

## Toxic effects of boric acid on the German cockroach

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**Abstract.** Boric acid is a slow-acting, inorganic insecticide whose mode of action has not been satisfactorily elucidated. Reported here is evidence which shows that ingested boric acid destroys the cellular lining of the foregut of German cockroaches, *Blattella germanica* (L.). This effect appears to be sufficient to bring about the death of the insects, perhaps ultimately by starvation. This finding is important because resistance to conventional insecticides may re-establish boric acid as a prominent cockroach control chemical.

**Key words.** Boric acid; mode of action; Dictyoptera; Blattellidae; *Blattella germanica* (L.).

Boric acid ( $H_3BO_3$ ) has been used as an insecticide for many years, especially against cockroaches<sup>1</sup>. Recently, its use has been limited because it is a slow-acting poison<sup>2</sup>. Several weeks may be required to produce a significant population reduction in the German cockroach, *Blattella germanica* (L.). In contrast, most of the nerve poisons in current use result in high mortality in 24–48 h<sup>3</sup>. However, a major resistance problem against many of the latter insecticides has developed<sup>4</sup>, thereby greatly diminishing their usefulness. As a result, interest has again centered on lesser-used compounds, including boric acid.

The mode of action of boric acid on insects has not been satisfactorily established. For a time, abrasion of the cuticle followed by slow desiccation was thought to explain its action. It can penetrate the cuticle and enter the body via that route<sup>2,5</sup>. It has also been established that, in preening themselves following exposure to boric acid powder, cockroaches ingest a significant amount of this material<sup>2</sup>. Thus, the gut appears to be a major route of entry of boric acid into the insect's body. While it had an observable effect on the foregut, boric acid was also present in the blood of the American cockroach, *Periplaneta americana* L., 5 min after ingestion<sup>5</sup>. In pursuit of a more definitive explanation, evidence is presented here which shows that boric acid has a major cytological effect on the foregut of the German cockroach.

### Materials and methods

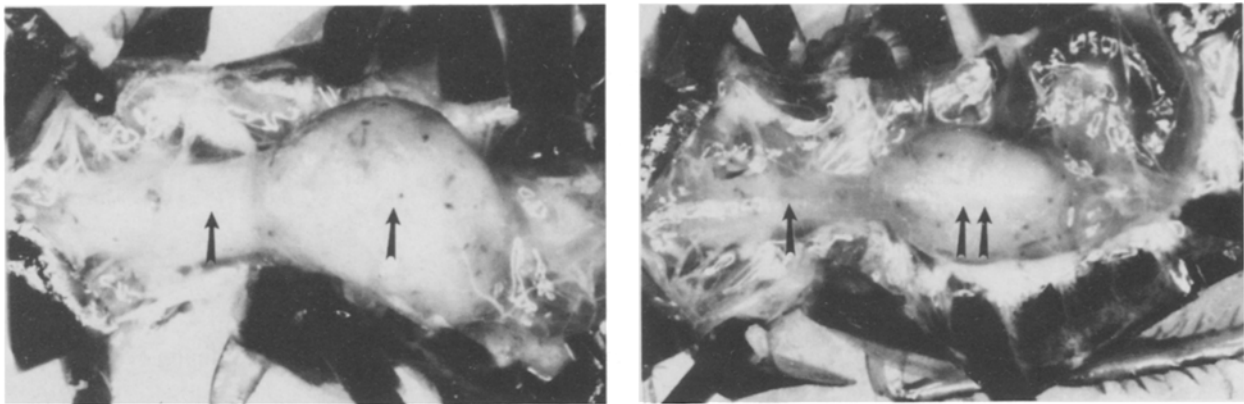
Nymphal German cockroaches (5th–6th instar) from a standard-laboratory colony were used. They were given water containing 2% boric acid plus 2% sucrose (w/v). Food (rat chow) consumption was measured daily. Mortality was assessed by probit analysis<sup>4</sup>. Nymphs were anesthetized with CO<sub>2</sub> and dissected for observation and/or removal of the entire gut on days 1 to 4 after initial exposure to boric acid. The dissected guts

were fixed in 10% formalin for at least 24 h. Following a series of alcohol dehydrations, the tissues were embedded in wax, sectioned, mounted on slides, and stained with hematoxylin-eosin. Cytological observations were made and photographs taken on bright field with a Zeiss Photomicroscope III.

### Results and discussion

Gross examination of the guts of treated insects on days 1 and 2 after treatment revealed that the foreguts were empty and slightly enlarged. By days 3 and 4, the foreguts of all treated insects examined contained no food, but were greatly enlarged and filled with gas bubbles (fig. 1A). Average food consumption during this period was less than 1 mg/insect. In comparable tests, 50% mortality was achieved in 3.8 days.

Figure 1B shows the foregut of an untreated cockroach in which the anterior part is empty, while a food bolus is present just anterior of the proventriculus. When present, the food bolus was obvious and no gas bubbles were observed in untreated cockroach foreguts. Comparable average food consumption here was 10 mg/insect. Histological examination of the foreguts of treated and untreated cockroaches revealed major differences. By day 3, the foregut cells of treated insects were completely destroyed (fig. 2A). In many cases, by day 4 after treatment about all that remained of cell structure was the basement membrane (fig. 2B). In spite of the damage, the gross enlargement of the foregut was evident as shown in figure 2C. By comparison, the foregut of untreated insects was intact and it was possible to identify each major component of this tissue (fig. 2D). In parallel experiments (not shown) boric acid administered as a 20% diet preparation (w/w) produced results essentially identical to those shown in figures 1 and 2, but it took 7.2 days to reach 50% mortality. These insects each consumed approximately 1.3 mg of diet which contained 0.25 mg of boric acid.



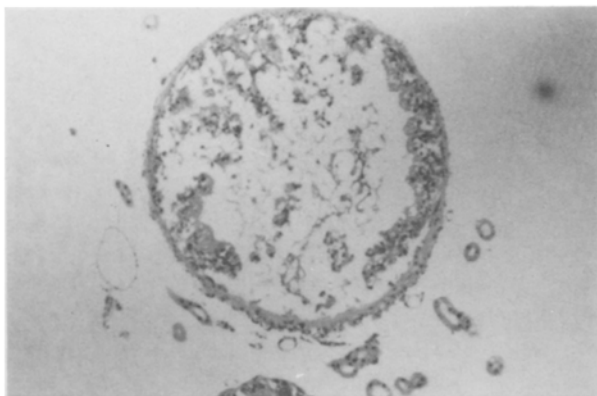
A

B

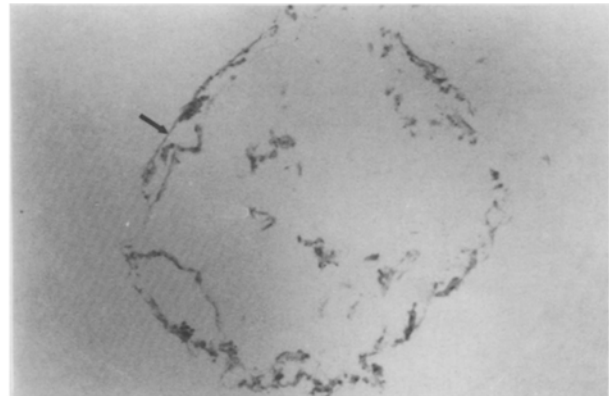
Figure 1. German cockroaches with a dorsal incision to expose the gut.

A Foregut of a nymph 4 days after exposure to boric acid in water. The foregut (arrows) is empty of food, but is greatly distended with fluid and gas.

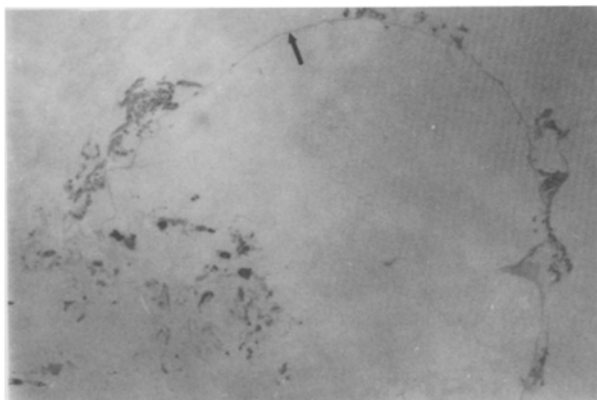
B Untreated nymph with an empty anterior foregut (single arrow), but with a food mass (double arrow) immediately anterior of the proventriculus.  $5.8 \times$ .



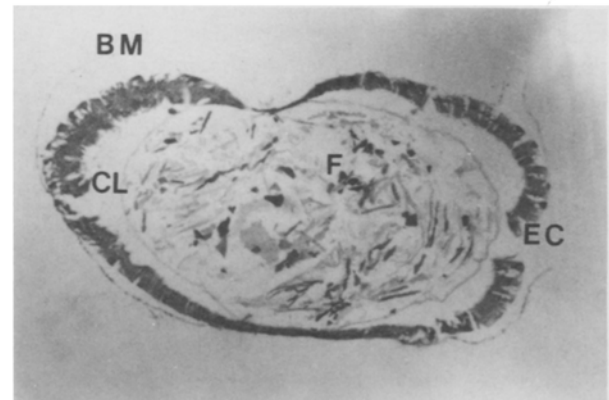
A



B



C



D

Figure 2. German cockroach foregut cross sections.

A From a nymph 3 days after exposure to boric acid in water. Note cellular debris in the lumen and the absence of intact cells.

B and C Same from nymphs 4 days after exposure with C showing gross enlargement of the foregut. The basement membrane (arrows) is all that remains intact.

D From an untreated nymph showing BM, basement membrane; EC, intact epithelial cells; CL, cuticular lining of the foregut; F, food bolus.  $235 \times$ .

Sections of proventriculus, midgut, and rectum from treated and untreated cockroaches were identical under light microscopy, indicating little or no damage to these tissues. Ebling et al.<sup>5</sup> also found no evidence for damage to the gut posterior of the foregut by gross examination. They attributed this finding to the tightness of control of materials passing through the proventriculus, but speculated that some dissolved boric acid might pass rearward.

The results presented here demonstrate clearly that German cockroach foregut cells are completely destroyed by the action of ingested boric acid. It was shown that cockroaches in that condition did not feed normally. While this finding does not exclude other possible actions of boric acid upon or within the insect's body<sup>5</sup>, it seems reasonable to conclude that the most probable

cause of death from ingested boric acid is starvation brought about by destruction of the foregut. This scenario is in agreement with the widely noted slowness of action of this compound<sup>2</sup>, especially when administered as a dietary component.

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