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Evaluating Efficacy of Stubble - Applied Insecticide Treatments for Alfalfa Weevil Control in Oklahoma

Abstract

Alfalfa *Medicago sativa* L. (Fabales: Fabaceae) is the nation's third most valuable field crop. In Oklahoma, alfalfa is also highly valued and ranks in the top three most economically important field crops. Insecticide resistance poses a significant risk to forage alfalfa production in the United States. The alfalfa weevil *Hypera postica* Gyllenhal (Coleoptera: Curculionidae) is an economically damaging pest of alfalfa in North America. Due to insect resistance to pyrethroids, limited alternative mode of action (MoA) groups are available for alfalfa weevil control. The objective of the study was to evaluate efficacy of stubble - applied insecticide treatments for alfalfa weevil control in Oklahoma. A field trial was conducted in Stillwater, Oklahoma (Payne County). Treatments consisted of five commercial insecticide formulations applied on alfalfa, as stand-alone applications or tank mixes at maximum label rates, early stubble, and prior to traditional threshold timing. Insecticide treatments, stand-alone or tank mix, in the stubble-treated field trial failed to provide expected control (90%) targeting alfalfa weevil larvae. No treatment provided control greater than 58%. Results from this study suggest stubble - applied treatments for alfalfa weevil control were not effective. There is a need for future research to explore if scouting protocols, based on the adult life stage, could be an alternative strategy.

Keywords: alfalfa weevil (AW), cross-resistance, mode of action (MoA), pyrethroids

Introduction

Alfalfa (*Medicago sativa* L. [Fabales: Fabaceae]) is the nation's third most valuable field crop, valued at over $10.8 billion USD (Nelson, 2020). In Oklahoma, approximately 175,000 acres of alfalfa are grown annually and generates a revenue of $148,211,000 USD (NASS, 2023), making it one of the top three commodities in the state, behind wheat and corn. Insect resistance to pyrethroids poses a significant risk to forage alfalfa production in the United States. In Oklahoma, varying levels of resistance to pyrethroids have been reported, however, resistance levels and their economic impacts have not been verified by research data. Given the fact that higher cost insecticide treatments are needed, and yield loss will arise due to lack of control, conservative estimates of revenue loss reaching 25% or more could easily occur. In 2002, estimated annual economic loss due to insecticide resistance in the U.S. was reported at $1 billion USD (Clark and Yamaguchi, 2001). Newer estimates put the loss at $10 billion USD (Gould and Koulikowski, 2018).

The alfalfa weevil *Hypera postica* (Gyllenhal) (Coleoptera: Curculionidae) is an economically damaging pest of alfalfa in North America (Pellissier et al., 2017). Larval feeding causes economic damage through defoliation, reduction in forage yield, quality, and value (Onstad and Shoemaker, 1984). Most of the damage occurs before the first cutting. These voracious eaters can defoliate an alfalfa field in a matter of days if left untreated.

In Oklahoma, management decisions are based on insect threshold and determined by monitoring degree day (DD) accumulation, plant height, and larval numbers (Seuhs et al., 2020). Collection of stems samples (30), representing approximately one square foot, are taken to determine the level of insect activity. The number of insects or level of damage beyond which management action should be taken is known as the action threshold, a fundamental concept in integrated pest management (UC IPM, 2024). Based on timing of occurrence, thresholds can vary depending on the variables listed above.

Historically, a plant height of 8-10 inches is achieved before threshold is reached and occurs in late March. However, in years where mild winters patterns develop, plants break dormancy earlier. In addition to early warming patterns for plant growth, the increase in DD accumulation promotes early alfalfa weevil activity.

Degree day accumulation begins 1 January each year. Once an accumulation of 150 DD is achieved, monitoring for AW larvae begins. Weather plays a key role during this time frame. Continuing cold and wet weather events can delay plant growth and insect activity. However, early springs can enhance both early plant growth and insect development. In early springs, plant height of 2.0 inches or less may develop about the same time AW activity begins. In some years, this can occur as early as late February. Therefore, timing, development, and number of insects needed for threshold can vary year–to-year.

The timely application of inexpensive pyrethroid insecticides (mode of action [MoA] group 3A) has been the primary method of management (IRAC, 2022; Wright et al., 2016). However, these products are becoming less effective due to increasing insect resistance. Lack of control of this perennial pest is forcing many alfalfa growers to make tough decisions on additional insecticide applications and the use of higher cost products or run the risk of losing entire alfalfa cuttings due to plant defoliation.

Alfalfa weevil is a non-native pest. As reported by (Bundy et al., 2005), AW was detected in the United States on three occasions, with each introduction recognized as an individual strain.

In the 1950s, insecticides became the primary method to reduce larval damage, however; by 1961 insecticide resistance issues began to develop (Bishop, 1964). After decades of routine use, AW has developed resistance to several pyrethroid products, especially those containing the active ingredients lambda-cyhalothrin and zeta-cypermethrin.

Based on current management recommendations, with limited rotational options, the loss of all pyrethroids due to resistance would severely limit alfalfa weevil management of forage alfalfa production. Therefore, new strategies are needed to address this expanding problem.

A strategy being considered in Oklahoma is the timely application of insecticides early in the season (stubble), before breaking winter dormancy and prior to the threshold being reached.

As discussed earlier, thresholds can vary depending on environment conditions, plant height, and number of insects present. While stubble treatments for AW control have been experimented with after the first cutting and new growth has begun (Hellman et al., 1979), little information is available utilizing this strategy in alfalfa that is dormant or close to breaking dormancy. This early season approach could coincide with traditional timing for spring herbicide application for weed control in Oklahoma, which usually takes place toward the end of February, and could be tank-mixed at a low cost to the producer.

Spring herbicide applications generally go out a couple of weeks before weevil activity begins. There is skepticism from producers and researchers that the lack of AW larval activity at that time would hinder effectiveness of tank mixes (University of Wyoming, 2020). Researchers at the University of Wyoming are starting to look at this strategy. Anecdotal reports from farmers indicate this strategy is helping, but there is no research data to back up these observations. This type of approach, in other commodities, has widely been viewed as precautionary and is contrary to typical integrated pest management (IPM) philosophies, but could create a “low-cost insurance” (as described in Ternest et al., 2020).

Therefore, the objective of this study was to evaluate efficacy of stubble-applied insecticide treatments for alfalfa weevil control in Oklahoma.

Methods

An experiment was conducted at the Agronomy Research Station in Stillwater, Oklahoma (Payne County). Stubble treatment timing was initiated based on typical spring herbicide applications in established alfalfa and before historical timing for alfalfa breaking winter dormancy (late February).

In this study, a warm weather pattern caused plant dormancy to end earlier than expected. The February mean temperature at time of application was 17.2 °C, compared to an average of 11.6 °C. Pre-treatment insect counts revealed (11 larvae/30 stems). Insecticide treatments were applied on 26 Feb and consisted of five commercial formulations labeled for alfalfa and applied as stand-alone applications or tank mixes, at maximum label rates, and an untreated check. Plant growth at the time of application was 1.5 inches. The test was randomized in a complete block design, replicated four times.

Commercially available insecticides including two pyrethroids (Warrior II [1.92 oz/acre], [Syngenta] and Mustang Maxx [4.0 oz/acre], [FMC]), two organophosphates (Malathion 57 EC [32.0 oz/acre], [FMC], and Dimethoate 400 EC [16.0 oz/acre], [purchased through local ag chemical dealer), and one oxadine (Steward EC [8.0 oz/acre] [FMC]) were evaluated. One non-labeled product, diamide (Tetraniliprole [3.5 oz/acre], [FMC]), was also included to determine if it could be an option in future alfalfa labeling.

Each plot measured 3.6 m by 7.6 m and the non-ionic surfactant “Prefer 90” was used with all treatments at a rate of 0.50% v/v. All insecticides were applied using a bicycle sprayer (12-foot boom) calibrated to deliver 20 gpa at (19 psi) traveling 3 mph.

Larvae were collected in each plot by carefully picking (30) random stems. Once collected, samples were placed in paper bags and transported in coolers to the laboratory. Samples were placed in Berlese funnels in preparation of insect counts. Samples were collected 7, 14, and 21 days after application (DAA). Yield was determined by clipping a 3 x 3 m area with a battery powered hand-held hedge trimmer on 25 April. Subsamples were dried for determination of moisture content and yields calculated on a dry weight/acre basis. Abbott’s formula was used to calculate percent efficacy for each insecticide treatment within each sample date, then averaged across all sample dates per treatment. Data were analyzed using an analysis of variance with mean separation determined using Fisher’s Protected LSD. (P = 0.05).

Results

Due to continued warming and increased degree - day accumulations through February, alfalfa had broken dormancy and small “first instar” alfalfa weevil larvae were starting to develop at the time of stubble applications. All insecticide treatments in the stubble - applied field trial failed to provide expected control (90%) of alfalfa weevil larvae (Table 1). Seven days after application three treatments, Mustang Maxx + Malathion (4.0 oz + 32.0 oz/A), Mustang Maxx + Dimethoate (4.0 oz + 16.0 oz/A), and Steward EC (8.0 oz/A), provided control that was significantly different from untreated plots. Through the remainder of the trial, only Steward EC and Tetraniliprole (14 DAA) and Mustang Maxx + Dimethoate and Tetraniliprole (21 DAA) were different from the untreated plots. Throughout the trial, there were no differences among treatments. Efficacy ranged from a high of 58.0% (Mustang Maxx + Dimethoate) to a low 26.0% (Warrior II). While the mean percent control of alfalfa weevil larvae was less than expected in all treatments, no significant differences in yield were observed.

Table 1. Mean number alfalfa weevil larvae, percent control, and yield, Stillwater, OK (Payne County, 2023). Means within columns followed by the same letter are not significantly different (p <0.05).

		Mean Number Larvae				
Treatment	**Rate oz/A**	**7DAA**	**14DAA**	**21DAA**	**Mean % Control**	**Yield Lbs/A**
Untreated		64.0 a	54.75 a	17.0 a		8161.0 a
Mustang Maxx + Malathion 57 EC	4.0 + 32.0	35.5 b	41.25 ab	6.5 ab	45.0	6387.0 a
Mustang Maxx + Dimethoate 400 EC	4.0 + 16.0	30.5 b	34.0 ab	4.5 b	58.0	8230.0 a
Steward EC	8.0	29.0 b	22.5 b	9.0 ab	54.0	7614.0 a
Tetraniliprole 200 CS	3.5	53.5 ab	23.25 b	3.0 b	52.0	8907.0 a
Warrior II 2.08 CS	1.92	46.5 ab	43.5 ab	12.0 ab	26.0	8702.0 a

Discussion

Results from this study suggest stubble - applied treatments for AW control were not effective. The highest percentage control for all treatments was 58%, well below expected levels of 90% (Finney, 1993). While most products cannot provide 100% control, Finney suggests that with farm crops, there are many factors that affect the level of control achieved at a given rate. For practical purposes, the label recommended rate is usually set at the level which gives a high level of control in a high proportion of circumstances, with the highest expected level at 90%.

Steward EC (indoxacarb), which has become the go-to product for AW control for many alfalfa growers, resulted in 54% when compared to untreated alfalfa. The stand-alone treatment of the pyrethroid Warrior II (lambda cyhalothrin) provided 26% control. Tank-mix treatments of the pyrethroid Mustang Maxx (Zeta-cypermethrin) and organophosphates (Malathion and Dimethoate) failed to reach 60% control. Tetraniliprole 200 SC (Tetraniliprole), a non-labeled product in alfalfa, has shown efficacy to certain weevil species in other crops was added to the test for comparison. No differences in yield were observed. This may have been due, in part, to partial suppression of insect activity, decline in insect pressure toward the end of the sampling period, and adequate moisture for continued plant growth through harvest on 25 April.

Application of stubble - applied insecticides were timed to coincide with traditional spring herbicide applications for weed control in established alfalfa, which normally occurs in late February, while alfalfa is still dormant. However, for this study, due to continued warming temperatures and degree day accumulation, alfalfa had already broken dormancy by late February. Both new plant growth and AW activity was approximately two weeks ahead of historical occurrence.

The IPM approach emphasizes the integration of pest biology, action thresholds, habitats, and cultural practices in controlling insect pests in crops (USDA, 2024). For Oklahoma alfalfa growers, IPM has been an effective and environmentally sensitive approach (OSU, 2022) to pest management that relies on a combination of common-sense practices.

Weather patterns can also help. As the weather moderates in late winter, degree days begin to accumulate. Degree days are a measurement of heat units over time calculated from daily maximum and minimum temperatures. Using an insect's baseline temperature for development, insect life cycles can be predicted. For alfalfa weevil, if warm weather continues during this period (> 8.8 °C), alfalfa weevil eggs hatch, and damaging larval populations may develop. However, wintry weather events in early spring are still likely in most years, which can help delay insect activity, allow increased plant growth, and delay threshold. Unfortunately, in this study, warm conditions prevailed throughout the early season allowing degree days to build and AW populations to increase earlier than expected. In addition, plant height was only 1.5 inches at time of application, decreasing the normal insect threshold level from approximately 30 larvae/30 stems to 11 larvae/30 stems.

While novel in its approach, previous Oklahoma studies utilizing early stubble applications for AW control have shown promising results. While little corroborating data could be found, it was hypothesized, by combining low-cost insecticide with herbicide applications before traditional threshold is reached and while plants were dormant, insecticide residual effects could be extended. The impact of more plant growth, increase plant tolerance to weevil populations, and targeting younger more susceptible larvae, as they become active (U Delaware, 2024), could aid producers in limiting future applications.

A one-time pyrethroid (a.i., lambda cyhalothrin) stubble treatment applied 21 Feb 2005, timed for traditional spring dormant herbicide application, revealed early first instar AW larval development at (3 larvae/30 stems). Insects were not at threshold level at time of stubble application. However, on 1 March, (73.25 larvae/30 stems) were recorded triggering threshold applications to be made. The one-time stubble treatment provided 93% control compared to 83% for threshold applications sampled 3-35 days after application (Mulder and Seuhs, 2007a).

In 2006, an additional evaluation was conducted with a one-time pyrethroid (a.i., lambda cyhalothrin) stubble treatment applied 28 Feb, with minimal weevil activity of (1larva/30 stems). The threshold occurred on 31 March with AW activity of (30 larvae/30 stems). Early stubble treatments continued to provide extended control in comparison to threshold treatments throughout the trial 3-28 days after application. Stubble treatment efficacy averaged 86% compared to 68% for threshold applications (Mulder and Seuhs, 2007b).

Early insect life stages are generally more susceptible to insecticides. Therefore, even small chemical residuals can influence newly active insects. It was anticipated that while minimal insect activity would be occurring at time of stubble application, residual effects of the treatment would last into early insect development. However, results from this study show not only alfalfa weevil insecticide efficacy lacking in pyrethroid treatments, but efficacy was also reduced when tank-mixed with organophosphates. These results seem to indicate that earlier, previously vulnerable, AW life stages may now also be resistant. While alfalfa weevil resistance to pyrethroids is well documented, less is known about potential resistance to other chemistries.

In a more recent study, early Warrior II applications (a.i., lambda cyhalothrin), applied at herbicide timing, significantly reduced AW populations compared to the untreated control (McClure et al., 2023). However, there were no significant differences between the early stubble-applied and standard threshold applications. Early applied treatments provided 60% control, while standard treatments 75%. These findings are similar to Oklahoma studies averaging 60% or less from alfalfa weevil threshold and early season stubble applications (Seuhs unpublished data, 2024). The low percent control suggests pyrethroid resistance may be developing at this location in the northwestern United States, a possibility given the recent findings of widespread resistance to pyrethroids in alfalfa weevil across the western U.S (Rodbell et al., 2024). Therefore, insecticide resistance continues to be a serious and growing problem for alfalfa producers. If resistance is occurring at a specific location, early season applications may not extend control as previously discovered.

Conclusion

Findings from this study are contrary to previous research which has suggested that stubble-applied treatments can reduce alfalfa weevil populations and extend control past threshold timing. Insect resistance to pyrethroids, and possibly other products, may be increasing. Early larval stages previously susceptible may now be resistant. The challenge remains of how to support producers with decision making regarding alfalfa weevil management. There is need for future research to explore if alternative scouting models can be an option. Current Oklahoma monitoring is based on larval activity and development. Scouting based on the adult stage, present earlier in the season, could be an alternative strategy targeting this pest before laying eggs, allowing another tool within an alfalfa integrated pest management system.

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Conflict of Interest

The author declares there are no conflicts of interest.

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