Comparative Toxicity of Aqueous Solutions of Boric Acid and Polybor 3 to House Flies (Diptera: Muscidae)

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J. Econ. Entomol. 85(4): 1209–1212 (1992)

ABSTRACT LC_{50}s and LT_{50}s of boric acid and polybor formulated in water and 10% sucrose were determined for 3- to 5-d-old adult house flies, *Musca domestica* (L.), of mixed sex. Differences between boric acid and polybor toxicities were significant in 10% sucrose, but not in water. However, borates formulated in water had significantly lower LC_{50}s than those formulated in 10% sucrose. Rate of kill for formulations in water was fairly uniform over time, whereas mortality from sucrose formulations was not observed until 17 h after treatment. Reasons for differences in the manifestation of mortality and possibilities for practical application are discussed.

KEY WORDS Insecta, *Musca domestica,* boric acid, polybor 3

BORIC ACID WAS the standard chemical used for control of larval muscoid fly populations in manure (Bishopp 1939, Midgley et al. 1943), sewage sludge (Olson & Dahms 1945) and compost (Lal & Srivastava 1950) until DDT and other chlorinated hydrocarbon pesticides became available (McGovran & Piquett 1945). Polybor 3 (Polybor, disodium octaborate tetrahydrate) also provided excellent larval control when added to the diets of laying hens, but it produced adverse side effects in the hens—e.g., decreased egg production and premature molting (Burns et al. 1959, Sherwood 1959, Tower et al. 1960). In contrast, boric acid in a sugar-bait formulation proved relatively ineffective against adult house flies, *Musca domestica* L., compared with organophosphorus compounds (Langford et al. 1954).

On their Material Safety Data Sheets, U.S. Borax (Los Angeles, Calif.) considers boric acid and polybor to be relatively innocuous. Both have acute oral LD_{50}s (rats) $\geq$2g/kg and neither is classified as a carcinogen or skin irritant. Eye irritation, if it should occur with either compound, is slight and reversible. A positive aspect of polybor is that its solubility (9.5%) is twice that of boric acid (4.72%) at 20°C.

The objective of our study was to compare the relative toxicities of liquid formulations of boric acid and polybor against house fly adults. These data will be useful for the formulation of liquid borate pesticides.

Materials and Methods

Boric acid and polybor were obtained from U.S. Borax and Chemical, Los Angeles, Calif. Aqueous solutions of both compounds were formulated in water and 10% sucrose on a wt/vol basis. Final treatment levels for boric acid and polybor in water and 10% sucrose were 0.15, 0.24, 0.325, 0.41, and 0.5%; and 0.5, 0.63, 0.75, 0.88, and 1.0%, respectively. Control treatments of water and 10% sucrose were used during each test. Treatments were administered in scintillation vials (20 ml) fitted with a cotton wick. Care was taken to saturate the wicks completely with solution as they were forced into the vials. Dry food (powdered milk, granulated sugar, powdered egg yolk; 6:6:1) was provided ad libitum in the caps of the scintillation vials.

Disposable test cages were made from 0.5-pint (236.6 ml) paper cans (The Fonda Group, Union, N.J.) by removing the bottoms and replacing them with disks of standard aluminum window screen. Cages were ≈3.4 cm high and 7.6 cm in diameter (inside measurements). After each test, the paper portion of the cages was discarded, but the screens were removed, cleaned, and reused.

Four cages (replications) of flies exposed to each borate treatment level and the appropriate untreated solvent (control) for 24 h constituted a test. Adult 3- to 5-d-old house flies (mixed-sex) from the USDA Gainesville multiresistant colony were used for all tests. Thirty-five flies were placed in each test cage while flies were chilled in a walk-in cooler at ≈1°C. Flies were generally cooled for <10 min and allowed to acclimate in

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0022-0493/92/1209–1212$02.00/0

Table 1. Responses of house flies to boric acid and polybor formulated in water and 10% sucrose (24-h mortality)

Treatment	n	LC_{50} (%)[a]	95% CI	LC_{90}	95% CI	Slope ± SE
Boric acid (H_2O)	431	0.37	0.33–0.42	1.01	0.79–1.51	2.94 ± 0.38
Polybor (H_2O)	425	0.44	0.41–0.50	1.04	0.82–1.54	3.44 ± 0.45
Boric acid (10% sucrose)	193	0.88	0.82–0.95	1.36	1.15–2.25	6.76 ± 1.81
Polybor (10% sucrose)	341	0.74	0.70–0.77	1.13	1.04–1.28	6.90 ± 0.75

[a] Wt/vol.

the treatment room for a minimum of 2 h before starting a test. The treatment room was maintained at 24°C and 65% RH.

About 15 min before treatments were introduced, overhead lights in the treatment room were extinguished and illumination was provided by two 15-W ultraviolet fluorescent tubes on a fly trap. The trap was ≈20 cm in front of a closed-back kneehole desk and oriented so that most of the light was directed into the kneehole. In this near-dark condition (<0.1 ft-c), flies rested on the screened portion of the cages (oriented up), and became still.

A clean paper can lid was used to introduce treatments. One scintillation vial containing a boric acid or polybor formulation was placed horizontially in the lid along with a scintillation vial cap containing dry food. The screened portion of a test cage, with flies, was lifted from its lid and placed on the clean lid containing the treatment vial and food. This technique allowed us to begin the experiment with 100% live flies because any dead or dying flies were left behind on the old lids. Escapees totaled <1%.

After all treatments were in place, overhead lights were illuminated until the end of the test. Mortality in each cage was recorded 4, 17, 21, and 24 h after treatment. The criterion for death was complete cessation of movement. During mortality counts, vials and vial caps were carefully moved with a piece of wire inserted through the screen so that no dead flies would be overlooked. At the end of each test, all flies were killed and total flies per cage was recorded.

Two tests were performed using both borates and both solvents. The pooled data were subjected to probit analysis (SAS Institute 1985) for estimation of LC_{50}, LC_{90}, and LT_{50}s. LC_{50}s and LT_{50}s with overlapping 95% confidence intervals were considered not significantly different. The LC_{50}s and LC_{90}s used for comparison were estimated from 24-h mortality data. We compared LT_{50}s from the highest dose of boric acid and polybor in each solvent.

Results and Discussion

LC_{50}s 24 h after treatment with boric acid and polybor in water (0.37 and 0.44%, respectively) were not significantly different (Table 1). LC_{50}s 24 h after treatment with boric acid and polybor in 10% sucrose (0.88 and 0.74%, respectively) were significantly different, although the slight numerical difference is probably of little practical importance. LC_{50}s of boric acid and polybor in water were significantly lower than LC_{50}s of boric acid and polybor in 10% sucrose. Slopes of probit lines for boric acid and polybor in 10% sucrose were steeper than those of boric acid and polybor in water (Fig. 1). Consequently, LC_{90}s of both compounds in both solvents—i.e., concentrations that may be in the range of practical application—were between 1.01 and 1.36% (Table 1).

LT_{50} estimates for 0.5% boric acid and polybor in water (22.3 and 19.7 h, respectively) were not significantly different (Table 2). LT_{50} estimates for 1.0% boric acid and polybor in 10% sucrose (21.0 and 18.1 h, respectively) were significantly different (Table 2). However, the slight numerical difference is of little practical importance. Slopes of the probit lines for boric acid and polybor in 10% sucrose were steeper than those of boric acid and polybor in water (Table 2).

These results indicate no significant difference between the relative toxicities of boric acid and polybor in water and a significant but probably inconsequential numerical difference between the relative toxicities of boric acid and polybor in 10% sucrose (Table 1). Our data suggested that the difference in mortality was actually related to the solvents and not to the borates. Likewise, differences between slopes of probit lines for boron compounds formulated in water and 10% sucrose did not indicate that flies did not respond heterogeneously, but did suggest a difference in the rate of mortality. These differences in rates of mortality also were reflected by the respective slopes of the lethal time probit regressions for boron compounds formulated in water and 10% sucrose (Table 2).

Carbohydrate solutions—e.g., 10% sucrose—are shunted directly to the crop and released as needed in other muscoid diptera (Venkatesh & Morrison 1980). Dietary carbohydrates were being supplied to our flies in the dry food, and energy utilization was limited by the small size of the test cages. Therefore, flies receiving the sucrose-base boron formulations were forced to consume additional carbohydrates from the only available water source. These carbohydrates

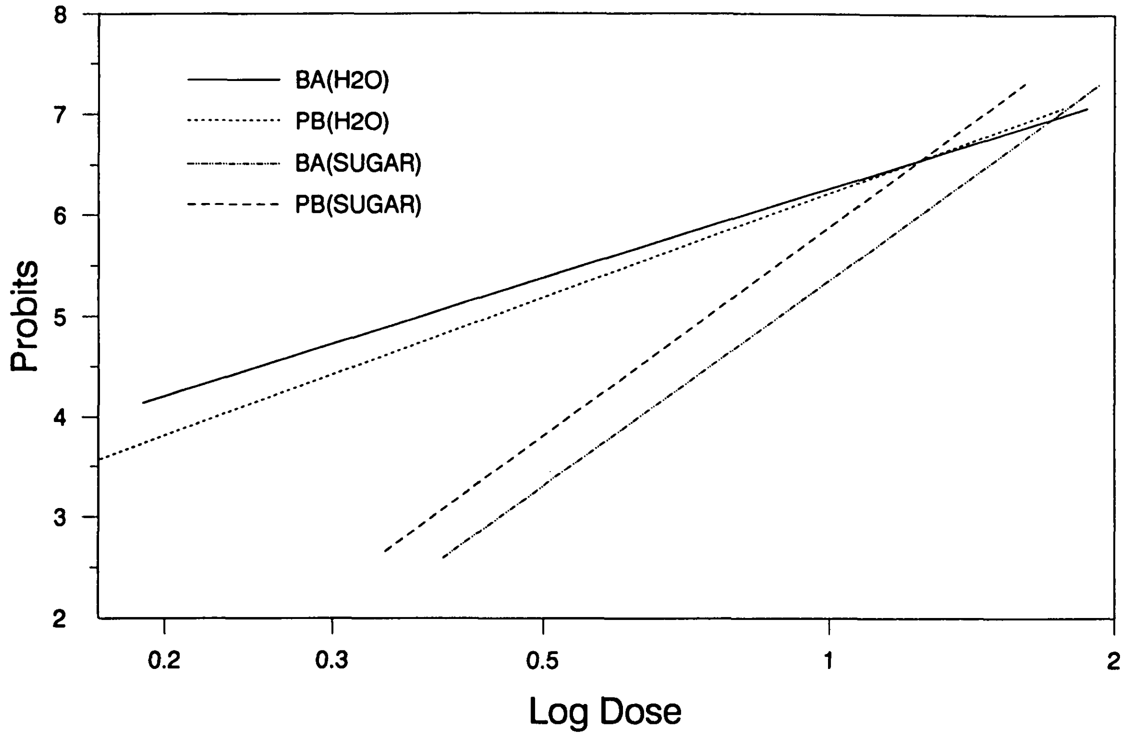

Fig. 1. Probit regressions for boric acid and polybor in water and 10% sucrose, respectively. BA, boric acid, PB, polybor.

were probably being stored in the crop and released in small amounts over time. In contrast, water-base boron formulations were probably being taken directly into the midgut. This would explain why fly mortality from water-based boron formulations was observed throughout the 24-h tests and fly mortality from 10% sucrose-based boron formulations was not observed until 17 h after treatment or later.

Because the relative toxicities of boric acid and polybor were similar numerically in the same solvents, more concentrated solutions of polybor in a sucrose base might prove worthwhile for practical use. In the field, sucrose should enhance the attractiveness of the solution because normal flight activity will require that more carbohydrate be used.

Table 2. Responses of house flies to the most concentrated formulations of boric acid and polybor (in water and 10% sucrose) over time

Formulation[a]	n	LT_{50} (h)	95% CI	Slope ± SE
0.5% Boric acid (H_2O)	328	22.3	19.6–26.3	2.75 ± 0.41
0.5% Polybor (H_2O)	408	19.7	17.7–22.2	2.87 ± 0.36
1.0% Boric acid (10% sucrose)	177	21.0	19.6–22.8	6.56 ± 1.60
1.0% Polybor (10% sucrose)	255	18.1	16.9–19.0	8.68 ± 1.40

[a] Wt/vol.

Acknowledgment

We thank F. Washington and G. Langley (USDA–ARS, Gainesville, Fla.), for their technical assistance in this study. This is Florida Agricultural Experiment Station Journal Series R-01687.

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Received for publication 17 June 1991; accepted 7 February 1992.