Chemical Control of Fungi Causing Decay of Fresh Prunes During Storage

THEMIS J. MICHAILIDES, Former Graduate Research Assistant, J. M. OGAWA, Professor, and P. L. SHOLBERG, Former Graduate Research Assistant, Department of Plant Pathology, University of California, Davis 95616

ABSTRACT

Michailides, T. J., Ogawa, J. M., and Sholberg, P. L. 1987. Chemical control of fungi causing decay of fresh prunes during storage. Plant Disease 71:14-17.

Fresh prunes can be held in cold storage with no internal breakdown for 2–3 wk. Amount of decay during storage and reduction of molds by chemical treatment were directly related to methods of harvest and temperature of incubation. Molds that caused decay were species of *Cladosporium, Monilinia, Rhizopus, Mucor, Penicillium, Botrytis, Alternaria,* and *Aspergillus*. Untreated prunes held at 4 C developed mold on the seventh day, and by the 20th day, 14, 39, and 94% of the prunes from Tulare, Yuba City (mechanically harvested), and Healdsburg (hand-harvested from the ground), respectively, had decayed. Prunes treated with chlorine (400 mg/L of water), etaconazole (450 mg/L of water), and potassium sorbate (20,000 mg/L of water) showed no mold until the 10th day of storage at 4 C and had significantly less decay on the 20th day. Prunes treated with the above chemicals and held at 20 or 28 C for 4 days showed lower amounts of decay than the untreated prunes; however, the effect of chemical treatments on prunes stored at 28 C was not consistent. Prunes mechanically harvested from Tulare and Yuba City showed significantly less decay than prunes hand-harvested from Healdsburg. There were no differences in the amount of decay between washed and unwashed prunes incubated at 4, 20, and 28 C.

The United States currently produces about 70% of the world prune crop (*Prunus domestica* L. 'French'), and California alone produces about 146,000 tons (dry wt) annually on 28,300 ha (1). This represents 99% of all U.S. prune production (3). As a result of extensive plantings in the 1960s, the Sacramento Valley became the dominant prune-growing area (75% of California's total prune acreage), producing 81% of California's dried prunes (3). The remaining 19% is produced in the San Joaquin Valley, Napa-Sonoma, and Santa Clara districts (Fig. 1).

Optimal harvest maturity for drying prunes is when the average fruit flesh firmness has dropped to 2.7–3.6 kg/cm^2 (7) and the soluble solids (sugars) content has increased to 24% or higher (10). Such maturity is ideal for quality dried prunes, but growers are not always able to harvest their prunes at optimum maturity because facilities for dehydration are limited. Improved fast cooling methods before dehydration may allow growers to harvest at optimum maturity, improve quality, and also extend the use of dehydrators. Prunes promptly cooled and stored can be held with no internal breakdown problems for 2–3 wk (7). During this time, molds can develop that cause losses. Therefore, chemical treatment of the prunes is necessary to prevent deterioration from mold during cold storage.

The method of harvest also can damage fresh prunes, making them more prone to invasion by fungal pathogens that cause deterioration. More injury occurs on prunes shaken to the ground for hand-harvesting than on those harvested mechanically onto catching frames (6).

The objectives of this study were 1) to determine the effect of harvest methods on mold development, 2) to study the efficacy of prestorage chemical treatment and washing on prune decay during storage, and 3) to identify the most common fungi that cause decay during storage of prunes harvested mechanically and by hand.

MATERIALS AND METHODS

Source of prunes, harvest method, and maturity. Prune fruits were harvested from three major prune-growing areas (Fig. 1), using the following harvest methods: 1) In Healdsburg, the prunes were hand-harvested from the ground after the trees were mechanically shaken; 2) in Yuba City, the prunes were harvested by a mechanical shaker with a catching canvas laid on the ground; and 3) in Tulare, the prunes were harvested either mechanically onto elevated catching frames or by hand directly from the trees into boxes. Fruit firmness was determined with a Hunter Spring Force Gage (AMETEK, Testing Equipment Systems, Lansdale, PA) (Series L) with a compression head of 8 mm diameter from samples of 10–20 fruits per site. Soluble solids (sugars) were determined with a juice Refractometer (ATAGO, NSG Precision Cells, Inc., 560 S. Broadway, Hicksville, NY) on 10–20 fruits per site.

Chemical treatment, incubation, and identification of fungal species. The prunes were treated either the day of or 1 day after harvest. Samples collected from each site were divided into 12 lots of 110–200 prunes each and placed in plastic containers. Three replicate containers were treated with the following: 1) household bleach (5.25% sodium hypochlorite) in a concentration of 400 mg of chlorine per liter of water (pH 9.8); 2) etaconazole (Vangard 10W) in a concentration of 450 mg a.i./L of water (pH 8.4); and 3) 2% potassium sorbate (K-sorbate) in a concentration of 20,000 mg/L of water (pH 8.4). Triton X-100 (a surfactant) was added at a concentration of 5 μl/L to each of the chemical

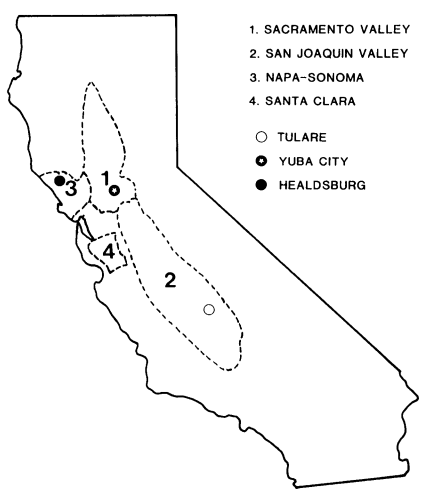

Fig. 1. Major prune production districts in California and locations of sampling sites.

Present address of third author: Agriculture Canada Research Station, Summerland, BC V0H 1Z0.

Accepted for publication 29 July 1986 (submitted for electronic processing).

The publication costs of this article were defrayed in part by page charge payment. This article must therefore be hereby marked "*advertisement*" in accordance with 18 U.S.C. § 1734 solely to indicate this fact.

solutions to improve their wettability. The prunes were dipped in each treatment, stirred manually for 2 min, then placed in plastic containers with waxed wire-screen bottoms and allowed to dry overnight on a laboratory bench. Fruit of three containers washed with tap water (pH 8.1) served as checks. Prunes were incubated at 4 C for 30 days and evaluated for decay development after 7, 10, 20, and 30 days of incubation. Additional lots of prunes treated as above were held at 20 and 28 C and examined after 4 days. Decay was evaluated visually when mycelium of decay pathogen was apparent on the surface and with the help of a dissecting scope when mycelium was not evident. Decayed prunes were placed individually on waxed screens in plastic containers and incubated at room temperature (22± 2 C) for 2–3 days to allow for growth, sporulation, and identification of each decay organism (2,4). The experiment was conducted once in 1982 and repeated in 1983.

Effect of washing. To determine the effect of washing on mold development in cold storage, prunes were hand-harvested from trees in Tulare, brought to the laboratory, and placed in 18 plastic containers (about 150 prunes per container). Prunes of nine containers were washed with tap water and the rest were left unwashed. All containers were dried overnight on a laboratory bench, then six containers (three with washed and three with unwashed prunes) were incubated at 4, 20, and 28 C for 30, 5, and 5 days, respectively. Prunes incubated at 4 C were examined every 5 days and those incubated at 20 and 28 C were examined daily and evaluated for decay.

RESULTS

Maturity of prunes. Fruit firmness of prunes ranged from 0.4 to 2.4 kg/cm^2 and soluble solids content from 22.4 to 29.0%.

Effect of harvest method on decay development. At incubation temperatures of 4, 20, and 28 C, prunes mechanically harvested and untreated showed significantly less decay than those hand-harvested from the orchard floor (Fig. 2). For example, after 20 days of incubation at 4 C, prunes mechanically harvested onto elevated frames had only 14% decay compared with 39% for fruit caught on canvas laid on the ground and 94% for fruit shaken to the ground and hand-picked. After 30 days of incubation at 4 C, 100% of prunes harvested from the ground by hand were decayed, whereas those harvested mechanically on elevated frames had 21% decay and those from canvas laid on the ground had 56% (Table 1). The differences were significant at $P = 0.05$

Similarly, after 4 days of incubation at 20 C, a significantly higher percentage of prunes (86%) harvested from the ground (Healdsburg) had decayed than prunes harvested mechanically (28 and 36% of prunes from Tulare and Yuba, respectively) (Fig. 2). Again, after 4 days at 28 C, a significantly higher percentage of decay occurred on prunes collected from the ground (95%) than on those harvested either on elevated frames (56%) or on canvas laid on the ground (80%) (Fig. 2).

Effect of chemical treatment. Untreated prunes harvested mechanically in Tulare and Yuba City showed first signs of decay development on the seventh day of incubation at 4 C. Prunes treated postharvest showed first signs of decay on the 10th day and had significantly less decay than the untreated prunes after 20 days (Table 1). However, at 30 days, no significant differences were evident

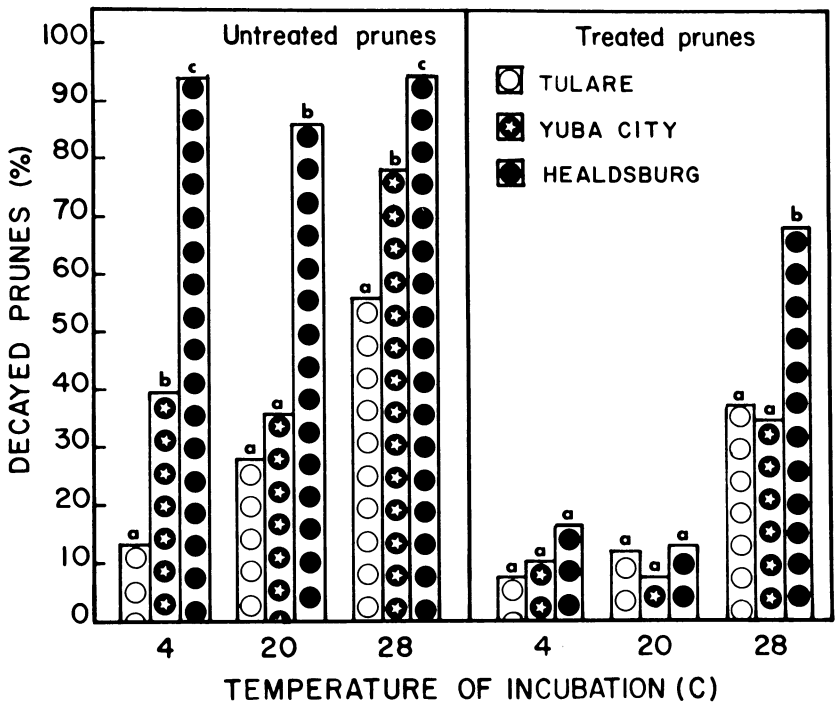

Fig. 2. Effects of harvest method, temperature of incubation, and chemical treatment on the percentage of decayed prunes stored at 4, 20, and 28 C for 20, 4, and 4 days, respectively. Prunes were harvested mechanically on elevated frames (Tulare), on canvas laid on the ground (Yuba City), and by hand from the orchard floor (Healdsburg). Different letters over columns indicate significant differences between harvest methods within each storage temperature (LSD = 13% at $P = 0.05$).

Table 1. Effects of harvest method and chemical treatment on incidence of decay of fresh French prunes incubated at 4 C and evaluated for decay at various times

		Harvest method[x] (source), incubation time (days), and percent decay[y]											
		Mechanical harvest								Hand harvest from ground (Healdsburg)			
		On elevated frames (Tulare)				On canvas laid on ground (Yuba City)							
Treatment	Concentration (g a.i./L)	7	10	20	30	7	10	20	30	7	10	20	30
Check	···	1	3	14 a[z]	21 a	2	6	39 a	56 a	1	4	94 a	100 a
K-sorbate	20	0	0	10 b	20 a	0	0	19 b	50 a	0	0	5 c	27 d
Chlorine	0.4	0	0	10 b	20 a	0	1	12 bc	34 b	0	0	36 b	80 b
Etaconazole	0.45	0	0	2 c	15 a	0	0	0 c	13 c	0	0	13 c	56 c

[x] Prunes from Tulare were harvested on 26 August, from Yuba City on 1 September, and from Healdsburg on 28 August.
[y] Means of three replicates (three plastic containers, each containing 150, 110, and 200 prunes from Tulare, Yuba City, and Healdsburg, respectively).
[z] Means within each column followed by the same letter are not significantly different at $P = 0.05$ according to Duncan's multiple range test.

between untreated and treated prunes for fruit harvested on elevated frames. Only the chlorine and etaconazole treatments of prunes mechanically harvested on canvas laid on the ground differed significantly by the 30th day (Table 1). Similarly, the chemicals delayed decay development on hand-harvested prunes for 10 days and resulted in smaller amounts of decay than on the untreated control. These differences continued until the 30th day of cold storage (Table 1).

Prunes mechanically harvested or hand-harvested from the ground, post-harvest-treated, and incubated at 20 C for 4 days had a significantly lower percentage of decay than the untreated control (Table 2). However, the effects of the three chemicals were not consistent on prunes incubated at 28 C. For example, for prunes from Tulare, the average percent decay of treated prunes was reduced, although the reductions were not significant. In contrast, reductions in percent decay of prunes harvested from Yuba City were significant ($P = 0.05$). However, on prunes harvested from Healdsburg, only K-sorbate reduced percent decay (Table 2).

Table 2. Effects of harvest method and chemical treatment on incidence of decay of fresh French prunes incubated at 20 and 28 C for 4 days

Treatment	Concentration (g a.i./L)	Method of harvest[x] (source), incubation temperature (C), and percent decay[y]: Mechanical harvest, On elevated frames (Tulare) 20	28	On canvas laid on ground (Yuba City) 20	28	Hand harvest from ground (Healdsburg) 20	28
Check	···	28 a[z]	56 a	36 a	80 a	86 a	95 a
K-sorbate	20	13 b	30 a	15 b	45 b	2 c	45 b
Chlorine	0.4	12 b	38 a	5 b	22 c	15 b	73 a
Etaconazole	0.45	11 b	44 a	2 b	32 c	22 b	86 a

[x] Prunes from Tulare were harvested on 26 August, from Yuba City on 1 September, and from Healdsburg on 28 August.
[y] Means of three replicates (three plastic containers, each containing 110–200 prunes).
[z] Means within each column followed by the same letter are not significantly different at $P = 0.05$ according to Duncan's multiple range test.

Effect of washing on mold development. There were no differences in percent decay of unwashed and washed prunes during the 30-day incubation at 4 C (Fig. 3A). First signs of decay appeared after 7 days. Both washed and unwashed prunes had decayed about 50% after 20 days and 60–65% after 30 days at 4 C (Fig. 3A). Also, there were no differences in mold development between washed and unwashed prunes incubated at 20 and 28 C for 5 days. At that time, about 70–75% of the prunes had decayed (Fig. 3B,C).

Fungi associated with stored prunes. More than six genera of fungi were associated with fresh prunes that decayed in cold storage (Table 3). Relative frequency of each genus isolated differed with locations, but *Cladosporium herbarum* (Pers.) Link ex Gray was the predominant fungus isolated regardless of location. For prunes harvested at Healdsburg, this fungus accounted for 84.6% of decayed prunes, significantly higher than the decay on prunes from Tulare or Yuba City (Table 3). The incidence of all other fungi was less than 10% except on prunes harvested from the ground, of which 15% decayed from *Mucor* spp. (*M. racemosus* Fres., *M. hiemalis* Wehmer, *M. genevensis* Lendner, *M. piriformis* Fischer, and *M. plumbeus* Bonorden).

For prunes incubated at 20 or 28 C, the prevalent fungi were *Rhizopus stolonifer* (Ehrenb.:Fr) Lind, *Monilinia fructicola* (Wint.) Honey, *M. laxa* (Aderh. & Ruhl.) Honey, *Botrytis cinerea* Pers.:Fr., *C. herbarum, Penicillium* spp., *Alternaria alternata* (Fr.) Keissler, *Aspergillus niger* van Tieghem, *A. ochraceous* Wilhelm., and various yeasts.

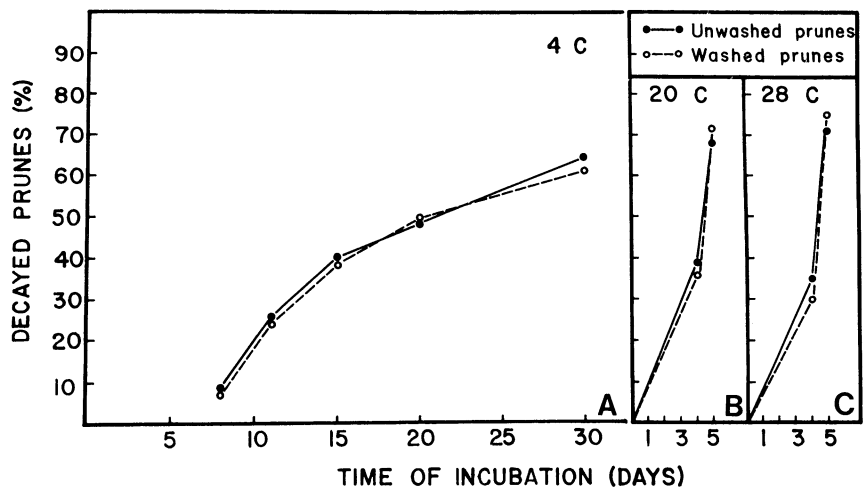

Fig. 3. Effects of washing of fresh prunes on the percentage of decayed prunes stored at **(A)** 4, **(B)** 20, and **(C)** 28 C for 30, 5, and 5 days, respectively. Each point represents the average of three plastic containers with about 150 prunes each.

Table 3. Fungi identified on fresh French prunes harvested mechanically from the trees (Tulare and Yuba City) or by hand from the orchard floor (Healdsburg) and incubated at 4 C for 30 days

Species[y]	Source and percent fruit decayed by each fungal species: Tulare	Yuba City	Healdsburg
Cladosporium herbarum	16.8 c[z]	50.5 b	84.6 a
Monilinia fructicola and *M. laxa*	2.0 a	0.3 a	0.0 a
Botrytis cinerea	0.0 a	0.3 a	0.1 a
Mucor spp.	1.4 c	4.2 b	15.1 a
Penicillum spp.	0.2 a	0.3 a	0.2 a
Others (*Alternaria alternata*, unidentified fungi, and yeasts)	1.0 a	0.0 a	0.0 a

[y] Identification of each fungal species was based on macroscopic and microscopic characteristics after incubation of fruit in cold storage and additional incubation of 2–3 days at 22 ± 2 C.
[z] Means within each row followed by the same letter are not significantly different at $P = 0.05$ according to Duncan's multiple range test.

DISCUSSION

Internal breakdown and mold development are two major problems that must be considered during cold storage of fresh French prunes. Either can be critical, depending on which appears first in cold storage. Internal breakdown of fresh prunes appears after 2–3 wk of cold storage, whereas mold development can occur earlier (7). Our results indicate that mold development occurred within a week after storage, depending on the method of harvest and incubation temperatures. As expected, more decay developed during cold storage on prunes hand-harvested from the ground (Healdsburg) than on those mechanically

harvested onto catching frames (Tulare and Yuba City). More decay developed at 20 or 28 C than at 4 C, regardless of harvest method, because most fungi grow optimally at 20–28 C.

Postharvest chemical treatment of prunes allows a longer period of cold storage by delaying the development of fungi. Although the three chemicals tested had similar effects on fruit harvested mechanically and incubated at 4 C for 20 days, the effects were different on prunes hand-harvested from the ground. For example, for mechanically harvested fruit, etaconazole was the most effective chemical, whereas etaconazole and K-sorbate were more effective in reducing decay incidence on hand-harvested prunes (Table 1). Thus, the different effects of chemical treatments on the level of decay appear to be related to the method of harvesting of prunes. Treatment of prunes with chemicals such as etaconazole makes storage possible for up to 3 wk. However, cold storage increases the cost of dried prunes, so before any plans are made, the cost must be weighed against the benefits from the increased value of quality prunes produced at optimal harvest and the reduced levels of decay.

Although all three chemicals significantly reduced decay for prunes incubated at 20 C, their effect was not consistent on prunes incubated at 28 C (Table 2). These inconsistencies may be due to excessive Rhizopus rot at 28 C, which was not controlled by any of these fungicides. Sholberg and Ogawa (8,9) reported that temperature within a bin of freshly harvested prunes is very close to 28 C, especially in the late afternoon. Under these conditions, untreated fruit is likely to decay from *Rhizopus* spp. before dehydration, resulting in poor-quality dried prunes because of high incidence of slip-skin maceration ("box rot") disorder (9). To avoid this damage, prunes, especially those harvested in the afternoon, should be processed as soon as possible if cold storage facilities are not available and chemical treatment is not planned.

Even though the first signs of decay on untreated prunes appeared in all instances on the seventh day after incubation at 4 C, decay must have started earlier, considering the incubation time required by each fungus pathogen. Therefore, if the prunes have not been treated, cold storage should not exceed 5–7 days. Because washing did not reduce decay, it is not considered a necessary step in prune dehydration, although most of the dehydrators have facilities for washing prunes to remove dust and foreign materials. If cold storage of prunes is planned, it would be more economical to store them without washing.

Fruit that came in contact with soil had a high incidence of *C. herbarum* and *Mucor* spp. (Table 3), indicating contamination of prunes with soil. This is supported by the fact that prunes harvested on canvases laid on the ground (an intermediate method between harvest from the ground and mechanical harvest on elevated frames) had an intermediate level of percent fruit decayed by *C. herbarum* or *Mucor* spp. Both of these are very common soil fungi (4), and prunes shaken to the ground may be injured and naturally inoculated. Our observations support this, since we noticed more injured prunes among those harvested from the ground than those harvested on canvases or elevated frames. Some fruit had particles of soil embedded in their tissue from forced landing of fruit on the coarse soil. Wounds are ideal sites for decay to start, and almost all the fungi identified in this study require wounds for infection (10). In contrast, fruit with less injury (mechanically harvested fruit) (6) is resistant to infection even though its surface may be contaminated with fungal pathogens. Because both washed and unwashed fruits had been harvested by hand and supposely had the same number of wounds, the rate of decay on this fruit was not proportional to the number of pathogens present on the fruit surface but to the number of wounds. This may explain why washed and unwashed prunes had very similar amounts of decay.

Regardless of harvest method and location, *C. herbarum* was the predominant fungus that developed on prunes (Table 3). *C. herbarum* is very common both in soil (2,4) and in the air (5). In contrast, only prunes collected from the ground had considerably high levels of *Mucor* spp., which are considered soil inhabitants (4). The diversity and levels of fungi isolated from prunes play a significant role in the effect of postharvest chemical treatment. The number and various types of fungi may also explain why the three chemicals used in this study had different results on prunes harvested by different methods.

In conclusion, for storage at 4 C of only 1 wk or less, prunes need not be washed or treated; for storage longer than 1 wk, chemical treatments are required.

ACKNOWLEDGMENTS

We wish to thank the Prune Advisory Board for financial support of this project and to acknowledge E. A. Bose and B. T. Manji for technical assistance. We also thank Don Simonich (Tulare), Dennis Serger (Valley View Packing, Yuba City), and Robert Loracco (Healdsburg) for providing the prunes used in this study.

LITERATURE CITED

1. Anonymous. 1986. California Crop and Livestock Reporting Service (Sacramento, Calif.) California Fruit and Nut Review. Vol. 6 (1). 4 pp.
2. Barron, G. L. 1968. The Genera of Hyphomycetes from Soil. Williams & Wilkins, Baltimore. 364 pp.
3. Connell, J. H. 1981. The prune industry in California. Pages 1-4 in: Prune Orchard Management. Division of Agricultural Sciences, University of California. Spec. Publ. 3269. 156 pp.
4. Gilman, J. C. 1957. A Manual of Soil Fungi. 2nd ed. Iowa State College Press, Ames. 450 pp.
5. Ingold, C. T. 1971. Spores in the air. Pages 173-199 in: Fungal Spores. Their Liberation and Dispersal. Clarendon Press, Oxford. 302 pp.
6. Miller, M. W., Fridley, R. B., and McKillop, A. A. 1963. The effects of mechanical harvesting on the quality of prunes. Food Technol. 14:113-115.
7. Mitchell, F. G., Sibbett, G. S., and Mayer, G. 1981. Cold storage of French prunes may expand dehydrator capacity. Calif. Agric. 35:20-22.
8. Sholberg, P. L., and Ogawa, J. M. 1983. Fungus causes deterioration of dried prunes. Calif. Agric. 37:27-28.
9. 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.
10. Wilson, E. E., and Ogawa, J. M. 1979. Fungal, Bacterial, and Certain Nonparasitic Diseases of Fruit and Nut Crops in California. Division of Agricultural Sciences, University of California, Berkeley. 190 pp.