

case with females. The only relatively nontoxic treatment to both sexes was 0.005% for 6 days, but it was only 50 to 75% effective in causing sterility.

DISCUSSION.—Of 79 tests conducted against the male boll weevil, 33% produced an effective level of sterility. Of the successful tests, 42% contained busulfan, almost half of which produced excessive mortality.

Of 80 tests conducted against the female boll weevil, 76% produced an effective level of sterility. Although 26% of the successful tests used busulfan, ENT 61168, and ENT 51904 were much more effective at nontoxic concentrations.

The best treatment for sterilizing both sexes without excessive mortality was busulfan at 0.1% in a 6-day feeding. This treatment was successful in 5 of 7 tests against each sex with only 29% of these tests producing excessive mortality.

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Oxodene: Longevity of Honey Bees^{1,2,3}

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ABSTRACT

Oxodene® (chlorine dioxide) at concentrations of 10 or 100 ppm in 50% sucrose solution significantly increased the longevity of caged worker *Apis mellifera* L., but higher concentrations reduced longevity. Bees that

were fed 10,000 ppm chlorine dioxide defecated excessively and died within 1 week. Compared with untreated bees there was no significant difference in consumption of food (sucrose solution) or water.

Antibiotics, bactericides, germicides, disinfectants, and similar compounds, when fed to honey bees, *Apis mellifera* L., have a variety of effects. A change in longevity is among the most noticeable. Tests have been conducted to determine the effects of several antibiotics and other materials on longevity of caged bees (Moffett 1952, 1953; Moffett et al. 1958; Hitchcock 1964). Oxodene® (chlorine dioxide) was another material submitted to the USDA for determination of its effects on honey bees.

MATERIALS AND METHODS.—Oxodene is an aqueous solution of stabilized chlorine dioxide used as a deodorizer, bacteriostat, germicide, fungicide, slimicide, and bleach. It is normally marketed as a colorless solution containing 10,000 or 20,000 ppm chlorine dioxide and has a slight odor of chlorine in the more concentrated solutions.

For the test, the Oxodene was mixed with 50% (wt/wt) sucrose solution (sucrose and once-distilled water) to provide 6 concentrations of chlorine dioxide of 0, 1, 10, 100, 1000, and 10,000 ppm.

Nonanesthetized adult worker honey bees of mixed ages from the same colony were placed in thirty 7.6×17.7×2.5-cm cages made of wood and galvanized screen on Nov. 22, 1967. Because Jones et al. (1964) reported a decrease in the longevity of bees anesthetized with carbon dioxide, nonanesthetized bees were used. Each cage contained an average 173 bees (range 142-251). The test solutions were each fed to the bees continuously (5 cages/solution) by placing 1 calibrated inverted 25-ml vial (with 2 pinholes in each top) on each cage. In addition a similar vial containing water was added to each cage. Solutions were changed every week to avoid possible contamination by molds.

The cages of bees were arranged randomly on 4 shelves of a Cenco® incubator with automatic temperature and ventilation controls. Darkness was maintained in the incubator except at times when data were collected or feeding took place. The average temperature was 32°C (range 30°-33°C). The relative humidity was not controlled and averaged about 17% (range 16-20%).

Mortality, consumption of food and water, temperature, relative humidity, and the condition of the

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³ Mention of a proprietary product does not constitute endorsement by the USDA.

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Table 1.—Longevity and mean cumulative consumption of Oxodene and water per cage of caged honey bees fed concentrations of Oxodene in sucrose solutions (5 cages/treatment). Laramie, Wyo. 1967-68.

Treatment (ppm chlorine dioxide)	Week										
	1	2	3	4	5	6	7	8	9	10	11
	<i>Mean^a survivors (%)</i>										
0 (controls)	99.0	97.1	97.0	96.3	95.8	83.8	65.8	51.5	41.4	28.9	11.58 ab
1	98.9	96.2	94.4	92.9	91.2	88.3	78.0	57.1	46.0	29.1	21.41 ab
10	99.2	98.2	98.2	97.5	96.6	94.8	92.6	90.4	86.7	69.1	48.82 c
100	98.8	97.3	96.5	96.3	96.0	95.5	93.2	87.0	79.9	49.5	36.17 bc
1000	97.9	69.1	Dead								
10,000	Dead										
	<i>Mean^a cumulative amount of Oxodene consumed (ml)</i>										
0 (controls)	29.6	58.0	80.4	102.8	120.0	143.4	161.2	176.6	186.0	195.0	201.4 a
1	33.8	66.6	86.6	108.6	129.8	147.2	161.6	174.0	183.2	190.0	195.8 a
10	26.0	53.2	72.8	89.8	108.2	130.0	150.6	169.0	181.8	197.0	209.0 a
100	26.2	49.4	66.2	81.8	93.6	109.6	127.2	145.8	158.4	169.0	178.0 a
1000	14.4	25.0	30.0	Dead							
10,000	4.8	Dead									
	<i>Mean^a cumulative amount of water consumed (ml)</i>										
0 (controls)	33.0	63.8	76.0	88.2	106.2	117.8	133.8	143.4	152.6	160.2	166.2 a
1	29.0	64.0	75.4	91.2	109.0	129.2	147.0	161.6	169.4	177.2	182.8 a
10	30.8	62.0	74.6	90.6	105.2	120.4	137.2	152.6	165.2	176.6	187.6 a
100	28.0	59.2	72.8	87.6	103.0	120.0	137.8	152.4	165.0	176.0	185.2 a
1000	26.8	48.0	55.2	Dead							
10,000	10.8	Dead									

^a The means of each treatment followed by the same letter are not significantly different at the 0.01 level by Duncan's multiple range test.

bees were recorded each day for 11 weeks. Dead or moribund bees (no longer able to take food) were removed daily by using the sliding bottom screen of the cage.

RESULTS AND DISCUSSION.—Ten and 100 ppm chlorine dioxide fed to caged honey bees increased their longevity significantly compared with all other doses tested, and bees fed these doses built honeycomb in the cages and actually stored some of the sucrose solution after dehydrating it below the concentration necessary for fermentation.

All bees fed 1000 or 10,000 ppm chlorine dioxide died before the test was concluded, and all those fed 10,000 ppm died within 1 week; 100% mortality did not occur in those fed 1000 ppm until 3 weeks. Before dying, these bees regurgitated a greenish liquid. Also, excessive defecation occurred among bees fed 10,000 ppm; these sick bees were very weak and had difficulty climbing the sides of the cage and maintaining balance. Each moribund bee was noticed, and sometimes mauled, by other stronger bees; death followed soon after.

At the completion of the experiment, an average of 11.58% of the bees fed unmedicated sucrose survived, and the average survival for those fed 1 ppm was 21.41%, which was not significantly different from the controls. However, survival in the groups fed 10 and 100 ppm was 48.82 and 36.17%, respectively (Table 1A), and these differences were statistically significant ($P < 0.01$).

The amount of food (sucrose solution) and water consumed by caged bees that survived the 11-week

test did not differ significantly among the treatment groups (Table 1B, C). However, the analysis does not include the ingestion of the groups fed 10,000 and 1000 ppm chlorine dioxide, because all these bees had died.

A compound that significantly prolongs the life-span of adult bees could be of great value to the beekeeping industry, because increased longevity could enable more bees to make more trips to the field to forage for nectar, pollen, water, and propolis. Increased longevity could result in a larger adult population and greater honey production, and the beekeeper who rents colonies for pollination purposes could expect more efficient pollination with a larger number of bees per colony. Thus, field tests to determine the effects of chlorine dioxide on field colonies are warranted.

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