Lack of Effect of Stone Fruit Rust on Yield of French Prune Trees and Survival of Urediniospores of the Pathogen on Leaves, Shoots, and Buds

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ABSTRACT

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Two prune (*Prunus domestica* 'French') orchards, one in Tulare County and one in Yuba County, California, were treated either two or three times in summer with mancozeb or sulfur or left untreated for 3 yr. Fresh and dry fruit weights per tree, number of dry prunes per kilogram, fresh to dry weight ratio, and percent soluble solids were determined each year. Significant differences in yield parameters were few, minor, and inconsistent. Preharvest defoliation did not occur in either orchard in any year, but postharvest leaf loss was faster and leaf infection greater in control and sulfur than in mancozeb treatments. The number of urediniospores on buds declined from November through February, and the number on 1- and 2-yr-old shoots declined from November through April. Viable urediniospores were detected on shoots in April of 2 yr and in May of 1 yr and on fallen leaves in May of both years.

Outbreaks of stone fruit rust (prune rust) disease of prune (*Prunus domestica* L. 'French'), caused by *Tranzschelia discolor* (Fuckel) Tranzschel & Litv., are frequent in many California prune orchards. Generally, the disease is more common and severe in orchards located in the northern (Sacramento Valley) than in the south central (San Joaquin Valley) areas of the Great Central Valley. This pattern reflects the greater average annual rainfall and more probable late spring or summer rains that occur in the Sacramento Valley than in the central San Joaquin Valley. Rust pustules first appear on leaves as early as late spring or not until late summer, and defoliation begins in midsummer or after harvest. Infections rarely occur on prune fruit or twigs. The disease is controlled by one to three applications of sulfur fungicides during late spring through summer.

Early and repeated defoliation from rust has been associated with yield losses in stone fruit trees. Prune rust was estimated to cause up to 30% reduction in long-term productivity of prune trees in New South Wales (11). Premature defoliation of rust-infected peach and nectarine trees was followed by decreased fruit yields in Florida, and peach trees that had been protected from rust by fungicide sprays the previous season had earlier return bloom and greater fruit set than did nonsprayed trees (2).

In California, direct damage to the tree or crop by prune rust has not been documented. However, most California prunes are marketed as dried fruit, and factors such as preharvest defoliation that lower the potential sugar content could reduce fruit size and dry weight. This would cause loss in yield and fruit quality. In the past, preharvest leaf infection and the accompanying excess defoliation created difficulty in removing leaves from fruit during mechanical harvest (16), but modern harvest equipment has overcome this problem.

The primary inoculum for the prune rust fungus in California is presumed to be urediniospores that have overwintered in the orchard. Although *T. discolor* is a macrocyclic rust, the aecial state, which occurs on the garden anemone (*Anemone coronaria* L.) (13,23), is rarely found in California (5). Passage through the alternate host apparently is not mandatory for survival of the fungus in mild climates such as those found in Pacific Coast states where French prunes are grown (16). Other *Prunus* species, especially almond (*P. dulcis* (Mill.) D. Webb and peach (*P. persica* (L.) Batsch), also are hosts to *T. discolor*, but each tree species is attacked by a different physiologic race of the fungus (1,10, 11,13,22). Thus, rust infections on nearby almond or peach trees probably do not contribute inoculum to disease outbreaks in prune trees.

In a study of prune rust in Australia, urediniospores on infected leaves, especially leaves remaining on the tree, were shown to be the overwintering structures as well as the primary inoculum for the next season (4). Urediniospores lodged in bark crevices and bud scales of peach did not contribute to inoculum of peach rust (6). Survival of prune rust urediniospores through winter in nature in California has not been documented. Because the alternate host is not present in or near prune orchards in California, we wanted to determine if urediniospores could survive here on infected or infested tree parts such as leaves, shoots, and buds.

The work reported here assesses the effects of prune rust on dry yield and fruit quality of French prune trees and validates the overwintering survival of urediniospores on shoots, buds, and fallen leaves in California.

MATERIALS AND METHODS

Yield experiments. The experiments were conducted for 3 yr in commercial French prune orchards planted in California's Central Valley. One was in Tulare County, a relatively dry prune-growing district of the southern San Joaquin Valley, and the other was in Yuba County, a wetter area in the Sacramento Valley. The Tulare County orchard, planted in 1964, had a history of prune rust, had never been treated for control of the disease, and had a permanent cover crop. The Yuba County orchard, planted in 1986, was clean-cultivated and treated annually with two

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applications of sulfur fungicide for prune rust control. An adjacent block of mature prune trees frequently sustained some preharvest leaf loss to prune rust in spite of annual sulfur treatment. Trees in both orchards were spaced 6.1 × 6.1 m and flood-furrow irrigated. Treatments were: 1) mancozeb 80W, 1.2 g a.i./L; 2) sulfur 92W, 3.3 and 6.6 g a.i./L in Tulare and Yuba counties, respectively; and 3) nontreated control. The rates of sulfur represented the standard for each region. Materials were applied to runoff with an FMC Bean handgun sprayer, operated at 1.03 mPa (150 psi), on 29 June and 3 August 1987, 27 June and 28 July 1988, and 26 June and 26 July 1989 in Tulare County and on 5 June, 7 July, and 3 August 1989, 7 June, 2 July, 1 August 1990, and 7 June and 3 and 31 July 1991 in Yuba County. Trees received the same treatments each year. Treatments were applied to single trees in 40 blocks arranged in a randomized complete block design.

Fruit were harvested during standard commercial harvest on 20, 24, and 17 August 1987, 1988, and 1989, respectively, in Tulare County and on 29 August 1989, 1990, and 1991 in Yuba County. In Tulare County, trees were shook by a mechanical harvester; fruit were collected on a catching frame and transferred to bins and weighed with a forklift system (designed by the University of California) fitted with a load cell to measure fresh weight. In Yuba County, trees were hand-harvested and fresh weights were measured on a portable electronic bench scale. One subsample of approximately 2 kg of fresh fruit was drawn from the harvested fruit of each tree, placed in mesh bags, and weighed (fresh weight). Samples were dried for 16 hr at 82 C by a conventional parallel flow dehydrator, then stored in open bins for 14–48 hr to cool and equalize the moisture content. Dried prunes were weighed and counted to determine the fresh to dry weight ratio (dry-away ratio) and the number of dry fruit per kilogram (dry count). Dry count is the conventional measure of fruit quality; large fruit are most desirable. An additional sample of 10 fruit was taken at harvest from each tree for extraction of soluble solids (sugar). Within 24 hr of harvest, halves of the flesh from each fruit were combined and ground in a blender, and the extracted pulp and juice were pressed through sections of cheesecloth. The sugar content of the extracted juice was measured with a hand-held, temperature-compensated refractometer (Cambridge Instruments, Buffalo, NY).

Leaf infection was evaluated at harvest (August) in both orchards and on 26, 3, and 18 October 1987, 1988, and 1989, respectively, in Tulare County and on 11 and 8 October 1989 and 1990, respectively, in Yuba County. We gathered 50 leaves from each tree arbitrarily on each date and estimated the percentage of the leaf blade with rust pustules. Defoliation was rated on these same dates and again on 6 and 13 November 1987 and 1989, respectively, in Tulare County and on 14, 6, and 3 November 1989, 1990, and 1991, respectively, in Yuba County. We rated defoliation as: 1 = 0–10%, 2 = 11–30%, 3 = 31–60%, 4 = 61–90%, and 5 = 91–100%.

Rainfall data were obtained from California Irrigation Management Information Systems stations located approximately 8.0 and 12.8 km from the Tulare County and Yuba County orchards, respectively.

Data were analyzed by analysis of variance and Duncan's multiple range test. Arcsine transformation was performed on data for percent healthy leaves and percent leaf area rusted prior to analysis.

Survival of urediniospores. Five 1-yr-old and five 2-yr-old shoots were removed from five nontreated control trees, and 12–15 leaves were collected from beneath each of these trees in the Yuba County orchard. Collections were made at approximately monthly intervals from November through May 1990 and from October 1990 though May 1991. Apical 10-cm sections were cut from the shoots, the buds were excised from these portions, and the sections were cut into 1- to 2-cm pieces. The combined pieces from each tree were placed in a test tube and covered with 5–20 ml of water. Three of the removed buds from each of the five shoots from each tree were combined in a test tube with 2 ml of water. One drop of Tween 20 was added to each test tube, and the tubes were agitated on a vortex mixer for 1 min. Urediniospore concentration was determined with a hemacytometer. Immediately after mixing, five 0.2-ml aliquots of the suspensions were placed onto acidified (2.5 ml of a 25% lactic acid solution, v/v, per liter of medium) potato-dextrose agar (APDA) culture dishes and incubated at room temperature (20–22 C) for 24 hr. The germinated urediniospores in two groups of 100 spores each were counted for all bud collections and for shoot collections made in October and November. Shoot collections made at later dates had too few urediniospores to provide two groups of 100 each, so all urediniospores present (27–106) were included in determining percent germination.

Urediniospores were removed from leaves with a miniature cyclone collector. Then, 2 ml of water and one drop of Tween 20 were added to the dry spores, five 0.2-ml aliquots were seeded onto APDA and incubated, and percent germination was determined as described above. All urediniospore counts and germination tests were performed within 6 hr of sample collection.

Table 1. Yield of French prune trees treated for three consecutive years for control of stone fruit rust, caused by *Tranzchelia discolor*, in an orchard in Tulare County, California

Treatment[x]	Weight per tree (kg)		Dry count[y]	Dry-away ratio	Soluble solids (%)
	Fresh	Dry			
1987					
Mancozeb	31.4	19.1	142.5	2.8 a[z]	26.4
Sulfur	28.1	16.2	139.7	3.1 b	26.1
Nontreated control	27.1	15.7	143.7	3.2 b	25.1
	NS	NS	NS		NS
1988					
Mancozeb	159.8	47.3	134.2 a	3.4	18.3 b
Sulfur	142.0	40.2	144.9 a	3.4	18.1 b
Nontreated control	160.5	42.8	162.3 b	3.6	16.8 a
	NS	NS		NS	0.7
1989					
Mancozeb	49.7	19.1	134.9	2.6	25.7
Sulfur	41.5	15.8	137.1	2.6	25.7
Nontreated control	40.3	15.5	138.1	2.6	26.1
	NS	NS	NS	NS	NS

[x] Mancozeb and sulfur applied to runoff at 1.2 and 3.3 g a.i./L, respectively, by handgun sprayer at 1.03 mPa on 29 June and 3 August 1987, 27 June and 28 July 1988, and 26 June and 26 July 1989. Forty single-tree replications of each treatment. Fruit harvested on 20, 24, and 17 August 1987, 1988, and 1989, respectively.

[y] Number of dry prunes per kilogram.

[z] Means down columns within each year followed by the same letter do not differ significantly ($P = 0.05$) according to Duncan's multiple range test. NS = not significant ($P = 0.05$).

RESULTS

Yield experiments. *Tulare County trial.* There were no significant differences among treatments in fresh or dry fruit weight per tree in any year, dry count in 1987 and 1989, dry-away ratio in 1988 and 1989, or percent soluble solids in 1987 and 1989 (Table 1). Dry count was significantly higher in the nontreated control than in the fungicide treatments in 1988. Dry-away ratio was significantly less in fruit treated with mancozeb than in those treated with sul-

Table 2. Effect of mancozeb and sulfur in the control of stone fruit rust, caused by *Tranzchelia discolor*, of French prune trees in an orchard in Tulare County, California

	Diseased leaves[y] (%)		Leaf area rusted[y] (%)		Defoliation rating[y]		
Treatment[x]	**August**	**October**	**August**	**October**	**August**	**October**	**November**
1987							
Mancozeb	0.0	33.6 a[z]	0.0	3.2 a	1.0	1.6 a	2.3 a
Sulfur	0.0	67.5 b	0.0	8.3 b	1.0	1.8 a	2.6 b
Nontreated control	0.0	84.5 c	0.0	17.5 c	1.0	2.2 b	3.2 c
1988							
Mancozeb	0.0	19.0 a	0.0	0.8 a	1.0	1.7 a	...
Sulfur	0.0	59.8 b	0.0	4.5 b	1.0	2.0 b	...
Nontreated control	0.0	86.8 c	0.0	14.2 c	1.0	2.4 c	...
1989							
Mancozeb	0.0	57.5 a	0.0	7.4 a	1.0	1.6 a	3.1 a
Sulfur	0.0	94.1 b	0.0	9.3 b	1.0	1.7 b	3.4 b
Nontreated control	0.0	100.0 a	0.0	14.9 c	1.0	2.5 c	4.4 c

[x] Mancozeb and sulfur applied to runoff at 1.2 and 3.3 g a.i./L, respectively, by handgun sprayer at 1.03 mPa on 29 June and 3 August 1987, 27 June and 28 July 1988, and 26 June and 26 July 1989.
[y] Average of 40 single-tree replications of each treatment. Fifty leaves per tree collected at harvest on 20, 24, and 17 August 1987, 1988, and 1989, respectively, and 26, 3, and 18 October 1987, 1988, and 1989, respectively. Percent leaf area rusted visually estimated for each leaf. Defoliation rated at harvest for October leaf collection dates and on 6 and 13 November 1987 and 1989, respectively, on a scale where 1 = 0–10%, 2 = 11–30%, 3 = 31–60%, 4 = 61–90%, and 5 = 91–100%.
[z] Means down columns within each year followed by the same letter do not differ significantly ($P = 0.05$) according to Duncan's multiple range test.

fur or in the nontreated control in 1987. Percent soluble solids was significantly lower in the nontreated control than in the fungicide treatments in 1988.

Leaf infection and defoliation were not observed at harvest (August) in any year (Table 2). By October each year there were significantly lower percentages of diseased leaves and leaf area rusted in mancozeb than in sulfur or nontreated control treatments, and rust infection was significantly less in the sulfur than in the nontreated control treatments. Similar separation of treatment means was found for defoliation ratings taken in October 1988 and 1989 and in November 1987 and 1989.

Yuba County trial. There were no significant differences among treatments in fresh and dry fruit weights per tree, dry-away ratio, or percent soluble solids in 1989 and 1991, in dry weight per tree in 1990, and in dry count in 1989 (Table 3). Significantly higher fresh fruit weight was found in the nontreated control than in the fungicide treatments in 1990. In that year, dry count was significantly less and percent soluble solids significantly greater in the mancozeb treatment than in the nontreated control, but the sulfur treatment did not differ significantly from either. Dry-away ratio was significantly lower in the mancozeb than in the sulfur and nontreated control treatments. Dry count in 1991 was significantly greater in the sulfur treatment than in the mancozeb or nontreated control treatment.

Table 3. Yield of French prune trees treated for three consecutive years for control of stone fruit rust, caused by *Tranzchelia discolor*, in an orchard in Yuba County, California

	Weight per tree (kg)		Dry	Dry-away	Soluble
Treatment[x]	**Fresh**	**Dry**	**count**[y]	**ratio**	**solids (%)**
1989					
Mancozeb	32.5	10.7	119.6	3.1	23.3
Sulfur	29.1	9.5	120.9	3.1	22.7
Nontreated control	31.7	10.7	118.4	3.2	22.7
	NS	NS	NS	NS	NS
1990					
Mancozeb	13.3 a[z]	4.8	100.2 a	2.8 a	22.5 b
Sulfur	14.4 a	4.7	102.1 ab	2.9 b	21.9 ab
Nontreated control	22.1 b	7.5	106.7 b	2.9 b	21.4 a
		NS			
1991					
Mancozeb	51.7	15.6	95.6 a	3.3	22.7
Sulfur	51.7	15.5	99.5 b	3.3	23.5
Nontreated control	46.8	14.4	93.5 a	3.2	23.4
	NS	NS		NS	NS

[x] Mancozeb and sulfur applied to runoff at 1.2 and 6.6 g a.i./L, respectively, by handgun sprayer at 1.03 mPa on 5 June, 7 July, and 3 August 1989; 7 June, 2 July, and 1 August 1990; and 7 June and 3 and 31 July 1991. Forty single-tree replications of each treatment. Fruit harvested on 29 August 1989, 1990, and 1991.
[y] Number of dry prunes per kilogram.
[z] Means down columns within each year followed by the same letter do not differ significantly ($P = 0.05$) according to Duncan's multiple range test. NS = not significant ($P = 0.05$).

Rust-infected leaves were present by harvest (August) each year, but defoliation had not yet begun (Table 4). In August 1989, there were significantly higher percentages of diseased leaves and leaf area rusted in the nontreated control than in the fungicide treatments. By October, disease control was significantly better in the mancozeb and sulfur treatments than in the nontreated control treatment. Percentages of diseased leaves and leaf area rusted did not differ in August 1990, but disease was greater in the nontreated control than in the fungicide treatments in October. In August 1991, the fungicide treatments provided equivalent disease control and were significantly different from the nontreated control. Defoliation was least in the mancozeb treatment, intermediate in the sulfur treatment, and greatest in the nontreated control treatment in October 1989 and November of each year. Leaf loss in October 1990 was greater in the nontreated control than in the fungicide treatments.

July and August were devoid of rain in both counties in all 3 yr of the experiments except for 3 mm of rainfall in Yuba County in August 1989. Rain fell in June of 2 yr and in most months from October through April in both locations.

Survival of urediniospores. Urediniospore counts from 1- and 2-yr-old shoots were higher in fall and winter (October through February) during 1989–1990 than during 1990–1991, but counts from buds were similar (Table 5). Percent germination of urediniospores from shoots, buds, and fallen leaves decreased over time. By April, buds from 1-yr-old twigs had grown into shoots, and too few urediniospores remained on 2-yr-old shoots in May to allow assessment of percent germination. Low percent germination was observed in urediniospores from fallen leaves collected in May of each year (Table 5).

DISCUSSION

Prune rust did not adversely affect yield or fruit quality in the current or following seasons in our experiments. In both orchards, the significant differences among treatments were few, minor, and inconsistent. We believe they were anomalous because the significant differences were not verified by expected differences in other yield parameters. For instance, lower dry-away ratios should be associated with higher soluble solids content but were not. Preharvest defoliation did not occur in either orchard during the course of this study; consequently, we cannot comment on the effects such defoliation might have on yield of French prune trees in California. If the accelerated postharvest leaf loss we observed was deleterious to the next crop, this effect was overshadowed by other horticultural factors, such as alternate bearing, and was not revealed by our experiments. We attribute the higher fresh weight found in the nontreated control than in the fungicide treatments in Yuba County in 1990 to fruit drop perhaps initiated by high ambient air temperatures following the last spray application. The maximum temperature on the day of treatment was 36 C, and beginning the following day, maximum air temperatures ranged from 39 to 42 C for the next 8 days.

Rust infections alter rates of photosynthesis, respiration, and transpiration and cause reduction in overall plant vigor and yield (3,7,8,12,17,20,21,25). In plants that do not shed their rust-infected leaves, reductions in yield can be traced to deleterious effects on these important physiological processes. Plants, such as prune trees, that abscise their infected leaves are subject to the damages associated with defoliation. Early severe defoliation either increases early fruit drop or decreases fruit size, and repeated defoliation during the growing season over several years slowly weakens trees and renders them unproductive (14,18,19, 22,24). Moderately to severely rust-infected leaves are not retained by prune trees in California; thus, defoliation is an important consequence of rust in-

Table 4. Effect of mancozeb and sulfur in the control of stone fruit rust, caused by *Tranzchelia discolor*, of French prune trees in an orchard in Yuba County, California

	Diseased leaves[y] (%)		Leaf area rusted[y] (%)		Defoliation rating[y]		
Treatment[x]	**August**	**October**	**August**	**October**	**August**	**October**	**November**
1989							
Mancozeb	14.2 a[z]	91.9 a	0.7 a	24.4 a	1.0	1.8 a	3.1 a
Sulfur	12.0 a	95.9 b	0.8 a	29.3 b	1.0	2.1 b	3.4 b
Nontreated control	76.2 b	100.0 c	14.2 b	60.7 c	1.0	4.2 c	4.4 c
1990							
Mancozeb	0.0	7.8 a	0.0	0.4 a	1.0	1.2 a	2.2 a
Sulfur	0.9	7.0 a	<0.1	0.4 a	1.0	1.3 a	2.5 b
Nontreated control	0.6	69.9 b	0.1	16.0 b	1.0	3.0 b	4.0 c
	NS		NS				
1991							
Mancozeb	3.1 a	...	<0.1 a	...	1.0	...	2.6 a
Sulfur	3.8 a	...	0.1 a	...	1.0	...	3.1 b
Nontreated control	14.3 b	...	0.4 b	...	1.0	...	4.1 c

[x] Mancozeb and sulfur applied to runoff at 1.2 and 6.6 g a.i./L, respectively, by handgun sprayer at 1.03 mPa on 5 June, 7 July, and 3 August 1989, 7 June, 2 July, and 1 August 1990; and 7 June and 3 and 31 July 1991.

[y] Average of 40 single-tree replications of each treatment. Fifty leaves per tree collected at harvest on 29 August 1989, 1990, and 1991 and on 11 and 8 October 1989 and 1990, respectively. Percent leaf area rusted visually estimated for each leaf. Defoliation rated at harvest for October leaf collection dates and on 14, 6, and 3 November 1989, 1990, and 1991, respectively, on a scale where 1 = 0–10%, 2 = 11–30%, 3 = 31–60%, 4 = 61–90%, and 5 = 91–100%.

[z] Means down columns within each year followed by the same letter do not differ significantly ($P = 0.05$) according to Duncan's multiple range test.

Table 5. Survival of *Tranzschelia discolor* urediniospores on French prune shoots, buds, and fallen leaves in an orchard in Yuba County, California, from winter 1989 to spring 1990 and from winter 1990 to spring 1991

	Average number of urediniospores[w]						Urediniospore germination[x] (%)							
	Shoot surface (mm²)				Bud from 1-yr-old shoot									
	1-yr-old Shoot		2-yr-old Shoot				1-yr-old Shoots		2-yr-old Shoots		Buds		Leaves[y]	
Month	**89–90**	**90–91**	**89–90**	**90–91**	**89–90**	**90–91**	**89–90**	**90–91**	**89–90**	**90–91**	**89–90**	**90–91**	**89–90**	**90–91**
October	...	10	...	9	...	73	...	17.3	...	12.6	...	13.6	...	...
November	766	23	523	18	1,360	1,800	22.1	16.8	11.6	18.2	10.2	9.4	8.9	6.9
December	...	7	...	7	...	890	...	4.6	...	5.8	...	1.0	...	4.1
January	790	1	799	4	470	150	4.3	0.9	5.1	2.0	2.6	0.8	1.1	1.6
February	10	2	15	2	290	313	2.0	0.0	8.8	0.7	0.9	0.3	0.2	2.6
April	...	...	3	1	...	...	...	...	1.6	NA[z]	...	...	0.6	0.4
May	...	...	0	0	...	...	...	...	NA	NA	...	...	0.3	1.2

[w] Apical 10-cm sections of five 1-yr-old shoots and five 2-yr-old shoots. Buds removed from 1-yr-old shoots collected from each of five nontreated trees, three buds from each of five 1-yr-old shoots.

[x] Germination percentages for urediniospore counts $>10/mm^2$ derived from two groups of 100; those for urediniospore counts less $<10/mm^2$ derived from 27–106 urediniospores.

[y] Ten leaves from beneath each of the same nontreated trees as shoots.

[z] NA = not available; too few urediniospores to assess percent germination.

fection in this crop. The most severe preharvest leaf infection, but without defoliation, that we encountered (Yuba County 1989) did not affect any yield parameter, but more severe leaf infection possibly would have been accompanied by earlier and more noticeable defoliation.

The early, preharvest defoliation of French prune trees reported from other parts of the world is not typical for California. Instead, prune rust is a late-season disease in most orchards there and as such does not appear to harm crop yield or fruit quality. Treatments to control prune rust should not be necessary for most French prune orchards in the state. Orchards at risk of chronic early rust infection, such as those situated along rivers or in high rainfall areas, may require annual fungicide treatment.

Mancozeb was selected for this study to impose the greatest possible difference in levels of rust between treatments. Its superior performance in control of prune rust documented here is consistent with that found by others (9,15). Mancozeb is not registered for use on prunes in California.

Urediniospores survived at least until May on fallen leaves on the ground. Viable urediniospores may also have been present on shoots, but we were unable to detect them. The large decline that we measured in both number and percent germination of urediniospores on shoots and buds agrees with that found by Ellison et al in Australia (4). However, they found that urediniospores survived on leaves on trees but not on leaves on the ground. In the Yuba County orchard, strong northerly winds, common to the region, removed all leaves from the trees by early winter. Although urediniospore survival might be greater on leaves found on branches or in tree crotches, perhaps infected fallen leaves also are sources of primary inoculum in California prune orchards.

We do not know when *T. discolor* first infects prune trees each season. Infections perhaps occur in spring after prune trees leaf out in March and remain quiescent until conditions favor disease development. Or, very low numbers of urediniospores may survive on leaves or shoots and not cause infection until late summer or early fall. The extremely low survival rate of urediniospores coupled with the dry summer climate may explain the late appearance of the disease in most orchards.

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