Discrimination of Sodium Tetraborate by *Anastrepha suspensa* Loew (Diptera: Tephritidae)[1]

Likui Yang,[2] Herbert N. Nigg,[2,3] Samuel E. Simpson,[4] Suzanne Fraser[5] and R. Edward Burns[5]

University of Florida, Lake Alfred, FL 33850 USA

J. Entomol. Sci. 36(3): 268-284 (July 2001)

Abstract Newly-emerged adults (4 h old) and 10-d-old *Anastrepha suspensa* Loew were exposed to 0 to 5% concentrations of sodium tetraborate for 7 d in choice and no-choice feeding tests. With an increase in sodium tetraborate concentration, mortality increased and occurred more quickly; egg production and egg hatch were reduced in both choice and no-choice tests. Fly mortality, egg production, and egg hatch indicated that flies fed about equally on control and sodium tetraborate-containing food when offered a choice. Egg production appeared to be more sensitive to sodium tetraborate than egg hatch. All flies died and no eggs were produced with 1, 3, and 5% sodium tetraborate even when flies were offered the choice of food without sodium tetraborate.

Key Words Discrimination, repellency, sodium tetraborate, *Anastrepha suspensa,* fruit fly eradication

Anastrepha suspensa Loew infests more than 80 species of tropical and subtropical fruit in 23 plant families in Florida (Swanson and Baranowski 1972). Because the larval stages of tephritid fruit flies develop inside fruit, the use of chemical insecticides for control of these fruit flies has focused on the adults (Budia and Vinuela 1996). A common method to control adult *A. suspensa* is a bait spray containing malathion (Simpson 1993, Calkins 1993); although alternative methods have been used to control adults of this fruit fly, such as the sterile insect technique (Holler and Harris 1993). Because the application of malathion over wide areas has resulted in environmental concerns and public protests, interest has shifted to compounds with low toxicity, including boron compounds.

Boron containing compounds, e.g., boric acid and its sodium salts, have been used to preserve wood for the control of bacteria, algae, fungus, and insects (Lloyd 1998) and have been shown to be effective against termites (Grace 1991), cockroaches (Bare 1945, Cochran 1995), ants (Klotz et al. 1997), and flies (Lang and

[1]Received 22 June 2000; accepted for publication 31 December 2000.

[2]University of Florida, Institute of Food and Agricultural Sciences, Citrus Research and Education Center, 700 Experiment Station Road, Lake Alfred, FL 33850.

[3]Author to whom requests for off prints should be sent.

[4]Florida Department of Agriculture and Consumer Services, Division of Plant Industry, 3027 Lake Alfred Road, Winter Haven, FL 33881.

[5]Florida Department of Agriculture and Consumer Services, Sterile Fly Laboratory, 1911 S. W. 34th Street, Gainesville, FL 32608.

Treece 1972, Hogsette and Koehler 1992) by acting as a larvicide, adulticide or sterilant.

Nigg and Simpson (1997) found that the oviposition of *A. suspensa* was delayed up to 7 d after one feeding with sodium tetraborate. Further study in this laboratory (unpubl. data) showed that both egg production and egg hatch of *A. suspensa* were reduced when flies were fed bait containing 0.5% sodium tetraborate for 24 h or 48 h. Sodium tetraborate has a low toxicity to mammals with an oral LD_{50} of 4500 and 4980 mg/kg for male and female Sprague-Dawley rats (Weir and Fisher 1972). It is currently registered with the U.S. EPA as an active ingredient for pesticidal formulations and is considered environmentally safe (Borax Europe Limited, Guildford, UK).

In order to be effective against fruit flies, the pesticide in a bait-pesticide combination should not be repellent to the target insect. Ideally, pesticide/bait combinations should be equally or more attractive to fruit flies compared to 'natural' food. Boric acid and disodium octaborate tetrahydrate were repellent to the house fly, *Musca domestica* L. (Mullens and Rodriguez 1992, Hogsette and Koehler 1994), at 2.25% and 3.0%, respectively, and the German cockroach, *Blattella germanica* L., at 6.25% (Strong et al. 1993). The fire ant, *Solenopsis invicta* Buren, was repelled by 5% boric acid (Klotz et al. 1997). The purpose of this study was to determine if toxicologically effective doses of sodium tetraborate in food were competitive with 'natural' food for *A. suspensa.*

Materials and Methods

Anastrepha suspensa 9-d-old pupae were obtained from Florida Department of Agricultural and Consumer Services, Division of Plant Industry, Gainesville. One day after emergence began, pupae were transferred to a new screened cage (30 × 30 × 30 cm) (BioQuip, Gardena, CA). Flies which emerged during 4 h were used for this experiment. All flies were held in the laboratory at 25 to 28°C and 50 to 70% RH, with a photoperiod of LD 12:12. Normal food was supplied as a yeast/sugar (1:3, w/w) patty for food and a 1% agar patty for water. Food with sodium tetraborate was prepared by adding the appropriate amount of sodium tetraborate in a mixture of sugar, yeast hydrolysate enzymatic (ICN Biomedicals, Inc., Aurora, OH), and agar (Fisher Scientific, Fair Lawn, NJ) (10:2:0.5, w/w/w) dissolved in 50 ml of glass-distilled water (Nigg et al. 1994, 1995). This preparation is termed an agar food patty. Egg-laying squares were prepared by dipping 4 × 4 cm double cheesecloth squares into a warm solution of petroleum jelly (EPACT Corp., Brooklyn, NY), paraffin gulf wax (Boyle-Midway Inc., New York, NY), and candle color dye (C-9 holiday red, Walnut Hill Co., Bristol, PA) (1:2:0.05, w/w/w) for a few seconds, transferring into cool tap water and drying at room temperature.

In experiment one, two groups of containers (950 ml plastic with screened lid) with 5 pairs of newly-emerged flies in each container were treated with 0.1, 0.2, 0.5, and 1% concentrations of sodium tetraborate by feeding for 1 wk. A separate set of flies was offered 1, 3, and 5% concentrations of sodium tetraborate for 1 wk. Each of these dosage sets were divided into two groups. Group one was offered two agar food patties which contained the same dose of sodium tetraborate (no-choice). Group two was offered an agar food patty without sodium tetraborate and another agar food patty which contained various concentrations of sodium tetraborate (choice). Each dose level had 5 replicates. Five containers in which flies were offered two agar food patties without sodium tetraborate were used as controls. One egg-laying square was placed on the screen top of each container. Agar food patties without and with sodium tetraborate were prepared and changed daily. After 7 d, both control food and sodium tetraborate agar food patties were removed and changed to a yeast-sugar patty and a 1% agar patty for water, normal food. The 1% agar patty for water was changed every other day on all cages. Dead flies in each container were recorded daily by sex, and these counts were continued for 20 d after sodium tetraborate dosing began. At the end of each experiment, all flies were killed in a −17°C freezer, and total male and female flies in each container were recorded. In a second experiment, two groups of 5 paired flies from the same population as the experiment above were set up at day 8, fed with normal food, and treated at day 10 as described above.

In a separate set of experiments, conducted exactly as described above, 1, 3, and 5% sodium tetraborate were offered to flies for 24 h only. After 24 h, the sodium tetraborate agar food patties were removed and replaced with normal food, and flies were monitored for 20 d for mortality, egg production, and egg hatch.

When oviposition occurred, eggs from each container were counted and recorded daily at 0800 h. These eggs were discarded. Then a clean egg-laying square (5.0 × 5.0 cm) was placed on the screen top of each container and covered with a small Petri dish (5.5-cm diam) containing a piece of wet paper towel. At 1500 h, eggs oviposited on these squares were counted, then rinsed into a small beaker with distilled water and transferred to black filter paper in a 9-cm diam plastic Petri dish and wetted with 0.07% acidified sodium benzoate (4.2 ml of 10% HCL in 1 liter solution). The Petri dishes were sealed with parafilm and placed in 30°C incubator. The number of hatched larvae in each Petri dish was checked and recorded daily for the next 7 d. Egg production was monitored continuously from the first oviposition day until the end of each experiment. Egg data were calculated as eggs per live female per day.

We made the assumption that if flies fed about one half the time on control food and one half the time on treated food in a choice container, twice as many should live, twice as many eggs would be oviposited and twice as many eggs should hatch compared to a container in which flies were offered only food which contained sodium tetraborate. For example, flies fed 0.5% sodium tetraborate and flies offered a choice between food containing 1% sodium tetraborate and food without sodium tetraborate, should survive about equally if the flies were neither repelled nor attracted to sodium tetraborate.

Data were analyzed using the general linear model (GLM) procedure (SAS Institute 1989). Significance differences among control and treatments ($P < 0.05$) were tested using Turkey's honestly significant difference test (SAS Institute 1989). Median lethal times (LT_{50}s) were estimated by probit analysis (SAS Institute 1989).

Results and Discussion

Mortality. Mortality in both male and female *A. suspensa* was positively related to sodium tetraborate concentration when flies were maintained on no-choice food. Male mortality was higher than female mortality in the first few days after treatment regardless of fly age (Figs. 1, 2 B and D). When flies were fed 0.2% or higher concentrations of sodium tetraborate, almost all males and females died after 7 d of feeding. The LT_{50}s estimated for female flies were longer than for males within same (0.1 to 1.0%) dosage level when both newly-emerged flies and 10-d-old flies were treated but were only statistically different at 0.5 and 1.0% sodium tetraborate for 10-d-old flies (Tables 1, 2). These data indicate that male flies were more sensitive to sodium tetraborate than female flies, an observation also made with organic pesticides (Nigg et al. 1994).

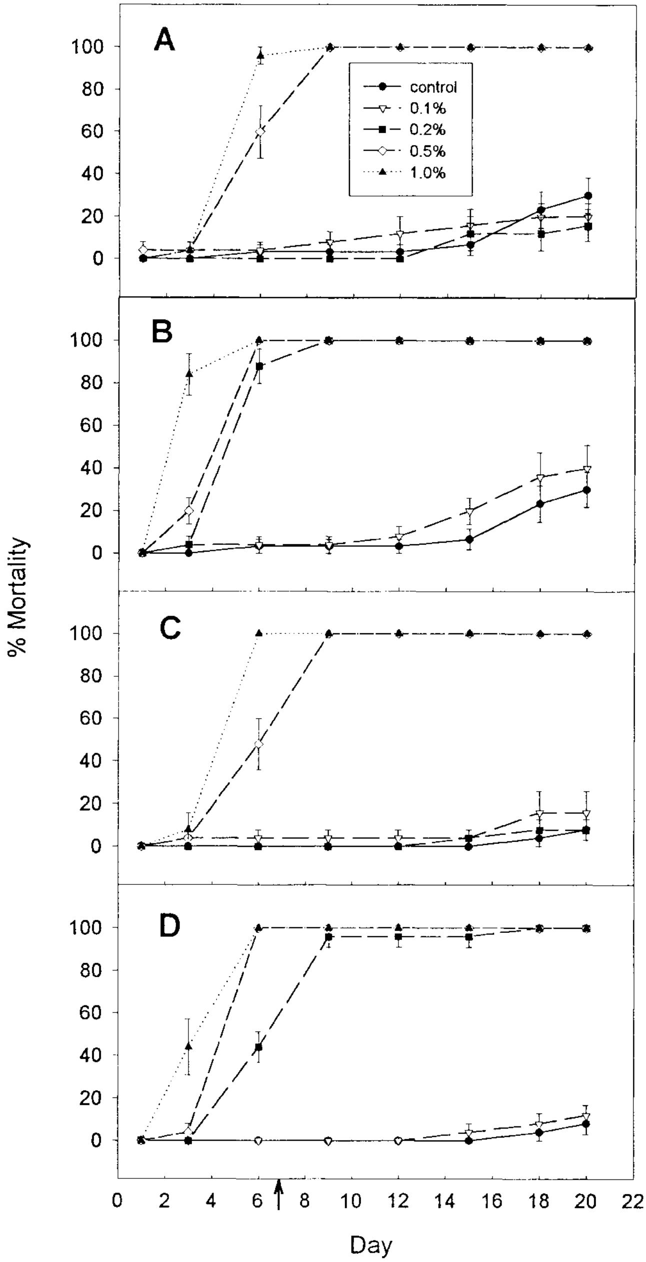

Fig. 1. Mortality of *A. suspensa* treated as 4-h-old adult with sodium tetraborate by feeding 7 d choice food (A & C) or no-choice food (B & D). A: Males, B: Males, C: Females, D: Females. ↑Treatment stopped.

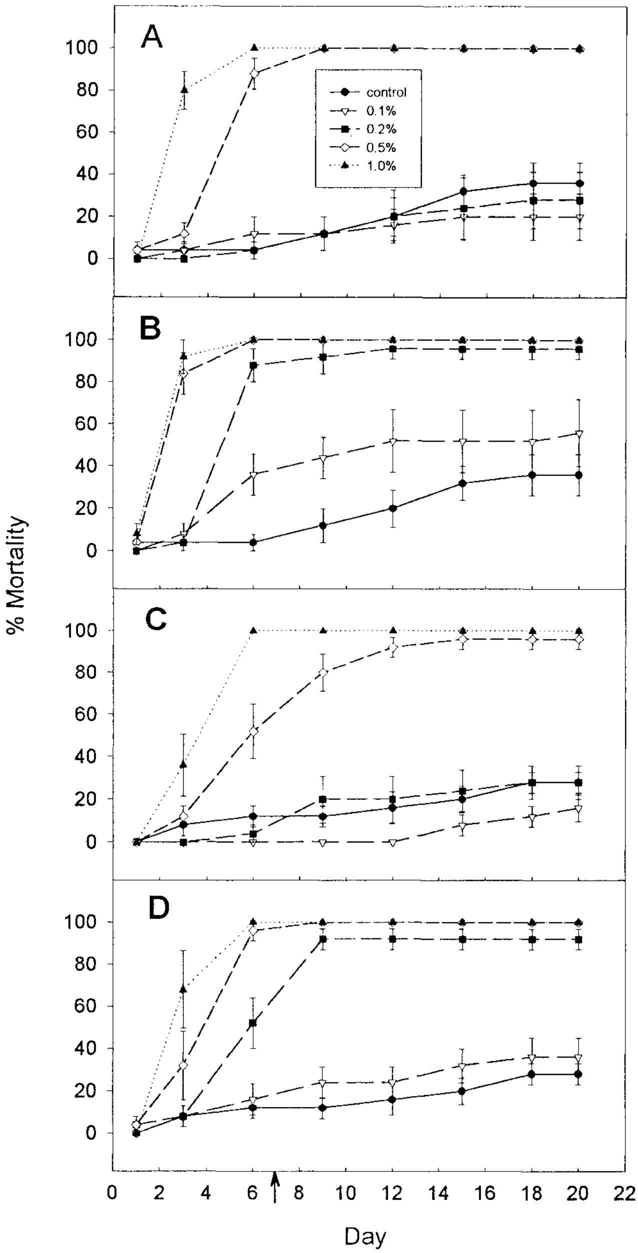

Fig. 2. Mortality of *A. suspensa* treated as 10-d-old adult with sodium tetraborate by feeding 7 d choice food (A & C) or no-choice food (B & D). A: Males, B: Males, C: Females, D: Females. ↑Treatment stopped.

Table 1. LT$_{50}$* of sodium tetraborate to *A. suspensa* treated as newly-emerged adult by feeding 7 d on choice or no choice food

Concentration (%)	Male		Female	
	LT$_{50}$ (95% CI)	Slope + SE	LT$_{50}$ (95% CI)	Slope + SE
		No choice		
0.2	5.29**	8.40 ± 81.9	6.04**	9.92 ± 24.2
0.5	3.72 (3.42-4.00)	9.55 ± 2.14	4.31 (4.03-4.57)	13.4 ± 4.87
1.0	2.53 (2.33-2.74)	6.61 ± 2.19	2.98 (2.73-3.21)	11.9 ± 4.42
		Choice		
0.2	>20	—	>20	—
0.5	5.77**	4.64 ± 17.3	6.03**	7.12 ± 29.4
1.0	4.41 (4.10-4.73)	10.6 ± 2.97	4.79 (3.09-8.79)	11.9 ± 4.42
Choice/no-choice ratio	1.7	—	1.6	—

* LT$_{50}$ is expressed as day.
** Poor fit of probit model prevented estimation of 95% CI.

Table 2. LT$_{50}$* of sodium tetraborate to *A. suspensa* treated as 10-d-old adult by feeding 7 d on choice or no choice food

Concentration (%)	Male		Female	
	LT$_{50}$ (95% CI)	Slope + SE	LT$_{50}$ (95% CI)	Slope + SE
		No choice		
0.2	4.72 (4.33-5.10)	7.06 ± 0.85	5.38**	4.57 ± 5.25
0.5	2.67 (2.44-2.89)	12.3 ± 4.85	3.01**	6.12 ± 5.48
1.0	1.96 (1.67-2.22)	5.96 ± 0.93	2.80 (2.55-3.05)	9.72 ± 2.49
		Choice		
0.2	>20	—	>20	—
0.5	4.62 (4.31-4.92)	10.0 ± 2.22	5.87 (5.29-6.50)	4.36 ± 0.30
1.0	2.42 (2.10-2.71)	5.97 ± 0.86	3.46 (3.12-3.78)	7.17 ± 1.10
Choice/no-choice ratio	1.2	—	1.2	—

* LT$_{50}$ is expressed as day.
** Poor fit of probit model prevented estimation of 95% CI.

In the choice test, mortality patterns in both males and females were similar to that found in the no-choice test. That is, mortality was concentration dependent, male mortality was higher than female, but mortality of males and females was lower compared to no-choice tests at the same dosage level of sodium tetraborate (Figs. 1, 2 A and C). The choice to no-choice ratios of LT$_{50}$s estimated for both males and females were 1.6 (male, newly emerged) and 1.5 (female, newly emerged). Flies given a choice between control food and 1.0% sodium tetraborate food had an LT$_{50}$

of 4.41 d (male) and 4.79 d (female) compared to 0.5% no-choice, 3.72 d (male) and 4.31 d (female) (Table 1) which indicates that 1% choice flies consumed about the same amount of sodium tetraborate as 0.5% no-choice flies. For 10-d-old flies the same ratios of the LT_{50} were about 1.5 for both males and females (Table 2). These results indicate that 1.0% or less sodium tetraborate did not repel newly-emerged flies, and these flies randomly chose between control food and sodium tetraborate food. For 10-d-old flies, individual LT_{50} ratios were 0.5% = 1.73 (male) and 1.95 (female) and 1.0% = 1.23 for males and 1.23 for females. It appears that the 10-d-old flies may have preferred food with 1% sodium tetraborate. These results are supported by the data of Table 3. In the 0.5% and 1% choice containers, all flies died within the 7 sodium tetraborate feeding days (and, of course did not oviposit). If flies had discriminated against food with sodium tetraborate, there would have been survivors as in the 0.2% no-choice containers (Table 3).

Comparable results were reported by Hogsette and Koehler (1994) who worked on house flies, *M. domestica,* using other boron compounds, boric acid, and polybor 3 (disodium octaborate tetrahydrate). They found that low concentrations of these two chemicals did not repel flies. However, when the concentration was increased to above 2.25% for boric acid and 3% for polybor 3, flies appeared to be repelled. Similar results also were found in *B. germanica* (Strong et al. 1993). In *S. invicta,* $\leq$1% of boric acid was necessary to obtain delayed toxicity and reduced repellency; 5% boric acid showed repellency (Klotz et al. 1997). In our 7-d feeding experiments all flies died in 48 h with no-choice of 1, 3, and 5% sodium tetraborate. In choice tests with 1, 3 and 5% sodium tetraborate, all flies were dead within 6 d. In the 24 h feeding experiments, mortality was lower when flies were given a choice regardless of dose and fly age when the same dose choice and no-choice experiments were compared (Figs. 3, 4).

Egg production. For 4-h-old adult flies, egg production was reduced over 14 oviposition days when flies were fed no-choice food containing 0.1% sodium tetraborate (Table 3). When the concentration was increased to 0.2% or higher, most flies were killed before oviposition began; no eggs were oviposited by survivors (Table 3, Fig. 5A). When given a choice of control and treated food, egg production was not affected when flies were treated with 0.1% and 0.2% sodium tetraborate; 0.5% and 1% sodium tetraborate killed most flies after 7 d of feeding and no oviposition was observed for survivors for 20 d after treatment (Table 3, Fig. 5B). These data suggest that flies did not discriminate overall against sodium tetraborate. The ratio of egg production of choice and no-choice containers was 3.8 for the 0.1% sodium tetraborate flies for the first week after treatment and 1.1 for the second week (Table 3). These ratios suggest that flies were not repelled by sodium tetraborate (Table 3). Once treatment was stopped for newly-emerged adults, egg production returned to control levels in surviving flies at the 0.1% sodium tetraborate dose (Table 3, Fig. 5).

Similar results were found in 10-d-old flies. That is, 0.1% sodium tetraborate in the no-choice test significantly reduced egg production in the treatment week and first week after treatment, but not in the second week after treatment. Higher concentrations stopped oviposition of survivors for 14 d after treatment. In the 7-d choice test, 0.5% and 1% sodium tetraborate reduced egg production in the first few days after treatment and stopped oviposition of survivors for the next 14 d (Table 4, Fig. 5 C, D). The egg production ratio of choice and no-choice experiments ranged from 0.7 to 12 (Table 4).

For flies treated with 1, 3 and 5% sodium tetraborate, no eggs were oviposited in choice and no-choice tests in the 7-d feeding experiment. In the 24 h feeding experi-

Table 3. Mean egg production of *A. suspensa* treated as 4-h-old flies by feeding 7 d with sodium tetraborate

Sodium tetraborate concentration (%)	N	Eggs/female/day (mean ± SD)					
		1st week after treatment*			2nd week after treatment		
		Choice	No choice	Ratio	Choice	No choice	Ratio
0	5	19.8 ± 5.0 a**	19.8 ± 5.0 a**	1.0	16.1 ± 2.2 a**	16.1 ± 2.2 a**	1.0
0.1	5	15.3 ± 7.3 a	4.0 ± 2.1 b	3.8	11.2 ± 1.8 b	10.6 ± 1.7 b	1.1
0.2	5	10.5 ± 6.2 ab	†		13.2 ± 2.1 ab	†	
0.5	5	†	‡		†	‡	
1.0	5	‡	‡		‡	‡	

* Due to immature flies no eggs were laid during the treatment week.
** Same controls for comparison.
† No eggs were oviposited by survivors.
‡ All flies died within 7 d after treatment began.
Means in each oviposition period followed by the same letter are not significantly different by ANOVA and Tukey's HSD test ($\alpha \leq 0.05$).

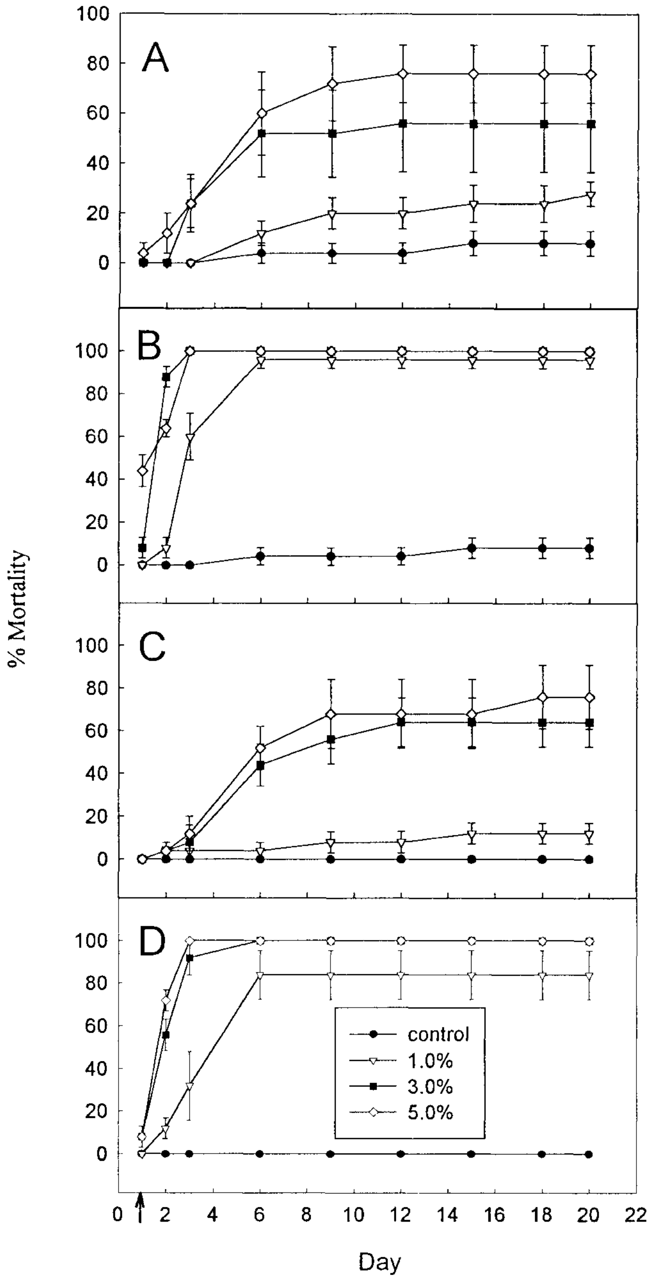

Fig. 3. Mortality of *A. suspensa* treated as 4-h-old adult with sodium tetraborate by feeding 24 h choice food (A & C) or no-choice food (B & D). A: Males, B: Males, C: Females, D: Females. ↑Treatment stopped.

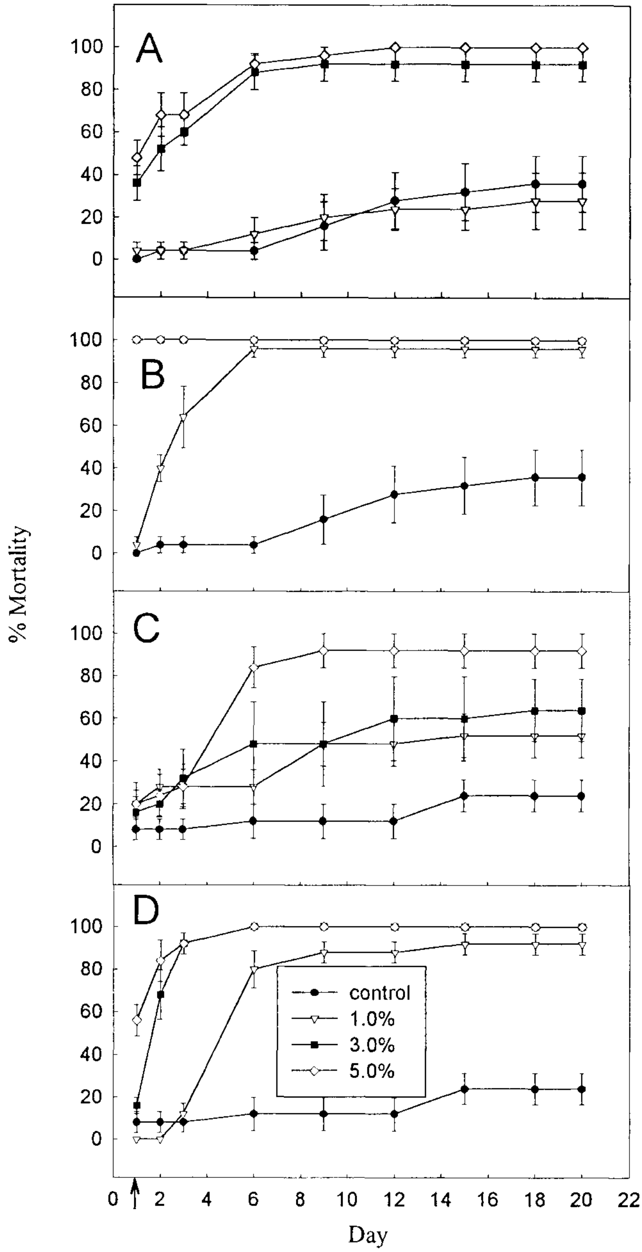

Fig. 4. Mortality of *A. suspensa* treated as 10-d-old adult with sodium tetraborate by feeding 24 h choice food (A & C) or no-choice food (B & D). A: Males, B: Males, C: Females, D: Females. ↑Treatment stopped.

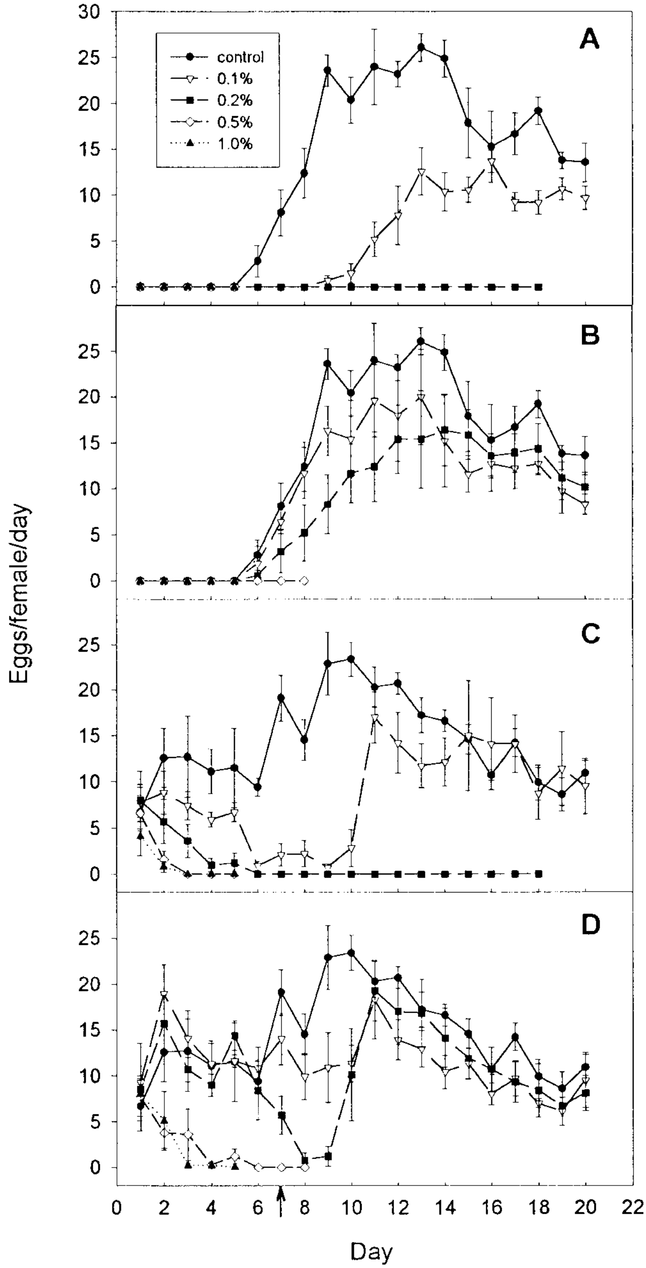

Fig. 5. Mean egg production of *A. suspensa* treated as 4-h-old adult or 10-d-old adult by feeding 7 d on choice or no-choice food. Four-h-old: A. No-choice, B. Choice; 10-d-old: C. No-choice, D. Choice. ↑Treatment stopped.

Table 4. Mean egg production of *A. suspensa* treated as 10-d-old flies by feeding 7 d with sodium tetraborate

Sodium tetraborate concentration (%)	N	Eggs/female/day (Mean ± SD)								
		Treatment week			1st week after treatment			2nd week after treatment		
		Choice	No choice	Ratio	Choice	No choice	Ratio	Choice	No choice	Ratio
0	5	12.1 ± 4.8 a*	12.1 ± 4.8 a*	1.0	19.4 ± 3.4 a*	14.9 ± 2.2 a*	1.0	11.5 ± 2.4 a*	11.5 ± 2.4 a*	1.0
0.1	5	12.8 ± 4.4 a	5.6 ± 2.1 bc	2.3	12.6 ± 3.1 ab	8.7 ± 3.2 b	1.4	8.0 ± 2.2 ab	12.1 ± 2.6 a	0.7
0.2	5	10.1 ± 3.4 ab	2.7 ± 2.1 c	3.7	11.3 ± 7.6 ab	0.9 ± 1.5 c	12	9.2 ± 1.9 ab	**	
0.5	5	2.4 ± 2.0 c	1.2 ± 0.7 c	2.0	1.5 ± 0.9 c	†		**	†	
1.0	5	1.9 ± 1.1 c	0.7 ± 0.9 c	2.7	†	†		†	†	

* Same controls for comparison.

** No eggs were oviposited by survivors.

† All flies died within 7 d after treatment.

Means in each oviposition period followed by the same letter are not significantly different by ANOVA and Tukey's HSD test ($\alpha \leq 0.05$).

ment, egg production was significantly reduced, but not eliminated for 4-h-old and 10-d-old flies, indicating some repellency of 3 and 5% sodium tetraborate in the short term (Table 5). With 10-d-old flies in the no-choice experiment, eggs were oviposited for 24 h with 3% and 5% sodium tetraborate and then egg laying ceased for 19 d. In the choice experiment with 3% and 5% sodium tetraborate egg laying ceased after 3 d. With 1% sodium tetraborate, 24 h no-choice, 10-d-old flies, oviposition ceased after 48 h; a few eggs were laid on days 8 through 15 after treatment. In the choice containers, egg production continued but at 50% or less of controls when flies were treated 24 h regardless of fly age (Table 5).

Egg hatch. For 4-h-old adult flies, egg hatch was reduced when flies were fed 0.1% or higher concentrations of sodium tetraborate for 7 d in the no-choice containers. In the choice containers, egg hatch was reduced by feeding 0.2% or higher concentrations of sodium tetraborate for 7 d (Table 6). The egg hatch of 10-d-old flies in the no-choice containers was not affected by feeding 0.1% sodium tetraborate for 7 d. When the sodium tetraborate concentration was increased to 0.2% or higher, the egg hatch of 10-d-old flies was reduced from about 70 to 35%; higher concentrations caused greater reductions (Table 7). In the choice test, 0.2% sodium tetraborate data were not statistically different from controls for 10-d-old adult flies, but 0.5 and 1% sodium tetraborate significantly reduced egg hatch (Table 7). The choice/no-choice egg hatch ratios for 0.2 and 0.5% sodium tetraborate were about 2 for 7 d and 14 d after treatment, but the ratio for 1% was 4.0 (Table 7). This is intriguing because the egg production ratio for 1% sodium tetraborate was 2.7 (Table 4). We suggest that egg production is more sensitive to sodium tetraborate than is egg hatch.

With 3 and 5% sodium tetraborate and 24 h feeding, the eggs which were laid by surviving females did not hatch in both choice and no-choice experiments. A 10-d-old female contains fully developed eggs (Yang et al. 1999). This suggests to us that one feeding of sodium tetraborate may have interfered with the fertilization process because eggs were laid, but did not hatch.

Based on our data, *A. suspensa* randomly chose between food without sodium tetraborate and food containing up to 5% sodium tetraborate. Mortality, egg production, and egg hatch of *A. suspensa* were correlated to sodium tetraborate concen-

Table 5. Mean egg production of *A. suspensa* over 20 d after treatment with 1, 3 and 5% sodium tetraborate by feeding 24 h

Sodium tetraborate concentration (%)	N	Eggs/female/day (Mean ± SD) 4-h-old flies: Choice	4-h-old flies: No choice	10-d-old flies: Choice	10-d-old flies: No choice
0	5	11.0 ± 3.3 a*	11.0 ± 3.3 a*	17.4 ± 5.4 a*	17.4 ± 5.4 a*
1.0	5	5.6 ± 3.8 b	0	8.9 ± 1.9 b	2.7 ± 6.0 bc
3.0	5	4.5 ± 5.1 b	**	2.9 ± 3.6 c	0.8 ± 1.4 c
5.0	5	3.6 ± 3.4 b	**	1.4 ± 2.6 c	1.0 ± 1.8 c

* Same controls for comparison.
** No eggs were oviposited by survivors.
Means for each fly age followed by the same letter are not significantly different by ANOVA and Tukey's HSD test ($\alpha \leq 0.05$).

Table 6. Mean percent egg hatch of *A. suspensa* treated as 4-h-old flies for 7 d with sodium tetraborate

Sodium tetraborate concentration (%)	N	Egg hatch (%) (Mean ± SD)					
		1st week after treatment*			2nd week after treatment		
		Choice	No choice	Ratio	Choice	No choice	Ratio
0	5	83.9 ± 13.6 a**	83.9 ± 13.6 a**	1.0	78.3 ± 14.5 ab**	78.3 ± 14.5 ab**	1.0
0.1	5	71.1 ± 25.1 a	31.0 ± 21.2 b	2.3	82.2 ± 16.9 a	25.2 ± 23.5 c	2.8
0.2	5	55.8 ± 26.9 b	†		61.4 ± 22.5 b	†	
0.5	5	†	†		†	‡	
1.0	5	†	†		‡	‡	

* Due to immature flies no eggs were laid during the treatment week.
** Same controls for comparison.
† No eggs were oviposited by survivors.
‡ All flies died within 7 d after treatment.
Means for each week followed by the same letter are not significantly different by ANOVA and Tukey's HSD test ($\alpha \leq 0.05$).

Table 7. Mean percent egg hatch of *A. suspensa* treated as 10-d-old flies for 7 d with sodium tetraborate

Sodium tetraborate concentration (%)	N	Egg hatch (%) (Mean ± SD)								
		Day 7-13 after treatment			Day 7-20 after treatment					
		Choice	No choice	Ratio	Choice	No choice	Ratio	Choice	No choice	Ratio
0	5	86.9 ± 10.8 a*	86.9 ± 10.8 a*	1.0	89.2 ± 9.9 a*	89.2 ± 9.9 a*	1.0	82.4 ± 18.1 a*	82.4 ± 18.1 a*	1
0.1	5	80.9 ± 20.3 ab	60.7 ± 29.6 ab	1.3	76.9 ± 16.3 b	40.2 ± 18.2 c	1.9	78.4 ± 10.6 ab	67.6 ± 26.8 b	1.2
0.2	5	64.1 ± 31.0 abc	35.4 ± 32.6 bc	1.8	75.9 ± 13.2 b	**		72.0 ± 19.2 ab	**	
0.5	5	40.7 ± 39.9 c	23.8 ± 11.7 bc	1.7	**	†		**	†	
1.0	5	45.0 ± 29.2 c	11.2 ± 15.9 c	4.0	†	†		†	†	

* Same controls for comparison.
** No eggs were oviposited by survivors.
† All flies died within 7 d after treatment.
Means for each time period followed by the same letter are not significantly different by ANOVA and Tukey's HSD test ($\alpha \le 0.05$).

trations; higher concentrations of sodium tetraborate caused higher mortality, greater reduction in egg production, and greater reduction egg hatch in both choice and no-choice tests. Our data suggest that *A. suspensa* would feed on sodium tetraborate/bait combinations used for fruit fly eradication or suppression programs at up to 5% sodium tetraborate. This discrimination study is, to our knowledge, the first conducted for fruit flies and bait/pesticide combinations. We suggest that pesticide discrimination bioassays be conducted for bait/pesticide combinations before their use in fruit fly suppression or eradication programs.

Acknowledgments

This study was supported in part by a Florida citrus grower box tax for research. Funds for this project were made available from the Citrus Production Research Marketing Order by the Division of Marketing and Development, Florida Department of Agriculture and Consumer Services. Florida Agricultural Experiment Station Journal Series No. R-07518.

References Cited

Bare, O. S. 1945. Boric acid as a stomach poison for the German cockroach. J. Econ. Entomol. 38: 407.

Budia, F. and E. Vinuela 1996. Effect of cyromazine on adult *C. capitata* (Diptera: Tehritidae) on mortality and reproduction. J. Econ. Entomol. 84: 826-831.

Calkins, C. O. 1993. Future directions in control of the Caribbean fruit fly (Diptera: Tephitidae). Florida Entomol. 76: 263-269.

Cochran, D. G. 1995. Toxic effects of boric acid on the German cockroach. Experimentia 51: 561-563.

Grace, J. K. 1991. Response of Eastern and Formosan subterranean termites (Isoptera: Rhinotermitidae) to borate dust and soil treatments. J. Econ. Entomol. 84: 1753-1757.

Hogsette, J. A. and P. G. Koehler. 1992. Toxicity of aqueous solutions of boric acid and polybor 3 to house flies (Diptera: Muscidae). J. Econ. Entomol. 85: 1209-1212.

1994. Repellency of aqueous solutions of boric acid and polybor 3 to house flies (Diptera: Muscidae). J. Econ. Entomol. 87: 1033-1037.

Holler, T. C. and D. L. Harris. 1993. Effect of sterile release of Caribbean fruit flies (Diptera: Trephritidae) against wild population in urban hosts adjacent to commercial citrus. Florida Entomol. 72: 251-257.

Klotz, J. H., K. M. Vail and D. F. Williams. 1997. Toxicity of boric acid-sucrose water bait to *Solenopsis invicta* (Hymenoptera: Formicidae). J. Econ. Entomol. 90: 488-491.

Lang, J. T. and R. E. Treece. 1972. Boric acid effects on face fly fecundity. J. Econ. Entomol. 65: 740-741.

Lloyd, J. D. 1998. Borates and their biological applications. The Int. Rec. Group on Wood Press. 29th Annual Meeting, Maastricht, Netherlands. Doc. No: IRG/WP/10044.

Mullens, B. A. and J. L. Rodriguez. 1992. Effects of disodium octaborate tetrahydrate on survival, behavior and egg viability of adult Muscoid flies (Diptera: Muscidae). J. Econ. Entomol. 85: 137-143.

Nigg, H. N., L. L. Mallory, S. Fraser, S. E. Simpson, J. L. Robertson, J. A. Attaway, S. B. Callahan and R. E. Brown. 1994. Test protocols and toxicity of organophosphate insecticides to Caribbean fruit fly (Diptera: Trephritidae). J. Econ. Entomol. 87: 589-595.

Nigg, H. N., S. E. Simpson, J. A. Attaway, S. Fraser, E. Burns and R. C. Littell. 1995. Age-related response of *Anastrepha suspensa* (Diptera: Trephritidae) to protein hydrolysate and sucrose. J. Econ. Entomol. 88: 669-677.

Nigg, H. N. and S. E. Simpson. 1997. Use of borax toxicants to control Trephritidae fruit flies. U.S. Patent 5,698,208; Dec 16, 1997, 28 panels.

SAS Institute. 1989. SAS/STAT user's guide, version 6, 4th ed. SAS Institute, Cary, NC.

Simpson, S. E. 1993. Caribbean fruit fly-free zone certification protocol in Florida (Diptera: Trephritidae). Florida Entomol. 76: 228-233.

Strong, C. A., P. G. Koehler and R. S. Patterson. 1993. Oral toxicity and repellency of borates to German cockroaches (Dictyoptera: Blattellidae). J. Econ. Entomol. 86: 1458-1463.

Swanson, R. W. and R. M. Baranowski. 1972. Host range and infestation by the Caribbean fruit fly *Anastrepha suspensa* (Diptera: Trephritidae) in south Florida. Proc. Florida State Hort. Soc. 85: 271-274.

Weir Jr., R. J. and R. S. Fisher. 1972. Toxicologic studies on borax and boric acid. Toxicol. Appl. Pharmacol. 23: 351-364.

Yang, L. K., H. N. Nigg, D. S. Achor and S. E. Simpson. 1999. Sodium tetraborate induced ovarian changes in *Anastrepha suspensa* Loew. Proc. Florida State Hort. Soc. 112: 69-72.