Integrated pest management in highway landscapes

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The State highways of California constitute an extensive and complex system which includes a wide variety of landscape types lining its 47,104 lane miles. Urban highway landscapes often consist of many exotic plant species selected for their tolerance of highway landscape conditions and for their aesthetic appeal. Highways in less populated areas frequently were landscaped by preserving much of the existing flora. These more "natural" landscapes, which range from low desert to alpine forest, generally require less pest management than areas landscaped with exotic ornamentals. Total highway landscape maintenance costs in California were nearly $24 million in 1976-77. The linear form of highway landscapes, their diversity of plant species, and high level of public contact are in marked contrast to the isolated, broadacre monoculture of some agricultural crops. Compared with agricultural crops, many highway landscapes can sustain higher levels of damage by phytophagous insects before an economic threshold is exceeded, a characteristic which greatly facilitates the development of successful pest management programs.

The pest management program described here was initiated in 1970, when Mr. D. V. Cassidy of the California Division of Highways approached the Insect Pathology Laboratory at the University of California at Berkeley for assistance with the control of the red-humped caterpillar, *Schizura concinna*, a devastating defoliator of highway landscapes. This initiative followed the successful control on highway landscapes of the California oakworm, *Phryganidia californica*, by the bacterium, *Bacillus thuringiensis*, a result of an informal cooperative research project of U.C. Berkeley and the California Division of Highways. From these beginnings, a program was established which has resulted in the successful management of the major insect pests of highway landscapes.

The major pests comprise five species of Lepidoptera, two species of aphids and an introduced psyllid. For all of these pests, the management program relies heavily on the maintenance of parasites and predators. Thus, when the results of continual monitoring indicated that the predetermined threshold number of a pest would be exceeded, intervention to suppress the pest population was made with effort taken to minimize the direct disruption of the parasites and predators.

Bacteria

For the lepidopterous larvae, the form of intervention used was the application of the bacterium *B. thuringiensis* instead of the non-selective insecticides used previously. The different lepidopterous pests, all of which defoliate broad-leaved trees, were the red-humped caterpillar, *S. concinna*, the California oakworm, *P. californica*, the fruit tree leafroller, *Archips argyrospila*, and the tent caterpillars, *Malacosoma californicum* and *M. constrictum*. These insects have different susceptibilities to *B. thuringiensis* and different doses are therefore required to effect control. These doses were determined by laboratory bioassay and subsequent proving trials under highway landscape conditions.

Simultaneously, techniques were developed for the measurement and modeling of the different rates and patterns of survival or field persistance of the *B. thuringiensis* on a range of highway host plants. The feeding rate of the larvae was measured by computer analysis of time-lapse photographs of leaves on which broods of larvae were feeding. By 1972, sufficient data on all of these, and on the coverage characteristics of the spraying equipment, had been obtained to permit field trials delivering a range of predetermined, effective doses of *B. thuringiensis* to *S. concinna* larvae infesting *Cercis occidentalis* trees.

These trials confirmed in practice the theory that when sufficient information is available, it is possible to accurately compensate for the fact that the target larvae consume a declining dose which is simultaneously changing in quality. It was thus possible to effect a preselected rate of mortality (and therefore of survivorship) in the pest population by adjustment of the effective delivered dose of *B. thuringiensis*. The ability to use the bacterium as a modulator of the pest population increases its value as a pest management tool, since the capability to leave some predictable proportion of the pest population as survivors facilitates the integration of parasites and predators into the general pest management program.

Parasites

In the case of *S. concinna*, the most important natural enemies were found to be two hymenopterous parasites, the ichneumonid *Hyposoter fugitivus* and the braconid *Apanteles schizurae*. Both of these parasites lay their eggs in second instar larvae of *S. concinna*. Laboratory experiments with *H. fugitivus* showed that the females can lay as many as 200 eggs. However, these experiments also showed that the longevity of the female parasites was very short, less than 48 hours, so that unless large numbers of suitable second instar *S. concinna* larvae were available when the parasites emerged, a relatively large proportion would not find suitable hosts in which to reproduce.

Although the dependence of the parasites on second instar *S. concinna* larvae cannot be altered, the probability that the parasites would find suitable hosts may be increased by increasing their longevity. Further laboratory experiments with a nectar source instead of water produced a dramatic increase in the longevity of the parasites, up to four weeks in exceptional cases. These experiments, with field observations on the changes in rate of parasitization of *S. concinna* larvae by *H. fugitivus*, suggested that the availability of a nectar source may be a factor limiting the parasite populations in the highway landscape. Attention was therefore shifted from the trees, which were hosts to the lepidopterous larvae, to the various species of ornamental flowering shrubs in the highway landscape which may serve as nectar sources for the hymenopterous parasites.

The shrubs, in massed plantings lining the highway pavement, were themselves subject to attack by insect pests, notably the aphids *Aphis gossypii* and *A. spiraecola*. To control these aphids, applications of organophosphate insecticides had been used, clearly a practice not likely to improve the probability of reproduction of any hymenopterous parasites or indeed any other beneficial insects visiting these shrubs. Typically, the aphid populations increased rapidly in the early months of the year, before their parasites and predators became active, so that some control was necessary.

To effectively suppress the early aphid populations with a higher degree of selectivity, a specially formulated coconut-oil soap spray was developed. This was applied at very high dilution by an orchard gun, the spray-rig moving at 4 mph along the highway. The soap spray reduced the aphid populations by about 75 percent leaving sufficient survivors to enable their parasites and predators to become established. As a further refinement, careful adjustment of the pressure of the soap spray allowed removal of only healthy aphids, leaving parasitized "mummies" adhering to the stems, thus assisting in the earlier establishment of biological control.

The albizzia psyllid, *Psylla uncatoides*, was first found in California in 1955 and became extremely abundant on acacias lining many of our California freeways. In 1971, the California Department of Transportation asked the Division of Biological Control at Berkeley to explore for natural enemies of the psyllid. The state of Victoria Australia, the native home of many of our acacias and evidently also the origin of the albizzia psyllid, was explored for parasites and predators. Four lady beetle species, one green lacewing species, and two parasite species, were found associated with the psyllid in Australia and were sent to California. Thousands of individuals of the predaceous species were reared in the laboratory and released up to 1974 at selected sites from the Bay Area to San Diego.

In the spring of 1977 one of the predators, a tiny, black lady beetle, *Diomus pumilio*, was found to be established in the Bay Area and San Luis Obispo. This psyllid egg predator became so abundant in some acacia plantings that the albizzia psyllids were relatively rare throughout the summer and fall of 1977. Another of the imported lady beetle species, *Harmonia conformis*, which did not become established in California, was introduced in Hawaii where it has brought the albizzia psyllid under control in the koa tree forests.

The management program for the eight pests just described has resulted in savings to the California Department of Transportation of thousands of dollars because chemical insecticides are no longer required. Also, risk of exposure of highway maintenance personnel and the traveling public to insecticides is reduced, as is chemical contamination of our environment.

Ongoing research

IPM research now in progress includes a project at U.C. Riverside on the biological control of the European Brown Snail *Helix aspersa* by means of the predatory snail *Rumina decollata* and a predatory staphylinid beetle *Ocypus olens*; a cooperative project with U.C. Berkeley Division of Biological Control and USDA on the biological control of the weeds yellow star thistle *Centaurea solstitialis* and morning glory *Convolvulus arvensis*, and a project on the biological control of Russian thistle *Salsoli kali* by means of two species of coleophorid moths.

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INTEGRATED FLY CONTROL

An integrated fly control program that reduced flies by 62 percent while eliminating the heavy use of chemical insecticides was put into effect by University of California Cooperative Extension.

Poultry farm advisors William D. McKeen and William F. Rooney, working out of the second largest egg producing county in the United States—San Bernardino—began seeking integrated management of the fly problem in 1970, responding to widespread complaints from home dwellers living near egg ranches. Direction and assistance were provided by W.R. Bowen, Extension entomologist, and other scientists at U.C. Riverside.

The investigative team worked out an effective, ecologically sound, and inexpensive method of fly control that relied heavily on encouragement of the fly's natural enemies. After partial cleanout, for example, poultry manure was left 8 to 12 inches deep to provide a substrate in which naturally-occurring predators and introduced parasitic wasps could thrive and to serve as a blotter to reduce moisture in fresh manure. Spraying insecticides on manure was discouraged to protect the beneficial insects.

—R. Boardman

An important feature of the Cooperative Extension fly control program in San Bernardino county, California, is this fly bait station. Farm Advisors William D. McKeen (left) and William F. Rooney show how the plastic screen holding poison is slipped over a plastic jug containing fly attractant. Bait stations are highly effective in killing adult flies.