the northern edge of the same highway in St. Catharines, Ontario, were assigned to four replications of seven trees each.

On November 30, 1987, individual trees within a replicate were sprayed with Folicote, RD 1725, RD 2033, RD 2034, RD 2035, or RD 2036 (Table 1). One control tree per replicate was not sprayed. During spraying, the prevailing weather was cloudy, overcast, and calm, and the air temperature was 7°C. Two hours after spraying was completed, a light drizzle started and continued for 24 hr. On December 14, 1987, January 12, 1988, February 9, 1988, and March 8, 1988, half of each tree was sprayed with a 2 percent rock salt (NaCl) solution. The experimental design was a split plot with film treatments as main plots, and nonsalted or salted sides as subplots.

Twig Samples

Samples consisting of four 30-cm twigs were taken both from unsalted and salted sides of each tree on December 29, 1987, January 27, 1988, February 23, 1988, March 24, 1988, and April 13, 1988, for microscopic examination and chemical analysis. On May 1, all flower and vegetative buds were counted in situ on three twigs per treatment. On May 10 (budbreak), viable buds were recounted and percentages of dead flower buds per twig were calculated. Twig dieback was determined as described. Data for twig dieback and percentage of dead flower buds were transformed to log $(x + 1)$ and arcsin $\sqrt{x}$, respectively, before analysis of variance.

Microscopy

On each sampling date, two twigs per treatment within two randomly selected replications were examined along their entire length under a stereo light microscope to assess the integrity of each film as the winter progressed. Several 1- to 2-cm fingernail scrapes along the twig gave an indication of the relative thickness of each treatment layer. A 1-cm specimen also was removed from each twig, at one-third the distance from the tip. Each specimen was mounted on an aluminum stub, air-dried for 72 hr, coated with gold-palladium, and examined at 20- to 25-mm working distance at 20 kV with a Hitachi S-570 scanning electron microscope (SEM) at four separate points, one on each side and two along the top of the specimen.

Chemical Analysis

Twig samples for chemical analysis were dried and ground. After dry ashing at 550°C, sodium (Na^+) was determined by emission spectrometry and chloride (Cl^-) using a Cl^- electrode (*11*). Na^+ and Cl^- background levels in twigs at both locations were determined from twig samples taken in November before the start of the experiments. The amounts of Na^+ and Cl^- were converted to percentages of the dry weight of the twig sample.

RESULTS AND DISCUSSION

Location 1

In the spring, Garnet Beauty peach trees closer to the highway (Row 1) had more twig dieback and accumulated more Na^+ and Cl^- than trees further from the highway (Table 2), similar to results of other researchers (*11,12*).

Untreated twigs accumulated large quantities of Cl^- (1.79 percent dry weight) and showed considerable damage (13.6-cm dieback) (Table 2). In contrast, burlapped twigs accumulated only 0.29 percent Cl^- and showed considerably less damage (5.3-cm dieback). All spray-treated twigs accumulated moderately less Cl^- (1.24 to 1.45 percent) and exhibited intermediate injury. Among spray treatments, twigs sprayed with RD 1726 and Joncryl had less dieback (8.7 and 7.4 cm, respectively). Accumulation of Na^+ was least in burlapped twigs (0.08 percent), high in Rhodorsil-treated twigs (0.36 percent), and in intermediate amounts (0.30 to 0.31 percent) in all other treatments, including untreated twigs.

Location 2

The Na^+ and Cl^- contents (Figure 1a) in twigs of Madison peach increased progressively during the winter, peaking or plateauing in late March. Twigs sprayed with RD 2033 accumulated the least quantities of Na^+ and Cl^- during the winter (Figures 1a and 1b) and tended to show the least dieback (4.1 cm) and dead flower buds (13 percent) (Table 3). Compared with nonsalted twigs, salted twigs accumulated significantly more Na^+ and Cl^- during the winter (Figures 1c and 1d), but contents apparently were not high enough to cause a difference in twig or flower bud injury (Table 3). There was no interaction between film and rock salt. Except for RD 2034, which accumulated more Na^+ and Cl^- than control twigs (Figures 1a and 1b), and had extensive twig injury (Table 3), reductions of salt content or injury by other films were not sufficiently large to be meaningful.

Film Integrity

Notwithstanding the drizzle that began soon after spraying was completed (on November 9, 1987), all formulations exhibited good coverage when twigs were examined 2 days later under a light microscope. There were apparent variations in surface morphology and thicknesses of the films, with RD 2033 appearing the thickest.

Under SEM, RD 1725 (Figure 2a) and RD 2030 (Figure 2b) appeared as heavily coated and velvety or smooth surfaces, with complete occlusion of the lenticels. Lenticular occlusions by RD 2034 often appeared as pebbly, flattened, and undefined areas (Figure 2c) in contrast to the character-

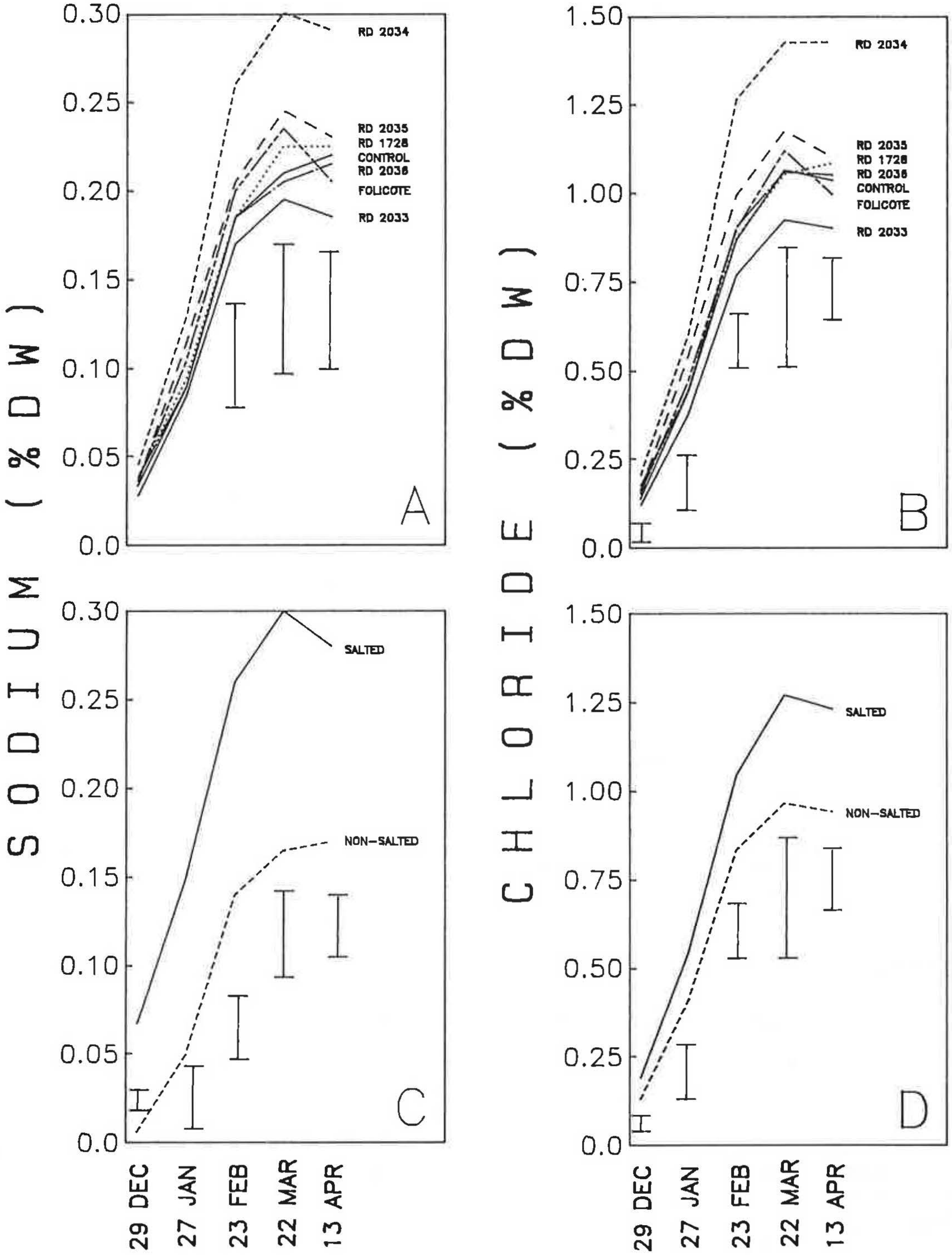

FIGURE 1 Contents of Na^+ and Cl^- during the winter in nonsalted and salted peach twigs covered with various film-forming products. Vertical bars represent least significant difference values at the 5 percent level of probability.

TABLE 3 DIEBACK AND PERCENTAGE OF DEAD FLOWER BUDS IN TWIGS OF MADISON PEACH TREES SPRAYED WITH VARIOUS FILM-FORMING PRODUCTS AND WITH REPEATED APPLICATIONS OF 2 PERCENT ROCK SALT SOLUTION

Treatments	Twig dieback (cm)[z]	% Dead flower buds[y]
	Film effects	
No film	6.0 bc[x]	46 ab
Folicote	5.9 bc	40 ab
RD 1725	11.0 ab	33 bc
RD 2033	4.1 c	13 c
RD 2034	7.9 abc	58 a
RD 2035	8.2 abc	45 ab
RD 2036	16.5 a	26 bc
	Rock salt effects	
Non-salted	7.5 a	32 a
Salted	9.6 a	38 a

[z] Analysis of variance conducted on values transformed to log (x+1).

[y] Analysis of variance conducted on values transformed to arcsin √x.

[x] Values in columns followed by the same letter are not significantly different from each other at the 5% level by Duncan's multiple range test.

as early as mid-December in certain films and plentiful by February or March (*10*), were seldom observed and appeared only in RD 2035 and once with Folicote in the present study.

GENERAL DISCUSSION

The field investigation conducted at Location 1 during the winter of 1987–1988 showed that all five products, Folicote, RD 1725, RD 1726, Rhodorsil, and Joncryl, moderately reduced buildup of Na^+ and Cl^- in peach twigs. There was a tendency for less dieback in all spray-treated twigs, but only those treated with RD 1726 and Joncryl 1938 had significantly less damage statistically ($p < 0.05$) than the unsprayed control. The burlap method of protection produced excellent results as exemplified by the dramatic reduction both in salt buildup and twig injury; it has been used on a small scale for years at Location 1. However, this method is not practical on a large scale.

In investigations conducted during the winter of 1986–1987 (*10*), several or all five of these products reduced salt and twig injury to white pine, red pine, and Austrian pine, but had little or no effect on peach. There was some prevention of injury on apple trees by one or more of these products, but results were more variable or treatments ineffective after treating various other deciduous species, including silver maple, lilac, and black willow (*10*). In related tests conducted on these same species during the winter of 1987–1988, all five products resulted in small but significant reductions in twig injury of red pine. Except for Rhodorsil, all spray-treated red pine twigs also contained less salt than unsprayed twigs. There were few or no consistent effects of the products on the other species.

The investigation conducted at Location 2 indicated that film thickness and resistance to weathering play an important role. Electron microscopy indicated a progressive deterioration of surface films during the winter, and this process was apparently accentuated by salt. One product, RD 2033, which deteriorated the least and was thickest, suppressed salt levels and reduced flower bud injury by providing persistent coverage throughout the winter. In contrast, RD 2034 had the opposite effect because of early and more rapid loss of physical integrity of this film. The increases in salt content in twigs despite the film barrier suggests that the film may have reacted chemically with the salt and influenced the physiology of the twigs. According to Simini and Leone (*13*), the physical and chemical properties both of salt particles and plant tissue can be altered by high relative humidity. However, differences in films are most likely related to prevailing environmental factors (*7*) and also to physical factors of the films such as composition, plasticity, or drying characteristics (*4*). For instance,

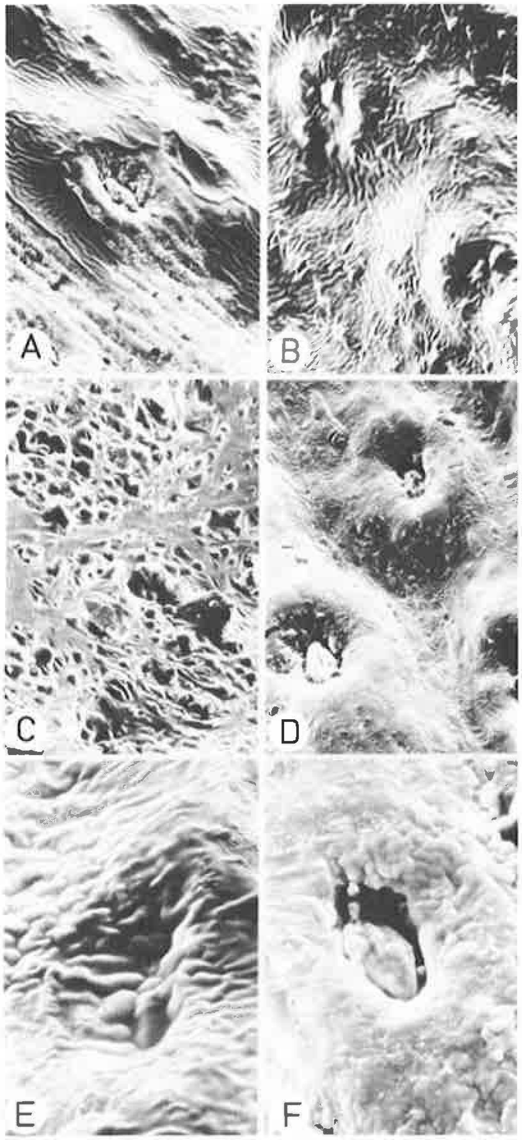

FIGURE 2 Surfaces of peach twigs 2 days after treatment in the fall with various film-forming products: (a) RD 1725 (×1,750); (b) RD 2036 (×1,750); (c) RD 2034 (×2,500); (d) RD 2035 (×2,500); (e) RD 2033 (×5,000); (f) Folicote (×5,000).

RD 1725 and RD 2036 are similar in composition; RD 2033 contains a different emulsifier than those of the other RD series; and RD 2034 is made of the most flexible and tacky plastic wax base. According to Davenport (*14*), phytotoxicity of film-forming products is usually caused by the emulsifier system rather than by the water vapor barrier.

CONCLUSION

The present study confirms that film-forming products reduce buildup of salt in twigs of roadside trees and provide some protection against salt spray injury. Although the results are interesting and significant, the products have not yet been tested under severe winter conditions. Winter temperatures during the past several years at the test locations have been

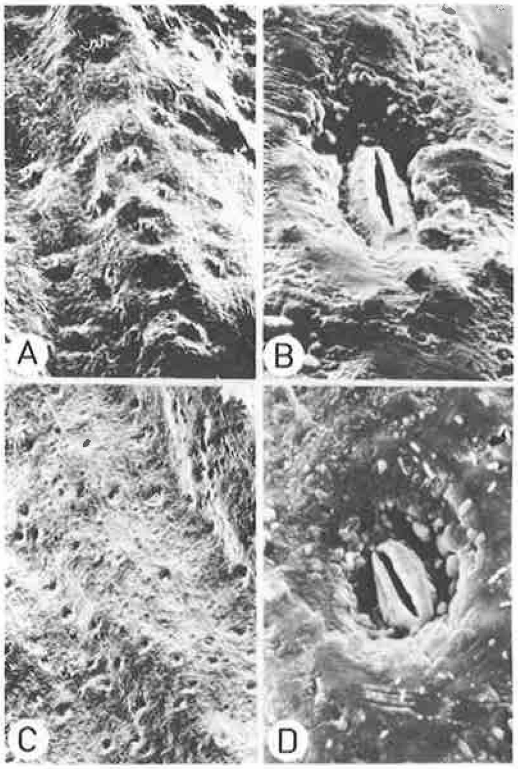

FIGURE 3 Surfaces of nonsalted control peach twigs in late December (a) ×875, (b) ×7,500; and corresponding twigs salted with 1 application of 2 percent rock salt solution (c) ×500, (d) ×5,000.

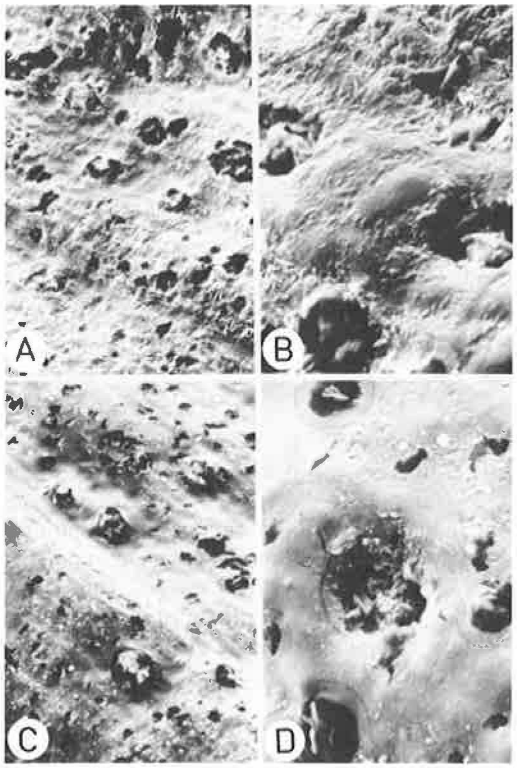

FIGURE 4 Surfaces of salted peach twigs in late December covered with RD 2034 (a) ×1750, (b) ×5,000; or RD 2035 (c) ×1750, (d) ×5000.

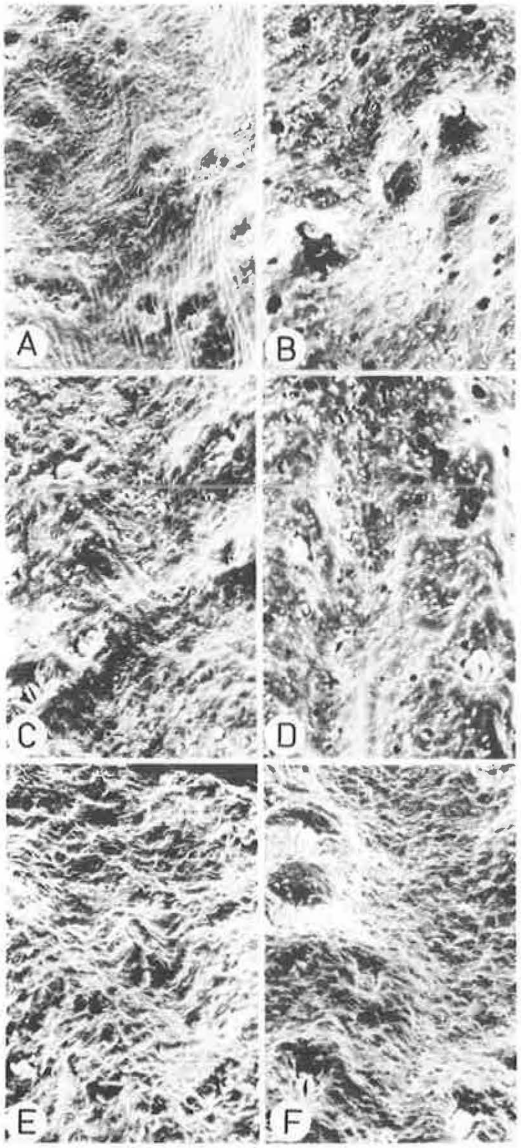

FIGURE 5 Surfaces of peach twigs in late March after fall treatment with various film-forming products: (a) RD 1725 (×875); (b) RD 2036 (×1,750); (c) RD 2034 (×1,750); (d) RD 2035 (×1,750); (e) RD 2033 (×1,750); and (f) Folicote (×1,750).

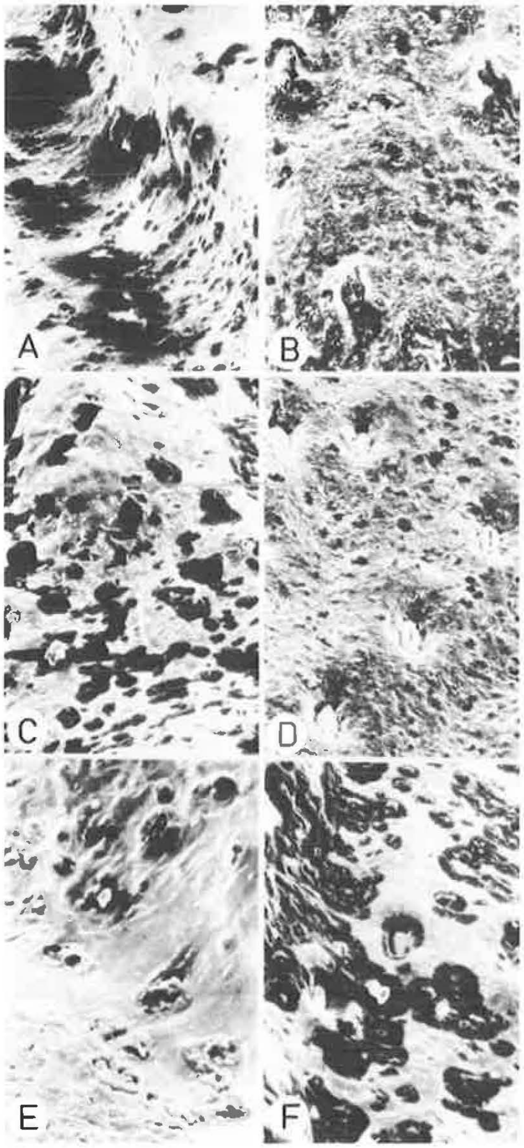

FIGURE 6 Surfaces of peach twigs in late March after fall treatment with various film-forming products and four successive monthly applications of a 2 percent rock salt solution: (a) RD 1725 (×875); (b) RD 2036 (×2,500); (c) RD 2034 (×1,750); (d) RD 2035 (×1,250); (e) RD 2033 (×1,750); and (f) Folicote (×1,750).

relatively mild with 1987–1988 being the most mild. Winter damage to fruit trees was below average during the winters of 1986–1987 and 1987–1988. Gale and Hagan (*7*) emphasized that field trials of film-forming antitranspirants often yield inconsistent results because varying environmental conditions can substantially alter their effects. Thus, large-scale or commercial use of any one or more of these products must await further testing under widely diverse winter conditions with other plant species.

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