## **Weed Management in Strawberries**

Report 2014/2015

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**Summary**

Weed management in strawberry is costly due to need for hand weeding labor. Alternative fumigants do not control weeds formerly controlled by the methyl bromide and chloropicrin mixtures (MB/Pic). Therefore, we continue to evaluate potential new herbicides and fumigants to reduce weed management costs in California strawberry. In the 2014/15 season we evaluated the herbicide clopyralid (Stinger ®), isoxaben (Trellis ®) and the fumigant allyl isothiocyanate (AITC, Dominus ®). Our objectives were (1) to investigate efficacy and timing of applying clopyralid by spray and drip and Isoxaben by spray and (2) to investigate efficacy of drip applications of AITC in different concentrations. The findings of the 2013/14 trials with clorpyralid were reconfirmed that it is generally safe to strawberry. However, all Isoxaben applications resulted in unacceptable stunting and injury to strawberry. The application of AITC at several rates was found to have less weed control efficacy than standard Metam and Pic-Clor 60 applications. However, high weed control efficacy was observed when Metam and AITC were applied together.

**Introduction**

The transition from Methyl Bromide (MB) to alternative fumigants and increasing restrictions on fumigant use requires new weed management strategies for California strawberry. Alternative fumigants are less effective on weeds than MB, while labor costs for hand weeding continue to increase. The evaluation of more effective herbicides and fumigant combinations is crucial to reduce or contain handweeding costs for strawberry production in California. Fumigants typically provide partial weed control, which can be supplemented by herbicides that control weeds during the production season. In previous projects, we have determined safe and effective rates of novel herbicides (clorpyralid, Stinger ®) and MB alternatives. The purpose of this project was to assess the weed control efficacy and the timing of clopyralid by drip and spray and isoxaben (Trellis ®)by spray applications at several intervals during the early growing season. We further evaluated the weed and pathogen control efficacy of AITC (Dominus ®) alone and in combination with Metam K (KPam ®). The overall goal of this research was to contain or lower weed control costs for strawberry producers and develop herbicides to complement existing fumigants.

**Objectives**

1. To investigate weed control efficacy and timing of clopyralid and isoxaben applied by drip chemigation and spray
2. To investigate weed control efficacy of drip applied AITC alone and in combination with Metam K.

**Objective 1: Weed control efficacy and timing of Clorpyralid () and Isoxaben applied by drip chemigation and spray**

**Methods:** Clorpyralid was applied at 0.16 and 0.33 pt/a 47 days PRE transplanting by spray, and in December and February by both spray and drip chemigation (Table 1). Additional treatments applied before transplanting were isoxaben at 0.66, 1 and 1.6 lb/a, oxyfluorfen at 0.5 and 1 pt/a, and flumioxazin at 1.5 and 3.0 oz pr/a, as well as a no herbicide control. All treatments are replicated four times and arranged in a randomized complete block design. The entire trial was fumigated with Pic-Clor 60 (Pic 60). Strawberry (‘Monterey’) was transplanted on November 17, 2014. To evaluate the weed control efficacy of applied herbicides, weed spectrum, weed counts and weed biomass were assessed periodically. To assess the effects of the treatments on safety to strawberry, phytotoxicity was regularly assessed, as well as plant perimeters and fruit yield. Data were analyzed using standard statistical methods (ANOVA, Fisher’s LSD, α=0.05) in R 3.3.0.

**Table 1:** Herbicides evaluated, rates, application method and application dates during the 2014-15 season.

|  |  |  |  |
| --- | --- | --- | --- |
| *Herbicide* | ***Rates*** | ***Application method*** | ***Application date*** |
| *isoxaben* | *0.66, 1.0 & 1.6 lb pr/A* | *spray* | *Oct. 1, 2014* |
| *oxyfluorfen* | *0.5 & 1.0 pt /A* | *spray* | *Oct. 1, 2014* |
| *flumioxazin* | *1.5 & 3 oz/pr /A* | *spray* | *Oct. 1, 2014* |
| *clopyralid* | *0.16 & 0.33 pt/A* | *spray* | *Dec. 18, 2014* |
| *clopyralid* | *0.16 & 0.33 pt/A* | *spray* | *Feb. 4, 2015* |
| *clopyralid* | *0.16 & 0.33 pt/A* | *drip* | *Dec. 18, 2014* |
| *clopyralid* | *0.16 & 0.33 pt/A* | *drip* | *Feb. 4, 2015* |

**Findings:** Isoxaben provided moderate to good weed control but injured strawberry and reduced fruit yields – no further work on this product is recommended. Overall clopyralid was fairly safe to strawberry causing little visible injury or yield reduction (Table 2). Generally the lower the rate of clopyralid or the later the application timing, the less the weed control. Standards flumioxazin (Chateau ®) and oxyflourfen (GoalTender ®) caused little crop injury or yield reduction and provided effective weed control.

**Table 2:** Weed densities (No./A), plant injury (scale 0= safe; 10 = dead) and yield (lbs/a). Data were analyzed with a one-way ANOVA (α=0.05) followed by a Post-hoc Fisher LSD test (α=0.05). Letters indicate significance levels.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatment | Rate/A | Weed Densities | Plant Injury | Yield |
|  |  | No. /A | 0=safe, 10=dead | Lbs. /a |
| flumioxazin | 1.5 oz pr | 871.2 bcd | 0.7 abcd | 61,340 ab |
| flumioxazin | 3.0 oz pr | 435.6 cd | 1.0 cd | 56,502 bc |
| oxyfluorfen | 0.5 pt | 1524.6 bcd | 0.5 abc | 59,973 ab |
| oxyfluorfen | 1.0 pt | 1089 bcd | 0.7 abcd | 59,849 ab |
| isoxaben | 0.66 lb pr | 1306.8 bcd | 1.9 ef | 49,106 d |
| isoxaben | 1.0 lb pr | 435.6 cd | 2.4 f | 46,607 d |
| isoxaben | 1.6 lb pr | 1089 bcd | 1.8 e | 49,909 cd |
| clopyralid | 0.16 pt October | 2178 ab | 0.5 ab | 62,174 ab |
| clopyralid | 0.33 pt October | 653.4 bcd | 0.9 bcd | 59,397 ab |
| clopyralid | 0.16 pt Dec. drip | 653.4 bcd | 0.8 abcd | 59,804 ab |
| clopyralid | 0.16 pt Dec spray | 871.2 bcd | 0.7 abcd | 64,104 a |
| clopyralid | 0.33 pt Dec. drip | 1742.4 bcd | 1.1 d | 57,718 ab |
| clopyralid | 0.33 pt Dec spray | 217.8 d | 1.0 bcd | 57,743 ab |
| clopyralid | 0.16 pt Feb. drip | 2178 bc | 0.7 abcd | 61,410 ab |
| clopyralid | 0.16 pt Feb. spray | 2395.8 b | 0.3 a | 64,197 a |
| clopyralid | 0.33 pt Feb. drip | 1306.8 bcd | 0.5 abcd | 60,937 ab |
| clopyralid | 0.33 pt Feb. spray | 435.6 cd | 0.5 ab | 61,229 ab |
| non-treated control |  | 4138.2 a | 0.4 a | 60,971 ab |

**Objective 2: Weed control efficacy of drip application of AITC alone treatment and in combination with Metam K**

**Methods:** Metam K, AITC and Pic 60 were applied by drip chemigation using 2 tapes per bed. A total area of 560 ft2 was treated per application. Metam K, AITC and Pic 60 rates and application information are listed in Table 3. All treatments are repeated four times and arranged in a randomized complete block design. Strawberry plants (‘Monterey’) were transplanted on Nov. 17, 2014. To evaluate the efficacy of the fumigation on weed seed germination, seed bags were placed at 2” and 6” depth (Oct. 3, 2014) for all treatments and one set of the control beds. These bags were recovered 3-7 days after fumigation, and returned to the lab to measure viability. To evaluate the efficacy of the fumigation on the citrus nematode, *Pythium ultimum* and *Verticillium dahliae* survival, inoculum bags were placed at 9” and 18” depth (Oct. 6, 2014). These bags were recovered 3-7 days after fumigation, and returned to cooperating labs for viability assays. Weed densities and yield data were collected throughout the season. Data were analyzed using standard statistical methods (ANOVA and post-hoc Fisher LSD, α=0.05) in R 3.3.0.

**Table 3:** Application rates and dates of Metam K, AITC and Pic 60 at the strawberry field trial in Salinas CA (2014/15).

|  |  |  |  |
| --- | --- | --- | --- |
| Treatment | Rate gal/A | Method | Date |
| Metam K | 31 | drip | Oct. 15, 2014 |
| Metam K | 62 | drip | Oct. 15, 2014 |
| AITC | 20 | drip | Oct. 15, 2014 |
| AITC | 40 | drip | Oct. 11, 2014 |
| Pic 60 fb AITC | 20 f.b. 20 | drip | Oct. 11, f.b. 15, 2014 |
| Pic 60 fb Metam K | 20 f.b. 31 | drip | Oct. 11, f.b. 15, 2014 |
| Metam K fb AITC | 31 f.b. 20 | drip | Oct. 11, f.b. 15, 2014 |
| non-treated | 0 | - | - |

**Findings:** *Nematode and Pathogen Control:* All of the fumigants reduced nematode, *Pythium ultimum* and *Verticillium dahliae* compared to the control (Table 4). There were few differences in in nematode and pathogen efficacy. However, AITC alone at 40 GPA had lower nematode and pathogen efficacy than Pic 60/Metam K, Pic 60/AITC and Metam K /AITC treatments.

**Table 4:** Nematode and pathogen control efficacy of treatments. Shown are the mean values. Data were analyzed with a one-way ANOVA (α=0.05) and mean separation with Fisher’s LSD test (α=0.05).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatment | Rate gal/A | Citrus Nematode (#/50g soil) | Pythium spec. (ppg soil) | Verticillium spec. (MS/g soil) |
| Metam K | 31 | 18 a | 42 ab | 3 ab |
| Metam K | 62 | 65 ab | 27 ab | 5 ab |
| AITC | 20 | 179 ab | 149 ab | 8 ab |
| AITC | 40 | 252 b | 221 b | 11 b |
| Pic 60 fb AITC | 20 f.b. 20 | 1 a | 0 a | 2 a |
| Pic 60 fb Metam K | 20 f.b. 31 | 1 a | 0 a | 1 a |
| Metam K fb AITC | 31 f.b. 20 | 3 a | 0 a | 8 ab |
| non-treated | 0 | 1806 c | 1239 c | 40 c |

*Weed Control:* The viability of weed propagules was significantly reduced by all fumigants compared to the non-treated. Metam K and Metam K/AITC treatments reduced the viability of yellow nutsedge and knotweed seed similar to combined Pic-Clor 60 treatments (Table 5)*.* Weed densities (assessed from January 2015 – June 2015) were similar among all fumigant treatment, and all fumigant treatments were better than the non-treated control (Table 6).

**Table 5:** Weed propagule control. Shown are the mean values of weed seed viability (%), assessed by the Tetrazolium method. Data were analyzed with a one-way ANOVA (α=0.05) followed by a Post-hoc Fisher LSD test (α=0.05). Letters indicate significance levels.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Treatment | Rate gal/A | Burning Nettle | Knotweed | Purslane | Yellow Nutsedge |
| Metam K | 31 | 17 d | 3 a | 6 b | 2 a |
| Metam K | 62 | 13 cd | 4 a | 3 ab | 0 a |
| AITC | 20 | 16 d | 4 a | 4 ab | 14 b |
| AITC | 40 | 11 abc | 12 b | 3 ab | 0 a |
| Pic 60 fb AITC | 20 f.b. 20 | 2 a | 5 ab | 3 ab | 1 a |
| Pic 60 fb Metam K | 20 f.b. 31 | 3 ab | 1 a | 1 a | 1 a |
| Metam K fb AITC | 31 f.b. 20 | 32 b | 8 ab | 4 ab | 3 a |
| non-treated | 0 | 81 e | 77 c | 79 c | 81 c |

*Crop injury and yield:* No remarkable effects on plant vigor and plant development were observed (data not shown). But significant difference were observed in the overall yield (April through September). The Pic 60 combination treatments had the highest yields (Table 6). Metam K/AITC, AITC @ 20gal/a and Metam K @ 62gal/a had yields on the similar level. The AITC @ 40 gal/a treatment showed yields on the same level than the non-treated control, Metam K @ 31 gal/a yielded on lower levels than the control (Table 6).

**Table 6:** Full-season marketable yield (April – September). Data were analyzed with a one-way ANOVA (α=0.05) followed by a Post-hoc Fisher LSD test (α=0.05). Letters indicate significance levels.

|  |  |  |  |
| --- | --- | --- | --- |
| Treatment | Rate gal/A | Weed Densities (No/A) | Marketable yield (Lbs./A) |
| Metam K | 31 | 12,197 b | 53,562 c |
| Metam K | 62 | 16,335 b | 58,314 abc |
| AITC | 20 | 12,632 b | 58,494 ab |
| AITC | 40 | 10,890 b | 56,978 bc |
| Pic 60 fb AITC | 20 f.b. 20 | 8,930 b | 60,103 ab |
| Pic 60 fb Metam K | 20 f.b. 31 | 11,326 b | 62,206 a |
| Metam K fb AITC | 31 f.b. 20 | 12,415 b | 58,499 ab |
| non-treated | 0 | 169,884 a | 56,422 bc |

**Conclusions**

*Clorpyralid and Isoxaben drip chemigation and spray application:* Clopyralid treatments did not reduce strawberry yields, and December as well as February spray applications of clopyralid at 0.33 pt/a provided the best weed control. Clopyralid spray applications in February at 0.16 pt/a provided modest weed control with no observed damages at the plants. Isoxaben is an effective herbicide, but was too injurious to strawberry.

*Drip application of AITC as stand-alone treatment and in combination with Metam K:*

The results of this field trial indicate that Metam K in combination with AITC or Pic 60 have sufficient weed and pest control to protect strawberry yields.