**On-Farm Research to Support the Registration of New Insecticides for Alfalfa**
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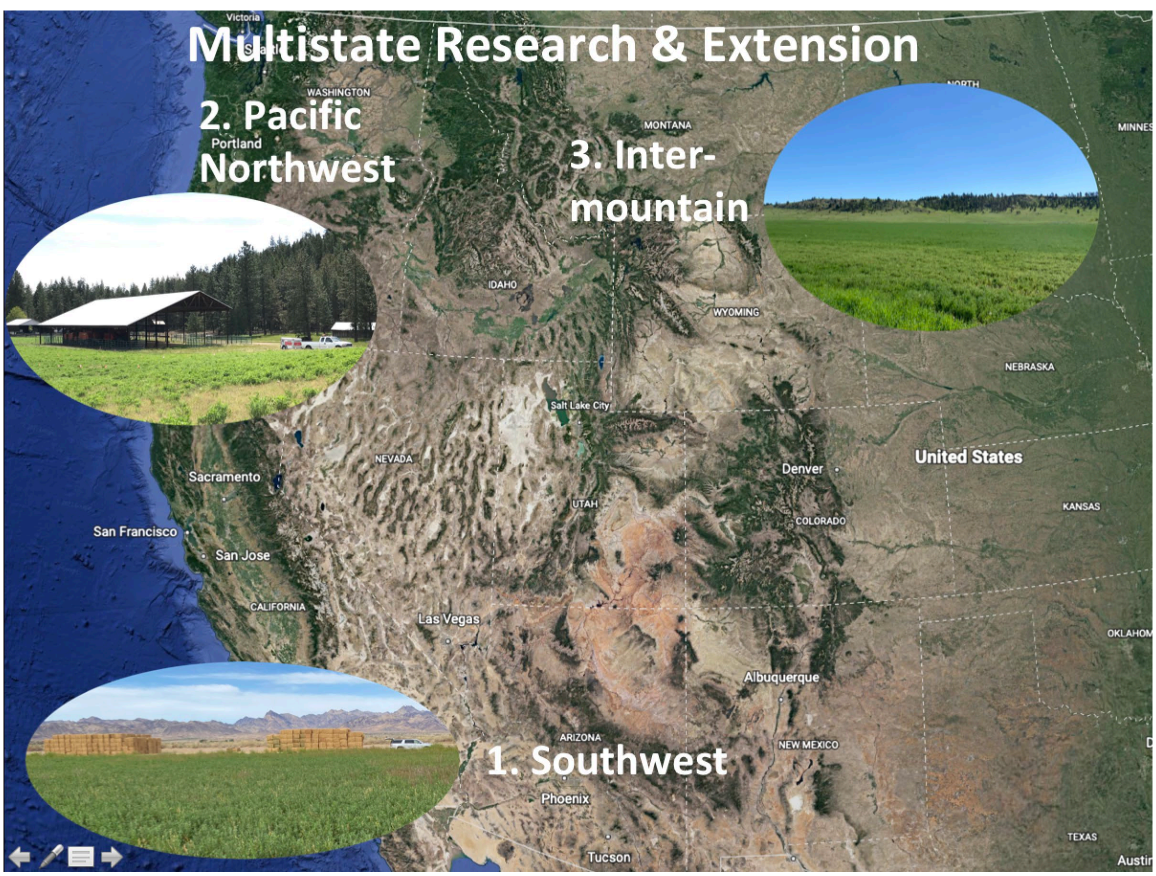
**March 1, 2021 – February 28, 2023**

## Summary


*Rationale and Objectives:* Alfalfa weevils have developed resistance to insecticides with pyrethroid active ingredients. Products such as Warrior II, Mustang Maxx, Baythroid XL, and generic formulations that are commonly used to control alfalfa weevil damage fail in areas where resistance has developed. During 2021 and 2022 insecticide trials were conducted in commercial alfalfa fields located in Arizona, Montana, and Washington States. New and currently registered insecticides were evaluated for alfalfa weevil control, including timing, rates, and mixtures, to provide best use recommendations.

*Study Description:* Commercial alfalfa fields known to have pyrethroid resistant alfalfa weevils were selected in three different regions of the Western US: 1. Parker AZ; 2. Goldendale & Yakima WA; and Lodge Grass MT (Figure 1.).


*Figure 1.* Commercial alfalfa fields known to have pyrethroid resistant alfalfa weevils were selected in three different regions of the Western US (Figure 1): 1. Parker AZ; 2. Goldendale & Yakima WA; and Lodge Grass MT.



*General Plot Layout:* Experimental plots measured 10’ X 30’ with 5 replicates for each treatment. An untreated 5’ buffer was maintained around every plot. Nineteen treatments were tested at multiple locations during the grant period (Table I.). Insecticides were applied at 25 PSI & 18 GPA using a Chapin™ 24v backpacker sprayer, a 4’ boom and TeeJet® nozzles (015 Green DG110-VS).

*Table I. List of treatment factors tested in multiple locations/states.*

| **Treatments** | **MOA** | **Active Ingredient** | **Rate oz/acre** |
|---|---|---|---|
| Warrior II-low rate | 3A | Lambda cyhalothrin | 1.28 |
| Warrior II-high rate | 3A | Lambda cyhalothrin | 1.92 |
| Steward-low rate | 22A | Indoxacarb | 6.7 |
| Steward-high rate | 22A | Indoxacarb | 11.3 |
| Exirel | 28 | Cyantraniliprole | 20.0 |
| Prevathon | 28 | Chlorantraniliprole | 20.0 |
| Besiege | 3A, 28 | Lambda cyhalothrin, Chlorantraniliprole | 10.0 |
| Endigo ZCX | 3A,4A | Thiamethoxam, Lambda cyhalothrin | 4.5 |
| Actara | 4A | Thiamethoxam | 3.46 |
| Mustang Maxx | 3A | Zeta-cypermethrin | 4.0 |
| Brigade | 3A | Bifenthrin | 6.4 |
| Permethrin | 3A | Permethrin | 8.0 |
| Baythroid XL | 3A | ß-cyfluthrin | 2.8 |
| Sevin XLR | 1A | Carbaryl | 48.0 |
| Diamethoate 400EC | 1B | Dimethoate | 16.0 |

*Analysis:* The day prior to spraying, and 3, 7 and 14 days (when available) after spraying insecticides, alfalfa weevil numbers were sampled with a 180° sweep net taken from each plot. At some locations 1 $ft^2$ stand samples were also cut and examined for larvae. Larvae were stored in 95% ethanol and for some sampling dates the larval stage was determined (1st, 2nd, 3rd, or 4th instars), (Figure 2.). The average numbers of alfalfa weevils were analyzed by ANOVA and Fisher (LSD) test.

*Summary Results:* All MoA3A pyrethroid insecticides were ineffective in areas with known resistance (control ranged from 40-80%), except for Brigade (bifenthrin, registered for seed alfalfa) (Figures 3, 4 & 5). In these same areas, Steward (indoxacarb) was effective at the lower 6.7 ounce/acre rate (control was typically > 90%). Higher rates of Steward may be necessary when early applications and extended persistence are required. Older product Sevin XLR (MoA 1) was not effective, and it produced phytotoxic yellowing of the alfalfa. Older product Dimethoate 400EC (MoA 1B) provided promising results, on its own in Montana, and mixed with a pyrethroid in Washington. Newer products Endigo and Actara (not registered) were effective only at 1 of 3 sites. Besiege, Prevalon, and Exirel provided unsatisfactory control of alfalfa weevil larvae in Montana (2021). One important result was learning that insecticide efficacy varied with geographic location. Another important result suggests that earlier timing of spray applications may provide better alfalfa weevil control. By conducting trials in the same commercial field in Montana for three consecutive years we were able to make a preliminary estimate of how quickly pyrethroid insecticides might regain their effectiveness (Figure 6.). When Steward MoA22A replaced MoA3A pyrethroids as the insecticide for three years control provided by Warrior increased from 0% to 80%.

*Figure 2. Insecticide timing. A) Early at peak 1$^{st}$ instars or B) Peak 2$^{nd}$ and 3$^{rd}$ instar stage).*

**A)**

**B)**

*Management Suggestions and Conclusions:* A specific MoA group insecticide should be applied once every three years at most; alfalfa weevil control methods should be rotated yearly. Forage alfalfa producers should use MoA3A pyrethroids no more than once every three years. The addition of dimethoate may improve efficacy of the pyrethroid when it is used. In most cases the 6.7 ounce/acre rate of Steward is effective, and Steward should be used only once every three years, to prevent resistance developing to this product. Products such as Endigo and Actara warrant further testing, particularly as early treatments, and efforts to register new MoA group insecticides for alfalfa continues to be a critical need for alfalfa weevil management.

*Figure 3. Percent (%) control of alfalfa weevils in the Southwestern Region 6 days after treatment (DAT). Insecticides applied at peak 2$^{nd}$ and 3$^{rd}$ instar stages.*

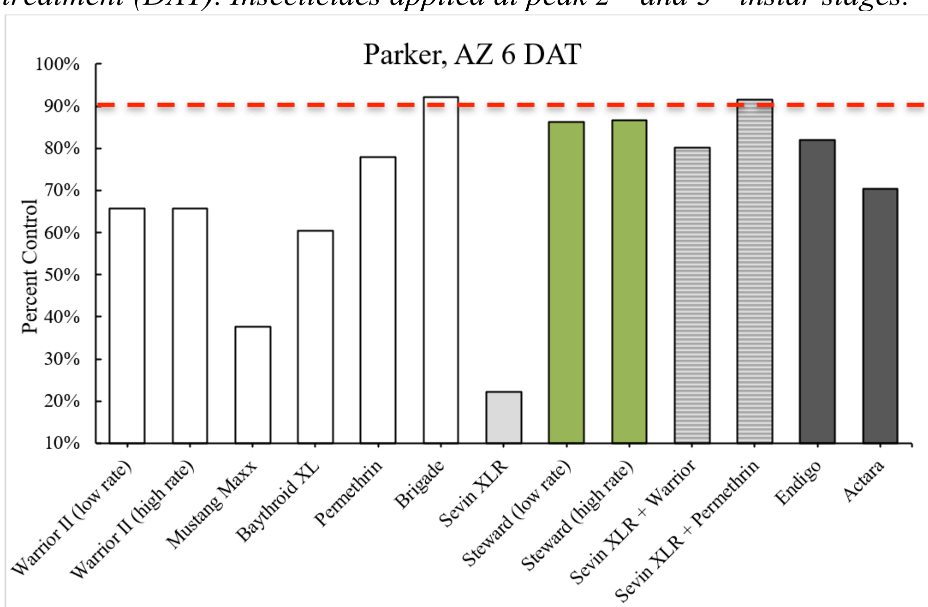


*Figure 4. Percent (%) control of alfalfa weevils in the Pacific Northwest Region6 days after treatment (DAT). Insecticides applied at peak 2nd and 3rd instar stages.*

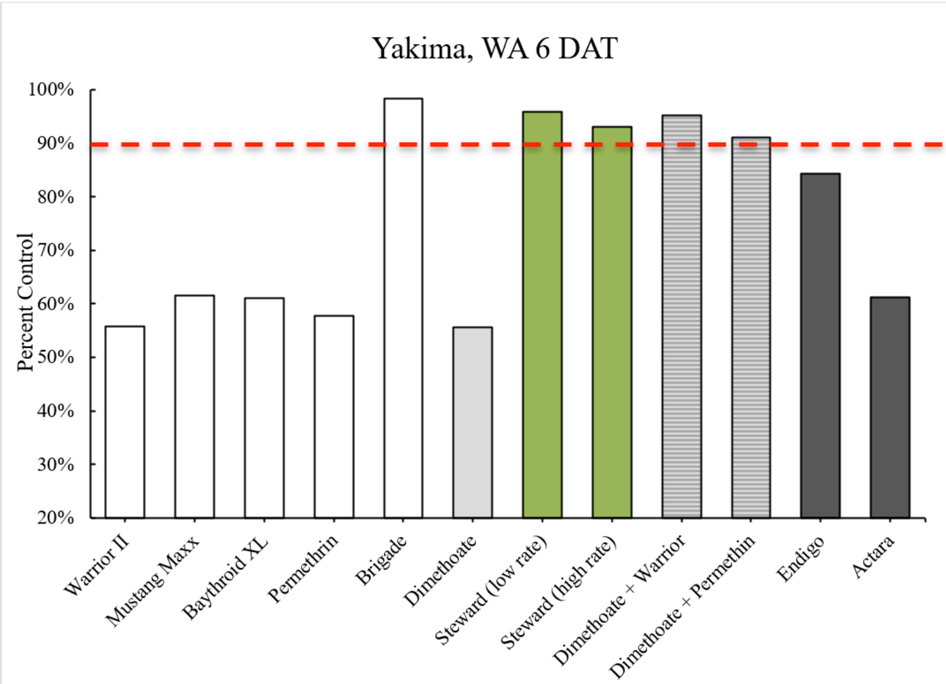



*Figure 5. Percent (%) control of alfalfa weevils in the Intermountain Region 6 days after treatment (DAT). Insecticides applied during peak 1st instar stage.*

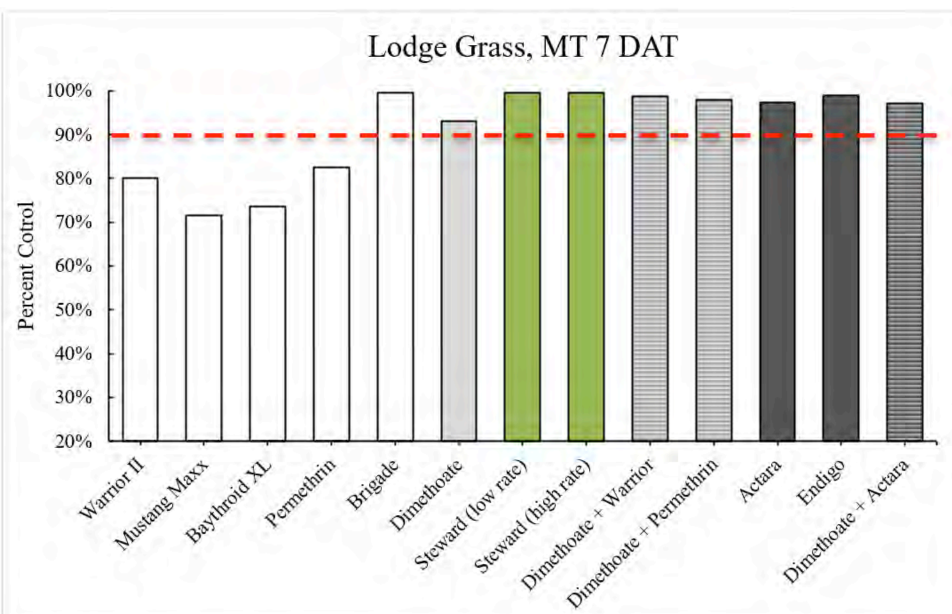
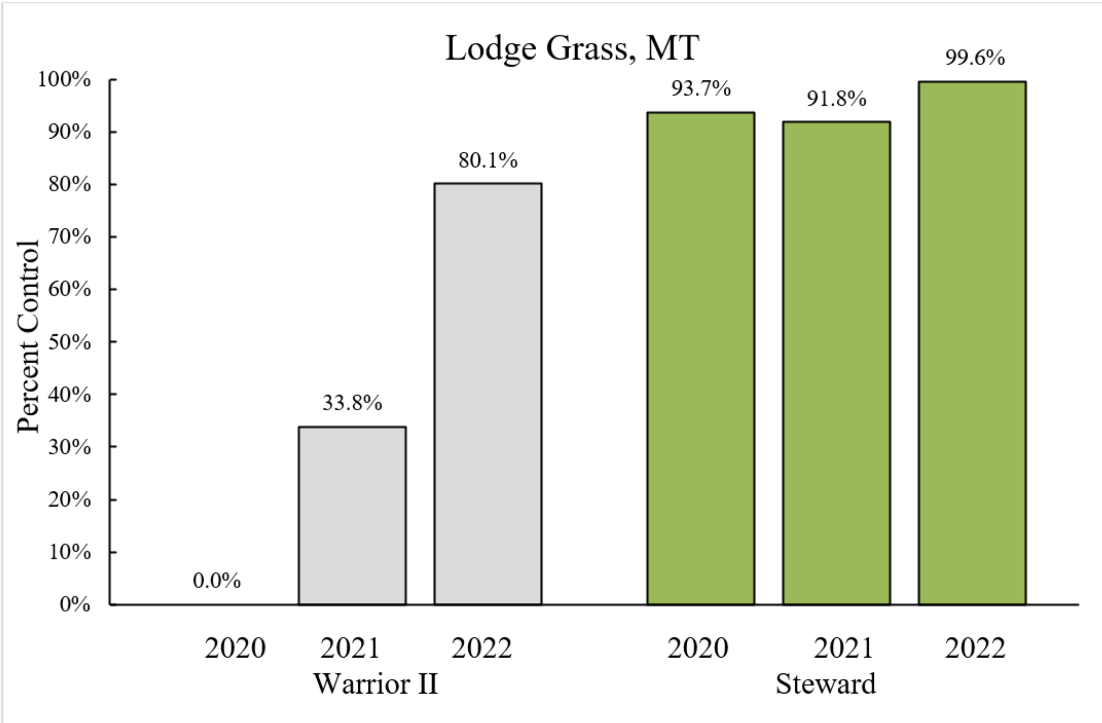


*Figure 6. Pyrethroid resistance declined (% control improved) during a three-year period when Steward replaced Warrior as the insecticide used in the commercial forage alfalfa field.*




## Extension and Outreach

*Articles*

**Wanner, K.W**., Caron[†], C., Goosey, H.B., Rodbell*, E.A. 2022. Efficacy of Select Insecticides to Control Pyrethroid Resistant Alfalfa Weevils. *Arthropod Management Tests*, 47, Issue 1, tsac062, https://doi.org/10.1093/amt/tsac062.

**Wanner, K.W**., Grettenberger, I., Rodbell, E.A. and Hendrick, M. Managing insecticide-resistant alfalfa weevils. Progressive Forage, 31 March 2022. https://www.progressiveforage.com/forage-production/pests-and-diseases/managing-insecticide-resistant-alfalfa-weevils

Vardiman, J., Schell, S., **Wanner, K.,** Rodbell, E., Ramirez, R., Bradshaw, J. (2022). Management of Insecticide Resistance in Alfalfa Weevil for the Intermountain West: Montana, Utah, Wyoming (MP-154 ed., pp. 6). University of Wyoming Extension.

**Wanner, K.W.** New efforts to research and manage alfalfa weevil. Progressive Forage, 29 March 2019. https://www.progressiveforage.com/forage-production/pests-and-diseases/new-efforts-to-research-and-manage-alfalfa-weevil

*Extension Talks - Regional and National*

Wanner, K.W. 2023. Defeating Resistant Super Weevils. Midwest Forage Association Symposium. February 21, 2023, Chula Vista, WI.

Wanner, K.W. 2022. Insects [alfalfa] with chewing mouthparts. 2022 World Alfalfa Congress, Alfalfa Irrigation & Pest Management Training Workshops. Workshop II – Pest Management. November 14-17, 2022, San Diego, CA.

Wanner, K.W. 2022. Insecticide Resistant Alfalfa Weevils in the Western US: Quantifying the Scope of Resistance and Implementing a Plan to Manage the Threat. 2022 North American Alfalfa Improvement Conference (NAAIC), June 7-9 2022, Lansing, MI (15 min presentation).

Wanner, KW. Insecticide Resistant Alfalfa Weevils in the Western US, an Update. Online presentation (30 min) to the Forage Genetics International R&D Group Meeting (June 20, 2022).

Wanner, KW. Insecticide Resistant Alfalfa Weevils in the Western US: Quantifying the Scope of Resistance & Implementing a Plant to Manage the Threat. 2022 North American Alfalfa Improvement Conference (NAAIC), June 7-9 2022, Lansing, MI (15 min presentation).

Wanner, KW. "Pyrethroid resistant alfalfa weevils", Online presentation (30 min) to the midwest regional working group of field crop entomologists. (June 6, 2022).

Grettenberger, I. (Author & Presenter), Wanner, K.W. (Author & Presenter), Rodbell, E., Hendrick, M. Alfalfa Weevil Management & Resistance Issues. Western Alfalfa & Forage Symposium, November 17, 2021, Reno NV.

Rodbell, E. (Author & Presenter), Wanner, K.W. (Author & Presenter). Insecticide Resistance for Alfalfa Weevils in Wyoming and Montana. Wyoming Pest Virtual Seminar Alfalfa Weevils, University of Wyoming Extension Webinar, March 2, 2021.

Wanner, K.W. Insecticide Resistant Alfalfa Weevils. Western Alfalfa Seed Growers Association, Las Vegas. (January 28, 2020).

Wanner, K.W. Management of Insecticide Resistance in Alfalfa. Alfalfa Integrated Pest Management Virtual Workshop, University of California, virtual. (December 4, 2020).

*Extension Talks - Montana*

Insecticide Recommendations for Grasshoppers, Wireworms and Pyrethroid Resistant Alfalfa Weevils. 2023 MABA/MGEA Annual Convention & Pesticide Workshop, January 25, Great Falls, MT.

Managing Grasshoppers and Insecticide Resistant Weevils. MSU Central Agricultural Research Center, Eddie's corner, December 13, 2022

2022 IPM Workshop - Hands-on work station, alfalfa weevil, 2 hrs, November 21, 2022

Pest Management Tour, Oct. 3-6, 2022. Biology and management of insecticide resistant alfalfa weevils. Billings, Roundup, Columbus, Big Timber and Harlowton.

Alfalfa Weevil Management & Insecticide Resistance Issues – 2022 Torgerson's Spring Hay Clinic. Great Falls, March 24; Lewiston, March 23; and Belgrade, March 22.

Wanner, K.W. (Author & Presenter), Rodbell, E. (Author & Presenter), Alfalfa Weevil Management and Insecticide Resistance. CCA and Dealer Training, August 6, 2021, Huntly MT.

Wanner, K.W. (Author), Rodbell, E. (Presenter). Managing Weevil & Aphids in Alfalfa. Virtual Alfalfa Training Event, Croplan by Winfield United, Virtual. (February 3, 2021).

Alfalfa Weevil Management and Resistance, December 1, 2020, Big Horn County Extension

2019 Pest Management Tour, Biology and Management of Alfalfa Weevil. Anaconda, Oct. 8; Deer Lodge, Oct. 8; Livingston, Oct 10; and Townsend, Dec 17.

## Full Report - 2021 Results

The effectiveness of 12 treatments to control alfalfa weevils resistant to lambda-cyhalothrin (Warrior II with Zeon Technology® and generic formulations) was evaluated in a commercial alfalfa field near Lodge Grass, Montana in Big Horn County MT. The mature stand was approximately 10 years old and maintained without irrigation (dryland production). Resistance to lambda-cyhalothrin was established based on lethal concentrations yielding 50% mortality ($LC_{50}$) in laboratory bioassays using treated glass vials. The $LC_{50}$ value recorded at this site was >3.3 ug/cm$^2$ compared to 0.03 – 0.1 ug/cm$^2$ recorded from susceptible populations in Powder River County MT located approximately 100 miles East (resistance ratio 33-330). In the first trial, Permethrin and Warrior II (MoA3A) were applied on 4 June 2021 with and without the synergist piperonyl butoxide (PBO) in comparison to Steward EC (MoA22A) and PBO only. In a second trial, the effectiveness of Besiege, Exirel, Prevathon, Endigo ZCX and Steward EC applied on 5 Jun 2021 were evaluated in comparison to an untreated check.

A 25-gallon FIMCO spray tank with a 10-foot spray boom (seven flat fan type nozzles each calibrated at 0.20 gallons/minute) mounted to the back of the ATV was used to apply the foliar insecticides at a rate of 18 gpa. Plots measured 25 x 100 feet and treatments were replicated four times in a RCB design. Alfalfa weevil populations were estimated before and after treatment by cutting a random 1 ft$^2$ area of the alfalfa stand (down to ground level) and by taking 10 sweeps per plot using a standard sweep net (15-inch diameter). Two random 1 ft$^2$ samples were removed from each plot (2 ft$^2$ total sample area per plot) one day prior to treatment, on 14 Jun (10 DAT in Trial 1, 9 DAT in Trial 2) and on 22 Jun 2021 (18 DAT in Trial 1 and 17 DAT in Trial 2). Ten sweep samples were taken from each block one day prior to treatment, and from each plot on 14 Jun 2021 (10 DAT in Trial 1, 9 DAT in Trial 2). The total number of alfalfa weevil larvae and adults were sorted from the samples and counted in an entomology laboratory at Montana State University, Bozeman, MT. Treatment effects were analyzed by ANOVA and significant differences between means determined by a Tukey HSD test (Minitab ver 19).

In the first trial pre-treatment counts were consistent between plots and treatment effects were significant at 10 (cutting sample and sweep net sample) and 18 DAT (cutting sample) (Table 1). All treatments significantly reduced alfalfa weevil counts / 2 ft$^2$ compared to PBO alone at 10 DAT. Also at 10 DAT numbers larvae per 10 sweeps were significantly lower in plots treated with Permethrin or Steward but not Warrior II. The addition of PBO to Permethrin and Warrior II did not result in significantly alfalfa weevil counts compared to PBO alone. Steward was the only treatment to reduce counts more than 90% compared to PBO only. In the second trial pre-treatment counts were consistent between plots and treatment effects were significant 9 (cutting sample and sweep net sample) and 17 DAT (cutting sample) (Table 2). Only Endigo ZCX and Steward significantly reduced the 2 ft$^2$ alfalfa weevil counts compared to the untreated check at 9 DAT. Also at 9 DAT numbers of larvae per 10 sweeps were significantly lower in plots treated with Endigo ZCX, Steward, or Exirel. Endigo ZCX and Steward were the only treatments to reduce counts more than 90% compared to the untreated check.[1]

Table 1.

| | | Total larvae per 1ft$^2$ cutting | | | *Total larvae* (10 sweeps / block) | *Total larvae* (10 sweeps / plot) |
|---|---|---|---|---|---|---|
| | Rate / acre | Pre-treatment | 10 DAT | 18 DAT | Pre-treatment[a] | 10 DAT |
| *Treatment/Form.* | oz form. | 6-4-21 | 6-14-21 | 6-22-21 | 6-4-21 | 6-14-21 |
| *Permethrin* | 8.0 | 103 | 22bc | 5bc | 270 | 310c |
| *Permethrin + PBO- 8 8EC* | 8.0 + | 141 | 21c | 10bc | 270 | 474bc |
| *Warrior II 2.08CS* | 2.0 | 115 | 56b | 30a | 270 | 820ab |
| *Warrior II 2.08CS+ PBO-8 8EC* | 2.0 + | 123 | 35bc | 14ab | 270 | 583abc |
| *Steward 1.25EC* | 6.7 | 220 | 6c | 1c | 270 | 87c |
| *PBO-8* | 8.0 | 157 | 107a | 17a | 270 | 1061a |
| *P>F* | | NA | <0.01 | <0.01 | NA | <0.001 |

Means within columns followed by a common letter are not significantly different ($P \leq 0.05$, Tukey LSD).
[a]Pre-treatment sweep samples consisted of 10 sweeps per block (n = 4 blocks).

Table 2.

| | | Total larvae per $1 ft^2$ cutting | | | *Total larvae* (10 sweeps / block) | *Total larvae* (10 sweeps / plot) |
|---|---|---|---|---|---|---|
| | Rate / acre | Pre-treatment | 9 DAT | 17 DAT | Pre-treatment[a] | 9 DAT |
| *Treatment/Form.* | oz form. | 6-5-21 | 6-14-21 | 6-22-21 | 6-4-21 | 6-14-21 |
| *Besiege 1.252CS* | 10.0 | 181 | 57ab | 23ab | 584 | 555ab |
| *Exirel 0.83SC* | 20.0 | 170 | 63ab | 5b | 584 | 254bc |
| *Prevathon 0.43SC* | 20.0 | 225 | 40ab | 16b | 584 | 428abc |
| *Endigo ZCX 2.7CS* | 4.0 | 203 | 11b | 8b | 584 | 55bc |
| *Steward 1.25EC* | 11.3 | 238 | 9b | 7b | 584 | 21c |
| *Untreated Check* | - | 206 | 143a | 37.75a | 584 | 938a |
| *P>F* | | NA | <0.001 | <0.001 | NA | 0.002 |

Means within columns followed by a common letter are not significantly different (P ≤ 0.05, Tukey LSD).

[a]Pre-treatment sweep samples consisted of 10 sweeps per block (n = 4 blocks)

## Full Report - 2022 Results

During 2022, sixteen treatments were tested at four field sites in three different states: Parker Arizona, Goldendale and Yakima Washington and Montana.

*Methods:* The efficacy of insecticide applications was evaluated for crop protection and control of alfalfa weevil (AW) larvae. Fields trials were established at four sites in the western United States, on populations of alfalfa weevil with known resistance to pyrethroids. Plot size was 10' X 30' and the experiments were a RCB design, (n = 5 blocks per treatment). The corner of each plot was marked with 2.5 ft survey flags. A 5' buffer was included in-between every plot and between blocks. The site in Goldendale, WA included a replicated trial and along with a demonstration strip trial. Treatments were not replicated for the demonstration strip trial and each strip was 10' X 120'.

Chapin™ 4 gallon, 24v backpacker sprayers were equipped with Chapin™ 4-nozzle poly spray booms. TeeJet® nozzles (015 Green DG110-VS) were spaced 17 inches apart and along the boom. The sprayers were equipped with built-in, inline pressure regulators, allowing for adjustment of the PSI. The inline pressure regulators were set at 25 PSI to deliver applications at an 18 GPA rate. While spraying, the boom was held approximately 14 inches above the alfalfa canopy. Plots were spray in two-passes, at a brisk walking speed of 7.2 seconds per 30 ft (length of plot). The rates of each treatment are listed in *Table i*. Each treatment was applied with Preference® adjuvant at a rate of 2 pints per 100 gallons. Tank mixture treatments (ex. Dimethoate + Warrior) always used the high label rate of both treatments.

The foliar spray trial was set up in 4 locations across the western United States: 1.) On 18 Feb a trial was sprayed on a flood-irrigated alfalfa stand in Parker, AZ (33.863426, -114.4288285). 2.) On 13 May a trial was sprayed on a pivot-irrigated alfalfa stand near Yakima, WA (46.3259328, -120.4360329). 3.) On 15 May and 16 May a replicated trial and non-replicated demonstration trial was sprayed on a dry-land alfalfa stand in Goldendale, WA, respectively (45.8892896, -120.9722321). 4.) On 8 Jun a trial was sprayed on a dryland alfalfa stand in Lodge Grass, MT (45.1772911, -107.2960665). (Appendices I – IV).

Comprehensive sampling was conducted at all trial locations. Prior to treatment, pre-spray samples were collected; these consisted of 10-sweep net samples and 1$ft^2$ cuttings from each untreated control (UTC) plot. Following treatment, plots were sampled using the 10-sweep method and/ or 1$ft^2$ cuttings. Post-treatment sampling was conducted at varying increments, the chief target date being 7 days after treatment (DAT). Samples were sealed in paper bags and stored in freezers at 0°F until processed. AW larvae from 10-sweep samples were counted and stored in 95% ethanol. 1$ft^2$ cuttings were sorted by hand and AW larvae were counted and stored in 95% ethanol.

Statistical analysis was performed using Minitab® 20. The data was recorded in Microsoft Excel. A general linear model (GLM) was used to determine significance of treatment and block effects. A Fisher (LSD) test was used to test for significant differences between treatment means.

## Results

**Parker, AZ**

10-sweep samples from 21 Feb (3 DAT) and 24 Feb (6 DAT) were analyzed. Mean canopy height at 6 DAT was approximately 10 inches. Significant treatment effects were detected at 3 DAT (Table 3., Figure 7.). The best treatment, Sevin XLR + Permethrin, had 93.9% less AW larvae when compared to the UTC. Significant treatments effects were also detected at 6 DAT (Table 4., Figure 8.). Sevin XLR + Permethrin was the best performing treatment, resulting in a 91.6% reduction in AW larvae compared to the UTC. However, Sevin XLR caused significant phytotoxicity of the alfalfa.

**10-sweeps, 3 DAT**

GLM results:

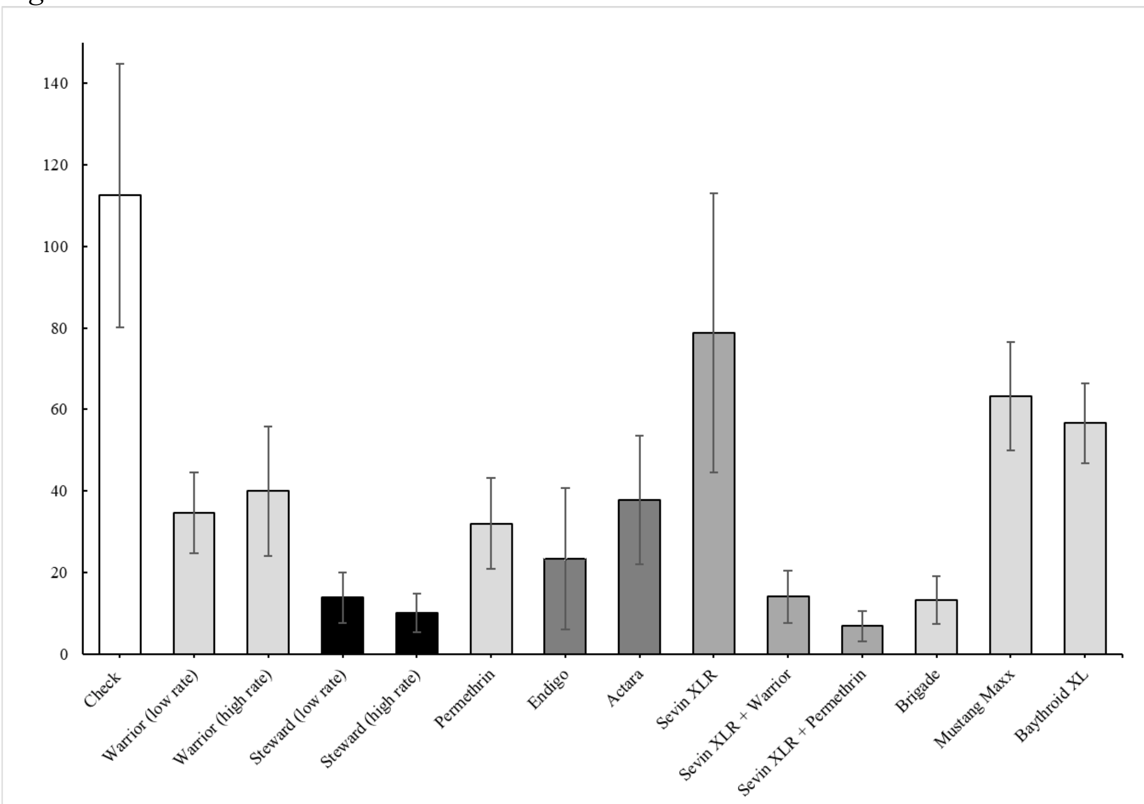
| Source | P-value |
|---|---|
| Treatment | <0.001 |
| Block | 0.136 |

*Table 3.*

| Grouping Information Using Fisher LSD Method and 95% Confidence | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Treatment | N | Mean | Grouping | | | | | | |
| Check | 4 | 111.3 | A | | | | | | |
| Sevin XLR | 5 | 78.8 | | B | | | | | |
| Mustang Maxx | 5 | 63.2 | | B | C | | | | |
| Baythroid XL | 5 | 56.6 | | | C | D | | | |
| Warrior (high rate) | 5 | 40.0 | | | | D | E | | |
| Actara | 5 | 37.8 | | | | D | E | | |
| Warrior (low rate) | 5 | 34.6 | | | | | E | | |
| Permethrin | 5 | 32.0 | | | | | E | F | |
| Endigo | 5 | 23.4 | | | | | E | F | G |
| Steward (low rate) | 5 | 13.8 | | | | | | F | G |
| Sevin XLR + Warrior | 5 | 13.3 | | | | | | F | G |
| Brigade | 5 | 13.2 | | | | | | F | G |
| Steward (high rate) | 5 | 10.0 | | | | | | | G |
| Sevin XLR + Permethrin | 5 | 6.8 | | | | | | | G |

*Means that do not share a letter are significantly different.*

*Figure 7.*




*Error bars represent one standard deviation.*

**10-sweeps, 6-DAT**

*Table 4.*

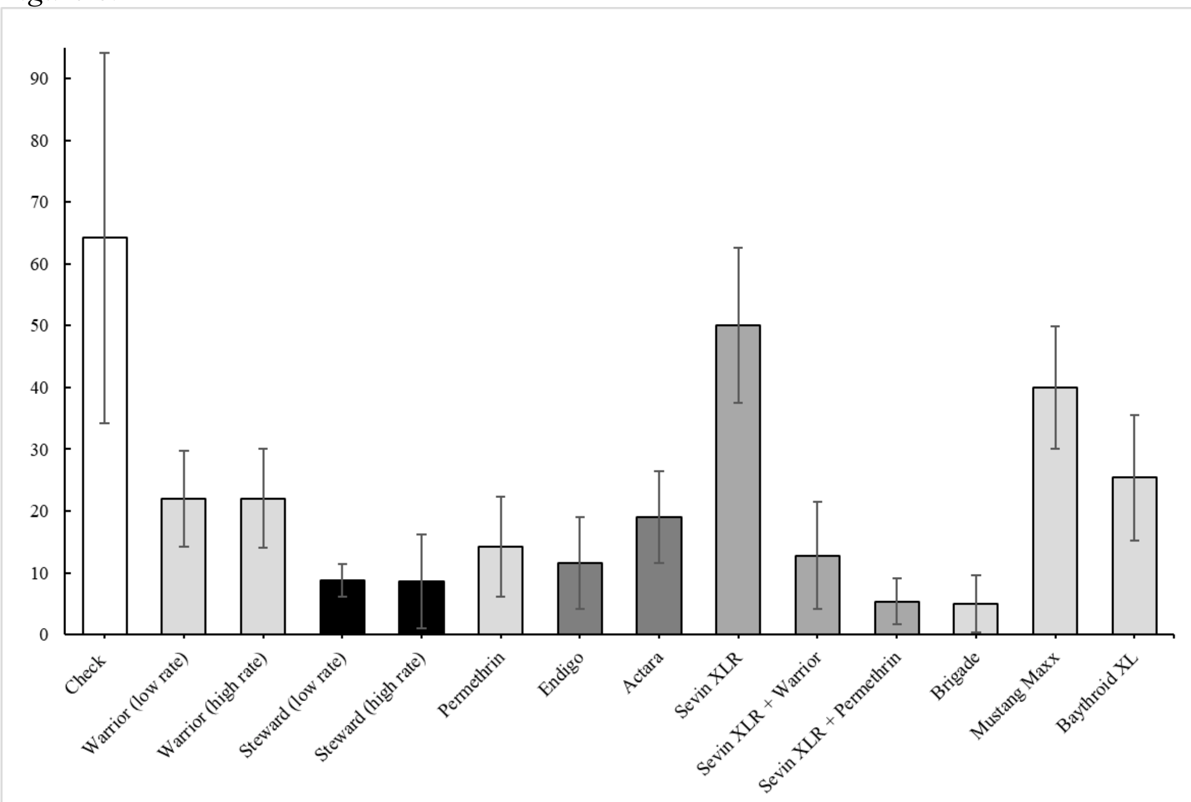
| Grouping Information Using Fisher LSD Method and 95% Confidence | | | | | | | |
|---|---|---|---|---|---|---|---|
| Treatment | N | Mean | Grouping | | | | |
| Check | 5 | 64.2 | A | | | | |
| Sevin XLR | 5 | 50.0 | | B | | | |
| Mustang Maxx | 5 | 40.0 | | B | | | |
| Baythroid XL | 5 | 25.4 | | | C | | |
| Warrior (low rate) | 5 | 22.0 | | | C | D | |
| Warrior (high rate) | 5 | 22.0 | | | C | D | |
| Actara | 5 | 19.0 | | | C | D | E |
| Permethrin | 5 | 14.2 | | | C | D | E |
| Sevin XLR + Warrior | 5 | 12.8 | | | C | D | E |
| Endigo | 5 | 11.6 | | | C | D | E |
| Steward (low rate) | 5 | 8.8 | | | | D | E |
| Steward (high rate) | 5 | 8.6 | | | | D | E |
| Brigade | 4 | 6.3 | | | | | E |
| Sevin XLR + Permethrin | 5 | 5.4 | | | | | E |

*Means that do not share a letter are significantly different.*

GLM results:

| Source | P-value |
|---|---|
| Treatment | <0.001 |
| Block | 0.265 |

*Figure 8.*




*Error bars represent one standard deviation.*

**Yakima, WA**
10-sweep samples were taken 6 DAT on19 May. On this date, mean canopy height was approximately 20 inches. Significant treatment effects were detected from the 10-sweep samples at 6 DAT (Table 5. Figure 9.). The best treatment, Brigade, had a 98.3% reduction in AW larvae when compared to the UTC. All treatments tested showed a significant reduction of AW larvae compared to UTC (figure).

**20-sweeps, 6-DAT**
GLM results:

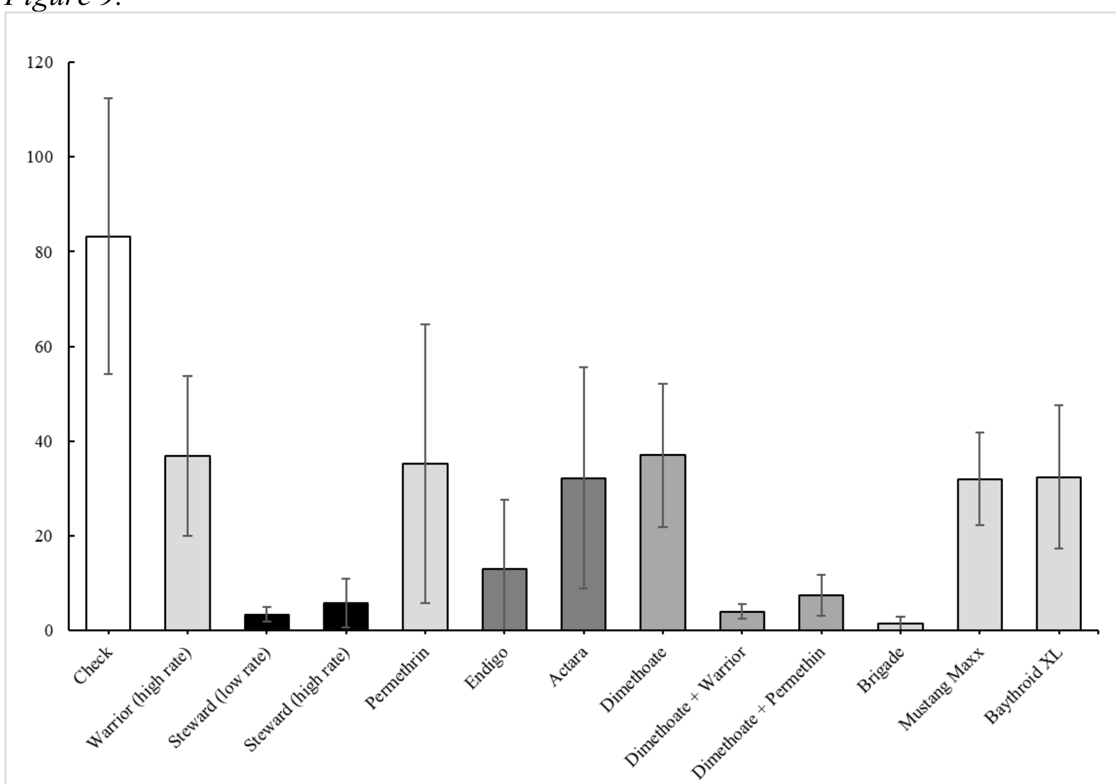
| Source | P-value |
|---|---|
| Treatment | <0.001 |
| Block | 0.565 |

*Table 5.*

| Grouping Information Using Fisher LSD Method and 95% Confidence | | | | | | |
|---|---|---|---|---|---|---|
| Treatment | N | Mean | Grouping | | | |
| Check | 5 | 83.2 | A | | | |
| Dimethoate | 5 | 37 | | B | | |
| Warrior (high rate) | 5 | 36.8 | | B | | |
| Permethrin | 5 | 35.2 | | B | | |
| Baythroid XL | 5 | 32.4 | | B | C | |
| Actara | 5 | 32.2 | | B | C | |
| Mustang Maxx | 5 | 32 | | B | C | |
| Endigo | 5 | 13 | | | C | D |
| Dimethoate + Permethrin | 5 | 7.4 | | | | D |
| Steward (high rate) | 5 | 5.8 | | | | D |
| Dimethoate + Warrior | 5 | 4 | | | | D |
| Steward (low rate) | 5 | 3.4 | | | | D |
| Brigade | 5 | 1.4 | | | | D |

*Means that do not share a letter are significantly different.*

*Figure 9.*




*Error bars represent one standard deviation.*

**Goldendale, WA**
Samples were collected from Goldendale on 20 May. The mean canopy height was 18 inches. At 5 DAT AW larvae were in the early instar stages, and the numbers captured from 10-sweeps, were not great enough to provide statistical significance between treatments. However, the numbers of AW larvae captured from the 1ft$^2$ cuttings (5 DAT) were significantly different between treatment (Table 6. Figure 10.). The best treatment, Brigade, resulted in an 85.8% reduction of AW larvae when compared to the UTC. 10-sweep samples from 26 May (11 DAT) also showed significant differences between treatments (Table 7. Figure 11.). The best treatment, Steward, had a 92.5% decrease in AW larvae compared to the UTC. Brigade plots were not sampled 11 DAT because crop destruction procedures took place prior to this sample date.
A non-replicated, demonstration trial showed varying levels of control between treatments and the UTC. At 10 DAT, Steward treatments and dimethoate treatments provided 90% or greater control when compared to the UTC, while pyrethroid treatment (warrior and permethrin) displayed unsatisfactory control of AW larvae (Figure 12.). The highest numbers of AW larvae captured by 10-sweep samples occurred on 9 Jun (24 DAT), (Figure 13.). Steward (high rate) was the best treatment, resulting in a 98.4% reduction of AW larvae compared to the UTC.

**1ft$^2$ cuttings, 5 DAT**
GLM results:

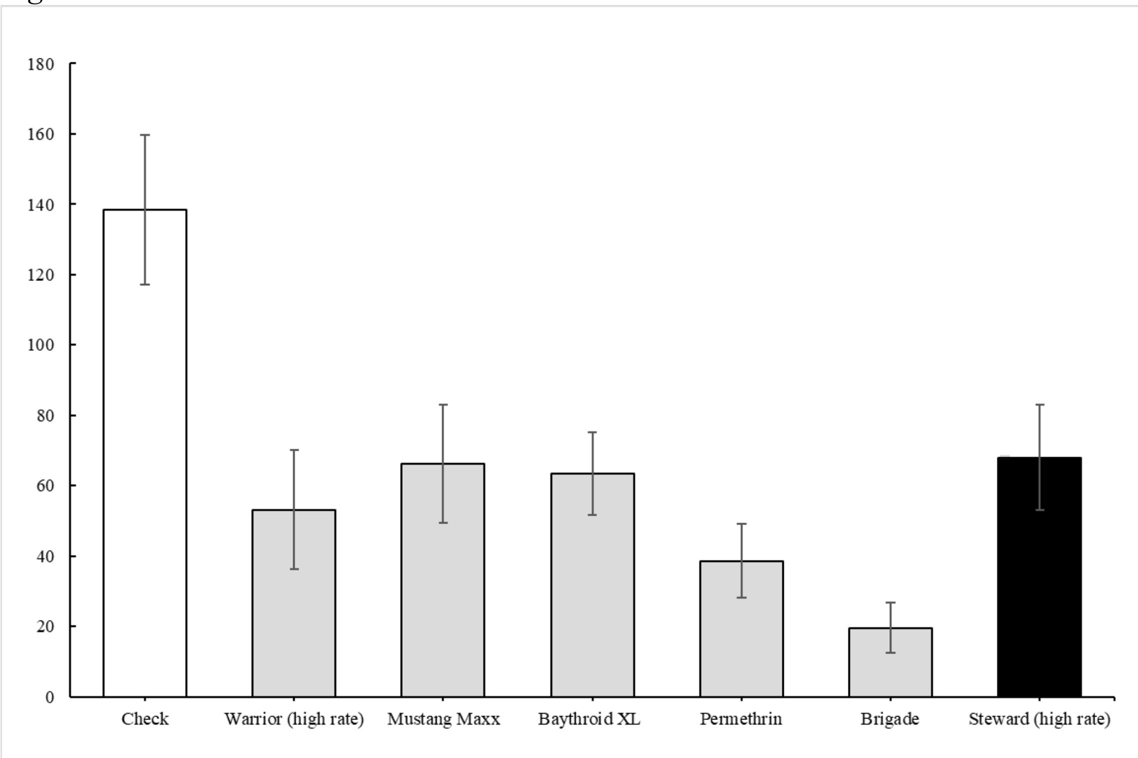
| Source | P-value |
|---|---|
| Treatment | <0.001 |
| Block | 0.525 |

*Table 6.*

| Grouping Information Using Fisher LSD Method and 95% Confidence | | | | | | |
|---|---|---|---|---|---|---|
| Treatment | N | Mean | Grouping | | | |
| Check | 5 | 138.4 | A | | | |
| Steward (high rate) | 5 | 68 | | B | | |
| Mustang Maxx | 5 | 66.2 | | B | | |
| Baythroid XL | 5 | 63.4 | | B | | |
| Warrior (high rate) | 5 | 53.2 | | B | C | |
| Permethrin | 5 | 38.6 | | | C | D |
| Brigade | 5 | 19.6 | | | | D |

*Means that do not share a letter are significantly different.*

*Figure 10.*




*Error bars represent one standard deviation.*

**10-sweeps, 11 DAT**

GLM results:

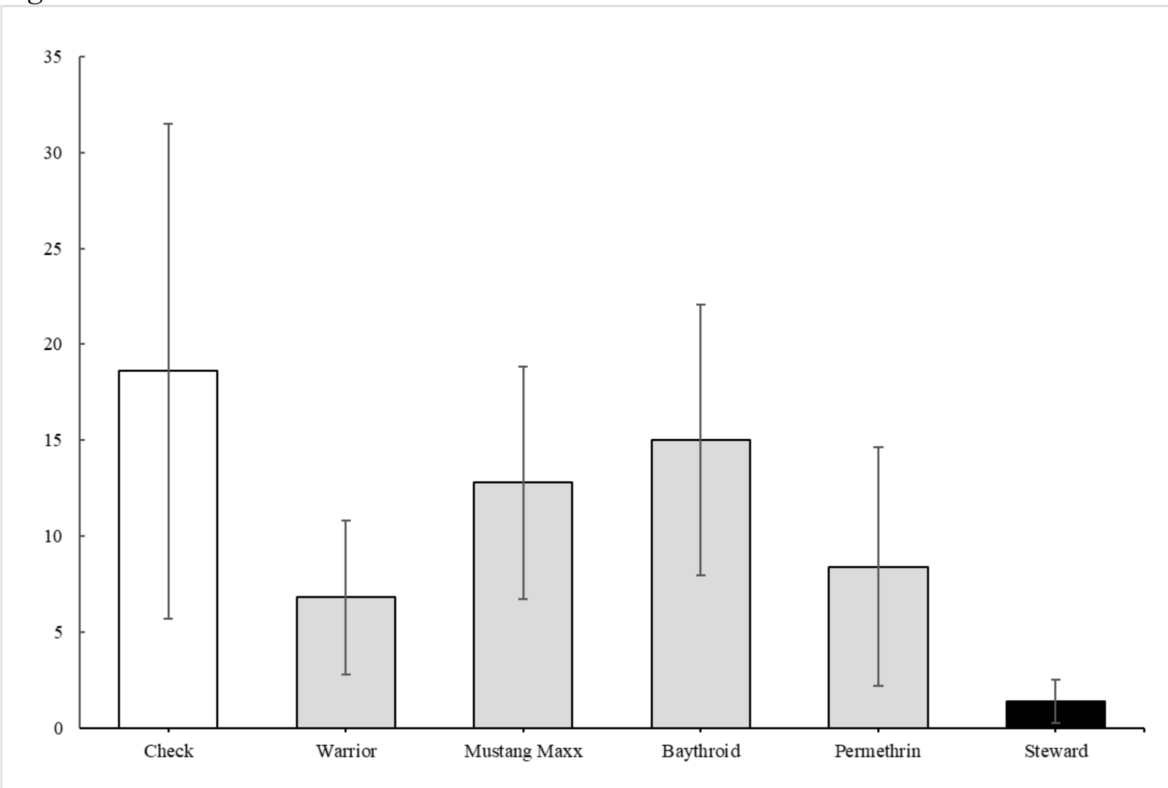
| Source | P-value |
|---|---|
| Treatment | 0.024 |
| Block | 0.859 |

*Table 7.*

| Grouping Information Using Fisher LSD Method and 95% Confidence | | | | | |
|---|---|---|---|---|---|
| Treatment | N | Mean | Grouping | | |
| Check | 5 | 18.6 | A | | |
| Baythroid XL | 5 | 15 | A | B | |
| Mustang Maxx | 5 | 12.8 | A | B | |
| Permethrin | 5 | 8.4 | | B | C |
| Warrior (high rate) | 5 | 6.8 | | B | C |
| Steward (high rate) | 5 | 1.4 | | | C |

*Means that do not share a letter are significantly different.*

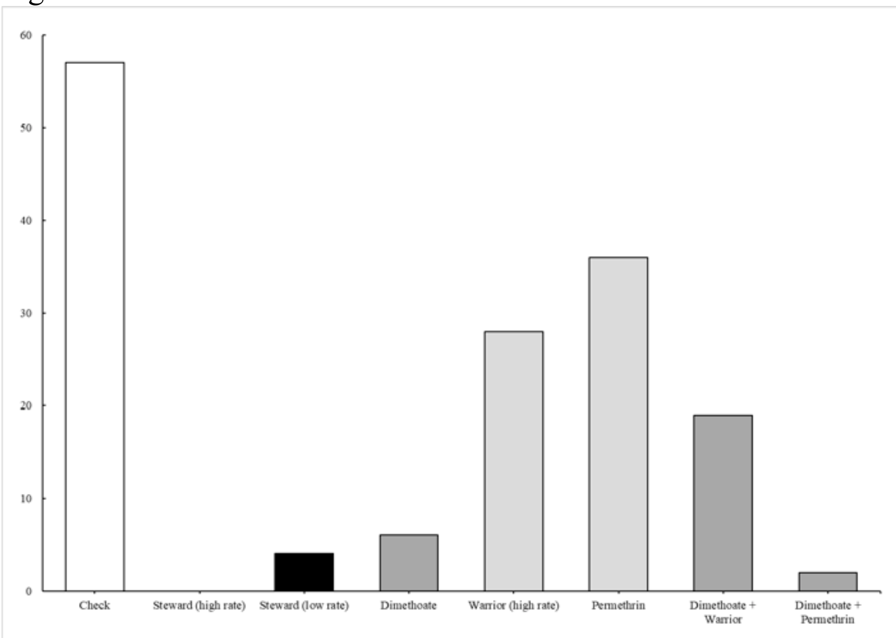
*Figure 11.*




*Error bars represent one standard deviation.*

**Demonstration Trial (Goldendale)**
10-sweeps, 10 DAT

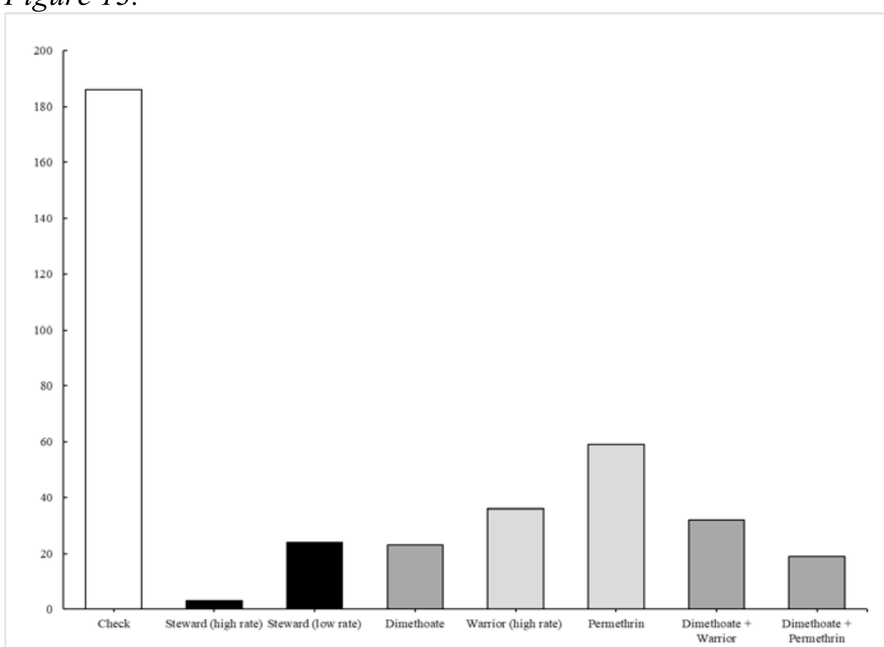
Figure 12.




*Treatments with similar mode of action are grouped by like color.*

10-sweeps, 24 DAT

*Figure 13.*




**Lodge Grass, MT**

Plots were sampled on 15 Jun (7 DAT). The analysis of both the 10-sweep samples and 1ft$^2$ cuttings revealed significant differences between treatments. Brigade was the best treatment for both sample types. Brigade plots had a 99.8% reduction of AW larvae in the 10-sweeps samples when compared to the UTC (Table 8., Figure 14.). Brigade resulted in a 94.9% reduction of AW larvae in the 1ft$^2$ cuttings when compared to the UTC (Table 9., Figure 15.).

**10-sweeps, 7-DAT**

GLM results:

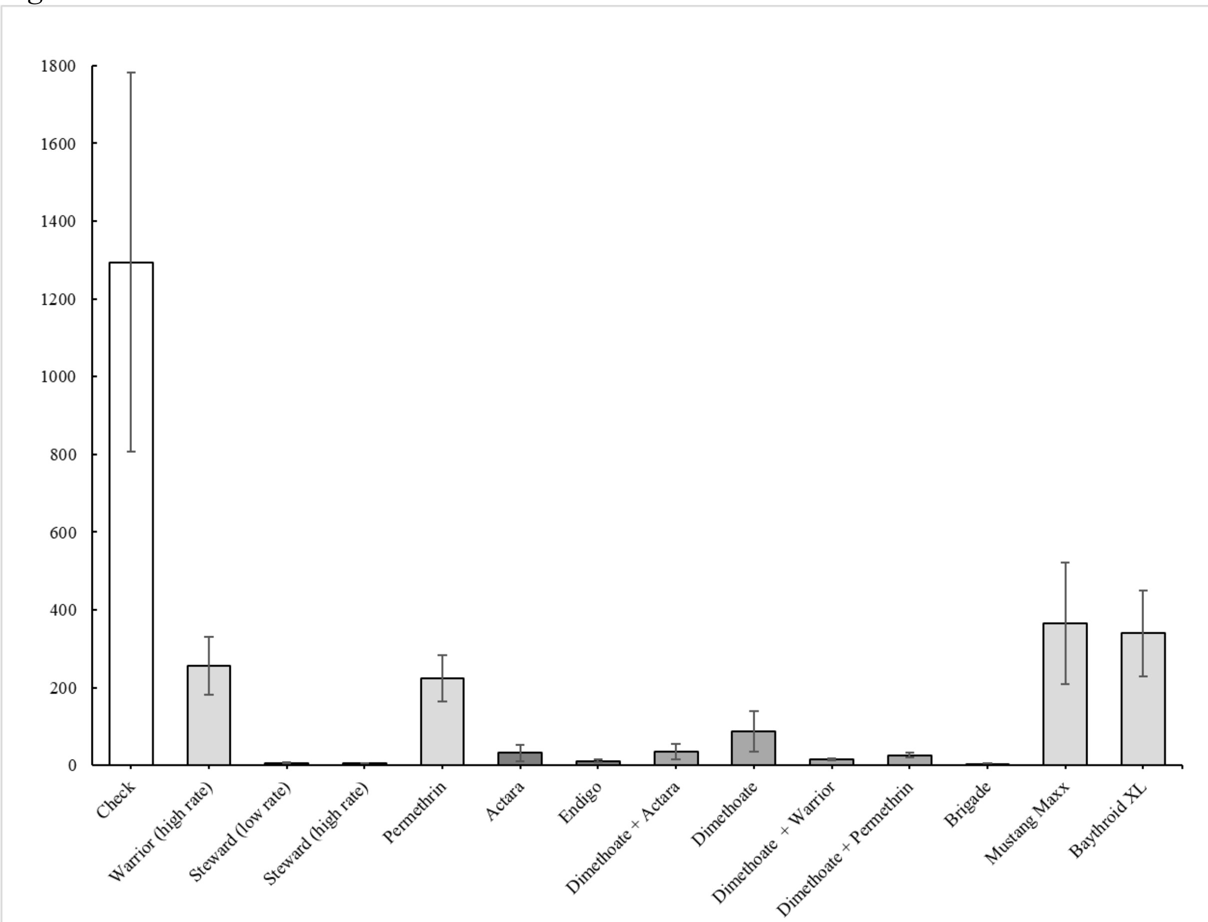
| Source | P-value |
|---|---|
| Treatment | <0.001 |
| Block | 0.736 |

*Table 8.*

| Grouping Information Using Fisher LSD Method and 95% Confidence | | | | | | |
|---|---|---|---|---|---|---|
| Treatment | N | Mean | Grouping | | | |
| Check | 5 | 1294 | A | | | |
| Mustang Maxx | 5 | 365 | | B | | |
| Baythroid XL | 5 | 339.2 | | B | | |
| Warrior (high rate) | 5 | 257 | | B | C | |
| Permethrin | 5 | 223.6 | | B | C | |
| Dimethoate | 5 | 87.8 | | | C | D |
| Actara + Dimethoate | 5 | 35.6 | | | | D |
| Actara | 5 | 32.2 | | | | D |
| Dimethoate + Permethrin | 5 | 25.8 | | | | D |
| Dimethoate + Warrior | 5 | 15.6 | | | | D |
| Endigo | 5 | 11 | | | | D |
| Steward (low rate) | 5 | 5 | | | | D |
| Steward (high rate) | 5 | 5 | | | | D |
| Brigade | 5 | 3 | | | | D |

*Means that do not share a letter are significantly different.*

*Figure 14.*




*Error bars represent one standard deviation.*

**1ft$^2$ samples, 7 DAT**

GLM results:

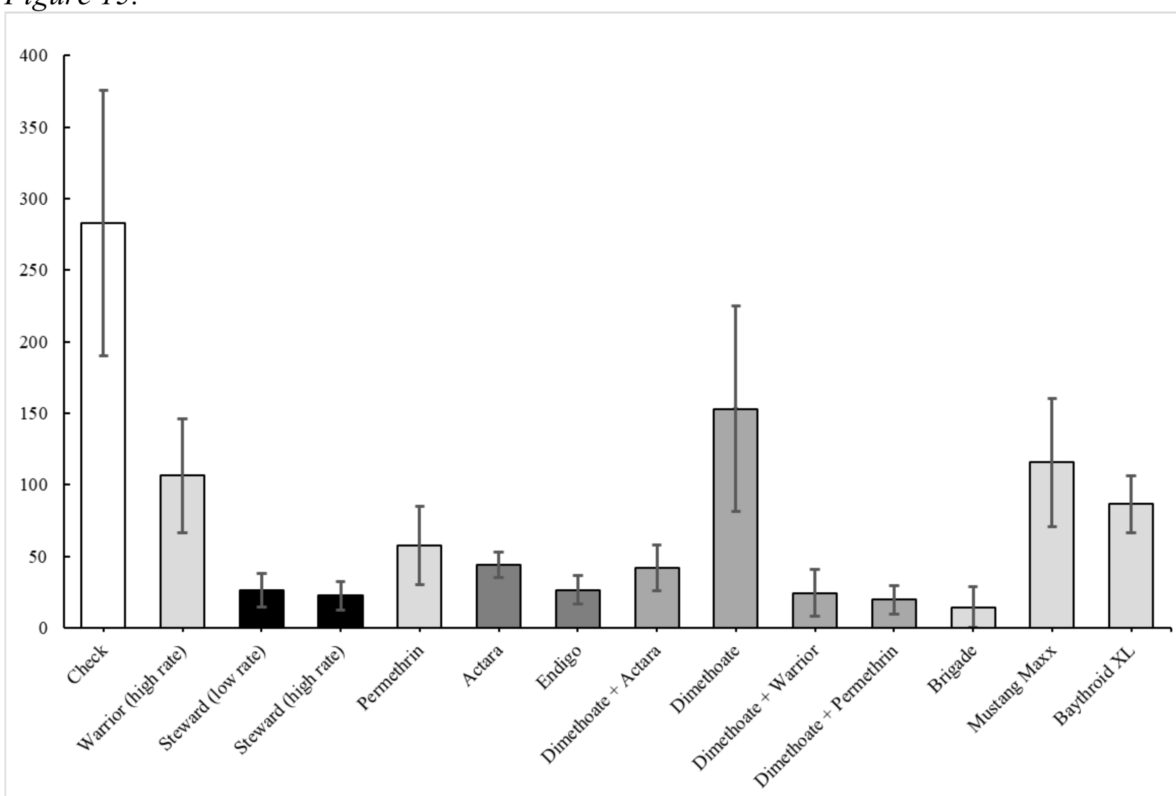
| Source | P-value |
|---|---|
| Treatment | <0.001 |
| Block | 0.126 |

*Table 9.*

| Grouping Information Using Fisher LSD Method and 95% Confidence | | | | | | | |
|---|---|---|---|---|---|---|---|
| Treatment | N | Mean | Grouping | | | | |
| Check | 5 | 283.0 | A | | | | |
| Dimethoate | 5 | 153.0 | | B | | | |
| Mustang Maxx | 5 | 115.8 | | B | C | | |
| Warrior (high rate) | 5 | 106.4 | | | C | | |
| Baythroid XL | 5 | 86.4 | | | C | D | |
| Permethrin | 5 | 57.8 | | | | D | E |
| Actara | 5 | 44.0 | | | | D | E |
| Actara + Dimethoate | 5 | 42.2 | | | | D | E |
| Endigo | 5 | 26.4 | | | | | E |
| Setward (low rate) | 5 | 26.2 | | | | | E |
| Dimethoate + Warrior | 5 | 24.2 | | | | | E |
| Steward (high rate) | 5 | 22.4 | | | | | E |
| Dimethoate + Permethrin | 5 | 19.6 | | | | | E |
| Brigade | 5 | 14.4 | | | | | E |

*Means that do not share a letter are significantly different.*

*Figure 15.*

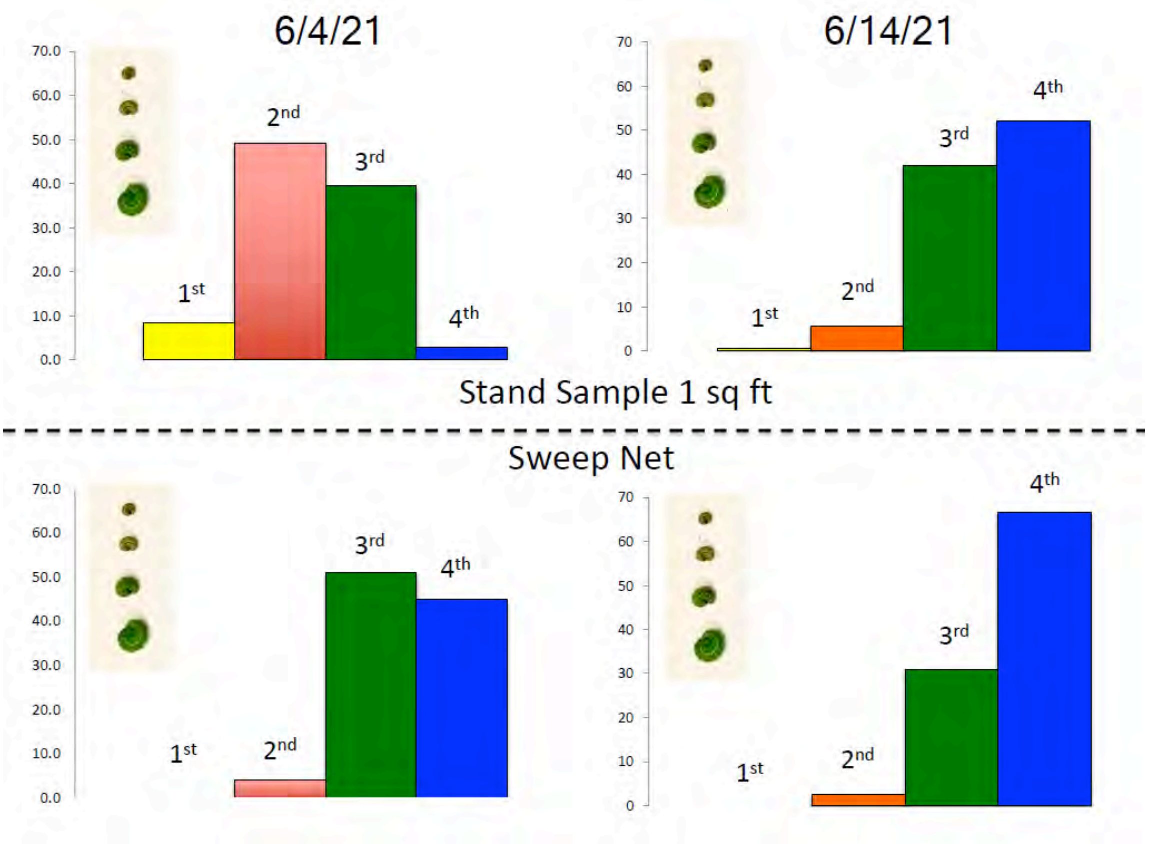



*Error bars represent one standard deviation.*

*Additional Analysis – Sweep Net Samples vs 1 ft² Stand Cuttings*

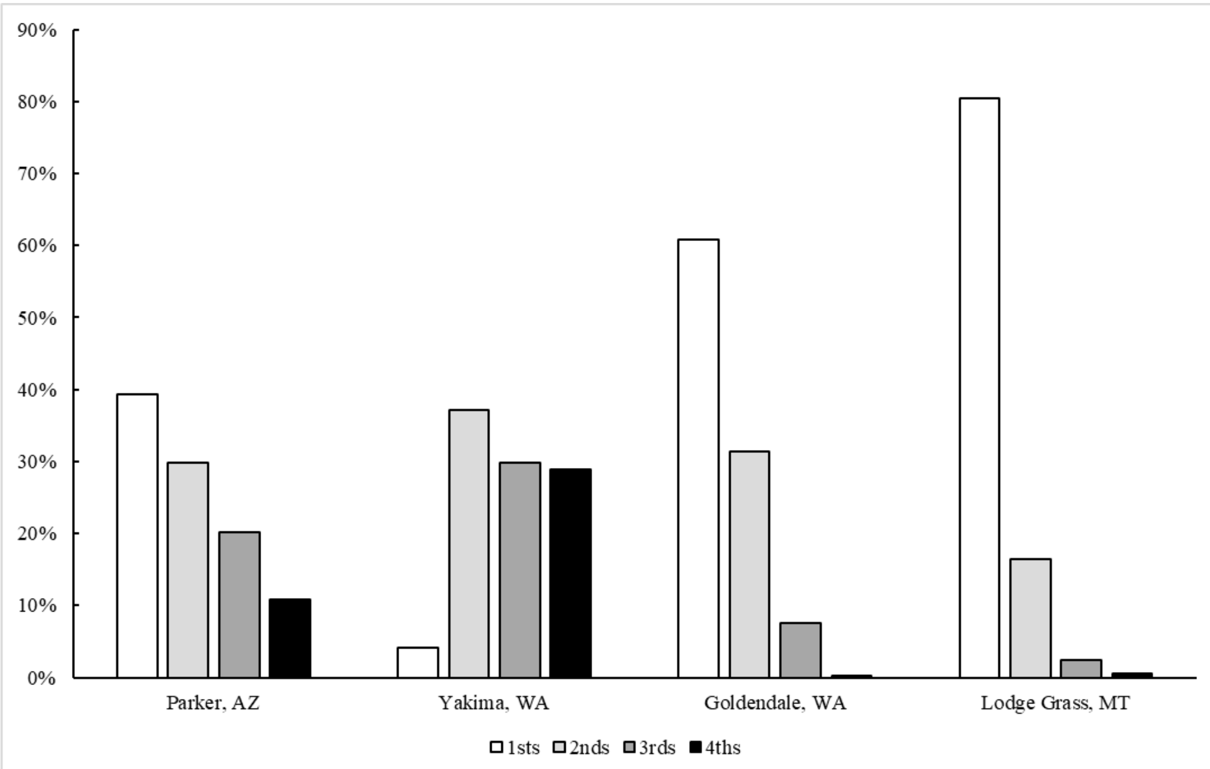
The two methods for sampling alfalfa weevils, sweep nets and cutting a 1 $ft^2$, were compared on two sampling dates at the field site in Montana. Sweep netting is the most common sampling method because it is relatively quick and cost effective. However, sweep nets do not effectively capture small 1st and 2nd instar larvae that are feeding inside the buds. This result is clearly demonstrated in Figure 16, where small 2nd instars were the most common stage on 6/4/21 (hand sorting of 1 $ft^2$ samples) but very few were captured in the sweep net samples. By 6/14/21, most of the larvae were larger 3rd and 4th instars, and there was no difference between the two methods. Hand sorting through the leaves and buds of 1 $ft^2$ is very labor intensive (45-60 minutes per sample) and is not feasible for routine sampling. It is a good method to conduct on the date that insecticides were sprayed to determine the stage of the larvae relative to treatment effectiveness. Early alfalfa weevil counts using sweep nets should be interpreted cautiously.

*Figure 16.*



*Additional Analysis – Larval Instar Stage Distribution on the Day Insecticides were Spayed*
During 2020 timing of spray applications in Lodge Grass, MT and Goldendale, WA were early, during peak 1$^{st}$ instar stage. Timing was the latest in Yakima, WA and intermediate in Parker, AZ.

*Figure 17. Percent control of larvae on day of treatment.*



*Appendix I - Spraying Parker, AZ 2022*

*Appendix II. 6 DAT- Parker, AZ 2022. Sevin XLR phytotoxic effect. Yellowing of leaves.*

*Appendix III. Goldendale, WA 2022 field site.*

*Appendix IV. Lodge Grass, MT 2022 field site.*