Biological Control of Principal Alfalfa Pests in California

by Daniel Gonzalez and Robert van den Bosch

Effective biological control of potential alfalfa hay pests was generally accepted until the Egyptian alfalfa weevil, Hypera brunneipennis (hereafter referred to as the EAW) became widespread in California's alfalfa fields. The current continuing spread of this pest presents an increasingly ominous threat not only to most of the state's 1,140,000 acres of alfalfa, but also to a broad range of other crops that are ecologically linked to alfalfa through the movements of nearly 1000 species of alfalfa-associated insects and mites. The most recent (1970) survey indicates that during that year, the cost of insecticidal alfalfa weevil control, together with the hay losses accrued, was more than $6 million of a total alfalfa-hay crop value exceeding $197 million annually. About two-thirds of these losses have been attributed to the EAW, according to the State Department of Agriculture, the heaviest losses having occurred in Imperial, San Joaquin, and Yolo Counties, where the EAW is well established and conditions are favorable for its increase. In each of these counties total costs attributable to the EAW exceeded $1 million in 1970. In Yolo County, damage and associated costs have been estimated at about $35 per acre. These present conditions may serve as harbingers of the impending severity of this problem, in that as of yet this pest is present but not well established in the large alfalfa-producing areas of Fresno, Madera, Kings, and Kern Counties.

The problem of the EAW as a potential major alfalfa pest becomes one of secondary importance when considering the broad-ranging and long-lasting effects that may result from poorly planned insecticide programs aimed at protecting alfalfa from this weevil. The actual EAW damage itself is a small part of the total picture. Under California conditions, alfalfa is a crucial crop, contributing to the stability of insect populations in our agricultural valleys. This can be explained in part by the large acreage given over to this crop, and by the fact that the same planting remains in the ground for several years, allowing alfalfa to provide a more stable environment than most other field or vegetable crops. However, the most important stabilizing factors are probably the physical and nutritive qualities of the crop, making it highly attractive to a very broad complex of insects. Thus, typically, there would be many kinds of insects feeding on any one potential insect pest, thereby preventing the pest's build-up to damaging numbers and resulting in successful biological control of that pest.

The above-mentioned characteristics of alfalfa provide a logical explanation as to why the crop is the source of a great many beneficial insect species which play a major role in the biological control of a number of California's major crop pests. In effect, alfalfa serves as a cost-free natural insectary producing a variety of parasites and predators which control its own potential pests as well as those in many other crops.

The value of beneficial insects in area-wide programs must not be overlooked. Insects are almost constantly on the move among crops, and this is particularly true in areas where alfalfa is present. An indiscriminately planned weevil chemical control program could result in massive kills of beneficial insects in alfalfa, thus draining the treated areas of much of their naturally occurring biological control. This in turn could lead to serious insect problems in all crops in the area. A case in point is the Imperial Valley, where large scale area-wide insecticide treatments on cotton, for pink bollworm "control," are resulting in atypically serious pest problems in sugar beets, lettuce, alfalfa, and in cotton itself. Massive insecticide treatments, such as those applied against pink bollworm often are more destructive of beneficial insects than of the target pest species. As a result, once wide scale treatments are begun in a given area, subsequent follow-up treatments usually become necessary to control the resurgent target species and previously innocuous ones released from their natural enemies. The result is a costly insecticidal treadmill which leads to an even more aggravated problem as the pests develop resistance to the chemicals. Other problems that may result from excessive or unjustified use of insecticides include excessive accumulation of residues, health hazards, legal complications, and the destruction of other beneficial or aesthetically pleasing species, including soil conditioning arthropods, pollinating insects, and wildlife. Finally there is the increased expense of employing insecticides, which involves recurrent costs for equipment, labor, and material.

It is essential to acquire an awareness of the broad ramifications that must be considered in searching for a solution to agricultural pest problems. In the case of alfalfa, it should be evident that an indiscriminately applied insecticide program would likely result in serious and sustained secondary pest problems from a variety of species, particularly aphids and Lepidoptera (see Table 1). It should be equally evident that biological control is one of the most important of several interrelated factors essential to the development of efficient solutions to agricultural problems. Biological control as discussed herein is developed as an integral part of the concept of pest management, in which all phases of a particular agricultural pest situation are coordinated on an area basis.

Review of Biological Control of Alfalfa Pests in California

A number of biological control programs of alfalfa pests are under contemplation; however, before describing these, it would be well to review the presently established and operating programs in which natural enemies have effectively regulated a pest species. Hagen et al., 1971, presented a more extensive review of the same programs and should be referred to if more detail than presented in this paper is desired.

The principal alfalfa pests of California and their parasites are listed, somewhat in the order of their economic importance, in Table 1. The EAW is by far the most important pest, and also the main exception to the otherwise largely successful biological control programs for alfalfa pests in California. Note in Table 1 that many of the parasites of the EAW have been imported from Europe; this point will be discussed later in this paper in relation to the failure thus far to control the EAW. Most of these same parasites were originally imported as biological control agents of the alfalfa weevil, *Hypera postica*. In much of lowland California where *H. postica* is established, it appears to be under reasonable control by the parasite *Bathyplectes curculionis*, a parasite ineffective against the EAW.

Control of the two aphid species has been effected through a combination of factors, including importation of the listed related parasites. Of equal or greater importance have been the development of alfalfa varieties resistant to the attack of the spotted alfalfa aphid, mortality caused by an entomophagous fungus, equally high mortality attributable to a complex of native coccinellids (lady bird beetles) and the use of a selective insecticide (Stern and van den Bosch, 1959). Smith and Hagen, 1966, give a convincing quantitative summary of the effectiveness of the predators utilized in the spotted alfalfa program. The native source of these predators is of critical significance, as they, along with native parasites and naturally occurring diseases, play important roles in the control of several of the insect pests listed in the table.

In the case of the last three species on the list, the lepidopterous pests, it is difficult to estimate the importance of predators since the role of the latter is quantitatively not well known. The difficulty can be partially explained by the fact that each predatory individual must constantly search for and find food throughout its life cycle in order to survive and reproduce. In other words, during its life span a particular predator must find hosts many times, and its success in doing this depends on several critical factors: ability to search for and find food, preference for certain host types, and reproductive capacity. All of these factors must be determined many times before a reasonable evaluation can be made of a predator's potential as a biological control agent. In contrast, a parasite usually develops on one host; thus, evaluation of its survival and effectiveness as a biological control agent becomes a much simpler task, and accordingly, is more frequently undertaken by researchers.

The lepidopterous pests are susceptible to naturally occurring, fairly specific viruses. If death is caused by a viral infection, the worms become characteristically darkened in color, have a wilted or flaccid appearance, and are often found hanging from stem or leaf. These natural epizootics have been poorly researched and little is known about the distribution and frequency of these viral attacks. It is known, however, that the viruses become an important mortality factor at irregular intervals and appear to be associated with abnormally high populations of the host species.

Numerous parasites attack the lepidopterous pests (see Table 1) and it should be remembered that these parasites, as well as the predators, provide cost-free pest mortality for the farmer.

The cultural practice of harvesting alfalfa in alternate strips to provide two different aged hay growths in the same field has been found to promote the effectiveness of biological control. In 1960, Schlinger and Dietrick conclusively showed that all of the important natural enemies of the spotted alfalfa aphid could be maintained at higher levels through this harvesting technique than would be possible under standard harvesting procedures. Van den Bosch et al., 1967, showed that the pea aphid parasite, Aphidius smithi was likewise favored by strip cutting and van den Bosch and Stern, 1969, reported that the practice favored most of the important predators and parasites of the lepidopterous pests.

Future Programs for Biological Control of Alfalfa Pests

Future programs in biological control of alfalfa pests will emphasize the preservation and augmentation of beneficial insects and the maintenance of alfalfa as a field insectary. The manner in which this objective will be implemented will be based on results obtained from the studies listed below. These studies will be undertaken simultaneously in selected growers' fields. Each field will be subdivided, with a specific study being carried out in each sub-area, thereby permitting a simultaneous evaluation of the various factors within each field and a comparison among the different fields involved. The following studies will be conducted:

(1) Augmentation of EAW parasites through introduction of ecotypes from climates similar to that of the inland California valleys. Many of the previously introduced species were from central and northern Europe, an area of strikingly different climate than that of the lowland valleys of California areas into which they were released. Except for B. curculionis, none of these parasites have been recovered in California, and even B. curculionis seems limited in i effectiveness by the hot, dry climatic conditions of interior California.

A program is already underway, which involves the collection of specific ecotypes of parasites from those areas in the Mediterranean Basin, Near and Middle East, where the climate is quite similar to that of the inland California valleys and the arid highlands of northeastern California. Not incidentally, part of the area of foreign search is also thought to be the native home of the EAW, and it is expected that more efficient natural enemies will be found.

Conservation of beneficial species with emphasis on the quantitative measurement of the role of specific predators as enemies of the major potential alfalfa pests. A broad insect survey on alfalfa is planned to more precisely identify the abundant predators and parasites essential for control of pests of alfalfa and associated crops. Relationships will be drawn between the periods of abundance of the beneficial insects and the corresponding periods of abundance or scarcity of the potential alfalfa pests. Subsequent studies will involve searching and feeding preferences between the specific predators and each of the potential pests. These studies are absolutely essential in order to avoid the types of insecticide-induced problems mentioned earlier in this paper. A philosophy of total elimination of insecticides is not implied; on the contrary, insecticides are recognized to be of considerable potential value, when applied as part of a total pest management program that takes all pertinent factors into account.

(3) Development of realistic economic thresholds. Cooperative research with E. Summers and W. Cothran has been planned for the development of levels of pest infestation that will realistically permit the conservation of beneficial insects in alfalfa. This area of study might well be considered the most critical of all in the developing phase of this program. Unless realistic and broadly based economic thresholds are employed, which take into account all major pests in the entire cropping system within an area, economical and ecological problems will result inevitably from undisciplined insecticide usage. The price of the attempted protection from the present insecticide programs will be prohibitively high when the costs of the secondary effects of the chemicals are added to the original treatment costs. Smith, 1971, presented a comprehensive analysis of the factors involved in the economics of crop protection. His paper should be read for a more extensive discussion of this subject.

(4) Use of naturally occurring viruses of lepidopterous pests. This area of research is vital, especially with induced pest problems which require specific methods of

control to prevent further upset of nontarget organisms. One of the most promising potential for control of the worm pests is seen in viral disease. The need for immediate research upon these viruses becomes imperative in view of the increasing possibility of a wide scale EAW insecticide control program, which will predictably lead to increased population levels of lepidopterous larvae. Under present regulation, it is understood that insect viruses may be field collected and used by individual growers on their own farms, provided commercial sale is not involved. Within these limitations, growers should be prepared to field collect virus-infected material to be processed and deep frozen for future use. Present plans include large scale field evaluations of these viruses aimed at obtaining government approval for their commercial use.

(5) Strip cutting and/or leaving border swaths of different aged alfalfa growth. This phase will be carried out simultaneously with the above four phases of study. Of particular interest is the effect of this procedure on the conservation of predators and parasites of the EAW in untreated, virus treated, and insecticide treated plots.

Conclusions

In summary, although some new biological control concepts will be tested, against the EAW in particular, perhaps the most promising aspect of these projected studies lies in the overall management approach. All biological control programs will be evaluated as integral parts of a system involving all other potential insect control measures. This management approach is not a researcher's dream; rather, it is closely patterned after a highly successful similar program carried out for the past six years on cotton. As indicated in the talk given by C. Summers and W. Cothran, parts of these studies have already been initiated on a small scale already, and a more intensive effort is planned for the coming year.

There are excellent prospects for developing an alfalfa pest management system in California. Not only will this be of direct benefit to the alfalfa industry but it could serve as a model for similar program development in other crops. This in turn would be of general economic benefit to California agriculture and to the California environment.

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A LIST OF PARASITES OF SOME CALIFORNIA ALFALFA PESTS

Principal Pests of Alfalfa in California	Host Stages Attacked	Parasite	Source of Parasite	Literature Reference
Hypera brunneipennis Egyptian alfalfa weevil	larva	Bathyplectes curculionis	Iran, Iraq, Southern Europe	vdB, et al., 1971
"	egg	Patasson luna	Southern Iran	Fisher, et al., 1961
"	larva	Bathyplectes anurus	Iran (4-8000'), Europe	vdB, et al., 1971
"	larva	Bathyplectes stenostigma	Sweden, Europe, Middle East	vdB, et al., 1971
"	larva	Tetrastichus erdoeisi	Iran	vdB, et al., 1971
	prepupa, pupa	Dibrachoides druso	Iran	vdB, et al., 1971 Fisher, et al., 1961
	adult	Microctonus aethiops	Europe, Iran	vdB, et al., 1971
	adult	Microctonus colesi	Europe, Middle East	vdB, et al., 1971
	adult	Microctonus sp.	Italy	vdB, et al., 1971
	prepupa, young pupa	Habrocytus sp.	Southern Iran	Fisher, et al., 1961
Hypera postica Alfalfa weevil	larva	Bathyplectes curculionis	Italy	Fisher, et al., 1961
Acyrthosiphon pisum Pea aphid	nymph, adult	Aphidius smithi	India	vdB & Hagen, 1966(a)
Therioaphis trifolii Spotted alfalfa aphid	1st or 2nd instar	Trioxys complanatus	Iraq, Iran, Italy,	vdB, 1957
"	2nd or 3rd instar	Praon exsoletum	Iraq, Iran, Italy, Israel, Turkey, Yugoslavia	vdB, 1957
	1st or 2nd instar	Aphelinus asychis	Iran, Israel, Italy, Turkey	vdB, 1957
Colias eurytheme Alfalfa caterpillar	larva	Apanteles medicaginis	Native	Allen & Smith, 1958
"	egg	Trichogramma semifumatum	Native	Stern & Bowen, 1963
"	larva	Hyposoter exiguae	Native	Allen & Smith, 1958
"	larva	Pristomerus pacificus	Native	Allen & Smith, 1958
"	?	Pterocormus instabilis	Native	Allen & Smith, 1958
"	pupal-larval	Achaetoneura archippivora	Native	Allen & Smith, 1958
"	pupal-larval	Euphorocera tachinomoides	Native	Allen & Smith, 1958
"	pupal	Brachymeria ovata	Native	Allen & Smith, 1958
"	pupa	Pteromalus urymi	Native	Allen & Smith, 1958
Prodenia praefica Western yellow-striped armyworm	larva	Apanteles marginiventris	Native	vdB & Hagen, 1966(b)

Principal Pests of Alfalfa in California	Host Stages Attacked	Parasite	Source of Parasite	Literature Reference
Prodenia praefica Western yellow-striped armyworm	egg-larval	Chelonus texanus	Native	vdB & Hagen, 1966(b)
"	larva	Meteorus vulgaris	Native	"
"	larva	Campoletis intermedius	Native	"
"	larva	Nepiera marginata	Native	"
"	larva	Hyposoter exiguae	Native	"
"	?	Pterocormus difficulis	Native	"
"	larval-pupal	Therion californicum	Native	"
"	?	Trachysphyrus tejonensis tejonensis	Native	
"	larval-pupal	Archytas californiae	Native	
"	larva	Eucelatoria armigera	Native	
"	larva	Phorocera claripennis	Native	
"	larva	Aphiochaeta spp.	Native	
Spodoptera exigua Beet armyworm	larva	Apanteles laeviceps	Native	
"	larva	Apanteles marginiventris	Native	"
"	egg-larval	Chelonus texanus	Native	"
"	larva	Meteorus vulgaris	Native	"
"	larva	Campoletis argentifrons	Native	"
"	larva	Hyposoter exiguae	Native	"
"	?	Melanichneumon rubicundus	Native	"
"	larval-pupal	Therion californicum	Native	"
"	egg	Trichogramma spp.	Native	"
"	larval-pupal	Achaetoneura archippivora	Native	"
"	larva	Eucleatoria armigera	Native	