# REFINEMENTS OF INTEGRATED PEST MANAGEMENT STRATEGIES FOR ALFALFA WEEVILS IN CALIFORNIA ALFALFA

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## ABSTRACT

Alfalfa is the number one valued field crop in California with 1 million acres and hay production of nearly $1 billion per year. Several insect pests injure alfalfa plants reducing crop yields and quality. The alfalfa weevil complex, comprised of the Egyptian alfalfa weevil (EAW), *Hypera brunneipennis*, and alfalfa weevil, *Hypera postica*, is the most damaging arthropod in California alfalfa. Weevil larvae are well-controlled with insecticides including organophosphate, carbamate, and pyrethroid materials. However, the occurrence of organophosphate insecticides in surface waters, particularly chlorpyrifos (Lorsban®), coinciding with the timing of treatment for EAW larvae, has placed added emphasis on finding alternative means to manage this pest. Pyrethroid insecticides and indoxacarb were recently registered in alfalfa but have drawbacks of being non-selective for natural enemies and somewhat less effective than other products, respectively. Alfalfa was one of the more heavily researched crops in the 1970's and 1980's and many IPM principles were developed from studies on alfalfa. However, pest management research efforts in alfalfa have declined during the last 15 years because of competing research/crop priorities, funding limitations, etc. In 2004, we re-evaluated the status of biological control of EAW larvae and the EAW treatment threshold under current production practices. Ten parasitoid species were released in CA for EAW from 1957-1988 and three were reported as established, but the incidence of these organisms has not been studied recently. Observations by Godfrey in 2002 and 2003 indicated relatively high natural mortality of EAW larvae. The second area that could facilitate EAW management in California is a re-evaluation of treatment threshold and sampling for EAW under the current production regime. Preliminary data were collected from one site in 2002-03 and 2004 studies expanded upon this work.

## INTRODUCTION

Sampling and economic thresholds are two of the central tenets of integrated pest management. Sampling involves collecting data from a small area of the field such that the results represent the

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entire field. If done properly, useful information can be obtained in a cost-effective manner. Economic thresholds are critical for determining the need for management actions as well as timing these activities. Designing integrated pest management plans for cropping systems is a never-ending job. Change, hopefully advancement, is always a key component of cropping systems. In alfalfa, for instance, cultivars change, new pests invade (such as the cowpea aphid), economics change (such as hay prices), new insecticides are registered and other ones are removed, production practices change, pests develop resistance or change in other ways, etc.

Without a sampling plan or a threshold value (or lacking a reliable, grower accepted value), management efforts resort to preventative treatments. Koehler and Rosenthal (1975) published results supporting a threshold of 20 EAW larvae per sweep. This threshold has been effectively used for numerous years and an insecticide application prior to the first cutting for EAW is routine in the Central Valley. This 1970's research is limited by assumptions of hay values of $50-$70 per ton, treatment costs of $6-8 per acre and low productivity (2500 lbs/A yields) alfalfa cultivars such as 'Lahontan', 'El Dorado Improved', and 'Caliverde'. Hay values and treatment costs today are commonly 3X the 1970 values and yields today are commonly 4500 lbs/A.

An additional trend that is influencing management of EAW in central CA is the use of alfalfa cultivars with higher levels of dormancy. Increased levels of dormancy result in less alfalfa growth in the fall after the last cutting and reduced amounts of alfalfa growth before the first seasonal cutting. This latter trait hinders sampling EAW larval populations with a sweep net, which is commonly used to make a treatment decision. EAW egg hatch is driven by temperature and often occurs before significant alfalfa growth has occurred.

Alfalfa fields, as a short-term perennial agroecosystem, support a wide range of arthropods, most of which have neither positive nor negative effects on the crop. In fact, alfalfa fields are important contributors to the biodiversity of agricultural systems (Putnam et al. 2001). Unfortunately, a few of these insects feed significantly on the alfalfa plants and therefore are classified as "pests". The alfalfa weevil complex, which includes the Egyptian alfalfa weevil and the alfalfa weevil, was introduced from the Mediterranean region to the U.S. in the early-mid 1900's. Given the multiple year nature of alfalfa fields, biological control was an obvious approach to managing these introduced pests. USDA and APHIS coordinated biological control efforts and millions of parasitoids (~10 species) were released. These organisms adapted quickly in the northeastern, midwestern, north central U.S. In fact, in the northeast, researchers have shown that weevil populations declined within 10 years of the releases, insecticide use on alfalfa dropped 73%, and benefit to cost ratios of 25:1 were shown for this program. However, in other regions including the west, the parasitoid species released were less effective and insecticide usage on alfalfa was unaffected by the program. Additional releases of new parasitoid species or strains were done in California in the 1980's. Pitcairn and Gutierrez (1989) reported that three species had established in CA; the larval parasitoids *Bathyplectes curculionis, B. anurus*, and *Tetrastichus* (=*Oomyzus*) *incertus* were reported as "widely established", "recently recovered", and "established central California", respectively, from the 1982-83 surveys. The status of parasitism of weevil larvae has not been evaluated since the late 1980's. This is another aspect of the alfalfa agroecosystem that can "change" and studies were designed to re-evaluate the incidence of these parasitoids. In studies in 2002 and 2003, larval populations failed to develop in some sites and several EAW larve appeared “sluggish” as though possibly parasitized (Godfrey and Putnam, 2002; Lewis, Godfrey and Putnam 2003).

Insecticides are another means to manage weevil larvae in alfalfa. Organophosphate and carbamate materials have been used extensively for weevil control for several years and are still effective. However, registrations of these materials are threatened, or possibly will be restricted because of environmental concerns, namely water quality. Although not highly pesticide-intensive, alfalfa is the state’s second largest single user of OP pesticides, and thus has a large footprint due to its acreage. It has been shown that alfalfa can contribute to off-site movement of pesticides and other potential pollutants in some watersheds, particularly in the Sacramento Valley, Delta, and N. San Joaquin Valley. In 2002, OP insecticides were involved in ~50% of the insecticide applications in alfalfa (~800,000 acre-treatments) and carbamate materials were applied in ~12% of the applications. These figures represent reductions in use over the last 4 years of ~10% and 8% for OP and carbamate materials, respectively. Pyrethroid insecticides (Warrior®, Mustang®, Baythroid®, and others) have been registered in alfalfa during the last five years and two of these products are now among the most commonly used insecticides in alfalfa. Long et al. (1999) demonstrated the positive attributes of pyrethroids for protection of surface waters; however, possible off-site movement in organic matter/sediment is now coming to light. In addition, the broad-spectrum nature of pyrethroids, i.e., toxicity to populations of beneficial organisms, can negate the “insectary” attribute of the alfalfa cropping system. Recently, indoxacarb was registered for use in alfalfa and is reportedly “easy on beneficials”.

## PROCEDURES

Biological Control Studies. Naturally-occurring biological control was assessed in several areas of the state. Studies were conducted in six counties of the Central Valley (Kern, Tulare, Merced, San Joaquin, Yolo [2 locations], and Colusa) and two intermountain locations (Siskiyou Co. and Shasta Co.). One field per area was sampled at a time when primarily eggs, larvae, pupae, and adults were present (larvae were collected multiple times from a field in several cases). EAW adults were collected with a vacuum sampler (D-Vac®) and larvae were collected from sweep net samples of alfalfa foliage. Eggs were recovered from foliage samples. Pupae were collected by collecting them from foliage and/or the soil surface. Recovered eggs, larvae, and pupae were held in the laboratory for natural enemy emergence; adults were dissected to detect parasitism. Larval parasitoids are apparently the most common and the greatest emphasis was placed on this lifestage.

Impact of Weevil Larvae on Alfalfa Productivity. Plots were established on the UC-Davis campus for this objective in 2004. In addition, additional research was conducted in grower fields in San Joaquin Co., Colusa Co, Shasta Co., and Siskiyou Co. Two approaches were used for the plots on the UC-Davis campus. For approach one, separate plots were treated at 5-7 day intervals with an effective EAW control product (Warrior at 3.8 oz./A) starting at the initiation of egg hatch. Once a regime was started, repeat applications were made if needed. Five timings along with a sixth treatment with no insecticide applied were planned for use. For the second approach, yield samples were collected from an insecticide efficacy comparison study that contained 14 treatments (plus an untreated). Many of the treatments were effective to highly effective on EAW larvae; therefore, two to four treatments/rates were added that would be moderately to marginally effective. No other insect pest reaches damaging levels during this part of the season (before the first cutting), so interference from control of other pests was minimal. The goal was to establish a gradient of EAW larval populations (by removing various percentages of the larval population) near the time of the peak population. Each treatment timing or treatment insecticide was replicated four times in plots (20 x 50' each) within a randomized complete block design. EAW larval populations were quantified in each plot every 7 days using the standard sweep net sampling method. Plots were harvested with a Carter harvester and fresh weight and dry matter yields and nutrient quality (% crude protein, %IVDDM) were determined. The timing approach was also used in the grower field sites. In addition, ten insecticide treatments were used to set-up a range of larval populations at a San Joaquin Co. site.

Sampling Studies. Studies were conducted in San Joaquin Co. and Yolo Co. to evaluate a revised sampling technique for EAW larvae. The recommended method in the rest of the U.S. is to carefully collect alfalfa stems, rap the stems within bucket with enough force to dislodge weevil larvae, and count larvae within the bucket. Larval counts from this technique were compared with those from sweep net sampling.

## RESULTS

Biological Control Studies. Parasitism averaged 6% (Kern Co.), 12% (Tulare Co.), 0.2% (Merced Co.), 1.5% (San Joaquin Co.), 14% (Yolo Co.), 0% (Colusa Co.), 17% (Siskiyou Co.) and 19% (Shasta Co.). No parasitism of weevil eggs was found and only a few weevil adults were parasitized. The majority of the parasitism was found in the larval stage by *Bathyplectes* spp.

Impact of Weevil Larvae on Alfalfa Productivity. EAW larval populations developed in the Davis field plots about 10 days later in 2004 than in 2003 (2002 was intermediate in terms of timing). Larval populations peaked at 27.8, 13.3, and 34.3 per sweep in 2002, 2003, and 2004, respectively. Larval populations were very slow to develop in 2004 and had a very brief, distinct peak on 18 March. Treatments (Table 1) were applied on 19 March and populations declined over the next 7-10 days. The registered products when applied at the recommended rates all provided at least 90% control except for Lorsban (Table 1). The effects on yield were minimal with untreated plots having one of the higher yields (Table 1). This contrasts with yield results in 2002 and 2003 which responded negatively to EAW larval populations. Significant linear relationships were found between average larval numbers and first harvest alfalfa fresh weight yield and first harvest alfalfa dry weight yield in 2002 and 2003. Predictions showed that populations of 10 larvae per sweep reduced fresh weight yields by 22.5% (2003) to 56% (2002) and dry weight yields by 22.8% (2003) to 48.6% (2002).

Treatment timing studies showed minimal yield losses at the Yolo Co. site and the San Joaquin Co. site (325 cultivar); larval populations at these two sites peaked at 12 larvae or less per sweep

(Table 2). Yield protection at the Colusa Co. site was erratic, i.e., none with treatments at the start of egg hatch and 6% with a treatment one week later. It is unclear if these yield losses resulted from larval injury. Larval populations at this site were low. Results from the Tango cultivar in San Joaquin Co. showed the greatest yield from treatment 1 week after the start of egg hatch. This application resulted in a 11.4% increase in yield compared with untreated plots. Larval populations peaked at 15.4 per sweep. At the two intermountain sites, the greatest yield protection resulted from the earliest treatment timing. Larval populations were extremely high at the Shasta Co. site.

In summary, the synchrony of EAW larval population and alfalfa growth/harvest appears to be very important in the yield loss determination. At the Davis site over the 3-year study (the only site thus far with multiple years of data), the yield loss in 2002 was greatest. In this case, the EAW larval pressure was sustained and populations approached the accepted threshold. The alfalfa harvest coincided with the cessation of larval feeding. Contrast this with 2003 which had a somewhat lower population than 2002 but more importantly the alfalfa was not ready to cut until 2-3 weeks after the peak feeding. This provided time for the crop to compensate for the damage and yield losses were less severe. In 2004, EAW larval populations were low-moderate and very short-term. Defoliation damage was slight. In addition, yield losses were nil even though the harvest was within a week of peak damage.

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Table 1. Treatment list, effects on EAW populations, and on alfalfa first harvest yield, Yolo Co., 2004.

| **Treatments** | **Rate/A (product)** | **% Control – 4 DAT*** | **% Control – 7 DAT** | **% Control – 13 DAT** | **Alfalfa Dry Weight Yield (lbs./A)** |
|---|---|---|---|---|---|
| Baythroid 2EC | 2.8 fl. oz. | 97.2 | 94.5 | 98.8 | 3009.8 |
| Furadan 4F | 1 qt. | 98.5 | 91.9 | 98.6 | 3489.1 |
| Imidan 70W | 1 lb. | 96.1 | 96.3 | 97.7 | 3474.2 |
| Lorsban 4E | 2 pts. | 78.6 | 77.2 | 83.8 | 3446.6 |
| Lorsban 4E | 1 pt. | 86.5 | 91.5 | 90.4 | 3422.6 |
| Lorsban 4E | 1.5 pts. | 90.1 | 86.4 | 88.3 | 3312.0 |
| Mustang 1.5EW | 3.2 fl. oz. | 97.2 | 97.1 | 99.2 | 3795.8 |
| Proaxis | 3.84 fl. oz. | 97.7 | 96.3 | 98.6 | 3247.2 |
| Steward SC | 2.56 fl. oz. | 93.7 | 92.3 | 85.4 | 3372.8 |
| Steward SC | 4.6 fl. oz. | 93.9 | 96.3 | 93.4 | 3232.1 |
| Tempo 1EC | 3.3 fl. oz. | 98.6 | 97.8 | 99.4 | 3206.2 |
| Untreated | --- | --- | --- | --- | 3306.6 |
| Warrior | 3.84 fl. oz. | 94.6 | 95.2 | 97.5 | 3102.0 |
| Warrior + Lorsban | 1.97 oz. + 0.75 pts. | 98.2 | 96.7 | 98.6 | 3383.6 |

Table 2. Influence of treatment timing on alfalfa first harvest yield at multiple locations, 2004.

| | **% Alfalfa Dry Matter Yield Increase Compared with Untreated Plots** | | | | | |
|---|---|---|---|---|---|---|
| **Treatment Timing** | **Yolo Co.** | **San Joaquin Co. - Tango** | **San Joaquin Co. - 325** | **Colusa Co.** | **Shasta Co. [B]** | **Siskiyou Co. [C]** |
| Start of egg hatch | 2.8 | 5.8 | 0 | 0 | 22.2 | 36.5 |
| 1 week later | 1.0 | 11.4 | 1.0 | 5.6 | 13.9 | 20.2 |
| 2 weeks later | 0 | 3.4 | 0 | 0 | 8.3 | 28.0 |
| 3 weeks later | 0.7 | 1.8 | 0 | 6.6 | --- [A] | 34.8 |
| 4 weeks later | --- [A] | 0 | 0 | --- [A] | --- [A] | 28.0 |
| Untreated (peak EAW larval popn.) | 8.2 | 15.4 | 11.8 | 9.1 | 90.0 | 39.3 |

[A] Treatment not made. [B] Treatments made 10 days apart. [C] Treatments made 5 days apart.