Response of Alfalfa Treated with Halosulfuron During the Summer of 1999

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Abstract

The response of alfalfa regrowth, yield and plant populations to halosulfuron applied following cuttings and irrigations in the summer and fall of 1999 was studied in an experiment conducted at the University of Arizona Maricopa Agricultural Center. A single application of halosulfuron applied when there was little alfalfa foliage slightly reduced plant heights for several cutting cycles with increasing rate decreasing plant height. The cumulative forage fresh weight yields for the October 4th, November 15th, and February 22nd harvests for treatments receiving no halosulfuron or 0.032, 0.047, or 0.063 lb a.i./A were (means ± std. dev.): 15.94 ± 0.91, 14.99 ± 0.66, 14.80 ± 1.74, and 14.46 ± 0.97 tons/A, respectively. The trend of decreasing cumulative forage fresh weight with increasing halosulfuron rate was significant (Adj. R^2 = 0.178, P = 0.015) indicating that for the three harvests after August 25th, halosulfuron had a small but negative effect on forage fresh weight. The harvest on April 5, 2000, the fourth harvest following the halosulfuron applications on August 25, 1999, indicated that there was no longer any residual effect of halosulfuron on alfalfa growth. Plant populations measured on April 10, 2000 were not affected by either one or two halosulfuron applications in this experiment. A set of sequential halosulfuron treatments applied when there was substantial alfalfa foliage (about 80% of the ground surface covered) severely suppressed alfalfa regrowth. Little regrowth occurred in these plots in October or November after the sequential applications compared to the untreated control or to the plots that received only the initial application of halosulfuron. The change in mean percent yield loss with successive harvests on November 15th, February 22nd and April 5th of 85, 40 and 14% indicated that the alfalfa plants were recovering from the halosulfuron applications. The cumulative forage fresh weight yields for treatments receiving sequential halosulfuron treatments (0.032+0.032, 0.047+0.047, or 0.063+0.063 lb a.i./A) were (means ± std. dev.): 11.67 ± 1.46, 10.85 ± 1.06, and 10.44 ± 0.98 tons/A, respectively, and were much less than the cumulative yield of 18.97 ± 1.17 tons/A from the untreated plots. The data suggest that the critical factor in determining the degree of alfalfa injury caused by halosulfuron is the amount of foliage present at the time of application.

Introduction

Alfalfa production is negatively affected by purple nutsedge (*Cyperus rotundus*). Purple nutsedge foliage reduces the quality of alfalfa hay and reduces stand life particularly when cutting cycles are shortened to produce high quality hay

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for dairies. Purple nutsedge is difficult to control in established alfalfa stands. The use of Zorial 5G® in alfalfa provides suppression of purple nutsedge when used for 2 or more years. Repeated Eptam 20G® applications during the summer can also reduce the amount of nutsedge foliage in the hay. Both of these herbicides have disadvantages associated with their use in alfalfa. Zorial has a long soil residual that can affect crop rotation. Eptam must be applied up to 6 times a season and does not always reduce field populations of purple nutsedge. The use of a postemergence herbicide effective on purple nutsedge in combination with the preemeergence herbicides Zorial or Eptam might increase the degree of suppression and decrease the time required to reduce purple nutsedge populations in alfalfa fields. Halosulfuron (currently marketed as Permit®, Battalion®, and Sempra® by Monsanto) is a postemergence herbicide with excellent activity on nutsedge species , however, many broadleaf crops such as cotton and alfalfa are only partially tolerant of this herbicide.

Alfalfa growth in central Arizona is greatly reduced during the summer months due to super-optimal temperatures. At the same time, purple nutsedge growth is enhanced due to reduced competition from alfalfa, the high temperature optimum for purple nutsedge growth, and the lack of light saturation in this plant due to its' C4 pathway of photosynthesis. Since alfalfa forage production is reduced and hay quality is low, the summer months may provide a window of opportunity when semi-selective postemergence herbicides could be applied in low desert alfalfa for purple nutsedge control. These herbicides could be applied just after a cutting to minimize the amount of alfalfa foliage present and thereby reduce herbicide uptake. The main factor limiting the success of such a strategy would the long-term effect of the herbicide on subsequent alfalfa yields and plant populations. Thus the objective of this study was to evaluate the effect of various halosulfuron rates applied either once or twice on the subsequent yield and population of treated alfalfa.

Materials and Methods

The experiment was conducted at the University of Arizona Maricopa Agricultural Center (MAC) in Maricopa, Arizona. Germain's WL525, a non-dormant alfalfa variety, was planted on November 25, 1998 at a rate of 25 lbs of seed per acre. The soil in the field was Casa Grande sandy loam that contained 68% sand, 14% silt, 18% clay and 0.77% organic matter and had a pH of 8.3. Previous crops grown in this field included small grains in 1998 that were not treated with herbicide and cotton in 1997 that was treated with Prowl, Caparol and Zorial Rapid 80. No herbicides were used in the alfalfa prior to the initiation of the experiment in August 1999 and there was no significant weed pressure in the experiment due to the previous cropping history. The experiment was arranged in a randomized complete block design with seven blocks and individual plots were 20 feet wide by 32 feet long. Halosulfuron was applied at rates of 0.032, 0.047, and 0.064 lb a.i./A in combination with 0.05% v/v non-ionic surfactant (X-77) on August 25, 1999. The herbicide was applied following a cutting (August 16, 1999) and an irrigation (August 20) when the alfalfa had little regrowth (stems were approximately 5 inches tall with each crown having between 2 to 6 trifoliate leaves). The herbicide was applied broadcast over the top of the alfalfa using TeeJet XR8003VS nozzles on a 20 foot tractor mounted boom traveling at 3.2 MPH spraying at 20 PSI which delivered a spray volume of 20 gallons per acre.

The environmental conditions at the time of application (11 a.m.) were: the air temperature was 94 F, the relative humidity was 50% and the wind velocity averaged 2.5 MPH. The soil surface was damp from the recent irrigation but there was no dew on the plants and there was bright sunlight at the time of application. A second set of halosulfuron applications at the above rates were made in some treatments on October 15, 1999 to evaluate the effect of two sequential applications. The second set of applications were also made following a cutting and irrigation. In contrast to the first set of herbicide applications, there was significant alfalfa regrowth (stems had 5 to 8 nodes with leaves and trifoliate leaves at each node providing about 80% ground cover) at the time of the second applications due to the more moderate temperatures in the fall. The applications were made using the sprayer described above and the environmental conditions at the time of application (6:00 p.m.) were as follows: the air temperature was 86 F, The relative humidity was 20% and the wind velocity averaged 2.5 MPH.

Standard alfalfa production practices were used to grow the alfalfa. Alfalfa injury was visually estimated on January 25, 2000. Alfalfa height was measured at various times after the halosulfuron applications (see data tables for dates) in two locations per plot by visually estimating the average height of the alfalfa plants adjacent to a measuring stick. Alfalfa populations were determined on April 10, 2000 by sub-sampling each plot twice using 0.5 m^2 squares and counting all crowns in the sampling squares. Alfalfa forage fresh weight was measured at various times after the halosulfuron treatments (see data table for dates) using a small plot forage harvester. Alleys between the ends of adjacent plots were cut with a sickle bar mower mounted on a small tractor reducing plot lengths to between 15 to 19 feet. Yield was measured by cutting a swath 5 ft wide (the width of the small plot harvester cutting bar) by the length of the remaining alfalfa. Actual plot lengths were measured at each harvest. The small plot forage harvester deposited the cut alfalfa in a weigh basket and the fresh weight of each sample was measured immediately after cutting using a digital hanging scale. For the analysis of the September height data and October harvest data, plots destined to receive a second halosulfuron treatment were pooled with treatments receiving a single application because the second set of halosulfuron applications were not made until after the October 4th harvest. For data collected after the second set of halosulfuron applications on October 15th, ANOVA including mean separation using Tukey's Honestly Significant Difference was performed using data from all treatments and then separate regression analyses were conducted for the treatments that received one halosulfuron application versus those that received two applications.

Results and Discussion

The initial application of halosulfuron on August 25, 1999 at rates of 0.032, 0.047, and 0.063 lb a.i./A reduced alfalfa regrowth 34, 36, and 37%, respectively, as measured by shoot height 19 days after treatment (Table 1). However, there was no halosulfuron rate response as indicated by a non-significant regression of height against rates (0.032, 0.047, and 0.063 lb a.i./A; Adj. R^2 = 0.023, P = 0.171). Differences in vegetative growth moderated as regrowth continued such that there were no significant fresh weight differences between treatments at the first post-halosulfuron harvest on October 4, 1999 (Table 2). There also was no halosulfuron rate response as indicated by a non-significant regression of forage fresh weight against rate (0, 0.032, 0.047, and 0.063 lb a.i./A; Adj. R^2 = 0.004, P = 0.279). Plant heights measured in November revealed small differences in regrowth following the October 4th harvest between plots treated once with halosulfuron and untreated plots (Table 1). There was a small decline in height as halosulfuron rate increased (0, 0.032, 0.047, and 0.063 lb a.i./A) on both November 1st (Adj. R^2 = 0.289, P = 0.002) and November 15th (Adj. R^2 = 0.115, P = 0.046). The rate response was small accounting for only 29% and 11% of the variation in the height data collected on November 1st and 15th, respectively. Similarly, plant heights measured on January 25, 2000 indicated that there was a small decline in height as halosulfuron rate increased (0, 0.032, 0.047, and 0.063 lb a.i./A; Adj. R^2 = 0.235, P = 0.005). The forage fresh weights measured on November 15th in plots treated once with halosulfuron were similar to the height data collected in November in showing a decline in growth with increasing halosulfuron rate (0, 0.032, 0.047, and 0.063 lb a.i./A; Adj. R^2 = 0.313, P = 0.001). Forage fresh weights measured on February 22, 2000 also showed a slight decline of fresh weight with increasing halosulfuron rate (0, 0.032, 0.047, and 0.063 lb a.i./A) similar to the height measurements on January 25th, however, regression analysis determined that the decline was not significant (Adj. R^2 = 0.060, P = 0.110).

The height data collected in plots receiving one halosulfuron application consistently showed a significant halosulfuron effect on alfalfa growth. The initial height suppression was dramatic although it did not result in a statistically significant reduction in forage fresh weight at the first harvest on October 4th. Plant heights measured in November 1999 and January 2000 showed a consistent but small halosulfuron rate response (i.e., decreasing height with increasing rate). In contrast, the forage fresh weight data collected in October and November 1999, and February 2000, were more variable in showing a statistically significant reduction in weight with increasing halosulfuron rate with only the November 15th harvest finding a significant rate effect. One possible explanation for the inconsistency in detecting a statistically significant halosulfuron rate effect between the height and fresh weight data is that the latter was more variable. This is illustrated by examining the coefficients of variation (CV) calculated from the height and fresh weight means and standard deviations for the untreated plots (Tables 1 and 2). For the height data collected on September 13th, November 1st, November 15th, and January 25th, the CV for the untreated plots were 4.8, 3.9, 3.8, and 3.7%, respectively. For the fresh weight data collected on October 4th, November 15th, February 22nd and April 5th, the CV for the untreated plots were 8.5, 6.4, 15.8, and 6.6%, respectively. Since the average CV for the fresh weight data was more than twice that of the height data, the fresh weight data from the first three harvests following the halosulfuron applications on August 25th were added together to determine cumulative yield. The cumulative forage fresh weight yields for treatments receiving no halosulfuron or 0.032, 0.047, or 0.063 lb a.i./A were (means ± std. dev.): 15.94 ± 0.91, 14.99 ± 0.66, 14.80 ± 1.74, and 14.46 ± 0.97 tons/A, respectively. The trend of decreasing cumulative forage fresh weight with increasing halosulfuron rate was significant [ton/A = 15.881 - (23.484 * rate lb a.i./A); Adj. R^2 = 0.178, P = 0.015] indicating that for the three harvests after August 25th, halosulfuron had a small but negative effect on forage fresh weight.

The harvest on April 5, 2000, the fourth harvest following the halosulfuron applications on August 25, 1999, indicated that there was no longer any residual effect from a single application of halosulfuron on alfalfa growth (Table 2) and no rate effect (Adj. R^2 = 0.0151, P = 0.245). Plant populations measured on April 10, 2000 also indicated that neither one or two applications of halosulfuron had a long-term effect on alfalfa populations in this experiment (Table 2). The small and transient effect of halosulfuron on forage fresh weigh yields was probably due to the small amount of alfalfa foliage (2 to 6 trifoliate leaves per crown) present at the time of the halosulfuron applications on August 25, 1999. This may have limited the amount of halosulfuron absorbed by the plants and stored in crown and root tissue. As shoot regrowth occurred following cutting, initial regrowth was fueled by carbohydrates from the crown and roots. Since halosulfuron is a symplastically mobile herbicide, it also would have been translocated to the new shoot foliage where it could suppress regrowth. However, as regrowth continued, the developing foliage would begin to photosynthesize producing carbohydrates and chemical energy that would both fuel continued shoot regrowth as well as replenish the store of carbohydrates in the crown and root tissue. Thus, it could be expected that low doses of halosulfuron might not have a large effect on forage yields.

The second or sequential halosulfuron treatments were applied when the stems of the alfalfa crowns had 5 to 8 nodes with leaves and trifoliate leaves at each node resulting in a canopy that covered about 80% of the ground surface. Thus, far more herbicide was absorbed by the plants than during the first set of halosulfuron applications. This increased dose or absorption significantly suppressed regrowth as measured by plant height on November 1st and 15th and on January 25th (Table 1). In fact, little regrowth occurred in the plots in October or November after the sequential applications compared to the untreated control or to the plots that received only the initial application of halosulfuron (Table 1). Interestingly, regression analysis of halosulfuron rate against the height of the sequentially treated plots found there was no significant trend with increasing rate on November 1st (Adj. R^2 = 0.000; P = 0.708), November 15th (Adj. R^2 = 0.051; P = 0.167) or January 25th (Adj. R^2 = 0.000; P = 0.442). The November 15th yield data showed that the second set of halosulfuron applications reduced alfalfa yields 80 to 88% (Table 2) and that increasing halosulfuron rates (0.032, 0.047, and 0.063 lb a.i./A) decreased reduced yields (Adj. R^2 = 0.455; P = 0.001). The yield losses at the February 22nd harvest ranged from 40.2 to 41.2% but there was no significant decline in yields with increasing halosulfuron rate (0.032, 0.047, and 0.063 lb a.i./A; Adj. R^2 = 0.000, P = 0.906). The yield losses at the April 5th harvest ranged from 8.6 to 18.5% and there was a significant decline in yields with increasing halosulfuron rate (0.032, 0.047, and 0.063 lb a.i./A; Adj. R^2 = 0.338, P = 0.003). The change in mean percent yield loss with successive harvests on November 15th, February 22nd and April 5th of 85, 40 and 14% indicated that the alfalfa plants were recovering from the halosulfuron applications. The cumulative forage fresh weight yields for treatments receiving sequential halosulfuron treatments (0.032+0.032, 0.047+0.047, or 0.063+0.063 lb a.i./A) were (means ± std. dev.): 11.67 ± 1.46, 10.85 ± 1.06, and 10.44 ± 0.98 tons/A, respectively. The trend of decreasing cumulative forage fresh weight with increasing halosulfuron rate was not significant (Adj. R^2 = 0.128, P = 0.062). The comparable cumulative yield of the untreated plots, 18.97 ± 1.17 tons/A, was significantly greater (1.62 to 1.82 times greater) than the sequentially treated plots. The second set of halosulfuron applications were made 11 days after cutting and were made after bale removal, irrigation and significant alfalfa regrowth. Comparison of the percent yield reduction on October 4th caused by a single 0.063 lb a.i./A halosulfuron application (3.78%) with the yield reduction on November 15th caused by a sequential 0.032 + 0.032 lb a.i./A application (80.4%) shows that the second set of halosulfuron applications had a far greater effect on the alfalfa due to the greater leaf area present at application and therefore greater halosulfuron absorption.

The data suggest that applying halosulfuron following a cutting and irrigation when there is little alfalfa leaf area during the hot summer months may have minimal effects on subsequent alfalfa growth. However, the data also indicate that halosulfuron applications made following a cutting and irrigation when there is a significant amount of foliage can result in substantial suppression of alfalfa regrowth making the use of halosulfuron commercially unacceptable. The critical factor in determining the degree of alfalfa injury appears to be the amount of foliage present a the time of application. Further research needs to address the effect of halosulfuron applications at various times after cutting during the summer and the relationship between the amount of foliage present at the time of application and subsequent growth retardation. Possible application times include: after cutting and bale removal but before irrigation; after cutting, bale removal and irrigation; and after a period of regrowth following irrigation. The latter treatment would be expected to be similar to the effect of the second set of halosulfuron applications reported here. Application of halosulfuron after cutting but before irrigation would allow treatment of substantial nutsedge foliage but water stress might affect the response of nutsedge to halosulfuron. Thus, future research also needs to address the effectiveness of such a treatment regime.

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Table 1. Height of alfalfa regrowth and injury following treatment with halosulfuron. The initial halosulfuron applications were made on August 25, 1999 to all treatments except the untreated control. A second set of halosulfuron applications were applied in three treatments on October 15, 1999. All halosulfuron applications included 0.05% v/v of the non-ionic surfactant, X-77.

Halosulfuron Rate	Height of Alfalfa Regrowth[1]				Injury[2]
	9-13-99	11-1-99	11-15-99	1-25-00	1-25-00
(lb a.i./A)	*(inch)*	*(inch)*	*(inch)*	*(inch)*	*(%)*
0	19.7 ± 0.9[3] a	16.5 ± 0.6[4] a	19.7 ± 0.7 a	9.4 ± 0.4 a	0.4 ± 0.7 b
0.032	12.9 ± 0.8 b	15.2 ± 0.9 ab	18.5 ± 0.7 b	9.0 ± 0.4 a	1.3 ± 2.5 b
0.047	12.5 ± 1.3 b	15.3 ± 0.8 ab	18.8 ± 0.6 ab	9.0 ± 0.5 a	0.6 ± 0.7 b
0.064	12.3 ± 1.1 b	15.0 ± 1.0 b	19.0 ± 0.5 ab	8.8 ± 0.4 a	0.6 ± 0.6 b
0.032 + 0.032	-	8.0 ± 1.2 c	8.9 ± 0.4 c	6.7 ± 0.6 b	6.9 ± 3.0 a
0.047 + 0.047	-	8.2 ± 0.6 c	8.6 ± 0.4 c	6.4 ± 0.5 b	7.2 ± 3.5 a
0.064 + 0.064	-	8.1 ± 0.8 c	8.5 ± 0.5 c	6.5 ± 0.5 b	7.9 ± 4.8 a

[1]Following the initial herbicide treatments, the alfalfa was cut on 10-4-99, 11-15-99, 2-22-00, and 4-5-00.

[2]Visual injury ratings on a 0 to 100% scale where 0% indicates no injury and 100% indicates plant death. Injury ratings were based on stunting and mottled yellow symptoms on leaves.

[3]Data are means ± standard deviations; means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Tukey's Honestly Significant Difference. For the analysis of the September 13 height data the treatments scheduled to receive either one or two halosulfuron applications were pooled since the second set of halosulfuron treatments had not yet been applied. Thus, n=7 for the control treatment and n=14 for the three different halosulfuron treatments.

[4]Data are means ± standard deviations of 7 replications; means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Tukey's Honestly Significant Difference.

Table 2. Alfalfa fresh weight yields at various times following treatment with halosulfuron and alfalfa populations on April 10, 2000. The first applications of halosulfuron plus 0.5% v/v X-77 were made on August 25, 1999 to all treatments except the untreated control. A second set of halosulfuron plus X-77 applications were applied to three treatments on October 15, 1999.

Halosulfuron Rate	Fresh Weight of Alfalfa				Population
	10-4-99	11-15-99	2-22-00	4-5-00	4-10-00
(lb a.i./A)	*(lb/acre)*	*(lb/acre)*	*(lb/acre)*	*(lb/acre)*	*(#/m^2)*
0	9080 ± 774[1] a	10295 ± 662[2] a	12515 ± 1975 a	15139 ± 1003 ab	50.2 ± 3.2 a
0.032	9195 ± 874 a	9017 ± 1031 b	11792 ± 1873 a	15607 ± 1333 a	49.9 ± 5.6 a
0.047	8957 ± 991 a	9238 ± 823 ab	11173 ± 2091 a	16035 ± 689 a	49.6 ± 3.8 a
0.064	8737 ± 771 a	8779 ± 327 b	11060 ± 1608 a	15597 ± 1014 a	51.8 ± 6.4 a
0.032 + 0.032	-	2022 ± 343 c	7481 ± 2286 b	13843 ± 958 bc	48.0 ± 5.2 a
0.047 + 0.047	-	1327 ± 347 c	7391 ± 2145 b	12984 ± 506 cd	46.5 ± 4.0 a
0.064 + 0.064	-	1180 ± 385 c	7353 ± 1665 b	12345 ± 1017 d	49.2 ± 3.8 a

[1]Data are means ± standard deviations; means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Tukey's Honestly Significant Difference. For the analysis of the October 4 fresh weight data, the treatments scheduled to receive either one or two halosulfuron applications were pooled since the second set of halosulfuron treatments had not yet been applied. Thus, n=7 for the control treatment and n=14 for the three different halosulfuron treatments.

[2]Data are means ± standard deviations of 7 replications; means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Tukey's Honestly Significant Difference.