Evaluation of Formulations and Release Rates of Benzaldehyde, an Attractive Fruit Odor for Plum Curculios

Jaime Piñero, Sara Hoffmann, and Ronald Prokopy
Department of Entomology, University of Massachusetts

In the 2000 Issue of *Fruit Notes*, we reported on a 2000 study showing that benzaldehyde in association with plum curculio (PC) pheromone (grandisoic acid) was the most attractive odor bait combination for PCs when compared with other odor baits affixed to panel and pyramid traps. In that study, we also found that although traps baited with benzaldehyde plus pheromone were very effective at determining the beginning, peak, and end of PC immigration into apple orchards from overwintering sites, benzaldehyde seemed to be less attractive to PCs after ~10 days of exposure to sunlight. Subsequently, we found that the clear high-density polyethylene vials used in that study allowed UV-polymerization of about 10% of the benzaldehyde contained in the vials, which may have diminished or masked some of the attractiveness of benzaldehyde. We concluded from that study that research should be aimed at improving the formulation and longevity of benzaldehyde and optimizing the amount of benzaldehyde used as odor bait.

Here, in an attempt to improve trap ability to capture PCs, we compared different formulations, release rates, and positions of benzaldehyde-releasing dispensers in tops of branch-mimicking cylinder traps placed on apple tree limbs. We also evaluated different amounts of benzaldehyde in association with PC pheromone in Circle traps, which are wrapped completely and tightly around apple tree trunks and are designed to intercept adults crawling up tree trunks.

Materials & Methods

We performed four different experiments. The first three were conducted in 2001 and involved use of black cylinder traps. The fourth was carried out in 2002 and involved use of Circle traps. All evaluations were performed in unsprayed sections of apple orchards or in backyards containing unsprayed apple trees.

Experiment 1. In this test, conducted from June 6 to July 3 (2001) in Atkins orchard (Belchertown, MA), we evaluated (using cylinder traps) four different formulations of benzaldehyde alone (without pheromone) released from dispensers placed either inside or outside of the trap tops. Formulations tested were: (1) Great Lakes IPM (Vestaburg, MI), (2) IPM Technologies (Portland, OR), (3) four 400-¼l high-density clear polyethylene vials (VWR Scientific Products; Boston, MA), each filled with 400¼l of benzaldehyde (as in 2000), and (4) one 1-ml low-density white polyethylene vial (Wheaton; Millville, NJ) filled with 1 ml of benzaldehyde. Unbaited traps served as a control treatment. For each formulation, the estimated release rate of benzaldehyde was about 10 mg per day except for the white vials, which released about 2.5 mg of benzaldehyde per day. Each treatment was replicated 4-5 times.

Traps were deployed in perimeter-row apple trees and on apple trees located in rows 2, 3, and 4. Traps were inspected for PC captures 2 to 3 times per week. At each inspection session, trap tops were rotated (within a replicate) one position (clockwise).

Experiment 2. This test, conducted from May 29 to July 3, 2001 in Atkins orchard, was aimed at evaluating different amounts of benzaldehyde released from 1-ml low-density white polyethylene vials in association with cylinder traps. Each white vial released about 2.5 mg of benzaldehyde per day.

Treatments evaluated were: (1) one white vial (placed inside a trap top), (2) one white vial (placed outside a trap top), (3), five white vials (inside), (4) five white vials (outside), (5) 15 white vials (outside), and (6) unbaited traps as a control treatment. For treatments 2 and 4, vials were hung vertically from the periphery of the trap top using copper wire, about 2 inches away from the trap base. For treatment 5, the 15 vials were hung from a wooden stick (about 10 inches long) using wire. The stick holding benzaldehyde-releasing vials was then attached horizontally to apple tree branches using wire so that bases of vials were located about 4 inches above a cylinder trap top.

In this test, benzaldehyde was evaluated in combination with grandisoic acid (PC pheromone) (ChemTica Internacional, S.A., San Jose, Costa Rica). One pheromone dispenser, releasing about 1 mg of grandisoic acid per day, was placed inside each benzaldehyde-baited trap top.

All vials containing benzaldehyde were replaced on June 15. Traps were deployed within a single row of apple trees and were inspected for PC captures 2-3 times per week. Trap tops were rotated one position (clockwise) at each inspection.

Experiment 3. This evaluation was performed from May 25 to June 20, 2001, simultaneously at the UMASS Cold Spring Orchard Research & Education Center in Belchertown, Atkins orchard, and in backyard trees in Amherst, MA. The experiment was aimed at determining the longevity of four different formulations of benzaldehyde alone (without pheromone) using cylinder traps. The formulations evaluated were the same as those described in experiment 1. All benzaldehyde-releasing dispensers were positioned inside cylinder trap tops. Traps were inspected for PC captures 2 to 3 times per week, rotating the trap tops one position (clockwise) at each inspection.

Experiment 4. This test was conducted from June 26 to July 2, 2002 in backyard trees in South Deerfield, MA, using Circle traps. The purpose was to determine the influence of different release rates of benzaldehyde, in association with PC pheromone, on PC captures. We evaluated three different release rates of benzaldehyde (10, 20, and 40 mg/day) together with a control treatment without benzaldehyde.

Benzaldehyde was released from 15-ml low-density white polyethylene vials (Wheaton, Millville NJ). Each vial was filled with 15 ml of benzaldehyde to achieve a release rate of ~10 mg/day. Each vial was hung by its neck from a wire and placed inside an inverted, green 266-ml plastic cup to provide additional protection for this chemical against polymerization by UV light and rainfall. Cups were hung from tree trunks using wire in such a way that bases of cups were about 4 inches above Circle trap tops. Depending on the treatment, either no, one, two, or four cups were positioned above the Circle trap tops.

In all, 32 Circle traps were deployed on unsprayed apple tree trunks. Each was baited with one of the abovementioned treatments and one dispenser releasing PC pheromone (release rate: 1 mg/day) placed inside the Circle trap top. Traps were inspected for PC captures one week after bait deployment.

Results

In the first experiment, no appreciable differences among odor-formulations were noticed when comparisons were made among vials placed outside of trap tops (Table 1). However, when vials were placed inside of trap tops, the '4 clear vials' formulation proved to be the most attractive formulation for PCs, followed by the '1 white vial' formulation. When PC captures by traps were compared according to position of vials

Table 2. PC captures by cylinder traps baited with benzaldehyde (in combination with PC pheromone) according to the number and position of 1-ml white vials.

Number of vials	Amount of benzaldehyde released per day (mg)	Inside	Outside	Total PCs
1	2.5	2	4	6
5	12.5	2	11	13
15	37.5	---	3	3
unbaited traps	0.0	---	---	1
TOTAL		4	18	23

Table 1. PC captures by black cylinder traps baited with four different formulations of benzaldehyde alone (without pheromone), positioned inside or outside of trap tops.

Formulation	Amount of benzaldehyde released per day (mg)	Inside	Outside	Total PCs
Great Lakes IPM	10.0	2	7	9
IPM Technologies	10.0	2	9	11
White vial	2.5	5	6	11
4 Clear vials	10.0	8	7	15
Unbaited traps	0.00	---	---	2
TOTAL		17	29	48

within the same formulation, we found that traps baited with the 'Great Lakes IPM' and 'IPM Tech' formulations deployed outside the trap tops captured 3.5 and 4.5 times (respectively) more PCs than traps having the same type of formulation but placed inside the trap tops. For both clear and white vials, no differences in captures were noticed between vials placed inside or outside the trap top (Table 1).

In the second experiment, traps having five white vials placed outside of trap tops captured the most PCs (Table 2). Traps having 15 vials (which released a total of ~37.5 mg of benzaldehyde per day) captured the fewest PCs, only slighter more than unbaited traps. Overall, about four times more PCs were captured when vials were positioned outside of trap tops than inside.

In the third experiment, wherein all formulations of benzaldehyde were placed inside of cylinder trap tops, results indicated that during the first 8 days of evaluation, traps baited with one white vial captured numerically more PCs than any other bait treatment (Table 3). From days 9-16, clear vials outperformed the other formulations. During this time

Table 3. PC captures by black cylinder traps baited with different formulations of benzaldehyde (placed inside of trap tops and without pheromone) according to the number of days elapsed after bait deployment.

Treatment	Amount of benzaldehyde released per day (mg)	1-8	9-16	17-24	25-32	Total PCs
Great Lakes IPM	10.0	6	4	5	4	19
IPM Technologies	10.0	4	0	5	0	9
1 White 1-ml vial	2.5	9	4	2	2	17
4 Clear vials	10.0	5	8	1	3	17
Unbaited traps	0.0	5	1	6	4	16
TOTAL		29	17	19	13	78

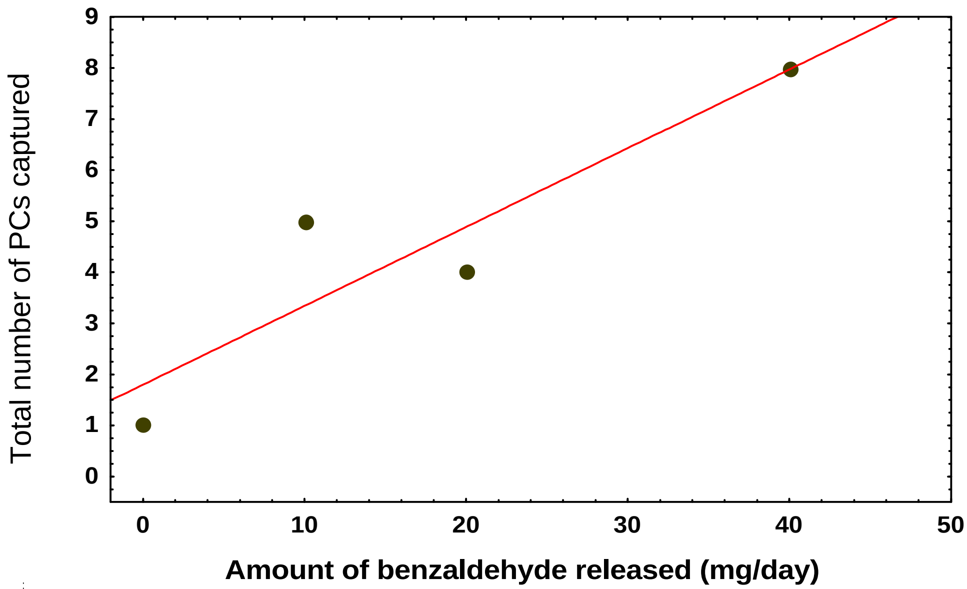

Figure 1. Relationship between total PC captures by Circle traps and amount of benzaldehyde released from 15-ml white polyethylene vials positioned ~4 inches above trap tops. Amounts of benzaldehyde released were 0, 10, 20, and 40 mg/day, each in association with PC pheromone (1 mg of grandisoic acid per day).

period, traps baited with the 'IPM Technologies' formulation did not capture any PCs. However, 17-24 days after the initial baiting, the 'IPM Technologies' and the 'Great Lakes IPM' formulations performed better than the white vial and the clear vials but, nevertheless, did not perform better than unbaited traps. From 25-32 days, all traps captured similar numbers of PCs except traps baited with the 'IPM Technologies' formulation, which captured no PCs. Overall, the formulations '4 clear vials', '1 white vial', and the 'Great Lakes IPM' were about equally attractive to PCs, whereas the 'IPM Technologies' formulation was the least attractive.

In the fourth experiment, wherein all dispensers of benzaldehyde were placed 4 inches above Circle trap tops, results show a strong linear relationship between the amount of benzaldehyde released (in association with PC pheromone) and the total number of PCs captured by Circle traps (Fig. 1). This suggests that, at least for Circle traps, the response of PCs to benzaldehyde in association with PC pheromone increases as the amount of benzaldehyde increases (up to the maximum release rate tested of about 40 mg per day).

Conclusions

Four conclusions can be drawn from this series of experiments.

First, white polyethylene vials releasing benzaldehyde performed as well as either the clear vials used in the 2000 field test or the other formulations of benzaldehyde evaluated (Great Lakes IPM and IPM Technologies). Therefore, white polyethylene vials (particularly the UV-light-protected 15-ml vials [see below]) can be used as devices to dispense benzaldehyde effectively in future tests.

Second, results from the first and second experiments suggest, for the most part, that when dispensers are placed inside of cylinder trap tops, the odor of benzaldehyde may become repellent at close range, thus reducing the ability of cylinder traps to capture PCs. This was particularly true for both the 'Great Lakes IPM' and 'IPM Technologies' formulations but not for the '1-white-vial' or '4-clear-vials' formulations (in experiment 1), and the '5-white-vials' treatment (in experiment 2). Consequently, we believe that benzaldehyde-releasing dispensers should be placed outside of trap tops to avoid close-range negative effects while preserving (or even enhancing) attractiveness to PCs. Results from experiment 4 (involving Circle traps), in which vials were placed outside of trap tops, further support this conclusion.

Third, 1-ml white vials releasing benzaldehyde were found to perform best during the first 8 days after deployment (experiment 3) and, after that time, their attractiveness decreased considerably. A close examination of the 1-ml white polyethylene vials revealed the formation of whitish/yellowish crystals in the area of necks of vials after 8 days of use. In contrast, the 15-ml white polyethylene vials used in experiment 4 showed no signs of such crystals on any parts of the vials after one week (experiment 4) or several weeks (data from other field studies) of use. This difference may be due largely to the type of screw cap used in association with the white vials in each year. In 2001, the 1-ml white polyethylene vials were enclosed by white polypropylene caps that lacked Teflon® liner as a sealant, and thus oxygen may have interacted with benzaldehyde altering its chemical composition. On the contrary, in 2002 the 15-ml white vials were enclosed by black phenolic Teflon®-lined caps, which apparently prevented oxygen from interacting with the benzaldehyde contained in the vials. Also, in 2002 the use of plastic cups provided extra protection against UV light and rainfall.

Fourth, results from the fourth experiment strongly suggest that there was an increase in PC captures by Circle traps associated with an increase in the concentration of benzaldehyde. In this experiment, the maximum release rate of benzaldehyde tested was ~40 mg per day. Hence, it is possible that even higher amounts of benzaldehyde may increase the attractiveness of benzaldehyde to PCs. This aspect is particularly important not only in relation to the determination of amount of benzaldehyde to be used to bait traps to monitor the onset, course, and end of PC immigration, but also to the determination of amount of benzaldehyde to be employed in perimeter-row odor-baited trap trees (see the 2002 winter issue of Fruit Notes) to follow accurately the course of plum curculio injury to fruit in commercial apple orchards in Massachusetts.

Acknowledgments

We thank Everardo Bigurra and Phillip McGowan for field assistance. This study was supported with funds provided by a USDA Northeast Regional IPM grant, a Hatch grant, a grant from USDA Crops at Risk program, and the New England Tree Fruit Research Committee.

* * * * *