Biological control of brownbanded cockroaches

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Cockroaches, described in a 1976 National Pest Control Association report as second only to termites in economic importance, have been the object of major control efforts by the pest control industry. Little consideration, however, has been given to natural enemies for cockroach control.

In 1948 it was reported that a parasitic wasp, *Comperia merceti* (Compere), "had practically wiped out" brownbanded cockroaches, *Supella longipalpa* from some places in Honolulu, and releases of the parasite were made. The wasp lays its eggs only in brownbanded cockroach egg cases, and the developing wasp larvae feed on the contents. In about 30 to 60 days, 3 to 24 adult parasites emerge from each egg case.

In recent years some research efforts have been directed at predominantly outdoor cockroach (*Periplaneta*) populations. Other wasp species released in Texas experiments reported in 1978 effectively suppressed *Periplaneta*. However, the question of how practical the use of natural enemies would be for controlling cockroaches in an operational structural pest management program remained unanswered.

In 1977 we had an opportunity to demonstrate the feasibility of egg-parasite releases for the suppression of *S. longipalpa* at the University of California, Berkeley. The brownbanded cockroach was probably first introduced on the campus about 13 years ago. Between 1967 and 1975 it had infested six large buildings containing more than 2,000 rooms. In these facilities brownbanded cockroaches largely replaced the German cockroach, *Blattella germanica*, which had previously been the major domiciliary pest. When the parasite *C. merceti* was first discovered in a small insectary room in 1973, little consideration was given to it except to note that both the parasite and the cockroach were abundant.

By 1975, however, without application of additional control measures, the host cockroach was difficult to find anywhere in the insectary or the rest of the entire 240-room building. On discovery of this initial success, we decided to compare potential control techniques—spray applications, baiting, trapping, and parasite rearing and releases. The results indicated that *C. merceti* had the greatest potential for use in almost all of the University research facilities harboring this cockroach. Major factors considered in the analysis were:

- Use of materials and techniques that would not affect the results of research being performed in treated or nearby facilities.
- Practicality within limitations of available staffing and materials.
- Requirements of the U.S. Food and Drug Administration, U.S. Department of Agriculture. U. S. Environmental Protection Agency, National Institutes of Health, and California Department of Industrial Relations governing pest control in the work place, animal care and research facil-

Vetch continued

planted 8 days before drainage was poor, and in experiment C, it was also poor from seed planted 4 days before drainage.

Counts made in November and February showed that most seedlings from seeds planted 4 to 32 days after drainage did not become established until the post-November rainy season. These late seedlings made good progress in 1959 but not in 1960, reflecting the benefit of early establishment.

Considering both experiments, planting from 2 days before to 2 days after drainage produced the best results with both species. In experiment B, Lana vetch produced over twice the number of plants and dry weight as purple vetch, but in experiment C, purple vetch was somewhat more successful than Lana vetch from plantings made 2 days before to 2 days after drainage.

These experiments support the following conclusions on planting vetch as a green manure in a maturing rice crop:

- The best time to broadcast the vetch seed by air is from 2 days before to 2 days after water leaves the field.
- Purple vetch and Lana vetch are the preferred species.

Amount of N fixed

Vetch green manure can be an economical source of nitrogen, fixing over 100 pounds of atmospheric nitrogen per acre under favorable conditions. The typical nitrogen-fixing potential on rice stubble is between 30 and 60 pounds per acre, a worthwhile contribution toward the nitrogen requirement of rice.

An estimate of the amount of nitrogen fixed by vetch can be obtained by cutting and obtaining the fresh weight of vetch from 16 square feet (for example, plants within a square made of four 4-foot laths) and multiplying by 20 to get pounds of nitrogen per acre.

Example: If from 16 square feet you cut 3 pounds of green vetch, $3 \times 20 = 60$ pounds of nitrogen per acre.

Samples should be taken from about 10 random locations in the field and averaged. The average value may then be used in considering the need for additional nitrogen from fertilizer for the next crop.

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ities, and use of materials within legal restrictions.

Of special concern were how faculty, staff, and students would react to the deliberate release of wasps into their facilities, and whether a parasite could be consistently effective under the varied conditions presented by a mixture of laboratories, animal rooms, offices, and classrooms.

Rearing and release

Releases of *C. merceti* have become the principal means of suppressing *S. longipalpa* on the Berkeley campus. Cockroaches were reared in an insectary in an infested building. Colonies were maintained in eight to ten 1-gallon glass jars. The parasites were reared in another building under ambient conditions (thermostat set at 68° F and variable humidity).

Cockroach egg cases (oothecae) harvested at two-week intervals were exposed to parasites in a sleeve cage for two weeks and then placed in shell vials (95 mm long by 23 mm diameter) and held at least three months for emergence. The number of egg cases per vial was limited (25 to 30), because overcrowding caused excessive parasite mortality. Sometimes egg cases were not parasitized; if cockroaches emerged, they were added to the cockroach colonies or destroyed.

As parasites emerged, they were placed in a sleeve cage and fed honey to increase their longevity. Older parasites were removed for release before newly emerged adults were introduced. Release sites were selected on the basis of cockroach reports from employees and surveys performed at night by the pest management staff.

Before parasites were released, employees were advised to keep windows closed. We also explained that the parasites do not sting people and that there were no effective alternative control measures that would not affect research results.

To accelerate the impact of parasitism on the cockroach populations, nonparasitized stages (nymphs and adults) were sometimes suppressed with traps.

Over 20,000 parasites were released between January 1978 and December 1979. Establishment of parasite populations was

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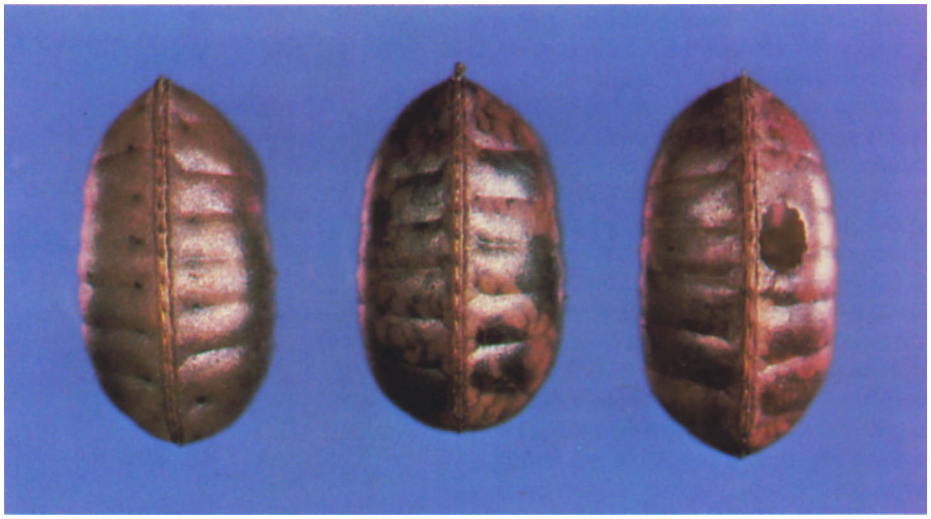

Brownbanded cockroach egg case on left, viewed from above, is normal. Center, blotchy-appearing case contains parasites. Wasps have emerged through hole in case on right.

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Parasitic wasp, *Comperia merceti*, lays eggs in egg case of cockroach.

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Brownbanded cockroach, *Supella longipalpa*, life stages. Shown clockwise from lower right: egg case, female, male, and nymph.

Establishment of Parasite Populations*

Floor	Number of egg cases placed	Number of egg cases hatching parasites	Egg cases hatching parasites	Number of egg cases hatching cockroaches	Egg cases hatching cockroaches
			%		%
1 (8 rooms)	112	20	16	43	36
2 (12 rooms)	174	6	3	77	44
3 (9 rooms)	116	12	10	47	41
4 (5 rooms)	59	5	8	24	42
5 (12 rooms)	148	28	19	57	39
TOTAL (46 rooms)	609	71	12	248	40

*Impact of *Comperia merceti* on egg cases placed in rooms where the parasites had been released at least 3 weeks previously. Other mortality factors not identified.

assessed by placing open petri dishes containing cockroach egg cases in cupboards and other out-of-the-way locations. After two weeks' exposure, the egg cases were placed in shell vials for emergence. Parasite emergence and reports of parasites from locations in addition to those where releases had been made indicated that the wasps had become established.

Parasite populations have not resulted in a contaminant problem in research laboratories, and many employees responded positively to the use of "good bugs" versus "bad bugs." In general, employees also seemed to be less offended by cockroaches after the parasites were introduced. However, resources were not available to assess psychological attitudes adequately.

Preliminary indications from nocturnal flashlight surveys for brownbanded cockroaches and a decrease in cockroach reports have indicated the potential effectiveness of *C. merceti* releases for controlling *S. longipalpa* in large buildings. Although others have reported that the parasite was not effective, because they found "flourishing" populations of the natural enemy and host together, we have found the host abundance has almost always been temporary. As is the case in other parasite-host interactions, however, additional parasite releases over a number of months may be required to effectively suppress cockroaches. A critical difference between our program and the observations of others has been the use of augmentative parasite releases.

Summary

In spite of the economic impact of cockroach populations, virtually no serious consideration had been given to the use of natural enemies to control them in an operational structural pest management program.

Since January 1978, *Comperia merceti*, an encyrtid parasite of cockroach eggs, has been reared and released as the principal measure employed for suppressing brownbanded cockroaches, *Supella longipalpa*, in research facilities at the University of California, Berkeley. This natural enemy of brownbanded cockroaches shows promise as the most effective and efficient approach for controlling this pest in large buildings.

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Short-rotation eucalyptus as a biomass fuel

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Eucalyptus species are prime candidates for woody biomass plantations, because they grow rapidly, reputedly accumulating as much as 40 metric tons dry matter per hectare per year on a wide range of sites in tropical locations. Planted at 17,790 trees per hectare in southern California and harvested twice annually at 3- to 4-month and 8- to 9-month intervals, *Eucalyptus grandis* yielded 22 oven-dried metric tons per hectare per year (10 tons per acre per year). The material harvested is largely herbaceous with only 24 to 33 percent dry weight. Indications are that the trees are relatively deeply rooted and mine water and nutrients below depths reached by most herbaceous perennial crops.

Evergreen, coppicing (resprouting) eucalyptus species are particularly well suited to a forage crop type of management, because they may be harvested frequently with sufficient foliage left to support rapid regrowth of axillary buds. These characteristics provide for maximum annual solar energy interception, reduce the need to replant after harvest, and, owing to the continuous high foliar density, decrease weed competition. The small plot designs used do not completely eliminate border effects but they do permit comparative studies of dry matter accumulations among species grown in similar conditions.

Like many forage crops, some eucalyptus species have nonresting naked buds, which develop rapidly to form a complete leaf canopy. Rapid leaf canopy development and proliferation of small-diameter shoots permit harvesting with hay cutters (essentially a mowing operation). This management system may also maximize energy content of the harvested biomass, because the highest concentrations of oils and protein occur in small shoots and leaves.

Disease and insect problems have not been of paramount importance in eucalyptus species grown outside their native environments. For this reason, their yields may exceed those recorded in their natural habitats. As a result, large-scale plantings of eucalyptus have been introduced into suitable areas of Africa, North and South America, and India.

The purpose of this study was, first, to determine the maximum dry matter of *Eucalyptus grandis* grown in small plots on very close spacing and harvested twice a year. We eliminated, as far as possible, external plant stresses, such as drought, nutrient deficiency, disease, and insect problems. In the next phase of the program, yield of a few species will be evaluated under dryland and low fertility conditions. A second goal, to measure the total energy content of the vegetative tissue and evaluate its suitability for gasification, awaits further study using a downdraft gasifier at the University of California, Davis (see *California Agriculture,* May 1980).

Plant materials and culture

Eucalyptus grandis was selected for the studies at Santa Ana, because it was the fastest growing of more than 20 species evaluated in an earlier study. It is also rated worldwide as one of the fastest growing species in warmer, frost-free regions.

In May 1977, uniform plants grown from seed were transplanted into four experimental field plots oriented north-south, each 300 square feet (28 square meters). Plants were spaced on 75-centimeter (cm) centers in four rows, each 75 cm apart. Each plot had 48 plants, 28 plants comprising the border; yield data were computed only for the 20 interior plants. The plants were large enough to cover the plot; light interception was greater than 50 percent.

Plots received regular irrigations and were fertilized with nitrogen and phosphorus. A preemergence herbicide was applied at planting time but may have been unnecessary because of the high planting density and foliar cover. In the two years since planting we have followed no general weed control practices, but the interior yield areas have remained essentially weed-free.

Individual plants were hand-harvested and fresh-weighed in the field. Several