nonchemical means of pest management in the highway landscape

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The highway landscape system in California, one of the most extensive in the world, covers many thousands of acres. Much of this landscape consists of plant communities bordering and dividing highways in urban areas, where the natural flora of the region is generally absent and where alterations in topography during construction of the highway have caused impoverished soils. As a result, the landscape may consist largely of a man-made community of introduced ornamental plants, growing under the conditions of stress induced by deficient soils, pollutants, and poor drainage. In such situations, attack by insect pests is often more severe than in landscapes where the natural flora has been retained relatively undisturbed; yet, it is generally in the urban areas where aesthetic standards are expected to be highest, and the corresponding tolerable injury levels the lowest.

In California, most pest outbreaks in the highway landscapes can be controlled by chemical insecticides, but there is a tendency to diminishing periods of control following application. That appears to be due to the lack of specificity of the chemicals used in that the insecticide treatment also eliminates beneficial species of insects. It is believed that many species of pest insects are able to migrate faster than their natural enemies and can re-infest an area previously treated and so multiply unchecked. Also, the predilection of urban gardeners for introduced ornamental plants provides breeding sites for some pests over large areas surrounding the highway. Unfortunately, most gardeners know little of biological control and do not manage their gardens to favor beneficial insects. Thus, one possible result of a chemical treatment is that control is provided for a time, then the pest reappears, now in the absence of natural enemies, and so the outbreak is often more severe than before. That phenomenon has been called pest resurgence. Further treatments are required to control the resurgence, and pest control costs increase as does the exposure of the landscape maintenance personnel and the public to potentially hazardous materials.

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A further complication is that the pest may develop resistance to the insecticide being used for control. That has happened many times in the control of pests of agriculture and public health but does not appear to have occurred to any extent with landscape pests in California. With or without resistance, the net result of this system is a tendency to more frequent treatments and to higher pest control costs.

A large proportion of the most damaging landscape pests in California are the caterpillars of various moths. For those, our efforts have been to devise programs with nonchemical means of control. We have substituted a bacterium, Bacillus thuringiensis, as a first phase replacement for the chemicals previously used. When applied, B. thuringiensis is lethal only to caterpillars and does not harm beneficial insects, fishes, birds, animals, or man. Because the beneficial insects are left unharmed, the probability of pest resurgence is greatly reduced and will be reduced further if beneficial insects can be managed to keep the pests in check. That is the objective of the second phase of the program development and should result in reduced pest control costs because of the reduction in number of control operations necessary per season. In California, several highway landscape pests are under investigation for nonchemical or biological control. One of those projects is described here.

In 1969, the California Division of Highways cooperated with the Insect Pathology Laboratory of the University of California, Berkeley, in a series of field trials for the biological control of the California oakworm, Phryganidia californica with B. thuringiensis. The results were so successful that the following year the division sponsored a new research project to develop and test nonchemical control methods for a variety of caterpillars causing damage to the highway landscape. The prime candidate for control was the red-humped caterpillar, Schizura concinna, a voracious defoliator of a wide variety of orchard and ornamental trees.

During the initial phases of the project, red-humped caterpillars were bioassayed against various commercial formulations of B. thuringiensis to obtain dose-response data necessary to evaluate the control potential of those formulations and to provide guidelines for application rates in the field. The results indicated that the red-humped caterpillar could be readily controlled by appropriate rates of B. thuringiensis, and extensive field trials in several areas of California proved that to be the case. To date, 25 intensive field trials, in which knapsack equipment was used for spot applications and large hydraulic spray rigs were used for extensive applications, have all given highly successful control and yielded valuable data whereby the application rates and selection of formulations have been further refined. These data are given in California Highway Research Report RN 71-8.

The first result of this project was that during 1970 and 1971 chemical insecticides formerly used were replaced with B. thuringiensis formulations for control of the red-humped caterpillar throughout California. Because B. thuringiensis, at the rates of application used, is specific for caterpillars and harmless to other forms of life, there was an immediate reduction in the possible exposure to hazardous materials of landscape maintenance personnel and those traveling on or residing close to highways where control of red-humped caterpillars was in progress.

A further benefit is that the natural enemies of the red-humped caterpillar are not harmed by B. thuringiensis and can begin to exert some degree of biological control. From the beginning, the project had included a study of the indigenous natural enemies of the red-humped caterpillar so that their potential for eventual control could be determined. It was found that 2 small parasitic wasps or parasitoids, Hyposoter fugitivus and Apanteles schizurae, could parasitize and kill red-humped caterpillars under highway landscape conditions. The elimination of the broad-spectrum chemicals permitted populations of the parasitoids to increase and persist in the highway landscape, but the incidence of parasitised red-humped caterpillars, although high during spring and early summer, declined rapidly during June. That decline in the parasitoid population occurred about the time that most shrubs ceased flowering and began to set fruit. The presence of flowers was believed to have been an important factor affecting the reproduction or longevity or both of the parasitoids.

A series of laboratory experiments was designed to ascertain the importance of flowers to the reproductive economy of H. fugitivus, the most effective parasitoid.

Successful breeding of H. fugitivus in the laboratory was accomplished in 1971, and it was quickly established that the parasitoid is indeed highly dependent on a nectar source for survival. Work is now in progress to select perennial shrubs that produce flowers acceptable as a nectar source to H. fugitivus and that have a long flowering period commencing at the end of June. The selected shrubs must also possess the characteristics necessary for survival when interplanted in the highway landscape and must not be so susceptible to any insect species occurring in the landscape that those insects become pests on the introduced shrubs.

Three of many species of shrubs tested have proved to be acceptable as nectar sources to H. fugitivus: jasmine, Trachelospermum jasminoides; myrtle, Myrtus communis varieties; and abelia, Abelia grandiflora. Under screen-cage conditions H. fugitivus adults survive 4 days in the absence of a nectar source and 14 days when flowers of T. jasminoides, M. communis, or A. grandiflora are present. Those species all have long flowering periods that occur at about the required time during the summer.

M. communis is the only species yet proved to be fully compatible with highway landscape conditions, but unfortunately that shrub yields few flowers. T. jasminoides and A. grandiflora produce flowers in profusion, but their compatibility with highway landscape conditions is yet to be determined.

Because the red-humped caterpillar has 5 or 6 generations per season, it is particularly likely to develop resurgences in landscape situations. When chemicals were the only means of control, several applications were required each season. Some areas of California reported 6 treatments of insecticide for the control of that insect during a single summer. In many areas, with the program described above, only a single application of B. thuringiensis, or none at all, has been required for control. The ultimate aim, of course, is for effective control to be maintained by the parasitoids so that no applications are needed. For that, the artificial nature of the landscape must be modified to provide the appropriate parasitoid-pest ratio, and that may not be possible in some areas even with the introduction of appropriate nectar sources. In those areas, the balance will be restored by a single B. thuringiensis application.

A further consideration is that a single pest should not be considered in isolation but should be included in the overall strategy for pest control in a given landscape area. The introduction of biological control for the red-humped caterpillar would be futile if broad-spectrum chemicals were still used for other pests in the same locality. In the Sacramento Valley of California, an example of that problem arises with the control of aphids on Pyracantha in the same areas where the red-humped caterpillar is a prime pest. The aphids may be readily controlled by various organo-phosphate insecticides, but that treatment would kill not only the parasitoids controlling the red-humped caterpillar, triggering a resurgence of that pest, but also the predators of the aphids that would otherwise produce adequate control later in the year. Where that problem has arisen, we have found that a spray of medicinal soft soap solution will physically remove approximately 70 to 75 percent of the aphids on Pyracantha and cause minimal harm to the parasitoids and predators. That treatment prevents the aphid populations from increasing too rapidly early in the year, and allows the aphid predators to catch up and exert satisfactory biological control. Thus, the control of the aphids on Pyracantha has been integrated with that of the red-humped caterpillars on the ornamental trees in the same landscapes and has, incidentally, further reduced the use of chemical pesticides.

The project described above is just one of several nonchemical pest management research programs sponsored by the California Division of Highways. Another example is the importation by the division, in cooperation with the University of California at Berkeley, of Australian insect predators for suppression of Albizzia psyllid, an insect that was accidentally introduced from Australia years ago and is now a pest in highway landscapes. The projects all form part of a long-established objective of the division to maintain its landscapes as economically as possible and with minimal use of chemical pesticides. As new developments occur, they must be fully implemented into the statewide pest control program before the benefits of the research are fully realized. The training of the landscape maintenance personnel in the new techniques

Table 1. Pesticide purchases.

Pesticide	1969	1971	Percentage Change
Carbaryl, Sevin, gal	620	25	-96
Diazinon			
Gal	1,619	390	-66
Lb		150	
Malathion, gal	675	0	-100
Methoxychlor, lb	413	0	-100
Bacillus thuringiensis			
Gal	110	313	+470
Lb		314	

of biological integrated control is accomplished by a series of illustrated lectures and demonstrations by University of California faculty, U.S. Department of Agriculture scientists, and other experts at the Highway Landscape Academy. Those lectures provide the essential contact the maintenance personnel need to fully understand the principles involved and to relate them to their own districts.

An indication of the progress made to reduce pesticide level is shown by data given in Table 1. A comparison of the relative costs of materials purchased in 1971 compared with those purchased in 1969 shows an estimated saving of 58 percent. Overall pest control savings, because they are more sensitive to labor costs than to those of materials, may be much greater as a result of fewer pest control operations.

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