Benefits of Applications of Chlorothalonil for the Control of Black Mold of Tomato

R. M. Davis, Department of Plant Pathology, University of California, Davis 95616; E. M. Miyao, R. J. Mullen, J. Valencia, and D. M. May, Cooperative Extension, Yolo-Solano, San Joaquin, Stanislaus, and Fresno counties, CA; and B. J. Gwynne, Department of Plant Pathology, University of California, Davis 95616

ABSTRACT

Davis, R. M., Miyao, E. M., Mullen, R. J., Valencia, J., May, D. M., and Gwynne, B. J. 1997. Benefits of applications of chlorothalonil for the control of black mold of tomato. *Plant Dis.* 81:601-603.

Chlorothalonil was applied 2, 4, 6, 2 and 4, or 4 and 6 weeks prior to tomato harvest in fields in four counties in California over a 3-year period to assess the economic benefits of chlorothalonil applications, if any, on the reduction of black mold caused by *Alternaria alternata*. The percentage of visually infected fruit was significantly reduced across all four sites in 2 of the 3 years. At one location, the incidence of black mold was reduced over 50% in all 3 years of the study by a single application of the fungicide. Overall, the mean yield of marketable fruit was 79.8 metric tons per hectare. An average of 5.1% of the fruit harvested in all locations and years had visible symptoms of black mold. Generally, the most effective treatment was a single application of the fungicide 6 weeks before harvest, with no further benefit from a second application of the fungicide. Based on the cost of the fungicide and its application, a single dose of chlorothalonil applied to plots in Solano County, where the highest incidence of disease occurred, would net the grower \$160.47 return per hectare. The application of fungicide resulted in significant economic benefits in tests in two of the counties, where the disease is historically a problem.

Black mold of processing tomatoes (*Lycopersicon esculentum* Mill.), caused by the fungus *Alternaria alternata* (Fr.:Fr.) Keissl. and to a lesser extent by *Stemphylium vesicarium* (Wallr.) E. Simmons, reduces yields when heavily infected fruit decay and fall from the vine, or truck loads with an 8% or greater incidence of mold are rejected at industry grading stations. An excessive incidence of diseased fruit can also increase the cost of sorting at harvest. Symptoms vary from small, superficial brown flecks on green fruit to large, sunken, black lesions on red fruit. In humid weather the fungus produces a black, velvety layer of spores on the surface of the sunken lesions (1).

The disease is present every year in California but the intensity of infection and severity of losses varies from year to year, depending on the weather (5). When free water forms on the surface of ripening fruit from rain, dew, or overhead irrigation, spores germinate in response to water-soluble nutrients on the fruit surface (5). Fungicide treatments are often recommended for the control of black mold on tomatoes scheduled for harvest after about

mid-September in the Central Valley of California, coincident with the occurrence of heavy dews (4). However, economic benefits of applications of fungicides to processing tomatoes produced in California need to be more clearly defined according to the Environmental Protection Agency (3). In 1991, it was estimated that approximately 15 to 25% of the total acreage of tomatoes in California (approximately 97,128 ha annually) received 1 to 3 applications of chlorothalonil or other fungicides to control the disease (2). The state-wide estimated yield loss to black mold without the use of fungicides was 5 to 15% of the crop. These estimates, however, were based on "expert opinion", and are considered inadequate for risk-benefit analysis (3).

This project proposed to clearly define the economic benefits, if any, of applications of the fungicide chlorothalonil to control black mold on processing tomatoes in California. Trials were conducted using a uniform set of protocols across several locations over a 3-year period.

MATERIALS AND METHODS

The experiment was conducted in four locations in California (commercial fields in San Joaquin and Stanislaus counties, the Westside Research and Extension Center in Fresno County, and the University of California, Davis, campus in Solano County) in each of 3 years. All sites had a history of tomato production. The plots were planted in approximately mid-May of each year

with the cultivar Brigade in single seed lines on rows with 1.5 m centers. Treatments in all trials, except one, were replicated six times. The exception in San Joaquin County in 1993 utilized four replications. Each plot (smallest experimental unit) was 3 beds wide by 12.2 m long. Normal grower practices were employed in site preparation and during testing. In most plots weeds were controlled with a pre-plant application of napropamide (Devrinol 2E, 2.24 kg a.i./ha, Zeneca, Inc., Wilmington, DE), a postplant application of trifluralin (Treflan 5EC, 0.56 kg a.i./ha, DowElanco, Inc., Indianapolis, IN), and cultivation. Weeds in plots in Solano County were controlled with cultivation and hand-hoeing. Insects were controlled with applications of dimethoate (Dimethoate 267E, 0.56 kg a.i./ha, Wilbur-Ellis Co., Fresno, CA). Chlorothalonil (Bravo 500, 500 g a.i./liter, ISK BioSciences, Inc., Mentor, OH) was applied through 4 standard flat fan nozzles (TeeJet 8002 VS, Spraying Systems Co., Wheaton, IL) on a 1.5 m boom at the typical use rate of 4.68 liters/ha with a CO₂ pressurized backpack sprayer adjusted to 243 kPa. The material was applied approximately 0.5 m above the plant canopy. Applications were made 2, 4, 6, 2 and 4, or 4 and 6 weeks prior to anticipated harvest.

At harvest (mid-September to early October when crops were considered marketable), all of the fruit in the center 3 m of each plot was hand-harvested, categorized into marketable red fruit (including sun-related blemishes, insect injury, and blossom-end rot), green fruit (including pinks and breakers), fruit with at least one black mold lesion that apparently penetrated the wall of the fruit, and fruit not marketable due to other rots, bird damage, and so on (culls). The fruit in each category was weighed. Data were subjected to analysis of variance, followed by single-degree-of-freedom orthogonal contrasts, using the procedures of the Statistical Analysis System (SAS Institute, Inc., Cary, NC). Some data (percentages of rotted fruit and other percentages) were converted to their arcsine-square root equivalents in order to normalize data sets prior to analysis.

RESULTS

When percentages of black mold in all trials were combined, the analysis of variance indicated interactions between loca-

Corresponding author: R. M. Davis
E-mail: rmdavis@ucdavis.edu

Accepted for publication 14 February 1997.

tion and year, location and treatment, and year and treatment (Table 1). The location and year interaction will receive no further discussion, since it was not unexpected that the incidence of black mold might differ between years at any one location. Overall, the total biomass of fruit across all locations was 88.6 t/ha. Of that total, 86.2% of the fruit was marketable at the time of harvest and disease assessment; 5.1% of the fruit harvested within the plots had symptoms of black mold; 3.4% of the fruit

was immature (greens or pinks); and 5.4% of the fruit was categorized as other culls. Much of the fruit affected by black mold was decayed to the extent that mechanical harvest would not have been possible. Also, some of the affected fruit would have been sorted and discarded before it reached the weighing station; thus, fruit lost to black mold was potentially a direct loss to the grower. Overall, treatments did not influence yields of total fruit biomass (data not presented).

Table 1. Analysis of variance of the percentage of tomato fruit exhibiting symptoms of black mold influenced by location, year, and fungicide treatment^z

Source	df	Sum of squares	F value	Prob. > F
Block	5	0.014357	0.90	0.4808
Location	3	0.783101	81.88	0.0001
Year	2	0.950325	149.05	0.0001
Treatment	5	0.082193	5.16	0.0001
Location × year	5	0.600846	37.70	0.0001
Location × treatment	15	0.155646	3.25	0.0001
Year × treatment	10	0.084582	2.65	0.0040
Location × year × treatment	25	0.051828	0.65	0.9016
Error	313	0.246730		

^z Percentages were converted to their arcsine-square root equivalents in order to normalize data sets prior to analysis.

Table 2. Influence of timing and number of applications of chlorothalonil on the percentage of tomato fruit exhibiting symptoms of black mold combined over the years 1993 to 1995

Applications of chlorothalonil (weeks before harvest)	Fruit exhibiting black mold symptoms (%)			
	County			
	Solano	San Joaquin	Stanislaus	Fresno
None	11.6 a ^y	6.6 a	2.3 a	5.3 a
2 weeks	8.0 bc	3.2 b	3.0 a	4.4 a
4 weeks	8.7 b	3.9 b	2.2 a	5.4 a
6 weeks	6.2 cd	3.4 b	2.4 a	5.8 a
2 and 4 weeks	7.7 bc	3.5 b	3.0 a	3.9 a
4 and 6 weeks	5.0 d	4.2 b	2.5 a	5.3 a
LSD, <i>P</i> = 0.05	2.32	1.64	NS	NS
Contrast	Sum of squares ^z			
None vs. all applications	0.089090*	0.049475*	0.001130	0.000529
One vs. two applications	0.011542	0.001295	0.001795	0.000712
Mean square error	0.003859	0.002414	0.002681	0.002853

^y Means in each column followed by the same letter are not significantly different according to Fisher's protected least significance test, *P* ≤ 0.05.

^z Contrasts noted with an asterisk are significant, *P* ≤ 0.05. Percentages were converted to their arcsine-square root equivalents in order to normalize data sets prior to analysis.

Table 3. Influence of timing and number of applications of chlorothalonil on the percentage of tomato fruit exhibiting symptoms of black mold combined over four locations

Applications of chlorothalonil (weeks before harvest)	Fruit exhibiting black mold symptoms (%)		
	1993	1994	1995
None	3.0 a ^y	9.8 a	7.7 a
2 weeks	2.1 a	6.4 b	6.0 b
4 weeks	3.0 a	7.9 ab	4.8 b
6 weeks	2.7 a	7.4 b	3.3 c
2 and 4 weeks	2.8 a	6.3 b	4.9 b
4 and 6 weeks	2.8 a	6.9 b	3.2 c
LSD, <i>P</i> = 0.05	NS	2.08	1.43
Contrast	Sum of squares ^z		
None vs. all applications	0.001216	0.043016	0.063550*
One vs. two applications	0.002203	0.002023	0.004382
Mean square error	0.002465	0.004516	0.001943

^y Means in each column followed by the same letter are not significantly different according to Fisher's protected least significance test, *P* ≤ 0.05.

^z Contrasts noted with an asterisk are significant, *P* ≤ 0.05. Percentages were converted to their arcsine-square root equivalents in order to normalize data sets prior to analysis.

Across all 3 years of the trial, all applications of chlorothalonil significantly reduced black mold incidence in Solano County (Table 2). Most effective treatments were a single application of the fungicide at 6 weeks before harvest or applications 4 and 6 weeks before harvest. In San Joaquin County, all treatments reduced the disease, but there were no significant differences (*P* = 0.05) among treatments. Applications of the fungicide did not significantly reduce black mold in plots in either Stanislaus or Fresno counties. Across all locations in 1993, applications of chlorothalonil did not significantly reduce the incidence of black mold (Table 3). In 1994 and 1995, most treatments significantly reduced the disease. In 1995, a single application of chlorothalonil at 6 weeks before harvest or two applications at 4 and 6 weeks before harvest were the most effective treatments. Overall, there was no additional benefit of two applications of the fungicide compared with a single application in any year or location.

DISCUSSION

Evaluations of economic impacts of fungicide sprays using specific protocols serve as a basis for decision-making regarding pesticide risk-benefit analysis. In Florida, fungicide sprays were shown to contribute substantially to the productivity and economic viability of the fresh market tomato industry (6). In this study, positive economic returns resulted from applications of a fungicide for control of black mold in processing tomatoes in California. The typical dosage rate of 4.68 liters chlorothalonil (Bravo 500)/ha was used (at an estimated cost to the grower of \$14.54 product/liter). The cost of an airplane application was \$18.53/ha (the cost of the less-used ground application was \$14.21/ha). For the economic analysis reported here, the air application cost was figured into the total cost of the application. The average value of a metric ton of processing tomatoes to the grower in 1993 to 1995 was \$57.33. At 79.8 t/ha, the gross income to the grower was \$4,574.93/ha. In Solano County, for example, 11.6% of the fruit was lost to black mold over the 3-year period of this study if left untreated. This amounted to a loss of \$530.69/ha (Table 4). If the grower used one application of chlorothalonil to control black mold, a net gain of \$160.47/ha would be realized. In this study, it was not economically justifiable to apply more than a single application of the fungicide. In San Joaquin County, 6.6% of the fruit was lost to black mold if left untreated, or a loss of \$301.95/ha. With one application of the fungicide, the grower would realize a net gain of \$59.82/ha.

Fungicides were generally not necessary for the control of black mold in Stanislaus and Fresno counties, where the disease is historically a minor problem. These coun-

Table 4. Percentage and value of tomato crop lost to black mold in experimental plots, cost of fungicide and its application, and net returns (based on an average yield of 79.8 t/ha at \$57.33/t)

Site	Treatment (chlorothalonil ^y)	% of crop lost to black mold	Value of crop lost to black mold (\$/ha)	Cost of fungicide ^z (\$/ha)	Net return (\$/ha)	Fungicide benefit (\$/ha)
Solano County	None	11.6	530.69	0	4044.24	...
	1 application, 6 wk before harvest	6.2	283.64	86.58	4204.71	160.47
San Joaquin County	None	6.6	301.95	0	4272.98	...
	1 application, 6 wk before harvest	3.4	155.55	86.58	4332.80	59.82
All sites combined, 1994	None	9.8	448.34	0	4126.59	...
	Mean of all applications	7.0	318.87	86.58	4169.48	42.89
All sites combined, 1995	None	7.7	350.44	0	4224.49	...
	Mean of all applications	4.4	203.13	86.58	4285.22	60.73

^y Chlorothalonil (Bravo 500, applied at 4.68 liters/ha) was applied 2, 4, 6, 2 and 4, or 4 and 6 weeks prior to harvest in duplicated field plots in four counties in each of 3 years.

^z The estimated cost of Bravo 500 to the grower was \$14.54 product/liter. The estimated cost of an application by airplane was \$18.53/ha.

ties are further south than Solano and San Joaquin counties, and experience warmer weather and less rainfall and dew. Fungicides are often used throughout the Central Valley of California, however, since entire loads of harvested tomatoes can be rejected if the incidence of black mold (infections that penetrate the fruit wall or affect 10% or more of the fruit weight) is above 8% at state inspection stations. Moreover, growers are threatened with the potential loss of entire fields of heavily infected tomatoes late in the season when the weather turns unfavorably cool and wet. In the absence of predictive models that forecast outbreaks of black mold, an application of a protectant fungicide applied several weeks

before harvest is relatively inexpensive insurance against the potential of an unharvestable crop. As predictive models gain reliability in the California processing tomato industry, applications of fungicides may be reduced or eliminated altogether when conditions are not conducive for disease occurrence.

ACKNOWLEDGMENT

This research was partially supported by a grant from the Western Region Pesticide Impact Assessment Program.

LITERATURE CITED

1. Butler, E. E. 1959. Fungi and rots in California canning tomatoes. Plant Dis. Rep. 43:187-192.
2. Davis, R. M. 1991. Vegetables - West. Fungi-

cide Benefits Assessment. U. S. Dept. Agric. States National Agricultural Pesticide Impact Assessment Program. Washington D. C.

3. General Accounting Office. 1991. Pesticides: Better data can improve the usefulness of EPA's benefit assessments. Rep. Comm. Energy Commerce, U.S. House of Representatives.
4. Miyao, E. M., Hall, D. H., Somerville, P., and Blaker, N. 1986. Fungicide control of tomato blackmold under rainy conditions. Calif. Agric. 40 (Nos. 7 and 8): 7-8.
5. Pearson, R. C., and Hall, D. H. 1975. Factors affecting the occurrence and severity of blackmold of ripe tomato fruit caused by *Alternaria alternata*. Phytopathology 65:1352-1359.
6. Pernezny, K., Datnoff, L. E., Mueller, T., and Collins, J. 1996. Losses in fresh-market tomato production in Florida due to target spot and bacterial spot and the benefits of protectant fungicides. Plant Dis. 80:559-563.