# Several copper fungicides control olive leaf spot

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***Tests evaluated control of olive leaf spot disease by several copper-containing fungicides and by various rates of Bordeaux mixture. Copper residues in all treatments were also monitored. There were differences among treatments in retention of copper residues but not in disease control.***

The principal symptom of olive leaf spot, often called peacock spot, is one or more dark green to black spots, sometimes surrounded by a yellow halo, on leaf blades. Petioles, fruit, and fruit stems are susceptible but rarely have lesions. The disease, caused by the fungus *Spilocaea oleaginea* (Cast.) Hughes, results in defoliation and death of shoots. Trees left untreated may decline in productivity. Cultivars vary in susceptibility, but all are susceptible.

The fungus survives the summer in old infections (holdover lesions) on leaves on the tree. Conidia, the asexual spores of the fungus, are produced on expanding margins of these holdover lesions in the fall, and rain dislodges and moves the conidia to new sites of infection. Disease often is more severe in the lower portions of trees, reflecting the downward movement of waterborne inoculum. Tree-to-tree spread is slow, because conidia are moved laterally only short distances. Infection occurs during rainy, foggy weather of late fall, winter, and early spring. New lesions and leaf drop become evident in the spring.

Olive leaf spot is readily controlled by Bordeaux mixture, a combination of copper sulfate, hydrated lime, and water. One application before winter rains in November or early December is effective. A second application in January or February does not substantially improve control.

Several other copper-containing fungicides, such as cupric hydroxide, tribasic copper sulfate, or copper oxide, frequently called "fixed" coppers, are registered for use in California olive groves but have not been tested for control of olive leaf spot. We conducted studies to compare the effectiveness of one or two applications of fixed copper fungicides with Bordeaux mixture (trial 1) and to test various rates of metallic copper in Bordeaux mixture for control of olive leaf spot (trial 2).

## Materials and methods

The experiments were conducted in 1985 and 1986 in a 30-year-old Manzanillo olive orchard in Woodlake, California. The orchard had a history of olive leaf spot and had been treated annually with Bordeaux mixture before these experiments. Materials were applied with 100-gallon-capacity hand-gun sprayer at 300 psi, using approximately 7.7 gallons per tree (500 gallons per acre). There were five single-tree replications of each treatment, and trees received the same treatment each year. Treatments were arranged in a randomized complete block design.

In trial 1, one and two applications of each of five fixed coppers were compared with Bordeaux mixture for control of olive leaf spot. The fixed coppers used were: Kocide 101, 53% copper in cupric hydroxide; Microcop, 53% copper in tribasic copper sulfate; COCS, 50% copper in basic copper sulfates and chloride; Nordox, 50% copper in cuprous oxide; and Copper Count N, 8% copper in copper ammonium carbonate. The Bordeaux mixture consisted of 10 pounds each of copper sulfate, 25% copper, and hydrated lime per 100 gallons water.

The rates, in pounds per acre of metallic copper, were: Kocide 101, 13.2; Microcop, 13.2; Bordeaux mixture, 12.5; COCS, 12.5; Nordox, 7.5; and Copper Count N, 3.9. The Bordeaux mixture, Kocide 101, Microcop, and COCS rates were selected to standardize the amount of metallic copper applied. Lower rates of metallic copper in Copper Count N and Nordox were used to avoid phytotoxicity. Trees receiving one application per year were treated in November and those treated twice a year were sprayed in November and again in January in both years.

In trial 2, four rates of metallic copper in Bordeaux mixture were compared: 6.2, 9.4, 12.5, and 15.6 pounds per acre. Rates were prepared by mixing 5, 7.5, 10, and 12.5 pounds copper sulfate, respectively, with equal parts of hydrated lime in 100 gallons water. Single applications of these four rates were made in November in both years.

Rainfall was measured at the University of California Lindcove Field Station, approximately 2.5 miles from the experimental site. Rainfall was 8.4, 10.3, and 17.2 inches in 1983-84, 1984-85, and 1985-86, respectively. Normal annual rainfall is about 11 inches.

We rated disease incidence in the spring of each year following treatment. Little disease developed in the spring of 1985, and leaf lesions were difficult to find. That year we used a scale of 0 (no old or new lesions evident) to 5 (both old and new lesions present) to rate disease severity. In 1986, disease incidence was greater, and 20 shoots (1 year old) were randomly selected from the lower periphery of each test tree on the day disease was evaluated. We counted lesions per

**TABLE 1. Control of olive leaf spot using one and two applications of five fixed copper fungicides and four rates of Bordeaux mixture, Tulare County, California**

| Material, pounds copper/acre | Disease evaluation*◊ 1985 Rating | 1986 Avg. lesions/400 leaves |
|---|---|---|
| **TRIAL 1: Fixed coppers vs. Bordeaux mixture** | | |
| **One application/year:** | | |
| Check | 2.8 a | 938.2 a |
| Nordox, 7.5 | 1.0 b | 0.0 b |
| Bordeaux mixture,§ 12.5 | 1.2 b | 14.8 b |
| COCS, 12.5 | 1.4 b | 0.6 b |
| Kocide 101, 13.2 | 1.6 b | 5.2 b |
| Microcop, 13.2 | 1.5 b | 1.2 b |
| Copper Count N, 3.9 | 1.7 b | 0.6 b |
| **Two applications/year:** | | |
| Nordox, 7.5 | 1.0 b | 0.0 b |
| Bordeaux mixture, 12.5 | 1.0 b | 0.0 b |
| COCS, 12.5 | 1.3 b | 0.6 b |
| Kocide 101, 13.2 | 1.1 b | 0.0 b |
| Microcop, 13.2 | 1.5 b | 1.6 b |
| Copper Count N, 3.9 | 1.1 b | 0.0 b |
| Least significant difference, P = 0.05 = | 0.7 | 136.2 |
| **TRIAL 2: Rates of Bordeaux mixture¶** | | |
| Check | 3.6 a | 1,060.0 a |
| 5.0-5.0, 6.2 | 1.8 b | 1.2 b |
| 7.5-7.5, 9.4 | 2.3 b | 3.4 b |
| 10.0-10.0, 12.5 | 1.8 b | 0.6 b |
| 12.5-12.5, 15.6 | 1.4 b | 0.4 b |
| Least significant difference, P = 0.05= | 0.8 | 125.4 |

* Five replications of single-tree plots (400 leaves/tree). 1985, rating system, based on ease of finding lesions: 1 = no lesions to 5 = several holdover and new lesions. 1986: Lesions counted on 20 mature leaves from each of 20 shoots per tree (400 leaves/tree).

◊ Means followed by the same letter do not differ significantly according to Duncan's multiple range test, P = 0.05.

§ 10 pounds each copper sulfate and hydrated lime per 100 gallons water.

¶ Pounds copper sulfate and hydrated lime per 100 gallons water.

leaf using mature leaves at 10 nodes (20 leaves) nearest the apex of each of 20 current-season shoots (400 leaves per tree).

The amount of copper residues present on leaves was monitored monthly from November through May for all treatments for both years. Five leaves were removed from each of 10 current-season shoots per tree and analyzed in the laboratory for copper concentration.

## Results and discussion

We found equivalent control of olive leaf spot in 1985 and 1986 among the four rates of metallic copper in Bordeaux mixture and among the fixed copper products and Bordeaux mixture. Disease levels in all treatments, whether in one or two applications, were significantly different from those in untreated trees (checks, table 1).

The negligible disease incidence in the first year of the experiment, the spring of 1985, perhaps resulted from low inoculum levels and/or two consecutive years (1983-84 and 1984-85) of low to normal rainfall. Low inoculum potential in the fall of 1985 would be expected from low disease incidence the previous spring, and holdover lesions, the sources of inoculum, were difficult to find in the fall 1985. Rainfall in 1985-86, the second year of the experiment, was 56% greater than normal and, although disease levels increased, incidence was much lower than might be anticipated for such a rainy year. This finding suggests that low inoculum potential may not be overcome readily by favorable climatic conditions. The importance of inoculum potential on disease incidence and control is the subject of another study.

Copper residues detected in trial 1 from December to April 1984-85 (35 to 150 days after treatment) and December through late February 1985-86 (35 to 115 days) were significantly greater following one application of Bordeaux mixture than Kocide 101, Microcop, or COCS (table 2). Results were similar following the second (January) application for the period February through May (45 to 120 days) in both years (table 3). Rates of Bordeaux mixture, Kocide 101, Microcop, and COCS were expected to provide equivalent amounts of copper. Residue analysis 1 day after treatment in 1985 showed significantly lower levels in the COCS treatment than in the Bordeaux mixture, Kocide 101 or Microcop. Residues decreased over time in all treatments and were higher from trees treated twice than from those treated once the previous year in the fall of 1985 (360 days). The highest copper residues were found in Nordox treatments throughout the experiment.

In trial 2, residues were significantly greater from trees treated with the 12.5-12.5 rate than from those treated with the other rates of Bordeaux mixture in December, January, and April (35, 70, and 150 days) in 1984-85 and from November to May (1 to 195 days) in 1985-86 (table 4). Amounts of copper detected increased from low to high for the 5-5, 7.5-7.5, and 10-10 rates, respectively, but statistical significance varied.

On six occasions, copper residue levels were higher than readings of the preceding date for trees treated annually. We attributed these reversals to sampling error or efficiency of spray coverage.

**TABLE 2. Change in amounts of copper residues on olive leaves treated once annually with copper-containing fungicides, Tulare County**

| Material, pounds copper per acre* | Copper/cm² leaf surface° | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1984-85 Days after treatment | | | | 1985-86 Days after treatment | | | |
| | 35 | 115 | 195 | 360 | 1 | 35 | 115 | 195 |
| | µg | | | | | | | |
| Check | 0.7 | 1.9 | 0.5 | 0.9 | 0.7 | 0.4 | 0.6 | 0.9 |
| Nordox, 7.5 | 18.9 | 13.7 | 12.6 | 4.7 | 20.2 | 17.2 | 8.8 | 5.0 |
| Bordeaux, 12.5 | 17.0 | 11.1 | 7.5 | 2.5 | 11.4 | 9.7 | 6.4 | 2.9 |
| COCS, 12.5 | 9.3 | 6.9 | 6.4 | 2.7 | 7.7 | 2.3 | 2.3 | 1.8 |
| Kocide, 13.2 | 7.3 | 6.0 | 6.2 | 1.9 | 11.2 | 4.9 | 3.9 | 2.4 |
| Microcop, 13.2 | 5.7 | 5.2 | 4.0 | 2.0 | 12.8 | 4.4 | 3.7 | 2.4 |
| Copper Count N, 3.9 | 5.0 | 4.7 | 2.4 | 1.5 | 7.9 | 4.6 | 3.3 | 1.4 |
| P = 0.05, LSD = | 2.4 | 4.9 | 5.2 | 1.9 | 3.1 | 1.7 | 1.9 | 3.3 |

* Materials applied Nov. 2, 1984, and Nov. 7, 1985 (day 0) by handgun sprayer to runoff, approximately 500 gal water/acre.
° Fifty leaves per tree analyzed for amount of copper on leaf surfaces, five replications of single-tree plots.

**TABLE 3. Change in amounts of copper residues on olive leaves treated twice annually with several copper-containing fungicides, Tulare County**

| Material, pounds copper per acre* | Copper/cm² leaf surface° | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1984-85 Days after treatment | | | | | 1985-86 Days after treatment | | | | |
| | 35 | 1 | 45 | 120 | 290 | 1 | 35 | 1 | 45 | 120 |
| | µg | | | | | | | | | |
| Check, | 0.7 | 0.8 | 1.9 | 0.5 | 0.9 | 0.7 | 0.4 | 0.8 | 0.6 | 0.9 |
| Nordox, 7.5 | 17.2 | 39.3 | 37.9 | 26.7 | 17.3 | 21.2 | 15.0 | 19.7 | 18.2 | 14.8 |
| Bordeaux, 12.5 | 14.3 | 30.9 | 26.9 | 18.6 | 11.1 | 13.1 | 9.9 | 24.1 | 18.7 | 13.4 |
| COCS, 12.5 | 9.3 | 31.0 | 20.5 | 12.8 | 8.5 | 10.5 | 3.3 | 19.1 | 12.9 | 9.2 |
| Kocide, 13.2 | 7.4 | 22.4 | 13.5 | 9.4 | 5.6 | 12.9 | 6.3 | 19.5 | 11.1 | 7.2 |
| Microcop, 13.2 | 5.5 | 25.5 | 12.7 | 9.2 | 4.8 | 14.7 | 5.3 | 20.6 | 11.3 | 8.5 |
| Copper Count N, 3.9 | 6.2 | 11.0 | 11.8 | 9.5 | 3.5 | 7.9 | 5.3 | 9.4 | 8.5 | 1.9 |
| P = 0.05, LSD = | 2.4 | 4.9 | 4.9 | 5.2 | 1.9 | 3.1 | 1.7 | 3.0 | 1.9 | 3.3 |

* First application Nov. 2, 1984, and Nov. 7, 1985; second application Jan. 6, 1985, and Jan. 10, 1986 (day 0). Materials applied by handgun sprayer to runoff, approximately 500 gal water/acre.
° See footnote ° table 2.

**TABLE 4. Change in amounts of copper residues on olive leaves treated with four rates of Bordeaux mixture, Tulare County**

| Bordeaux rate* | Copper/cm² leaf surface° | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1984-85 Days after treatment | | | | 1985-86 Days after treatment | | | |
| | 35 | 115 | 195 | 360 | 1 | 35 | 115 | 195 |
| | µg | | | | | | | |
| Check | 0.5 | 1.5 | 0.2 | 0.8 | 0.8 | 0.7 | 0.5 | 0.3 |
| 5.0-5.0 | 3.4 | 3.3 | 1.7 | 1.0 | 12.5 | 9.6 | 7.1 | 3.3 |
| 7.5-7.5 | 5.7 | 5.4 | 2.2 | 1.3 | 16.9 | 12.3 | 8.6 | 4.6 |
| 10.0-10.0 | 17.5 | 11.0 | 7.6 | 3.5 | 17.6 | 12.7 | 10.7 | 5.4 |
| 12.5-12.5 | 24.1 | 15.8 | 10.1 | 3.9 | 27.8 | 18.5 | 16.2 | 14.9 |
| P = 0.05, LSD = | 5.1 | 6.6 | 3.1 | 1.8 | 4.1 | 3.2 | 2.5 | 2.9 |

* Materials applied by handgun sprayer Nov. 2, 1984, and Nov. 7, 1985 (day 0). Equal amounts (lb) copper sulfate and hydrated lime mixed in 100 gal water and applied to runoff, approximately 500 gal water/acre.
° See footnote ° table 2.

## Conclusions

Disease control was the same in these experiments, regardless of material or rate used, number of applications, or levels of detectable copper residues. Apparently, copper in any form will control olive leaf spot when disease pressure is low. Further studies may establish other requirements for disease management when disease pressure is greater.

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