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The fungicide captan was applied to almond trees for the control of Coryneum blight (*Coryneum beijerinckii* Oud.) and Hendersonia leaf blight (*Hendersonia rubi* Sacc.). Applications were made by ground air-carrier sprayers (low- and high-volume gallonages), by helicopter, and by fixed-wing aircraft. The extent of disease control was determined for each method of application and compared to captan deposits on leaves and on glass microscope slides placed in the trees at various levels.

Susceptibility of Almond Leaf to Coryneum Blight, and Evaluation of Helicopter Spray Applications for Disease Control

Coryneum beijerinckii conidia germinated equally well on both surfaces of almond leaves. The underside of leaves was more prone to infection than the upper side and deposits on both surfaces were required for effective disease control. Helicopter spray applications with captan gave excellent disease control, provided the spray droplet size and air speed were reduced from those normally used in commercial helicopter spray applications. The finer spray droplets and slower helicopter speed resulted in considerably more captan deposit on both surfaces of leaves and glass slides. The amount of this deposit was determined by chemical analyses and its fungitoxicity was determined by bioassay with conidia of *C. beijerinckii.*

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Susceptibility of Almond Leaf to Coryneum Blight, and Evaluation of Helicopter Spray Applications for Disease Control[1]

INTRODUCTION

CONCENTRATED SUSPENSIONS of captan applied as a spray by ground equipment effectively controlled infection by *Coryneum beijerinckii* Oud. on almonds (*Prunus amygdalus* Batsch.), but were ineffective when applied by fixed-wing and helicopter aircrafts (Kilgore, *et al.*, 1964).[2] Fungicide deposits from fixed-wing aircraft spray applications were large on upper surfaces of glass slides suspended in trees, but were small on bottom surfaces of the slides. Concentrate ground spray applications deposited large amounts of fungicide on both surfaces of leaves and glass slides (Kilgore *et al.*, 1964; Ogawa and Yates, 1962). The helicopter was tested because of the need for air applications during early spring when the ground is too wet for ground equipment. Helicopter spray applications gave comparatively high amounts of spray on the lower surfaces of glass slides, thus indicating that this type of equipment is more suitable for such studies as this than are fixed-wing aircraft.

The following studies were undertaken: (1) Evaluation of susceptibility to infection of upper and lower surfaces of almond leaves to determine if fungicide should be deposited on both surfaces of the leaves, (2) measurement of the amount of fungicide deposited on both surfaces of leaves by helicopter equipment applying sprays of two droplet sizes, and (3) effectiveness of such deposits in controlling Coryneum blight.

SUSCEPTIBILITY OF ALMOND LEAF SURFACE TO DISEASE DEVELOPMENT

Procedure for Spore Germination Test. Leaves of young almond trees (cultivar Ne Plus Ultra) growing in 5-gallon cans in the greenhouse were detached at the base of the petiole and placed in sterile Petri dishes containing filter paper and distilled water. A suspension of 8 x 10^4 Coryneum spores per ml of water was applied over one half of the upper and lower surfaces of each leaf. The leaves were incubated in Petri plates at 18° C in the dark for 6, 22, and 48 hours. Determinations of per cent spore germination were made after leaves were mounted on glass slides and slightly heated in cotton blue and lactophenol.

Leaves attached to the tree were sim-

[1] Submitted for publication March 18, 1964.

[2] See "Literature Cited" for citations referred to in the text by author and date.

TABLE 1

COMPARISONS OF CORYNEUM CONIDIAL GERMINATION ON UPPER AND LOWER SURFACES OF NE PLUS ULTRA ALMOND LEAVES

Status of leaf	Hours incubated in saturated atmosphere	Average per cent spore germination	
		On upper surface of leaf	On lower surface of leaf
Detached*...	6	34	68
Detached....	22	66	58
Detached....	48	78	72
Attached†....	6	0	0
Attached.....	22	63	61
Attached.....	48	52	59

* Incubated at 18°C in Petri dish.
† Incubated at 21°C in large saturated atmosphere chambers holding young trees (about 36 in. high) in 5 gal. cans.

TABLE 2

CORYNEUM LESIONS ON ATTACHED UPPER AND LOWER NE PLUS ULTRA ALMOND LEAVES INCUBATED 16 DAYS

Hours trees were held in saturated atmosphere	Numbers of lesions resulting from inoculations on March 11		Numbers of lesions resulting from inoculations on May 6†	
	On upper surface	On lower surface	On upper surface	On lower surface
6............	1*	1	0*	0
12............	2	19	0	0
24............	9	76	0	0
36............	5	29	0	0
48............	20	77	6	52

* Inoculations of 8 leaves each on 2 shoots.
† Leaves were more mature than those getting inoculations on May 11.

ilarly inoculated and then incubated at 21° C in a saturated atmosphere for 6, 22, and 48 hours. Spore germination was determined as described above.

Results. Table 1 shows that Coryneum spores can germinate well on both surfaces of almond leaves and that there is little difference in germination rates on upper and lower surfaces of detached or attached leaves. The faster germination on leaves in Petri dishes may be related to controlled temperature conditions of the incubator, as there were day and night temperature fluctuations in the large chamber which held the trees. Unipolar germination was most common, followed by bipolar. In no instance did all four cells of the spore germinate during the 48-hour incubation period. No more than 77 per cent of the spores germinated.

Inoculation and Development of Coryneum Lesions

Eight leaves on each of two shoots of experimental trees were inoculated as described above. Trees were incubated at 21° C in a saturated atmosphere for 6, 12, 24, 36, and 48 hours, and removed to the greenhouse bench. Three experiments were performed in this manner.

Results. In the first experiment (February 25, 1963) five leaves inoculated on the lower surfaces developed 13 lesions, while no lesions appeared in 7 days on leaves inoculated on the upper surfaces. One leaf inoculated on the upper surface later developed lesions.

Table 2 shows that in two other experiments more lesions developed on lower leaf surfaces than on upper leaf surfaces of trees held in the moist chamber for 12, 24, 36, and 48 hours. The lack of lesion development in the May 6 experiment could be explained by the fact that the more mature leaves required a longer incubation period for infection.

HELICOPTER SPRAY APPLICATION

Description of Experimental Plot. Test plots were located near Sutter City, California. Each plot consisted of three rows of almonds, the center row being experimental trees and the other two serving as buffer rows to minimize the effect of spray drifting from other plots.

In orchard A (fig. 1) three blocks containing seven rows of 48 trees were used. The two outside blocks were sprayed and the center block was used as a control. Helicopter spray application was

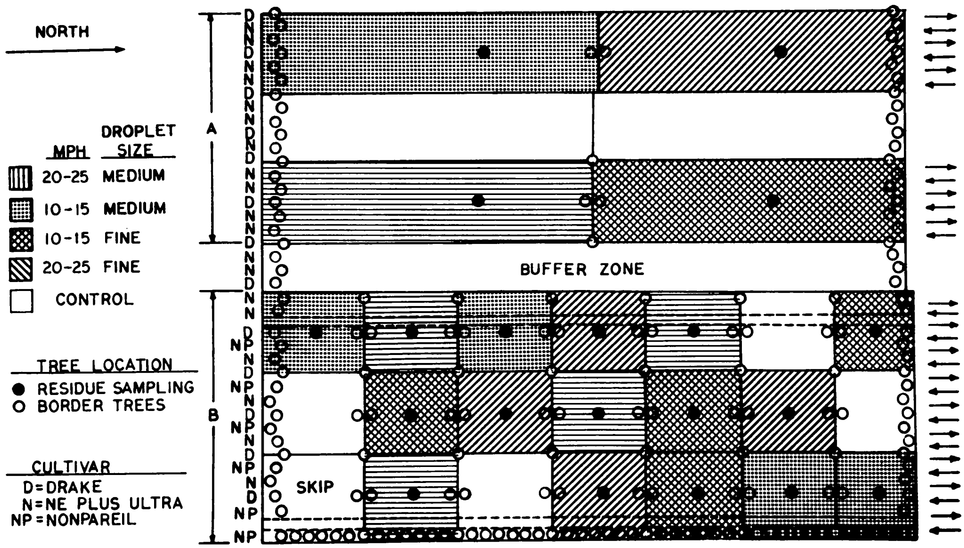

Fig. 1. Helicopter spray application plot, 1963. Arrows on right indicate direction of flights; tree rows were spaced 24 feet apart.

TABLE 3

TYPES OF APPLICATIONS AND WEATHER CONDITIONS

Spray droplet size	Forward speed of helicopter	Application rate		Weather		
		Spray per acre	Captan per acre	Average wind velocity	Temperature	Relative humidity
*mmd**	*mph*	*gallons*	*pounds*	*mph*	*°F*	*per cent*
Medium (320 μ)..........	10–15	27	5.4	2.8	63.5	55
Medium (320 μ)..........	15–20	32	6.4	1.9	56.8	68
Fine (240 μ)..............	10–15	25	5.0	2.5	65.7	51
Fine (240 μ)..............	15–20	30	6.0	2.1	68.5	46

* Mass median diameter.

made on half of the two outside blocks with each of the four treatments; no other fungicides were used before or during the experimental period. Chemical control had not been practiced in orchard B for at least 5 years prior to this study, but orchard A had received the usual yearly applications for disease and insect control. Shot-hole lesions on shoots were abundant in both plots. Each plot was seven trees long and seven trees wide; four plots were used and replicated four times in a random pattern.

Time and Method of Captan Spray Application. A single spray of 50 per cent captan (N-trichloromethyl-4-cyclohexene-1,2-dicarboximide), known to be effective in shot-hole control, was applied on March 25, 1963. This was about 2 weeks after petal-fall; no disease symptoms were evident on the newly developed leaves at that time. Table 3 shows the types of applications, weather conditions during treatment, and amount of captan used for each treatment.

In 1962, sprays were applied with ground air-carrier equipment, with a fixed-wing airplane, and with a helicopter. Aerial applications produced less deposit on the lower surfaces than did ground applications, so a series of applications were designed to determine if aerial application equipment or techniques could be modified to increase spray deposit on lower surfaces. A Bell model 47G-2 helicopter was selected because it could operate at low speeds close to the treetops. The factors to be evaluated in the trials were the effects of air circulation, or "downwash" air velocity, and the particle size of spray deposits. It was decided to increase the intensity of air circulation by reducing the forward speed of the helicopter, and to try to increase deposit by reducing particle size.

Helicopter Spray Applications. The helicopter applications mentioned above were made at a speed of approximately 25 mph, using an atomization system that produced spray droplets having a mass median diameter (mmd) of 380 to 450 microns. Forward speeds for other tests were 15 to 20 mph, and 10 to 15 mph. The two nozzle types selected produced a mass median diameter of 320 microns and 240 microns, and nozzles were arranged to maintain approximately the same application rate. Thus, the four combinations of speed and particle size in these tests were as follows:

1. Medium atomization (320 microns, mmd), 10 to 15 mph; atomization produced by sixty-seven 50° hollow-cone nozzles (Spraying Systems, disc type with a 1/32-inch orifice and a number 45 whirl plate), uniformly spaced on a 33-foot boom with a nozzle pressure of 52 psi.
2. Medium atomization (320 microns, mmd), 15 to 20 mph; atomization produced by one hundred 53° hollow-cone nozzles (Spraying Systems, disc type with a 1/32-inch orifice and a number 45 whirl plate), uniformly spaced on a 33-foot boom with a nozzle pressure of 72 psi.
3. Fine atomization (240 microns, mmd), 10 to 15 mph; atomization produced by sixty-seven 140° hollow-cone nozzles (Spraying Systems, wide-angle cone-jet spray tips, T 12 W with a 0.078-inch orifice), uniformly spaced on a 33-foot boom with a nozzle pressure of 58 psi.
4. Fine atomization (240 microns, mmd), 15 to 20 mph; atomization produced by one hundred 140° hollow-cone nozzles (Spraying Systems, wide-angle cone-jet spray tips, T 12 W with a 0.078-inch orifice), uniformly spaced on a 33-foot boom with a nozzle pressure of 58 psi.

Bioassay of Captan Deposits. The disease-controlling efficacy of captan deposits on upper and lower leaf surfaces was determined by bioassay techniques. After the helicopter spray applications on March 25, 1963, two shoots were cut from the center tree of each plot and immediately placed in moist sand to prevent wilting. One leaf from each shoot was sliced at the midrib and placed on a moist filter paper in a Petri plate with one of the halves inverted. Five ml of water agar containing *Coryneum beijerinckii* conidia were poured into Petri dishes and allowed to solidify, then another 5 ml of water agar were added to the Petri dish. Plugs of agar with spore were cut with a cork borer 6 mm in diameter, and two plugs were placed on each half-leaf with the spores next to the leaf surface. The Petri dish with the leaf was then placed in a plastic container in an atmosphere of 100% RH and held at 18°C. Germination data were taken after 24 hours.

Another sample of leaves was collected and tested 4 days later and immediately after a rain (March 29, 1963). Weather conditions between the time of spray application and the second harvest of leaves were as follows: 0.32 inches of rain on March 27, temperatures 10° to 18°C; 1.78 inches of rain on the 28th, temperatures 8° to 13°C, and 0.05 inches of rain on the 29th,

TABLE 4

COMPARISON OF CAPTAN DEPOSITS ON SLIDES AND LEAVES

Spray droplet size	Forward speed of helicopter	Spray deposit on upper surface of slide, Position in tree: High*	Low*	Average	Spray deposit on lower surface of slide, Position in tree: High	Low	Average	Ratio of deposit on surface of slides (lower/upper)	Total spray deposit on: Slide	Leaf	Ratio
	mph	*μg/in.²*			*μg/in.²*			*Per cent*	*μg/in.²*		*Per cent*
Medium (320 μ).....	10–15	53.49‡	36.90	45.20	4.29	3.16	3.90	8.63	66.26	79.86	82.97
Medium (320 μ).....	15–20	50.44	37.39	43.91	2.87	3.19	3.03	6.90	75 11	112.24	66.92
Fine (240 μ)..	10–15	33.36	44.70	39.03	3.25	3.5	3.38	8.66	53.08	55.44	95.74
Fine (240 μ)..	15–20	32.76	28.28	30.4C	3.50	4.11	3.17	10.43	50.34	59.16	85.09

* High is *upper* half and low is *lower* half of tree.
† Single composite of leaf sample from each of four plots.
‡ Averages from 80 double slides, figures corrected for an application rate of 4.0 pounds of captan per acre (table 3 gives application rate).

TABLE 5

BIOASSAY OF CAPTAN DEPOSIT WITH CORYNEUM CONIDIA ON ALMOND LEAVES

Spray droplet size	Forward speed of helicopter	Inoculated surface	Average per cent germination*: After spray	Four days later†
	mph			
Medium (320 μ)............................	10–15	upper	0.6 A	22.85 NS
		lower	1.2 A	14.90 A
Medium (320 μ)............................	15–20	upper	1.7 A	27.67 NS
		lower	6.8 A	13.85 A
Fine (240 μ)................................	10–15	upper	1.9 A	20.52 NS
		lower	2.2 A	13.40 A
Fine (240 μ)................................	15–20	upper	3.2 A	21.95 NS
		lower	14.3 A	9.67 A
Untreated check...........................	.....	upper	61.7 BC	27.62 NS
		lower	75.0 C	26.20 B

* Germination of Coryneum conidia was observed after 24 hours incubation at 18°C in dark. Data converted to arc sin √percentage for statistical treatment, using Duncan's multiple-range test. Statistical groupings ($P = 0.05$) for vertical comparison shown by letters following the numbers. Values having a letter in common do not differ significantly.
† Collected 4 days after the first sample. 2.15 in. of rain fell between the first and second collection of samples.

temperatures 6.5° to 17°C; total rainfall: 2.15 inches.

Analysis of Captan Deposits. The upper surfaces of glass slides had deposits of captan ranging from 30 to 45 μg/in.² (table 4). Slides placed high in the tree had greater deposits of captan. The lower surfaces of all the slides had only about one-tenth the amount of deposits on the upper surfaces; deposits of captan on the lower surfaces were not affected by position on the tree (table 4).

Comparison of the amount of deposit of fine and medium size droplets shows that on upper surfaces the medium spray droplets gave higher deposits of captan than did the fine spray droplets, but produced no distinct differences in the amount of deposit on the lower surface—although more deposit was usually obtained with medium spray droplet application at 10 to 15 mph. Total deposit on the leaf surface was slightly more than that on the glass slides. Medium spray droplets deposited more captan on the leaf than did fine spray droplets.

Bioassay Results. Immediately after spraying, the deposits on upper and lower leaf surfaces significantly reduced conidial germination (table 5). Germination rates on the upper and lower surfaces of the control leaves were not significantly different. The per cent of germination on treated leaves was slightly higher on the lower than on the upper surfaces. The lowest germination rate on both leaf surfaces resulted from medium spray droplet application at 10 to 15 mph. These data further substantiate the presence of an effective deposit of chemical on the lower surfaces, and confirm data obtained on glass slides suspended in the trees. There was no reduction of germination on the upper surface of leaves after 2.15 inches of rain.

EVALUATION OF DISEASE CONTROL

The incidence of shot-hole disease was evaluated by examining 100 leaves from each quadrant of the tree (disease data were not taken on fruit because frost prevented setting of sufficient numbers of fruit). Excellent control of Coryneum blight on leaves was shown on both test plots with each of the four treatments (table 6). Degree of control did not differ significantly between treatments, although the lowest disease incidence occurred in some of the plots treated with medium-sized droplets sprayed at a speed of 10 to 15 mph.

TABLE 6

CORYNEUM BLIGHT CONTROL BY HELICOPTER SPRAY APPLICATION, 1963

Spray droplet size	Forward speed of helicopter	Average per cent leaf infection*			
		Orchard B		Orchard A	
	mph	April 12†	April 18‡	April 12§	April 18‖
Medium (320 μ)	15–20	2.7 A*	4.6 A	1.4 A	2.6 A
Medium (320 μ)	10–15	4.8 A	4.6 A	2.5 A	3.0 A
Untreated check	.....	....	....	24.2 B	21.4 B
Fine (240 μ)	10–15	4.2 A	3.9 A	2.5 A	5.3 A
Fine (240 μ)	15–20	5.6 A	4.8 A	4.6 A	5.1 A
Untreated check	.....	20.9 B	23.2 B	36.6 B	34.2 B

* 400 leaves inspected on each tree. Significance at 1% level. Data converted to arc sin $\sqrt{\text{percentage}}$ for statistical treatment. Duncan's multiple-range test used. Statistical groupings (P = 0.01) for vertical comparison are shown by letters following the numbers. Values having a letter in common do not differ significantly.

† Average of one tree in each of four replications.

‡ Average of four trees in plot.

§ Average of five trees in each of four replications.

‖ Average of 11 trees in plot.

DISCUSSION

The data presented indicate that helicopter applications of captan spray can effectively control Coryneum blight disease on almond. Previous tests by O'Reilly (1957) with airplane spray applications showed ineffective control. Kilgore, Yates, and Ogawa (1964) obtained data showing that little fungicide was deposited on lower surfaces of glass slides by fixed-wing and helicopter aircraft, and this resulted in poor shot-hole control. However, ground sprayers deposited greater amounts on lower surfaces of glass slides and controlled the disease. Under optimum spray conditions in 1961 the high-volume ground sprayer deposited 39.2 $\mu g/in.^2$ of captan on the upper surfaces of glass slides and 25.5 $\mu g/in.^2$ on the bottom surfaces.

In 1962, under optimum spray conditions for aircraft and poor spray conditions for ground sprayers, the ground sprayer deposited only 24.4 $\mu g/in.^2$ of captan on the upper glass surfaces. During 1961 and 1962, fixed-wing aircraft applications deposited from 15.3 to 39.1 $\mu g/in.^2$ of captan on upper surfaces of glass slides, and only 0.43 to 0.4 $\mu g/in.^2$ on lower surfaces. In 1962, the helicopter deposited 41.7 $\mu g/in.^2$ of captan on upper surfaces of glass slides and 1.7 $\mu g/in.^2$ on the lower surfaces of glass slides, whereas in 1963 the deposit was 45.2 $\mu g/in.^2$ and 3.9 $\mu g/in.^2$ respectively.

These figures indicate that effectiveness in disease control during 1963 could be related to higher deposit on the upper surfaces, as well as to significant deposit on the lower surfaces. Tests showing that Coryneum conidia germinate equally well on both leaf surfaces, and that lower surfaces are more susceptible to infection and disease, suggest that spray deposit on the lower surface is necessary for disease control. The deposits of captan on the lower surfaces of glass slides compared favorably with inhibition of Coryneum conidia germination on lower leaf surfaces. Greater inhibition of conidial germination was observed on the upper leaf surface than was noted on the lower leaf surface, although the statistical significance of this could not be established.

Apparently, medium spray droplet applications at 10 to 15 mph gave the best disease control because more captan was deposited on the lower glass surfaces, and because greater inhibition of spore germination on upper and lower leaf surfaces resulted from the greater amounts deposited.

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141

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