Russeting and Russet Scab of Prune, an Environmentally Induced Fruit Disorder: Symptomatology, Induction, and Control

THEMIS J. MICHAILIDES, Assistant Research Plant Pathologist, Department of Plant Pathology, University of California, Berkeley/Kearney Agricultural Center, Parlier 93648

ABSTRACT

Michailides, T. J. 1991. Russeting and russet scab of prune, an environmentally induced fruit disorder: Symptomatology, induction, and control. Plant Dis. 75:1114-1123.

Typical symptoms of russeting of immature fruit of French prune (*Prunus domestica*) originate as shiny, lacy areas on the stylar end of fruit and become brown and scabby (russet scab) on ripe fruit. These areas have a thin (1.9–3.8 μm) cuticle, lack epicuticular wax, and bear abnormal stomata. In contrast, healthy areas have a thick (8–12 μm) cuticle, abundant epicuticular wax, and normal stomata. Russeting and russet scab have been most severe when rainfall has occurred during and 1 wk after full-bloom stage. Russeting symptoms were induced by 1) hand-spraying entire trees with distilled water until runoff at 6 p.m., midnight, and 6 a.m. for four consecutive days, 2) spraying shoots bearing blossoms in full-bloom stage at 6 p.m. and 6 a.m. and keeping the shoots in plastic bags covered with paper bags for 3–4 days, and 3) intermittent misting (10–20 s every 10 min) with distilled water for 28 hr during full bloom using a mist generator and environmental monitoring system (a misting system operated automatically by a 21X Campbell datalogger). In all experiments, water applied on blossoms at full-bloom stage induced russeting and increased its severity on immature prune fruit. The severity of russeting symptoms on immature fruit correlated positively ($r > 0.90$) with the incidence of russet scab on dehydrated ripe fruits. Fungicides, such as captan, captafol, dichlone, folpet, ziram, and chlorothalonil, applied at full bloom, reduced the severity of russeting and the percentage of fruit with russet scab even though fungi were not isolated from the scab areas. However, a single captafol application on prune trees 2 wk after full bloom failed to control russet scab.

Additional keywords: jacket scab, lacy scab, scab year

Prune (*Prunus domestica* L. 'French') orchards in California occupy approximately 30,000 ha and have a total crop value of about $165 million (2). After extensive plantings in the 1960s, the Sacramento Valley, with 75% of its acreage in prune orchards, became the dominant prune growing area, producing 80% of California's dried prunes. The rest are produced in the San Joaquin Valley, Napa-Sonoma, and Santa Clara districts.

Although the market for fresh French prunes is increasing yearly, especially in exports to the Orient (10), the majority of French prunes are still produced for drying. The two major disorders affecting dried French prunes are the slip-skin maceration disorder (box rot), caused by postharvest decay of prunes (primarily by *Rhizopus* spp. [24]), and russet scab (RS), the cause of which is unknown. Both of these disorders, however, originate in the fresh fruit and show their extent after dehydration of prunes. Depending on weather conditions, RS can cause major financial losses for prune growers and processors.

Accepted for publication 20 May 1991 (submitted for electronic processing).

First recognized in the early 1930s, RS is present every year, although it causes losses only in years of heavy rain (referred to as "scab years") during or shortly after bloom. Initially, it was referred to as "lacy scab" because of the netted pattern on the fresh fruit. Because the lacelike russeting symptoms occur on the stylar end of prune fruits, the cause was thought to be the adherence of the jacket to the fruit after petal fall and it was called "jacket scab." However, Corbin et al (6) named the disease russet scab to also describe the appearance of affected dried (commercially dehydrated) prunes.

Initially, it was thought that RS was caused by thrips feeding under the shuck (jacket = calyx) of the immature fruit, but there were no data to support this assumption (33). Similarly, microorganisms have not yet been associated with russet scab, although certain fungicides applied at full bloom, such as captafol, captan, or dichlone (quintar), reduced the incidence of RS (6).

Unlike russeting in apples (*Malus domestica* Borkh.) and pears (*Pyrus communis* L.) (4,9), russeting in prunes has not been associated with the application of chemicals to the flowers or young fruits, except for the application of fixed copper (cupric hydroxide [Kocide 101]) (17). Orchards receiving no sprays during the growing season frequently show severe RS. Repeated isolations from samples of fruit collected during different growth stages in several years failed to reveal any consistent association of RS with microorganisms. Montgomery (21) associated the widespread russeting and cracking of Cox apple in England in 1958 with exceptionally heavy rainfall during June and August. Martin (16) reported that high atmospheric humidity prompts the development of a thin cuticle. These reports (16,21), along with observations that RS is more severe when rainfall is above normal during spring (6), suggest that RS may be a disorder caused by deficient wax deposition in some surface areas of developing fruit. The purpose of this study was to describe the symptoms and the histology of RS, elucidate its etiology (by inducing it), and investigate its control. Preliminary reports of this study have been published (18,19).

MATERIALS AND METHODS

Symptomatology. Developing fruit showing symptoms of russeting were observed regularly from spring through the end of summer, photographed at different stages, and compared with healthy fruit (not showing any russeting symptoms).

Light microscopy. Healthy fruits and immature or mature fruit samples showing russeting and RS symptoms, respectively, were harvested from an experimental prune orchard of the University of California, Davis. To compare the morphological (topographical) differences of russeted areas with those of healthy ones, imprints of respective areas were taken on microscope slides, using cyanoacrylate adhesives as described by Wilson and Pusey (32). Surface imprints were examined with a Zeiss microscope and photographed with a 35-mm camera. For thin-sectioning, fruit pieces (5 × 5 × 3–5 mm) including their outer surface were fixed in 2% glutaraldehyde in 0.01 M PO_4 buffer (pH = 7.2) for 24 hr and washed twice in distilled water for 15–30 min per wash. Samples were dehydrated stepwise in a series of 15, 30, and 50% solutions of ethanol for 2 hr. They were then dehydrated in solutions of 50% for 24 hr and in 70, 85, 95, and 100% ethanol for 1–1.5 hr.

After removal of 100% ethanol, samples were placed in pure tertiary butyl alcohol (TBA), which was replaced after 1.5, 24, and again after 1.5 hr. Samples were infiltrated with melted paraffin oil, using two to three additional paraffin changes to eliminate TBA. Samples were embedded in paraffin, sectioned at approximately 10-μm thickness with a rotary microtome (Model 820, American Optical Company, Buffalo, NY), and stained with Sudan IV (12) in 70% ethanol. The sections were then mounted in a solution of 0.2% phenol and 50% glycerol and photographed with a Zeiss microscope equipped with a 35-mm camera. At least 18 specimens were examined for each kind of fruit samples.

Scanning electron microscopy (SEM). Both immature and mature healthy fruits and fruits with RS symptoms were cut into 15- to 20-mm^2 sections, fixed in 2% glutaraldehyde in 0.01 M phosphate buffer (pH = 7.2) for 24 hr, rinsed in three half-hour changes of distilled water, dehydrated in ethanol (stepwise in 30, 60, 80, 95, 95, and 95% for 1 hr in each step), and stored in 100% ethanol until used. The tissue sections were then critical-point dried with carbon dioxide, mounted on SEM stubs, coated with 60% palladium-40% gold, observed with a scanning electron microscope (International Scientific Instruments DS-130 [dual stage, 10 kV, 1.2 A]), and photographed.

Relationship of russeting severity index (RSI) of immature fruit and RS of dehydrated fruit. Because RS initially appears as shiny areas (russeting) of different size, an experiment was conducted to determine whether all sizes of russeting before dehydration or only those beyond a certain size will appear as RS symptoms on the prunes after dehydration. Prunes were harvested from trees not sprayed with chemicals or water and classified into five categories on a scale of 0–4 according to the size of the shiny areas (severity of russeting) as follows: 0 = no shiny areas (healthy), 1 = small shiny spots (2–4 mm in diameter) close to the stylar end, 2 = small shiny area(s), 3 = large shiny area(s) like a band surrounding the stylar end of the fruit, and 4 = large, rough, shiny zones (sometimes with brownish red spots) around the lower part (stylar end) of the fruit (Fig. 1A). Six subsamples of 40–60 fruits from each category were placed in plastic net bags, marked accordingly, and dried in a commercial dehydrator at 80 C for 18–19 hr. In another experiment, 22–44 green fruit in each category were tagged (total of 133), evaluated again just before harvesting, placed in separate bags according to symptom severity as described earlier, and dried in a commercial dehydrator. After dehydration, the prunes were scored for RS either in the laboratory or at Sunsweet Growers Inc., Yuba City, CA, by California Department of Food and Agriculture (CDFA) commercial inspectors, whose judgments are based on two industrial criteria: 1) tough or thick scab exceeding 10 mm in diameter and 2) unsightly scab of another character (including "wind scab") (18) exceeding 20 mm in diameter.

Effects of calyx (shuck) retention on RS. Because russeting and, subsequently, RS initiate at the stylar end in the area where the shuck is retained, an experiment was conducted to determine whether retention of shucks has any effects on the incidence and severity of RS. In 1983, during petal fall to shuck-split stage (10 April), 20 young developing fruits on each of six replicate trees were tagged by hanging a paper tag on their peduncles as follows: 20 fruits with their shucks still attached, 20 fruits without shucks, and 20 fruits from which the shucks had been removed. Shucks were carefully removed with a pair of forceps to avoid touching or wounding the young fruit. On 30 May, all fruits from each treatment were evaluated for severity of russeting without removing them from the trees. In September, fruits were harvested, dehydrated commercially, and scored for RS. This experiment was repeated in part in 1990, when fruit with retained shucks and fruit without shucks were compared on several trees in a commercial orchard in Fresno County.

Induction of russeting and RS. Russeting in other crops has been associated with high humidity or with rain or dew on the fruit (9). To determine if rain or high relative humidity had any effect on incidence and severity of RS of prune, three prune trees were each covered with a polyethylene film (0.025-mm thickness) laid over a wooden frame constructed over each tree at full bloom. Two of the covered trees were hand-sprayed (pressure of application was 18–20 kg/cm^2) with 18–20 L of distilled water per tree at 6 p.m., midnight, and 6 a.m., beginning on the evening of 19 March and continuing until the morning of 22 March. The third covered tree (control) was not sprayed. All of the trees were protected from rain until 31 March when the polyethylene film was removed. Temperature and RH were recorded with two hygrothermographs (Model H-311, Weather Measure Corp., Sacramento,

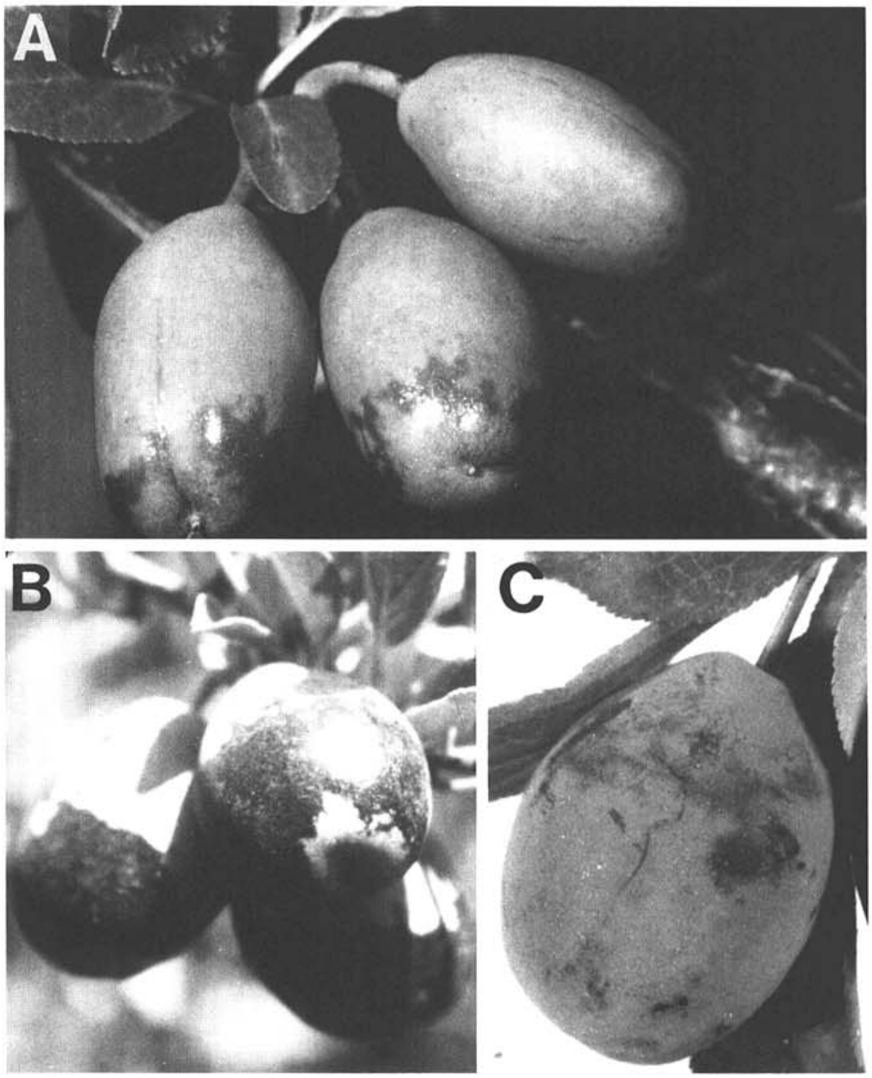

Fig. 1. Russeting symptoms on prune fruit. **(A)** Immature fruit (two lower fruits with russeting; upper fruit is healthy); **(B)** russet scab on mature fruit; and **(C)** ripe, healthy prune.

CA), placing one under a sprayed tree and the other under the unsprayed tree. During daytime, the four sides of polyethylene film were rolled up to prevent accumulation of excessive heat inside the construction. Three samples of 100 prunes each were harvested from each tree (total of 900 fruit) on 20 July and evaluated for russeting on a scale of 0–4 as described earlier.

In another orchard at the University of California, Davis, experimental field, four prune trees at full bloom were each sprayed with 12–15 L of distilled water at 6 p.m., midnight, and 6 a.m. for four consecutive days (22–25 March 1982). Four unsprayed trees served as controls. Rains did not occur during the period of the experiment, but a rain of 2.5 mm occurred on 26 March. At harvest time, 100 prunes were hand-picked from each tree, evaluated for RS, and compared with fruits collected from the unsprayed control trees. This experiment was repeated in 1988.

In the same orchard, at full bloom, five random branches with only opened flowers (closed flowers were removed) on two trees were sprayed to runoff with distilled water using a hand-sprayer at 6 a.m. and 6 p.m. for two consecutive days. Five branches on each of the two trees (from which all closed blossoms were removed) were left unsprayed and served as controls. Samples of 35 prunes each were collected on 9 May and evaluated for russeting symptoms on a scale of 0–4.

In another experiment, 40 shoots were selected randomly and divided into four groups of 10 shoots each on each of three replicate trees in full bloom. Twenty of these shoots were sprayed with distilled water and covered with an inner plastic and an outer brown paper bag. A wet paper towel was placed in each plastic bag to maintain a high RH. Ten of these bagged shoots were shaded with a canvas (plastic + paper + shade treatment), and the other 10 were left unshaded (plastic + paper + light treatment). The third group of 10 shoots per replicate tree were sprayed with water and covered with only a paper bag (paper + light treatment). The fourth group of 10 shoots were sprayed with water and left uncovered (controls). All fruits on these shoots were harvested on 12 July and evaluated for russeting symptoms on a scale of 0–4. Temperatures in both plastic and paper bags, whether shaded or unshaded, were recorded with a two-point thermograph (Model 4020, Weathertronics, Inc., Sacramento, CA). This experiment was repeated once.

To determine whether RS could be induced by continuous misting, a mist generator and environmental monitoring system (MGEMS) (1) was placed in the middle of a row of prune trees. A 1.3-cm polyethylene drip hose with 38 wide-angle misting nozzles (Monarch MW-B, 160° angle, 1.77 kg/cm^2 minimum pressure) (W. A. Westgate Co., Inc. Davis, CA) was positioned among the blossoms on six trees so that six to seven nozzles per tree were located only on the south side of the canopy. A datalogger (Model 21X, Campbell Scientific, Inc., Logan, UT) was programmed to trigger the nozzles to produce mist bursts of distilled water for a 10- to 20-s period every 10 min. The MGEMS operated for a total of 28 hr when the trees were at 80% full bloom (29 March–1 April). After the initial 4-hr misting, begun at noon on 29 March, three of the six trees were sprayed to runoff with captan (Captan 50W) at a concentration of 2.4 g a.i./L of water and all six trees were misted for an additional 24-hr period, beginning at 6 a.m. on 30 March. On 18 July, 100 immature prunes were collected from the south (misted by MGEMS) and north (unmisted) sides of each tree and evaluated for russeting. On 18 August, 100 ripe prunes from the south and north sides of each tree were harvested, dehydrated, and evaluated for RS as described earlier.

Control trials. To determine the effect of fungicides on the incidence of russeting and RS, either several or all of the following chemicals were sprayed to runoff in an experimental prune orchard at the University of California, Davis, when the trees were at 60–90% full bloom: triforine (Funginex 1.6 EC, 0.95 ml a.i.); CGA 64121 (Vangard 10W, 0.35 g a.i.); captafol (Difolatan 4F, 3.75 ml, or Difolatan 80S, 1.8 g a.i.); iprodione (Rovral 50W, 0.46 g a.i.); prochloraz (Sportak 50W, 0.46 g a.i.); captan (Captan 50W, 2.4 g a.i.); dicloran (Botran 75W, 1.8 g a.i.); sodium hypochlorite (Clorox 5.25%, 4 ml a.i.); benomyl (Benlate 50W, 2.4 g a.i.); folpet (Phaltan, 2.4 g a.i.); dichlone (Phygon 5F, 0.5 ml a.i.); diniconazole (Spotless 25W, 0.13 g a.i.); myclobutanil (Systhane 40W, 0.18 g a.i.); ziram (Ziram 76%, 2.4 g a.i.); and chlorothalonil (Bravo 500 or Bravo 720, 1.9 and 1.25 ml a.i., respectively). (All chemical concentrations are given as grams or milliliter per liter of water.)

Five to eight single-tree replications were used for each treatment in a completely randomized block design. In 1988, two orchards (A and B) at the University of California, Davis, were sprayed when trees were at about 80% full bloom. During May or June, 50–100 random green fruits per replicate tree were evaluated for russeting symptoms and 100 ripe fruits per tree were evaluated for RS just before and again after commercial dehydration. Commercially, prunes with RS symptoms >10 mm in diameter are scored as scabbed. Only results obtained in "scab years" are presented because no significant differences were observed between sprayed and unsprayed trees in years with low incidence of scab.

Weather data. Weather data on the frequency and levels of rainfall in March, April, May, and June during 1982–1990 were obtained from CIMIS Station 6, which is adjacent to experimental plots of the University of California at Davis.

Statistical analyses. Data on the relationship of russeting severity index of immature fruit and RS of dehydrated fruit were analyzed by linear regression (REG procedure), data on all other experiments were analyzed by ANOVA, and when *F* values were significant, means were compared with Duncan's multiple range test for mean differences using Statistical Analysis Systems software (SAS Institute, Inc., Cary, NC).

RESULTS

Symptomatology—Macroscopic symptoms. The first symptoms of russeting (i.e., shiny areas close to or under the shuck) appeared on young, immature fruit 3–4 wk after full bloom. Later (about 2 mo after full bloom), these shiny areas became very distinct and formed an incomplete, irregular, lacy band on the lower half of the prune fruit (Fig. 1A). As fruit matured and changed color from green to purplish red, affected

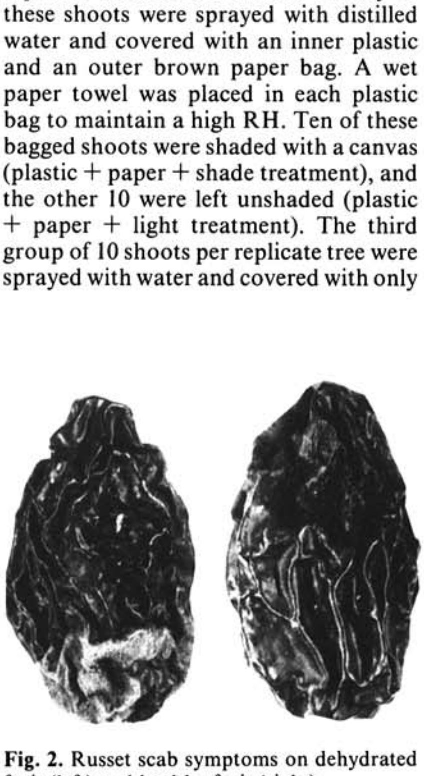

Fig. 2. Russet scab symptoms on dehydrated fruit (left) and healthy fruit (right).

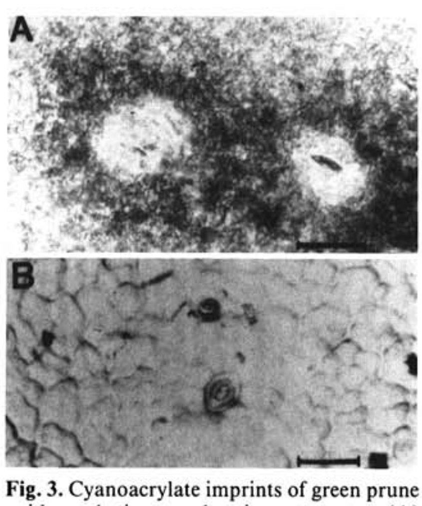

Fig. 3. Cyanoacrylate imprints of green prune epidermal tissues showing stomata. **(A)** Healthy fruit and **(B)** russeted fruit. (Bar = 50 μm)

areas seemed to lack the epicuticular wax (bloom) (Fig. 1B), which was abundant on the unaffected areas and on healthy fruits (Fig. 1C). One week before harvest, russeted areas became rough on the surface, turned brown, and dried. After commercial dehydration, affected areas cracked and became scabby, whereas unaffected areas and the surface of fruit without RS had smooth and shiny wrinkles (Fig. 2).

Light microscopy. Cyanoacrylate imprints of prune epidermal tissue showed that unaffected areas were covered with epicuticular wax (Fig. 3A). Stomata of healthy fruit were normal, closed, and elliptical, surrounded by dense layers of epicuticular wax (Fig. 3A). In contrast, stomata of affected areas were round and open, and the surface of fruit lacked epicuticular wax, allowing viewing of the detailed topography and outlines of epidermal cells (Fig. 3B).

In cross sections of unaffected (healthy) fruit tissues, the cuticle was thick (8–12 μm) and uniformly stained with Sudan IV (Fig. 4A), but in cross sections of affected areas, the cuticle was thin (1.9–3.8 μm) and stained only slightly or not at all with Sudan IV (Fig. 4B). Also, fractures of the cuticle were noted only on russeted areas, not on the unaffected areas.

Scanning electron microscopy. Scanning electron microscopy showed differences in the surface of healthy and russeted areas. Healthy areas were covered with dense grains, flakes, and strands of epicuticular waxes (Fig. 5A and B), but the surface of russet scabbed areas lacked all forms of epicuticular wax (Fig. 5C and D) and appeared smooth with cuticular fractures (arrows in Fig. 5C and D). The surface of RS areas were bumpy, and the absence of epicuticular wax allowed viewing the outlines of the outer surface of the epidermal cells (Fig. 5D), whereas the layers of epicuticular wax flakes and grains prevented viewing the outlines of epidermal cells of healthy fruit (Fig. 5A and B).

Stomata on healthy fruit appeared normal and were surrounded by epicuticular wax grains, flakes, and strands (Fig. 6A). On mature fruit, stomata were less elliptical but still retained their

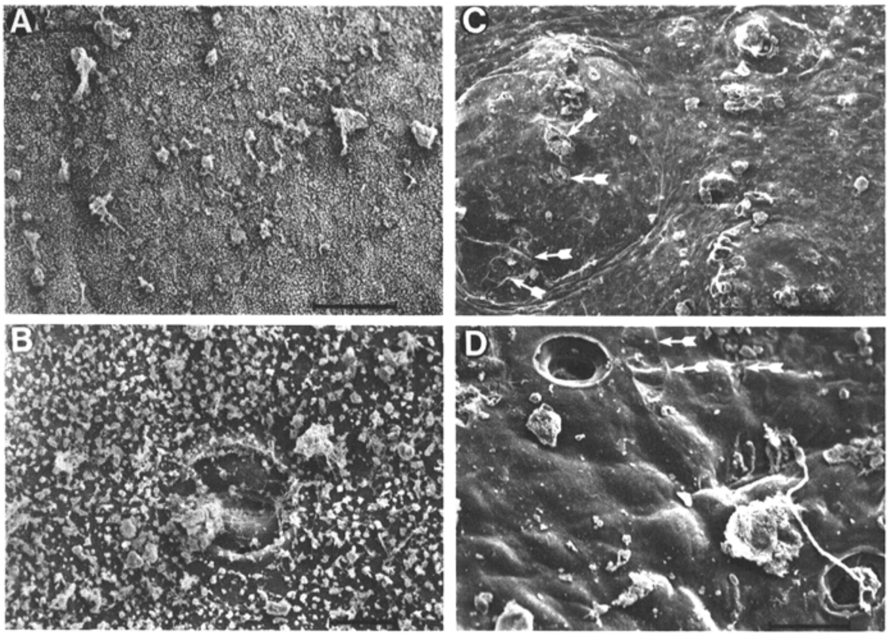

Fig. 5. Scanning electron micrographs of epidermal tissue of **(A and B)** healthy immature prune and **(C and D)** russeted fruit. Arrows in C and D indicate initiation of fractures of the thin cuticle. (Bar [A, C, and D] = 100 μm; [B] = 20 μm)

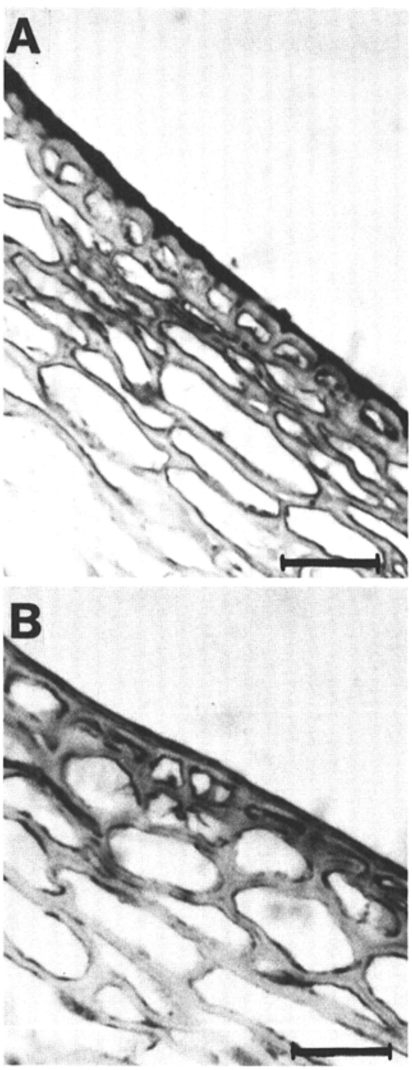

Fig. 4. Cross sections of **(A)** healthy and **(B)** russeted immature prune fruit. (Bar = 50 μm)

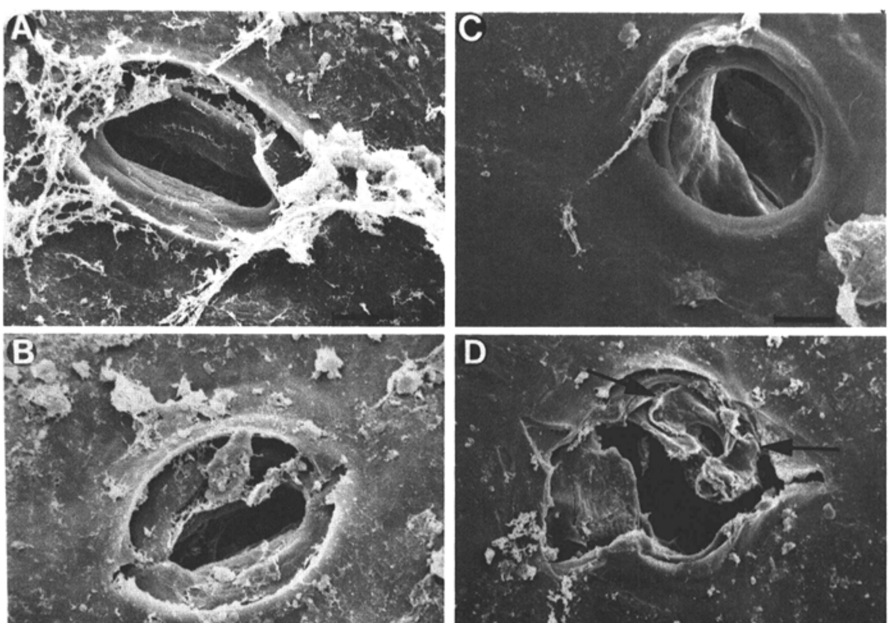

Fig. 6. Scanning electron micrographs of stomata in healthy fruit and fruit with russet scab. **(A)** Stoma covered with epicuticular wax strands; **(B)** normal stoma on older fruit; **(C)** round, open stoma in russet scabbed area; and **(D)** fractures initiated from a stoma in russet scabbed area in an older fruit (arrows show remnants of malformed guardian cells). (Bar = 10 μm)

original elliptical shape (Fig. 6B). Stomata of russeted areas, however, were round and fixed in an open position (Fig. 6C) and, on mature fruit, became the centers of fruit fracturing, losing their shape entirely (Fig. 6D).

Relationship of RSI of immature fruit and RS of dehydrated fruit. There was a high positive correlation ($r > 0.90$) between severity of symptoms of russeting before dehydration and RS after dehydration in evaluations made both by the commercial inspectors and in our laboratory. Approximately 90–95% of the prunes in category 4 had RS symptoms after dehydration, whereas categories 0 and 1 had only 1–3% prunes with RS after dehydration. In our evaluation, category 1 had 13% fruit with RS but only 3% according to commercial inspectors' evaluations. Categories 2 and 3 had intermediate percentages (40–81%) of prunes with RS. The relationship of severity of symptoms of russeting before dehydration can be expressed by linear equations (Fig. 7) ($r > 0.90$, $P < 0.01$). Of the total 133 fruit tagged on 5 May, 100 fruit were still available for classification on 1 September. Of this fruit, only fruit classified in categories 2 (2%) and 3 and 4 (8%) showed symptoms after dehydration. Similar results were obtained in the second experiment.

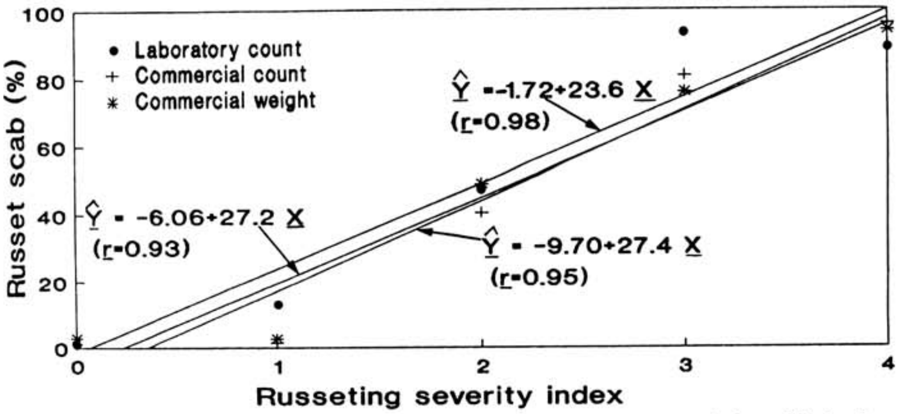

Fig. 7. Relationship of symptom severity of russeting of French prune before dehydration with amounts of russet scab of prunes after dehydration (r significant at $P < 0.01$).

Table 1. Induction of russeting of immature prune by spraying entire trees with distilled water

Year	Treatment[v]	Fruit with russeting (%)[w]	Russeting severity index[x]
1982	Sprayed	17.3**[y]	0.30**
	Unsprayed	9.3	0.15
1988	Sprayed	69.3[z]	3.1*
	Unsprayed	54.7[z]	2.2

[v] Two trees covered with polyethylene film (1982) and four uncovered trees (1988) were handgun sprayed to runoff with distilled water at 6 p.m., midnight, and 6 a.m. for 3 days (19–22 and 22–25 March in 1982 and 1988, respectively).

[w] Three samples of 100 prunes per tree (July 1982) and 100 prunes per tree (August 1988) were hand-picked and evaluated for russeting.

[x] Russeting severity index was based on five (0–4) severity categories where 0 = healthy and 4 = the most severe russeting.

[y] * = Significant difference at $P \leq 0.05$ and ** = $P \leq 0.01$ from the corresponding unsprayed control, based on a pairwise t test.

[z] Values were corrected for a 12–22% "wind scab."

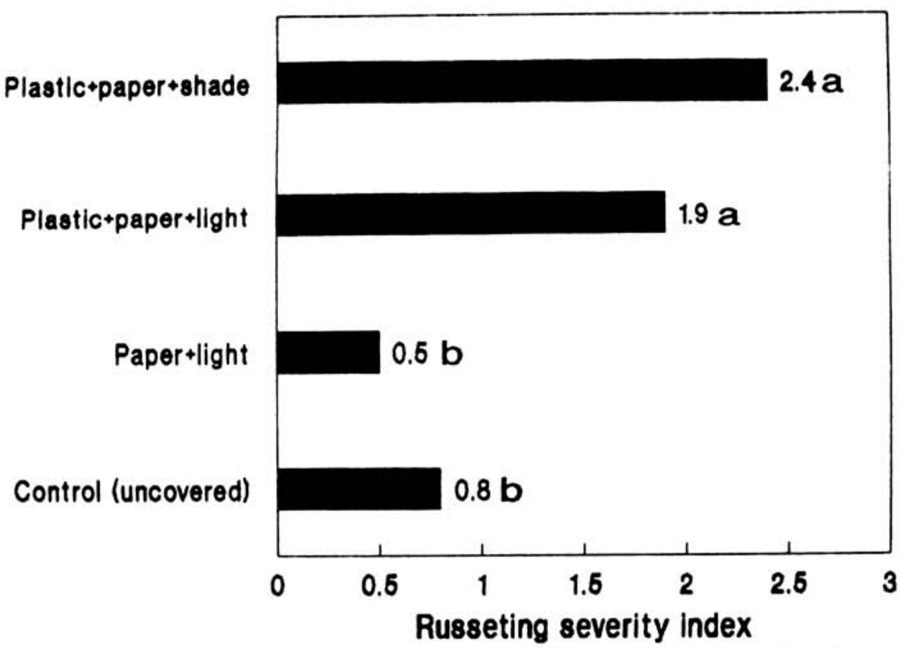

Fig. 8. Induction of russeting symptoms of French prune by spraying shoots at full bloom with distilled water, covering them with plastic and paper bags for 5 days, and shading with a canvas or leaving them unshaded. Numbers followed by the same letters do not differ significantly ($P = 0.05$) according to Duncan's multiple range test.

Effects of calyx (shuck) retention on RS. The removal of shucks did not reduce significantly the percentage of fruit with severe RS. Sixty-nine percent of the fruit with shucks removed artificially developed russeting in categories 3 and 4 (average RSI 2.7) by 30 May, whereas 76% of fruit with retained shucks had russeting symptoms in categories 3 and 4 (average RSI 3.2). Among prunes without shucks at the time they were tagged, 82% developed russeting in categories 3 and 4 (RSI 2.8). Among the three groups of fruits, the differences in percentages of fruit with russeting in categories 3 and 4 or in RSI were not significant. Results from the experiment in 1990 showed no significant differences in either the incidence or the severity of russeting between fruit bearing shucks and those without shucks at the time they were tagged.

Induction of RS. In 1982, 17.3% of fruit collected from trees sprayed with water showed russeting (RSI 0.30), compared with 9.3% of fruit from the unsprayed trees (RSI 0.15) (Table 1). Both the incidence of russeting ($F = 65.83$, 1 df, $P < 0.01$) and the RSI ($F = 68.26$, 1 df, $P < 0.01$) were significantly different between sprayed and unsprayed trees. The maximum RH recorded under the sprayed trees ranged from 84 to 99% (average 92%) and the average duration of RH >90% was 14 hr; maximum air temperatures for the four nights during this experiment ranged from 24 to 29 C. In contrast, the maximum RH recorded under the unsprayed tree ranged from 70 to 90% (average 82%) and the average duration of RH > 80% was 9–9.5 hr. The minimum and maximum air temperatures ranged from 7 to 14 and 24 to 29 C, respectively. In 1988, although the incidence of fruit with russeting did not differ significantly between sprayed and unsprayed trees, the RSI of fruit from sprayed trees was significantly ($P < 0.05$) greater than that of unsprayed trees (Table 1).

In 1984, RS incidence and severity on prunes developed from washed blossoms increased significantly in comparison with that of prunes developed from unwashed blossoms. Sixty-five percent of prunes from washed blossoms showed russeting symptoms with an average RSI of 1.3, and 26% of this fruit belonged in categories 3 and 4. In contrast, 31% of fruits developed from unsprayed blossoms were russeted, and their average RSI of 0.45 was significantly lower than that of fruit from sprayed trees ($t = 10$ for incidence and $t = 12.34$ for RSI, both with $P < 0.05$).

Seventy to 82% of fruits developed on shoots sprayed with water and covered with plastic and paper bags kept under either shade or light showed symptoms of RS with an average RSI of 1.9–2.4 on 12 July. In contrast, 24–37% of the fruit from shoots not sprayed and either covered with a paper bag or not covered had RS symptoms and exhibited an average RSI of 0.5–0.8 (Fig. 8). After dehydration, 5–8% of the fruit from shoots covered with plastic + paper kept under sunlight or under shade were scored with RS, whereas none of the controls showed RS (paper + light or uncovered treatments).

Prunes misted with the MGEMS developed significantly more russeting than those unmisted ($F = 5.7$, 1 df, $P < 0.05$) (Table 2). On the immature fruit only, captan reduced russeting on the misted prunes but had no effect on the unmisted prunes (Table 2). No significant differences in RS were found among the treatments on the ripe or dried prunes (Table 2).

Relationship of rainfall to RS incidence and severity. Years such as 1982, 1983, and 1986, with frequent and high amounts of rainfall in March and with rain occurring within 1 wk after full bloom were associated with high incidence and severity of RS (Table 3). In contrast, years such as 1984, 1985, and 1987–1990 with infrequent rainfall during the week after full bloom and with low precipitation in March, were associated with low incidence and severity of prune RS (Table 3). In 1988, although rains did not occur after full bloom in March, a relatively high incidence of russeting was recorded on immature fruit (at preharvest).

Control trials. The effects of fungicide applications were evident only in "scab years" when conditions favored scab development. For instance, in 1982 and 1983, treatment with captan, quintar, folpet, or captafol reduced the incidence and severity of RS over that found in the untreated control or prunes sprayed with dicloran or sodium hypochlorite (Tables 4 and 5). Triforine, iprodione, or benomyl had intermediate results (Tables 4 and 5). Only captan, dichlone, folpet, and captafol treatments resulted in significantly lower percentages of fruit with RS after dehydration (Table 5). Evaluations by commercial inspectors (based on fruit weight) also showed that a significantly smaller amount of fruit harvested from trees sprayed with benomyl, captan, dichlone, folpet, or captafol had RS than fruit harvested from untreated control trees or those treated with triforine, dicloran, sodium hypochlorite, or iprodione (Table 5). Although a late application of captafol in 1982 reduced the incidence of russeting of immature fruit and of RS of dehydrated fruit, it did not reduce the disease severity index (Table 4).

The fungicide trial in 1986 indicated that triforine had an adverse effect, significantly increasing the severity of russeting on immature fruit in comparison with the control (Table 6). Among the other fungicides, ziram, chlorothalonil, and captan significantly reduced the severity of russeting on immature and ripe fruit and of RS on fruit after dehydration (Table 6). In 1988

Table 2. Effects of misting flowers of French prune trees with an automated system[w] on the development of russeting and russet scab

Treatment[x]	Fruit with russeting (%) (18 July)	Russeting and russet scab index on[y]: Immature fruit (18 July)	Ripe fruit (18 Aug.)	Fruit after dehydration
Unsprayed + misted	38.3 a[z]	0.9 a	0.2 a	0.1 a
Captan + misted	30.3 a	0.6 ab	0.2 a	0.1 a
Unsprayed + unmisted	21.3 b	0.3 b	0.3 a	0.1 a
Captan + unmisted	19.7 b	0.3 b	0.4 a	0.1 a

[w]Misting Generator and Environmental Monitoring Systems (1).
[x]Captan at 2.4 g a.i./L was applied with a handgun sprayer at 6 p.m. on 29 March 1987 after a 4-hr misting of the trees; the trees were misted for 24 more hours beginning at 6 a.m. on 30 March.
[y]Russeting and russet scab index values are the average of three single-tree replications of 100 fruits for each time of evaluation. Five (0–4) severity categories were used where 0 = healthy and 4 = the most severe russeting.
[z]Numbers in each column followed by the same letter do not differ significantly ($P = 0.05$) according to Duncan's multiple range test.

Table 3. Relationship between numbers of rains and levels of rainfall during March after full bloom of French prune at the experimental plots of the University of California, Davis, and russeting and russet scab incidence and severity

Year	Date of full bloom in March	Interval[t] (days)	March: Rains[u] (no.)	March: Rainfall (mm)	April: Rains[u] (no.)	April: Rainfall (mm)	Incidence of russeting and russet scab (%)[v]: Preharvest (May–July)	Harvest (August)	Russet scab index at harvest[w] (August)
1982	19	7	7	76	11	138	78	23	2.2
1983	11	1	12	125	9	78	73	35	2.1
1984	14	0	4	12	3	8	24	9	0.4
1985	19	7	3	35	1	8	ND[x]	21	0.3
1986	5	2	9	123	3	18	82	75	2.0
1987	28	13	0	0	2	4	36	13	0.6
1988	13	37	0	0	2	32	48[y]	4[y]	0.7
1989	12	1	5	43	3	6	TR[z]	TR	<0.3
1990	15	43	0	0	2	7	TR	TR	<0.1

[t]Between full bloom and the next measurable rainfall.
[u]Rainfall data were obtained from CIMIS Station 6, which is adjacent to experimental plots at the University of California, Davis.
[v]One hundred fruit from each of five to eight unsprayed trees were evaluated for russeting symptoms; all (0–4) russet scab severity categories were included.
[w]Russeting and russet scab index is based on five (0–4) severity categories; 100 fruit from each of six to eight unsprayed trees were evaluated just before commercial harvest.
[x]ND = Not determined.
[y]Values were corrected for 21–28% of fruit with "wind scab" symptoms.
[z]TR = Trace.

Table 4. Evaluation of fungicides for control of russet scab of French prune, 1982

Treatment[s]	Immature fruit with russeting[t] (%)	Russeting severity index[u]	Fruit with russet scab after dehydration[v] (%)	Russet scab index[w]
Control	78 a[x]	2.3 a	23 a	2.2 a
Triforine	67 ab	ND[y]	10 b	2.1 a
CGA 64121	61 ab	ND	6 bc	1.9 ab
Captafol[z]	42 b	2.0 a	10 b	1.7 ab
Iprodione	50 b	ND	4 bc	1.6 b
Prochloraz	48 b	ND	1 c	1.5 b
Captafol	15 c	0.7 b	1 c	0.8 c
Captan	13 c	0.5 b	1 c	0.7 c

[s] All fungicides were applied with a handgun sprayer (15 L per tree) on 19 March at 50% bloom, except captafol, which was applied either on 19 March or 4 April.
[t] Fifty fruit per tree were recorded.
[u] Russeting severity index was based on 60–80 immature fruit on a scale of 0–4 on 11 May.
[v] Eight kilograms of fresh fruit were dehydrated and evaluated for russet scab.
[w] Russet scab index was based on 100 dehydrated fruit on a scale of 0–4.
[x] Numbers in each column followed by the same letter do not differ significantly ($P = 0.05$) according to Duncan's multiple range test.
[y] ND = Not determined.
[z] Applied on 4 April.

Table 5. Evaluation of fungicides for russeting and russet scab control of French prunes as determined by symptoms before and after dehydration, 1983

Treatment[w]	Russeting severity index[x]	Russet scab after dehydration[y]		
		Evaluation by count (%)		Evaluation by weight (%)
		Laboratory	Commercial inspectors	Commercial inspectors
Control	2.0 ab[z]	35.4 a	8.1 bc	9.7 a
Triforine	1.9 ab	27.3 ab	16.8 a	10.4 a
Dicloran	2.3 a	26.5 ab	9.2 b	11.7 a
Sodium hypochlorite	2.6 a	25.2 ab	10.1 b	11.4 a
Iprodione	1.4 a–c	16.4 bc	7.0 b–d	8.9 a
Benomyl	1.5 a–c	12.5 cd	1.9 cd	3.0 b
Captan	1.1 a–c	2.9 d	1.0 cd	2.6 b
Dichlone	0.6 bc	2.6 d	1.0 cd	2.4 b
Folpet	0.6 bc	2.3 d	1.0 cd	2.1 b
Captafol	0.3 c	1.2 d	0.3 d	0.8 b

[w] A single blossom spray applied with a handgun sprayer (15–20 L per tree) at 60% full bloom on 11 March.
[x] Russeting severity index based on 50 random prunes per tree recorded on a scale of 0–4 on 9 May.
[y] Based on 5- to 7-kg samples of fresh prunes harvested from each of three replicated trees on 1 September.
[z] Means in each column followed by the same letter do not differ significantly ($P = 0.05$) according to Duncan's multiple range test.

Table 6. Effects of various fungicides on russeting and russet scab of French prune, 1986

Treatment[v]	Russeting and russet scab index on:[w]		
	Immature fruit (13 June)	Ripe fruit (19 Aug.)	Fruit after dehydration
Control	2.0 b[x]	2.1 a	0.5 a
Triforine	2.6 a	2.0 ab	0.4 ab
Diniconazole[y]	1.8 bc	1.6 bc	0.3 bc
Iprodione	1.8 bc	1.5 cd	0.2 cd
Myclobutanil	1.7 bc	1.6 bc	0.2 cd
Ziram	1.4 c	1.2 d	0.1 de
Chlorothalonil[z]	0.9 c	0.6 e	0.0 e
Captan	0.9 c	0.5 e	0.0 e

[v] Fungicides were applied with a handgun sprayer on 5 March when prune trees were at 60% full bloom.
[w] Russeting and russet scab values are the average of six replications based on 25, 100, and 100 fruits for immature, ripe, and dried fruit, respectively. Five (0–4) disease severity categories were used where 0 = healthy and 4 = the most severe russeting or russet scab.
[x] Means in each column followed by the same letter do not differ significantly ($P = 0.05$) according to Duncan's multiple range test.
[y] Triton X-77 in a concentration of 0.63 ml per liter was added to the fungicide suspension.
[z] Bravo 500.

in orchard A, all fungicides reduced the incidence and severity of russeting on immature fruit evaluated on 12 July (Table 7). However, only ziram and captan showed a trend toward reducing the incidence of russeting of fruit before dehydration; none of the fungicide applications reduced the incidence of RS on dehydrated fruit (Table 7). In orchard B, among the fungicides tested, only captan and ziram reduced both the incidence and the severity of russeting (Table 8).

DISCUSSION

The uniqueness of RS on prunes is indicated by its usually developing in the area where the shuck of the fruit hangs (Fig. 1), although in some years russeting does develop over the rest of the fruit surface. Russeting of apples and pears associated with chemicals may develop at any location on the fruit surface. However, Koch and Alderman (14) reported a stem end russet of Yellow Newton apples not associated with any of the chemicals tested; they suggested that the russet in the stem end of Yellow Newtown apple was closely associated with high humidity, a factor that can vary from season to season with rainfall distribution, fog, and irrigation.

The light and scanning electron microscopy indicated that russeting of immature prune fruit was associated with areas of fruit bearing a very thin cuticle with little or no epicuticular wax and open, abnormal stomata. Open stomata show a reduced resistance to gaseous diffusion, a condition which may lead to excessive transpiration (11). Localized drying of the fruit surface, which led to fractures and the characteristic scabby areas (particularly on ripe fruit), could be attributed to excessive loss of water through the opened, probably nonfunctional, stomata found on the russeted areas. The excessive dehydration of these areas leads to premature shriveling of the fruit hanging on the trees. Similarly, russeted apples are especially susceptible to shriveling in storage (28). In contrast, unaffected (healthy) areas of prune fruits had a thick cuticle covered with epicuticular wax and normal, elliptical stomata. The shape of stomata seemed normal even on ripe fruit (Fig. 6B). Epicuticular wax, flakes, grains, or strands surrounded the stomata of the healthy fruit surface, which after dehydration becomes a flexible, wrinkled, shiny dark brown surface that is commercially desirable (Fig. 3).

The experiments on the relationship of RSI of immature fruit and RS on dehydrated fruit showed a high positive correlation ($r > 0.90$) between severity of symptoms of russeting before dehydration and RS after dehydration as determined both by our evaluation of RS and by commercial CDFA inspectors. About 90–95% of the prunes in category

4 developed scorable RS symptoms after dehydration of fruit. Results from commercial evaluation were based on criteria that were a little different from those used in our laboratory. The evaluation in our laboratory was more precise because we included scab defects on prune fruit smaller in size than those included by the commercial inspectors.

Applying water, either by spraying with a handgun sprayer, a hand-sprayer, or an automated mist system (1), at full bloom and 28–96 hr after full bloom induced RS and increased the severity of RS. Fruit that developed from blossoms sprayed with water and kept in plastic bags under RH > 98% showed greater incidence and severity of russeting. The involvement of water in inducing russeting and RS development is revealed by the results shown in Table 3. Only years with frequent rains (more than seven) after full bloom in March showed high incidence and severe symptoms of RS. Years with less frequent rains (fewer than five) after full bloom in March did not suffer from prune RS. Dalbro (7) found that the incidence of russeting on Cox's Orange Pippin apple in different years was closely related to the number of rainy days. These findings are in agreement with a report by Corbin et al (6) in which they noted the close relationship of severe RS incidence to years with above normal rains during bloom or during the jacket (calyx)-fall stage of prunes. They first used the term "scab years," commonly used today by prune growers.

Although the time of prune blooming varies from year to year and between southern and northern counties within a given year, records kept during the past 30 yr (6) (Table 3) indicate that full bloom occurs occasionally in the first week of March but more commonly comes between the second and last week of March in the Sacramento Valley. The results of this study can help predict the incidence and severity of RS in any 1 yr by examining the frequency and amounts of precipitation during and after full bloom in March with a rainfall occurring within 1 wk after full bloom. It seems that rain frequency and amount of precipitation in April is not critical. For instance, in 1986, only three rains occurred in April, accounting for 18 mm of precipitation, but the incidence and severity of RS recorded for this year were in the same range as those recorded for years 1982 and 1983, in which nine and 11 rainfalls occurred in April, accounting for 138 and 78 mm of precipitation, respectively (Table 3).

The fact that under natural conditions RS symptoms generally initiate at the stylar end under the jacket (retained calyx) of the fruit clearly indicates involvement of free water or humidity in the development of RS. Apparently, after a rain, high humidity and even free water can be expected to remain under the jacket of the fruit for a longer period than on the hydrophobic surface of the fruit, which is not covered by the jacket. When blossoms were sprayed or misted with water and/or covered with plastic bags, russeting occurred not only in the areas covered by the jacket but also on the rest of the fruit surface. Similarly, Tukey (28) showed that apple fruits enclosed in polyethylene bags developed severe russeting evenly over the entire surface whereas those bagged in moisture-pervious Kraft paper bags had an excellent smooth finish and nonbagged fruit remained russet free.

Martin (16) reported that free water or high RH has drastic effects on cuticle formation of plants. Skoss (27) reported that lack of water or low RH prompts a thick cuticle with increased content of epicuticular wax and presence of free water or high RH causes the development of a thin cuticle with decreased amounts of deposited epicuticular wax. Cross sections of russeted areas of prune exhibited thin or nonexistent cuticles in contrast with those of unaffected fruit, which were deeply stained with Sudan IV (Fig. 4). Scanning electron microscopy revealed the limited or nonexistent epicuticular wax on the surface of these areas of prune fruit sprayed with water or sprayed with water and kept under high (>98%) RH for at least 72 hr in comparison with nonaffected areas or fruit not sprayed with water. We are currently investigating the stage at which prune blossoms are most receptive to induction of RS through the application of water.

The application of water by any method during late bloom of prune trees induced RS. Shading of bagged shoots bearing the sprayed flowers tended to increase severity of russeting. Skoss (27) showed that leaves of English ivy (*Hedera helix* L.) grown in the sun produced heavier cuticles of greater wax content than did leaves grown in the shade. In addition, Whitecross and Armstrong (31) showed that a reduction in light intensity level resulted in an apparent reduction in surface deposition of epicuticular wax on leaves of *Brassica napus* L. The occurrence of russeted areas under the shuck (jacket) is, therefore, favored not only by the free moisture present but also by the shading of the jacket. This theory is supported by observation in the field of russeted areas surrounding the stylar end in a continuous bandage except for the area in the proximity of the suture (Fig. 1A). Usually, the jacket either splits over this

Table 7. Effects of various fungicides on russeting and russet scab of French prunes in orchard A, 1988

Treatment[u]	Russeting severity index (12 July)[v]	Percentage of prunes with russet scab symptoms on:[w] Immature fruit (12 July)	Ripe fruit (22 Aug.)	After dehydration (6 Sept.)
Control	2.4 a[x]	76.3 a	31.7 ab	11.5 a
Iprodione	1.5 b	57.0 b	33.0 ab	7.3 a
Chlorothalonil[y]	1.0 bc	39.3 c	34.7 ab	9.2 a
Chlorothalonil[z]	1.0 bc	38.8 c	41.8 a	8.2 a
Captan	0.9 c	36.8 c	25.6 b	8.2 a
Ziram	0.7 c	30.5 c	25.6 b	8.2 a
Triforine	0.7 c	29.8 c	36.2 ab	10.2 a

[u] Fungicides were applied with a handgun sprayer on 13 March when prune trees were at 80–90% full bloom.
[v] Russeting severity index was determined from 100 fruit from each of the six replicated trees and based on a severity index scale of 0–4.
[w] Percentage of fruit with russet scab includes fruit of 1 through 4 severity categories; values are the average of six 100-fruit replications.
[x] Means in each column followed by the same letter do not differ significantly ($P = 0.05$) according to Duncan's multiple range test.
[y] Bravo 500.
[z] Bravo 720.

Table 8. Effects of various fungicides on russeting of French prune in orchard B, 1988

Treatment[u]	Incidence of russeting[v] (%)	Russeting severity index[w]
Control	77 ab[x]	2.2 ab
Triforine	74 ab	1.9 a–c
Iprodione	65 ab	1.6 a–c
Chlorothalonil[y]	82 a	2.3 a
Chlorothalonil[z]	85 a	2.2 ab
Captan	60 b	1.5 bc
Ziram	57 b	1.2 c

[u] Fungicides were applied with a handgun sprayer on 13 March 1988 when prune trees were at 80% full bloom.
[v] Incidence of russeting was based on eight 50-fruit samples and includes fruit of severity categories 1 through 4 harvested on 20 May.
[w] Russeting severity index was based on five (0–4) severity categories where 0 = healthy and 4 = the most severe russeting.
[x] Means in each column followed by the same letter do not differ significantly ($P = 0.05$) according to Duncan's multiple range test.
[y] Bravo 500.
[z] Bravo 720.

area (suture) or it does not touch because of the special topography (shallow surface of the suture). In our experiments, although artificial removal of shucks from the developing fruit did not reduce the russeting significantly, fruits with shucks tended to develop more severe russeting (RSI 3.2) than those without (RSI 2.8). This indicates that retention of shucks on the young developing fruit for a few additional days may not be critical for the induction of RS. In contrast, Skene (25,26) reported the most severe russeting in the peduncle cavity of both king and axillary fruits of Cox's Orange Pippin apple, an area where fruits would most probably hold water after a rain.

This study shows that, unlike russeting in some fruit crops, such as apples and pears (4,9,22,30), russeting in French prunes was not associated with the application of chemicals to the flowers or young fruits, except for an application of fixed copper (Kocide 101), which induced RS on both immature and dehydrated fruit (17). With the exception of triforine in 1986, which resulted in an increase of russeting of immature fruit, none of the fungicides used in these tests increased the incidence or severity of russeting in prunes.

Because RS has not been associated with any microorganisms (19), its control by a single application of captan or its analogues during full bloom is surprising. Corbin et al (6) also reported that captan or dichlone (Phygon XL 50W) applied at green bud or full bloom significantly reduced RS of dehydrated fruit. Although applications of folpet (an analogue of captan) stimulated the development of leaf cuticle of poplar tree and grapevine (3), there is no evidence of such effects on the cuticle of prune fruit (T. J. Michailides, *unpublished*). The fact that other fungicides, such as triforine, CGA 64121 (Vangard), sodium hypochlorite, dicloran, and iprodione, did not reduce RS indicates that control of RS by captan and its analogues may be related to the specific configuration of these chemicals. Moreover, the failure of captafol to reduce RS on dehydrated fruit when not applied until 2 wk after full bloom (Table 4) strongly indicates that the developmental stage of the prune flowers and/or young fruits is significant in the effectiveness of captafol for reducing RS. Corbin et al (6) also showed that a late (petal-fall) application with captafol was ineffective in reducing RS whereas early (green bud or full-bloom) application(s) significantly reduced it. However, there is no added benefit in reduction of RS by applying a fungicidal spray during the green-bud stage if a fungicide has been applied at full bloom.

Various researchers (5,13,20,22) have reported the ability of captan to reduce russet of Delicious, Golden Delicious, and several other apple cultivars. Tuzet, a mixture of thiram, ziram, and an organo-arsenic compound, inhibited russet of Golden Delicious, especially when applied after petal fall (15,29). Studies in 1988 showed that ziram reduced russeting of prune. The various effects of chemicals on RS and the differences in results among analogues or different formulations can be attributed partially to different adjuvants and/or surfactants incorporated in these chemicals. Surfactants have been reported to affect russet induction in apples (23).

Severe russeting leads to downgrading of the fruit by causing minute cracks, excessive shriveling of the affected areas of fresh fruit, and the development of severe RS on dehydrated fruit; such fruit are subsequently used for production of prune juice. High levels of dehydrated fruit with RS or other blemishes result in increased costs for manually sorting these fruits (8). Despite the increasing demand for fresh French prunes (10), fruit with severe russeting cannot be used for the fresh market. In addition, RS can predispose and provide avenues for infection by fungi, such as *Rhizopus* spp., *Monilinia laxa* (Aderhold & Ruhland) Honey, and *M. fructicola* (G. Wint.) Honey (T. J. Michailides, *unpublished*). Observations in the field showed initiation of brown rot or a decay caused by a *Phomopsis* sp. from russeted areas of the fruit.

Another disorder, "wind scab," affects prunes and causes symptoms similar to RS. Symptoms of this damage occur on areas where leaves, shoots, or adjacent fruits brush the surface of the fruit, damaging the cuticular layers and creating russeted, scabby areas. Wind scab, however, can be distinguished from RS by the shape (it is usually longitudinal along the axis of the fruit) and the location (usually on the fruit sides) of the affected areas (18). Because of strong winds during the spring of 1988, 21–28% of the dehydrated fruit harvested from orchards A and B showed "wind scab."

In summary, russeting of prune is associated with areas having a thin cuticle without epicuticular wax and open, probably nonfunctional stomata. Severity of russeting on immature fruit was correlated significantly ($r > 0.90$) with levels of RS in dehydrated fruit. Russeting symptoms were induced by applying distilled water, either by hand-spraying or misting blossoms at full bloom stage and/or by covering the blossoms with plastic and paper bags to create >98% RH. Years with high incidence and severe RS ("scab years") were associated with frequent rainfall and >75 mm precipitation in March either during full bloom or occurring within 1 wk after full bloom. In contrast, in years with infrequent rainfall and <43 mm of precipitation little RS developed. Control of RS with fungicides (e.g., captafol and its analogues or ziram) is possible but the mechanism by which these compounds control RS is unknown. Experiments are in progress to determine the exact stage at which the prune blossoms and developing young fruits are most sensitive to water for the development of RS and to define the mechanism by which certain fungicides control RS even though microorganisms were not associated with the russeting.

ACKNOWLEDGMENTS

I thank D. P. Morgan for technical assistance, B. L. Teviotdale for reviewing the manuscript, E. Giacolini for providing trees for the 1990 study, and the California Prune Board for financial support of this project.

LITERATURE CITED

1. Adaskaveg, J. E., Shaw, D. A., and Ogawa, J. M. 1990. A mist generator and environmental monitoring system for field studies on shothole disease of almond. Plant Dis. 74:558-562.
2. Anonymous. 1987. California at a Glance. Crop Year 1986. California Farmer Publishing Co., San Francisco. 6 pp.
3. Barner, J., and Röder, K. 1964. Die Einwirkung von fungiciden auf die ausbildung des Blatteckgewebes und das verhalten einiger pflanzen parasiten. Z. Pflanzenkrankh. Pflanzenpathol. Pflanzenschutz 71:210-215.
4. Bondoux, M. P. 1969. La rugosité (russeting) de la pome Golden Delicious. Pomol. Fr. 11(5):141-149.
5. Carlone, R. 1958. Side effects of a non-copper fungicide on apples. Frutticoltura 20:43-52.
6. Corbin, J. B., Lider, J. V., and Roberts, K. O. 1968. Controlling prune russet scab. Calif. Agric. 22(1):6-7.
7. Dalbro, K. 1959. Iagttagelser og forsøg vedr. skrubben frugt og bladpletter hos Cox's Orange (Observations and experiments on fruit russeting and leaf spot of Cox's Orange). Tidsskr. Planteavl. 62:112-147.
8. Delwich, M. J., Tang, S., and Thompson, J. F. 1989. Development of a prune blemish and surface defect sorter. Pages 116-129 in: Prune Research Reports. California Prune Board, San Francisco.
9. Flore, J. A., and Dennis, F. G., Jr. 1990. Disorders caused by environmental factors. Russet. Page 86 in: Compendium of Apple and Pear Diseases. A. L. Jones and H. S. Aldwinckle, eds. American Phytopathological Society, St. Paul, MN.
10. Goble, R. 1989. Fresh prunes head for Orient. Page D1 in: The Fresno Bee, 30 July.
11. Hsiao, T. C., and Fischer, R. A. 1975. Mass flow porometers. Pages 5-11 in: Measurement of Stomatal Aperture and Diffusive Resistance. Bull. 809 Wash. State Univ. Coll. Agric. Res. Cent.
12. Jensen, W. A. 1962. Botanical Histochemistry. W. H. Freeman & Co., San Francisco. 408 pp.
13. Kirby, A. H. M., and Bennett, M. 1967. Susceptibility of apple and pear varieties to damage by certain organic fungicides. J. Hortic. Sci. 42:117-131.
14. Koch, E. C., and Alderman, D. C. 1970. Stem end russet of Yellow Newtown, in notes for today's apple growers. Univ. Calif. Agric. Ext. Serv. Newsl. 5 pp.
15. Kremer, F. W. 1963. Causes of russeting on Golden Delicious apples. Pflanzenschutz-Nachr. Bayer Ger. Ed. 16(1):17-22.
16. Martin, J. T. 1964. Role of cuticle in the defense against plant disease. Annu. Rev. Phytopathol. 1:81-100.
17. Michailides, T. J., Morgan, D. P., and Teviotdale, B. 1990. Determining the cause of prune russet scab and control trials. Pages 108-131 in: Prune Research Reports. California Prune Board, San Francisco.
18. Michailides, T. J., and Ogawa, J. M. 1988. Control and induction of russet scab and wind bruise damage ("wind scab") of French prunes.

Pages 94-104 in: Prune Research Repo\ts. California Prune Board, San Francisco.
19. Michailides, T. J., and Ogawa, J. M. 1988. Russet scab correlated with nonwaxy areas of prune fruits and its chemical control. (Abstr.) Phytopathology 78:1531-1532.
20. Mitchell, A. E., and Kretchman, D. W. 1957. Relationship of spray chemicals and cold injury to russeting of golden delicious apples. Trans. Ill. State Hortic. Soc. 25-26:43-48.
21. Montgomery, H. B. S. 1959. Russeting and cracking of Cox's Orange Pippin apples. Pages 163-164 in: Annu. Rep. East Malling Res. Stn. Kent.
22. Myburgh, A. C., Heyns, A. J., and Strydom, D. K. 1966. The inducement of russeting by pesticides on Golden Delicious apples. Dec. Fruit Grower 16:314-318.
23. Noga, G., and Wolter, M. 1990. Netzmittel als Auslöser von Apfelfrucht-Berostungen (Russeting of apple fruits as induced by surfactants). Gartenbauwissenschaft 55:20-26.
24. Sholberg, P. L., and Ogawa, J. M. 1983. Relation of postharvest decay fungi to the slip-skin maceration disorder of dried French prunes. Phytopathology 73:708-713.
25. Skene, D. S. 1965. Cracking and russeting in apple fruits. Pages 99-101 in: Annu. Rep. East Malling Res. Stn. Kent.
26. Skene, D. S. 1982. The development of russet, rough russet and cracks on the fruit of the apple Cox's Orange Pippin during the course of the season. J. Hortic. Sci. 57:165-174.
27. Skoss, J. D. 1955. Structure and composition of plant cuticle in relation to environmental factors and permeability. Bot. Gaz. Chicago 117:55-72.
28. Tukey, L. D. 1959. Observations on the russeting of apples growing in plastic bags. Proc. Am. Soc. Hortic. Sci. 74:30-39.
29. Van Schreven, A. C., and Vlasveld, W. P. V. 1960. The influence of Tuzet on the colour and keeping quality of apples. Meded. Dir. Tuinbouw. Neth. 23:459-466.
30. Walter, T. E. 1967. Russeting and cracking in apples: A review of world literature. Pages 83-95 in: Annu. Rep. East Malling Res. Stn. Kent.
31. Whitecross, M. I., and Armstrong, D. J. 1972. Environmental effects on epicuticular waxes of *Brassica napus* L. Aust. J. Bot. 20:87-95.
32. Wilson, C. L., and Pusey, P. L. 1983. Cyanoacrylate adhesives in the study of plant diseases. Plant Dis. 67:423-424.
33. Wilson, E. E., and Ogawa, J. M. 1979. Fungal, bacterial, and certain nonparasitic diseases of fruit and nut crops in California. Bull. Univ. Calif. Agric. Sci. 190 pp.