Control of Difficult Weeds in California Strawberry Production.

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INTRODUCTION

Strawberries for fresh market and processing were grown on 21,200 ha in the United States in 2005, a crop valued at $1.4 billion (USDA ERS 2007). Nearly 90% of U.S. strawberries were grown in the California coastal areas around Watsonville (36% of California production area), Oxnard (33%), and Santa Maria (18%) (USDA ERS 2007); fruit is harvested from January to June in the southern region of the state and from March to October in the northern region.

Strawberry transplants are particularly sensitive to competition with weeds early in the season (Fennimore et al. 2005). Soil fumigation and opaque plastic mulch are standard practices costing $1,750-5,000 per ha that provide some initial weed control (Daugovish et al. 2004), however weeds with hard seed coats such as little mallow and clovers escape fumigation and germinate during production season. Oxyfluorfen and flumioxazin herbicides were effective against broadleaf weeds when tested in vegetable production (Daugovish et al. 2006, Hatterman-Valenti and Auwarter 2007, Shrefler and Webber 2004) and are registered for strawberry in California but their use has been limited. Flumioxazin is new to strawberry industry in California, while oxyfluorfen applications raised concerns due to potential crop injury. Oxyfluorfen moves with water vapor from the soil surface to strawberry foliage, a process known as "lift off" or codistillation (Fennimore et al. 2005) and can injure the plants. Alternative fumigants are less effective than methyl bromide in controlling yellow nutsedge. Shoots of nutsedge penetrate opaque mulch and rapidly establish in strawberry beds. When applied via drip fumigants do strawberry beds, the furrows remain non-fumigated, allowing weed growth. Yet another increasing problem is with weeds with wind dispersed seed which establish in strawberry planting holes and furrows throughout the season. One of the common wind dispersed species – horseweed has been recently reported to be resistant to glyphosate.

Our studies focused in four areas: pre-plant application of oxyfluorfen to beds, control of yellow nutsedge in non-fumigated strawberry, furrow weed control, and control of wind-dispersed weeds.

MATERIALS AND METHODS

Pre-plant application of oxyfluorfen to beds

Eight randomized complete block (RCB) experiments (2002-2006) with four replications each evaluated weed control and crop injury with 0.6 or 0.3 kg· a. i. ha^{-1} of oxyfluorfen applied 30 days before strawberry transplanting. Individual plots were 1.5 m wide and 30 m long at Oxnard, California and 1.3 m wide and 6.1 m long at Salinas, California. Following application,

beds were either immediately covered with PVC mulch or remained bare until 4-5 weeks after planting.

Yellow nutsedge control.

An RCB experiment with five replications was conducted at Oxnard, California (2006-2007) to compare emergence of yellow nutsedge and crop performance in beds covered with black PVC mulch alone and beds were Novovita paper (recycled newspapers, gypsum) was laid under mulch. In 2007-2008 this experiment was repeated but Novovita paper was installed between the two layers of plastic mulch, and, as additional treatments, weed barrier matt and water resistant Tyvek (DuPont) home wrap paper were tested under black PVC mulch. All plots were 1.5 by 8 m.

Furrow weed control.

An RCB experiment with three replication at Camarillo, CA compared weed control with flumioxazin at 0.1 kg a. i.·ha^{-1} and oxyfluorfen 0.3 kg a. i. ·ha^{-1} applied to furrows 30 days pre-transplant. Individual plots were 12 by 35 m. In an additional RCB experiment with four replications at Santa Paula, CA we evaluated weed control and crop safety of flumioxazin applied at 0.1 kg·a. i. ha^{-1} to furrows or over the bed top during strawberry fruiting in March 2007.

Herbicide evaluation for control of fleabane and sowthistle.

This RCB experiment at Santa Paula, California with four replications evaluated flumioxazin at 0.1 kg·a. i. ha^{-1} and oxyfluorfen at 0.3 kg a. i.·ha^{-1} for fleabane and sowthistle control at Santa Paula, CA. Weed seed were collected locally, mixed with sand and dispersed manually on moist bed tops to simulate natural deposition. Herbicides were applied the next day, the beds were immediately covered by clear mulch and strawberry was transplanted 30 days later.

In all studies weeds were counted by species, injury evaluated in percent and weeding time recorded for two persons per plot at Oxnard, Camarillo and Santa Paula. Analyses of variance for weed numbers, percent injury and weeding times were performed with the GLM Procedure in SAS (SAS Systems, Cary, NC) with the overall error rate controlled by Tukey-Kramer adjustment.

RESULTS AND DISCUSSION

Pre-plant application of oxyfluorfen to beds.

Averaged over the eight studies, oxyfluorfen at 0.3 kg a. i.·ha^{-1} provided 89-100% control of little mallow and most other broadleaf weeds, but only 0.6 kg a. i.·ha^{-1} rate controlled of yellow sweetclover 45-95%. Weeding times in oxyfluorfen treated plots were, on average, 37-

63% less that in untreated controls. Oxyfluorfen did not control yellow nutsedge and injured strawberry when plastic mulch was not present before transplanting. However, when mulch was laid prior to crop transplanting the co-distillation of herbicide was greatly reduced and no injury occurred. This indicated that with proper application, oxyfluorfen is an effective, economical and safe herbicide that especially valuable in controlling hard-seed weeds that survive fumigation.

Yellow nutsedge control.

In fall and winter the combination of paper under plastic completely eliminated yellow nutsedge germination that otherwise germinated through plastic at a density of 5 plants m^{2-1} per week. However, in spring when the paper disintegrated due to contact with wet soil and when soil temperature increased above 16ºC the nutsedge resumed germination at a rate of 3 to16 plants m^{2-1} per week in all treatments. This indicated that paper with greater water resistance or/and protected from contact with wet soil may be needed for a season- long control. In 2007-2008 the weed barrier matt, paper layered between two plastic mulch layers and water resistant Tyvek (Du Pont) paper all provided 100% control of nutsedge shoots that otherwise germinated through plastic at a density of 0.6 plants m^{2-1} per week. This study suggests that persistent mechanical barriers prevent nutsedge germination and are especially valuable in non-fumigated and organic production in the absence of other nutsedge control tools.

Furrow weed control

At Camarillo, both oxyfluorfen and flumioxazin treatments reduced weed densities (primarily wind-dispersed weeds) 84-95% at 4 weeks after application, about 68% at 8 weeks, and reduced weeding time 50% or more compared to untreated control. This study showed that pre-plant furrow application of oxyfluorfen and flumioxazin to furrows were safe and effective, however, additional in-season weed control in furrows is needed. At Santa Paula, flumioxazin provided complete (100%) control of burning nettle (*Urtica urens*), little mallow and nettleleaf goosefoot (*Chenopodium murale*) in furrows and did not injure strawberry. However, when applied over the bed top, flumioxazin damaged strawberry fruit and foliage resulting in significant fruit losses for 3 weeks after application. This indicates that flumioxazin may be useful for in-season weed control but caution should be exercised to prevent herbicide drift to strawberry plants during furrow application.

Herbicide evaluation for control of fleabane and sowthistle

Both, oxyfluorfen and flumioxazin controlled sowthistle near 100% and did not injure strawberry. Fleabane failed to germinate until 12 weeks after strawberry transplanting and was not controlled by either herbicide at that time. In this and in previous studies we have observed that wind-blown weeds continuously reinfest the strawberry planting holes and furrows as they blow in from the surrounding areas. Thus, destruction of seed sources in and outside the production field is essential in minimizing weeding expenses associated with this wind-dispersed weeds.

Overall, this weed management program identified cost-effective management tools for difficult to control weeds in California strawberries. We continue investigation of mechanical barriers and herbicides to control difficult weeds.

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