Chemical Control of Prune Leaf Rust (*Tranzschelia discolor* f. sp. *domesticae*) in California

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ABSTRACT

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The effects of wettable sulfur (WS), mancozeb, and timing of mancozeb applications in controlling prune rust (*Tranzschelia discolor* f. sp. *domesticae*) of French prunes were evaluated. In an experimental plot of prunes, unsprayed trees had 44% and WS- and mancozeb-sprayed trees had 21 and < 1% rusted leaves, respectively. In vitro urediniospore germination on acidified potato-dextrose agar amended with 5, 10, or 15 μg a.i./ml of WS or mancozeb was reduced 11, 33, and 38% with WS and 97, 97, and 97% with mancozeb. Results of three mancozeb sprays (in June, July, and August 1983) proved that the last application alone was sufficient for controlling prune rust. Sprayed trees had fewer infected leaves and also fewer rust pustules per leaf. On unsprayed trees, most of the infected leaves had ≥ 16 pustules per leaf. In a commercial prune orchard already infected by rust, two mancozeb sprays (in July and August) protected the sprayed trees for 3 mo from further rust infections, whereas 100% of the leaves on unsprayed trees were infected.

Prune leaf rust, caused by the fungus *Tranzschelia discolor* (Fuckel) Tranzschel & Litvinov f. sp. *domesticae* (1), is widely distributed in California and may be a serious problem in certain years (2,4,8). During early stages of infection, symptoms of the disease are distinct, angular, yellow-orange lesions on the top surfaces of leaves that correspond to light brown to reddish pustules on the lower surfaces (6). These are the uredinia (sori) of the fungus that produce urediniospores during summer and teliospores later during summer and fall.

When extensive, the disease causes premature defoliation of the prune trees (6–8). Defoliation not only creates difficulties in mechanical harvest operations (3) but also reduces the vigor of the trees. To avoid early defoliation of the trees, chemical control of the disease is required. Wettable sulfur (WS) is the only fungicide registered in the United States for control of prune rust. The objective of this investigation was to study the effect of mancozeb (Dithane M-45) as an alternative fungicide to control prune rust. Appropriate number and timing of mancozeb applications for control of prune rust were also investigated.

MATERIALS AND METHODS

1981 and 1982 Experiments. To determine the efficacy of WS and mancozeb sprays in controlling prune rust, prune trees (*Prunus domestica* L.) in the experimental plot of the Department of Plant Pathology at University of California, Davis, were sprayed with a handgun sprayer on 15 August, 23 September, and 19 October of 1981 and 1982. The dosages used were 20,167 and 5,378 g a.i./ha for WS and mancozeb, respectively. The experimental layout was a completely randomized block design with eight single-tree replicates. Evaluation of disease incidence was made during the first week in November (about 3 wk after the incidence of first rust symptoms) by collecting randomly 400 leaves per tree (100 leaves per tree quadrant).

Urediniospore germination tests. Because urediniospores are the infective stage of the fungus (6,8), to explain results obtained in the field, we tested the effects of WS and mancozeb on urediniospore germination. Urediniospores from rust pustules on leaves were vacuum-collected, washed twice with sterile distilled water, and plated on plates containing acidified potato-dextrose agar (APDA) amended with 5, 10, or 15 μg a.i./ml of WS or mancozeb. The fungicides and the acid (2.5 ml of 25% lactic acid per liter) were added to the medium after autoclaving the agar, and urediniospore germination was recorded after 22–24 hr of incubation at 18 C. Data were analyzed by a two-way factorial analysis of variance (ANOVA). Factors included fungicide tested and rate of fungicide.

1983 Experiments. To determine the appropriate number and timing of mancozeb applications, prune trees at the Davis campus plot were sprayed with mancozeb at a concentration of 5,378 g a.i./ha on the following schedule: one spray (20 June), one spray (27 July), one spray (19 August), two sprays (20 June and 27 July), two sprays (20 June and 19 August), two sprays (27 July and 19 August), and three sprays (20 June, 27 July, and 19 August). The test plot was a completely randomized block design with six single-tree replicates in each treatment. Disease incidence was evaluated 3 wk after the appearance of first rust symptoms, using 100 leaves collected at random from each tree. Symptoms were classified into four disease severity categories according to the number of pustules per leaf, as shown in Table 1. ANOVA and mean calculations were conducted with the Statistical Analysis Program (SAS) (5) and mean comparisons with orthogonal contrasts.

To evaluate the efficacy of mancozeb when the disease was already present, an experimental plot was set up in a

Table 1. Control of prune leaf rust (*Tranzschelia discolor* f. sp. *domesticae*) with mancozeb in an experimental prune orchard at University of California, Davis (1983)

Treatment[a]	Dates of spray(s)	Leaves with rust pustules (%)[b] 1-5	6-10	11-15	≥16	Total rusted leaves[c] (%)
Check	...	21.2	10.2	9.8	36.0	77.2
Mancozeb	20 Jun.	11.7	3.7	2.5	11.7	29.5
	27 Jul.	10.3	2.5	1.2	3.5	17.5
	19 Aug.	0.8	0.2	0.0	0.7	1.7
	20 Jun./27 Jul.	5.5	1.2	0.5	0.8	8.0
	20 Jun./19 Aug.	0.5	0.3	0.2	0.2	1.2
	27 Jul./19 Aug.	0.0	0.0	0.0	0.2	0.2
	20 Jun./27 Jul./19 Aug.	2.5	0.2	0.0	0.0	2.7

[a] Concentration of mancozeb was 5,378 g a.i./ha.
[b] One hundred leaves per tree were harvested on 25 November 1983 and evaluated for rust pustules.
[c] Results are expressed as an average of six replicates. Mean differences of total rusted leaves were determined with orthogonal contrasts.

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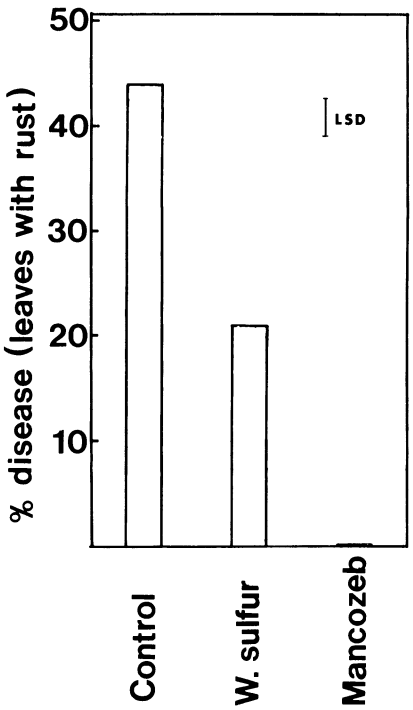

Fig. 1. Control of prune leaf rust (*Tranzschelia discolor* f. sp. *domesticae*) by wettable sulfur or mancozeb sprays. Results are expressed as an average of eight replicates. Variance and mean calculations were conduced with the Statistical Analysis Program (5); for LSD, $P = 0.05$.

commercial prune orchard in Butte County, California. Eight random single-tree replicates were sprayed with mancozeb (5,378 g a.i./ha) on 29 July and 12 August 1983, and eight random unsprayed trees were used as controls. Sprayed and unsprayed trees were surrounded by unsprayed prunes (buffer trees). To determine the rust incidence before the chemical applications, 50 leaves were collected just before the first spray, and 100 were collected 5 and 88 days after the second chemical application. Diseased leaves were classified into four categories according to the number of pustules per leaf (Table 2).

RESULTS

1981 and 1982 Experiments. Because of lack of rain in early fall of 1981, disease incidence was very low (7%), and it was not possible to make any comparisons. In contrast, in 1982, disease incidence was high and unsprayed trees had 44% infected leaves. Trees sprayed with WS had 21% and those sprayed with mancozeb had only 0.6% infected leaves (Fig. 1). Most of the infected leaves from unsprayed or sprayed trees had one to two pustules per leaf, and only a small percentage had three to five pustules per leaf.

Urediniospore germination tests. Both WS and mancozeb reduced urediniospore germination significantly. Concentrations of 10 and 15 μg a.i./ml of WS resulted in significantly lower percent germination than did the 5 μg a.i./ml concentration (Table 3). Plates amended with mancozeb had 97% reduction in urediniospore germination for all concentration levels tested (Table 3).

1983 Experiments. Incidence of rust in 1983 was higher than that in 1982 or 1981 as indicated by the higher percentage of infected leaves (Fig. 2) as well as by the greater number of pustules per leaf (Table 1). Unsprayed trees had 77.2% infected leaves, significantly higher than that of trees sprayed once, twice, or three times ($F = 11.86$, $P = 0.01$; Fig. 2). Trees sprayed in August had 1.7% infected leaves; those sprayed in June, 29.5%; and those sprayed in July, 17.5%. Orthogonal comparisons of treatment means indicated the following: For trees sprayed once, those treated in August had a significantly lower percentage of infected leaves than those sprayed in June ($F = 8.46$, $P = 0.01$). There were no significant differences in disease incidence whether the trees received one, two, or three applications if they received an August spray; however, rust incidence was significantly higher on trees sprayed in June, July, or June and July than on trees that received at least one August application ($F = 10.71$, $P = 0.01$). Most of the infected leaves of unsprayed trees had ≥16 pustules per leaf, whereas most of those sprayed with mancozeb had one to five pustules per leaf (Table 1). The only exceptions were trees that were sprayed on 20 June and had the same percentage of leaves with one to five or with ≥16 pustules per leaf (Table 1).

In the commercial orchard in Butte County, rust incidence recorded on 17 August did not differ much from that recorded on 29 July, just before the first mancozeb spray (Table 2), but differences in disease incidence between first and third or second and third leaf-sampling dates were dramatic. On 8 November 1983, unsprayed trees had 99.8% infected leaves and those sprayed with mancozeb had only 6.8% infected leaves (Table 2). Most of the infected leaves of unsprayed or sprayed trees recorded on 29 July, just before the first spray, had one to five pustules per leaf (Table 2). In contrast, most of the infected leaves (73.2%) of unsprayed trees recorded on 8 November had ≥16 pustules per leaf. Most of the infected leaves (5.8%) of trees sprayed with mancozeb had retained their low number of one to five pustules per leaf (Table 2).

Table 2. Control of prune leaf rust (*Tranzschelia discolor* f. sp. *domesticae*) with mancozeb in a commercial prune orchard in Butte County, California (1983)

Treatment[w]	Date of leaf collection	Leaves with rust pustules (%)[x] 1-5	6-10	11-15	≥16	Total rusted leaves[y] (%)
Unsprayed	29 Jul.	21.0	2.8	0.5	3.3	27.6 b[z]
	17 Aug.	24.5	1.9	1.3	2.6	30.3 b
	8 Nov.	3.4	6.8	16.4	73.2	99.8 a
Sprayed	29 Jul.	15.0	0.8	0.5	1.5	17.8 c
	17 Aug.	12.0	0.5	0.0	1.0	13.5 cd
	8 Nov.	5.8	0.9	0.1	0.0	6.8 d

[w] Two chemical sprays were applied, one on 29 July and a second on 12 August 1983 (concentration of mancozeb 5,378 g a.i./ha).
[x] Fifty leaves per tree were collected on 29 July 1983, and 100 leaves per tree each on 17 August and 8 November 1983.
[y] Means of eight replicates.
[z] Numbers followed by a different letter are significantly different ($P = 0.05$) according to Duncan's multiple range test.

Table 3. Effect of wettable sulfur and mancozeb on the germination of urediniospores of prune leaf rust (*Tranzschelia discolor* f. sp. *domesticae*) on acidified potato-dextrose agar plates amended with the fungicides and incubated at 18 C for 22–24 hr

Treatment	Concentration (μg/ml)	Urediniospore germination[a] (%)	Reduction in germination over control[b] (%)
Control	···	57.25	0
Wettable sulfur	5	51.00	11
	10	38.25	33
	15	35.50	38
Mancozeb	5	2.00	97
	10	1.50	97
	15	2.00	97

[a] Percent urediniospore germination was determined from 100 spores in each of four replicate plates; test was repeated twice.
[b] Data were analyzed by a two-way analysis of variance. Concentration means that exceed LSD 6.88 are different ($P = 0.05$).

DISCUSSION

Trees sprayed with mancozeb in 1982 had essentially no infected leaves. Most of the infected leaves of unsprayed trees or trees sprayed with WS had only one or two pustules per leaf, indicating that rust

incidence was also low in 1982; however, it was at a level high enough to allow us to determine differences between the treatments and conclude that mancozeb was far more effective than WS in protecting prune leaves from rust infections.

The urediniospore germination experiments explain the better leaf rust control obtained in the field by mancozeb spray(s). Only 3% of urediniospores germinated in plates of APDA amended with 5, 10, or 15 μg a.i./ml of mancozeb. This drastic reduction of urediniospore germination explains why trees sprayed with mancozeb had only 0.6% infected leaves. Urediniospores are thought to be the overwintering structures of the fungus (8) infecting leaves during the current or the following growing season, and urediniospore germination is therefore essential for disease development. Chemicals that prevent urediniospore germination will be very effective in controlling this disease. This was true with WS and even more with mancozeb. These results agree with those of Duruz and Goldsworthy (2), who studied chemical control of peach rust, also caused by *T. discolor* (now f. sp. *persicae* [1]), and reported that liquid lime-sulfur consistently inhibited the germination of urediniospores in culture media and that liquid lime-sulfur proved to be the most effective against peach rust.

The experiments in 1983 indicated that the last spray application (in August) was the most effective in controlling prune rust compared with the sprays in June or July (Fig. 2). The fact that there were no significant differences in the level of disease whether the trees received one, two, or three sprays if they received an August spray indicates that one spray in August is sufficient for optimum control of prune rust. The increased effectiveness of spray applied in August can be explained by the greater residues of mancozeb compared with residues from earlier applications (June or July). The mancozeb spray in June provided disease control at an intermediate level between unsprayed trees and those sprayed later; this was indicated not only from the total percentage of rusted leaves but also from the equal percentages of leaves with one to five and ≥16 pustules per leaf (Table 1). In contrast, most of the infected leaves of unsprayed trees had ≥16 pustules per leaf, whereas most of the infected leaves from trees sprayed in July or August once, twice, or three times had only one to five pustules per leaf (Table 1).

Results in the commercial plot where the mancozeb sprays were applied when rust was present indicated that two sprays protected leaves that were free of infection at the time of chemical application for at least 3 mo. Furthermore,

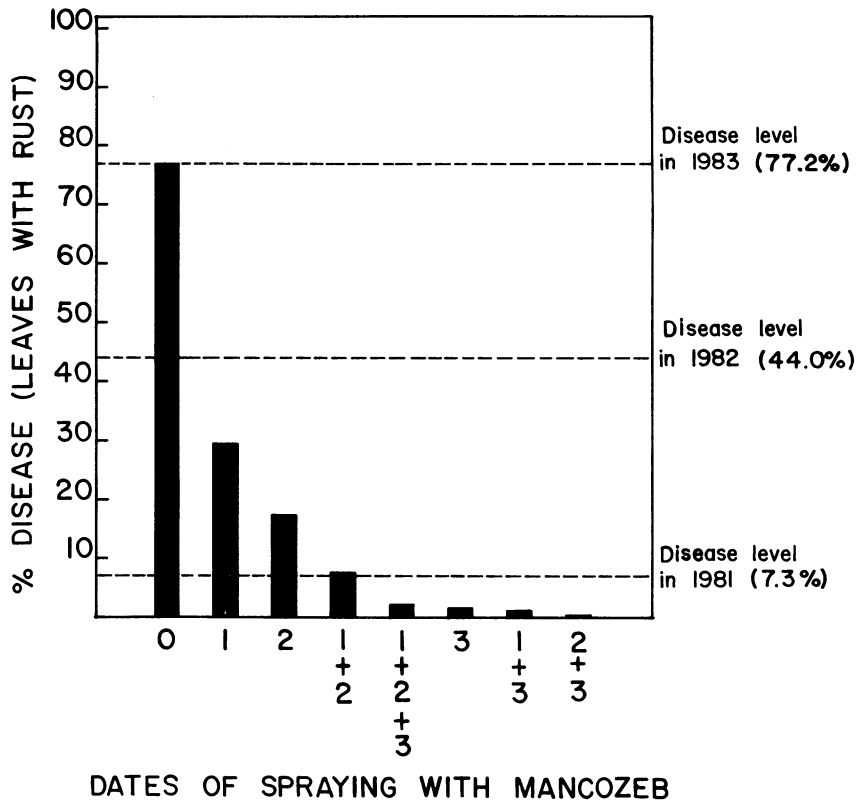

Fig. 2. Control of prune leaf rust (*Tranzschelia discolor* f. sp. *domesticae*) by mancozeb spray(s) on trees in University of California Davis Campus (dates of sprays: 1 = 20 June 1983, 2 = 27 July 1983, and 3 = 19 August 1983). Results are expressed as an average of six replicates. Treatment means were compared using orthogonal contrasts.

the chemical sprays prevented leaves that had few (one to five) pustules per leaf from being reinfected by the rust. The significantly lower level of infected leaves on sprayed trees recorded on 8 November than that recorded on 29 July or 17 August can be attributed to the defoliation that occurred. Wilson and Scott (9) reported very good control of peach rust with two sprays of ferric dimethyldithiocarbamate (Fermate) in August in a commercial peach orchard. They (9) suggest that even one application in autumn would be sufficient to protect the twigs against infection by rust until the beginning of the next season.

Conclusion. Mancozeb provided much better control of prune rust than WS, and this can be explained by the much higher reduction of urediniospore germination. Uninfected prune trees can be protected against leaf rust even with one spray if applied in midsummer for areas around Davis, CA, but when the disease is already present (determined by the obvious rust symptoms), two sprays with mancozeb would protect the uninfected leaves from infection and prevent further spread of rust on leaves that already had some pustules. After residue analyses are obtained, registration of mancozeb for control of prune rust could be considered.

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