Final Report

Control of Kochia in Established Seed Alfalfa

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Summary
Alfalfa seed is an important niche crop on irrigated land in Southern Alberta, but presents a number of challenges, one of which is the control of kochia (*Kochia scoparia*). Previous work has shown that Authority® (sulfentrazone) and Valtera™ (flumioxazin), two group 14 pre-emergence herbicides, are well tolerated by established seed alfalfa. A preliminary trial conducted under field conditions in 2013 suggested that early spring tillage of dormant alfalfa followed by application of sulfentrazone or flumioxazin may result in better weed control. To provide a more definitive answer to this question, a trial was designed to determine if shallow spring tillage of dormant alfalfa does indeed improve the efficacy of Authority® against kochia when used alone or in combination with Valtera™ or Velpar® (hexazinone). Field trials were conducted in the county of Newell on two commercial seed alfalfa fields. The treatments consisted of tillage and pre-emergence herbicide applications. The herbicide treatments consisted of Authority® at 250 ml/ha and 500 ml/ha, Authority® at 125 ml/ha mixed with Valtera™ at 105 g/ha, Authority® at 250 ml/ha mixed with Valtera™ at 210 g/ha, Authority® at 125 ml/ha mixed with Velpar® at 500 g/ha and Authority® at 250 ml/ha mixed with Velpar® at 1000 g/ha. The results demonstrated that Authority® by itself, or in a tank-mix with either Valtera™ or Velpar®, has the potential to effectively control kochia in established seed alfalfa. All herbicide treatments achieved at least 95 % control of kochia seedlings. Tillage had no effect on herbicide efficacy with respect to kochia, but did improve control for other broadleaf weeds at one site and decrease control at the other site. Overall these findings support the use of Authority® and/or Valtera® on established seed alfalfa.
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**Introduction**

Alfalfa seed is an important niche crop on irrigated land in Southern Alberta. It can be a profitable crop to grow, but presents a number of challenges, one of which is the control of kochia (*Kochia scoparia*), which is not effectively controlled with herbicides currently registered for use on seed alfalfa. In addition to its negative impact on yield and seed quality, kochia is of concern due to the potential of glyphosate resistance can substantially increase weed control costs in subsequent crops.

Previous work has shown that Authority® (sulfentrazone) and Valtera™ (flumioxazin), two group 14 pre-emergence herbicides labelled to control kochia, are well tolerated by established seed alfalfa and can (Howard et al. 2013). They are absorbed through the roots or leaves and inhibit protoporphyrinogen oxidase, an enzyme of chlorophyll and heme biosynthesis, which results in a chain of events that ultimately leads to the disruption of cellular membranes, hence the necrotic and dried appearance of affected plants (Dayan and Duke 1997; Yamato et al. 1995). Currently there are six weed species for which resistance to group 14 herbicides has been reported, but only one—flixweed—is a significant weed in Alberta (Heap 2015). Both products provide residual control, but sulfentrazone is more persistent.

A preliminary trial conducted under field conditions in 2013 suggested that early spring tillage of dormant alfalfa followed by application of sulfentrazone or flumioxazin may result in better weed control. The use of spring tillage may also be beneficial to reduce the amount of crop residues, which may lead to a more rapid warming of the soil and potentially greater yields. The objective of this trial was to determine if shallow spring tillage of dormant alfalfa improves the efficacy of Authority® against kochia when used alone or in combination with Valtera™ or Velpar® (hexazinone). The latter was included because it is currently the standard pre-emergence herbicide applied to established seed alfalfa. In addition to herbicide efficacy we also measured the impact on crop growth, seed yield and germination rates of the harvested seed.

**Materials & Methods**

Field trials were conducted in the county of Newell on two commercial seed alfalfa fields. Site A was located at latitude 50° 27' 30" North and longitude 111° 46' 07" West, while site B was located at latitude 50° 37' 34" North and longitude 111° 45' 37" West. Field A was a two year old stand of the Pickseed cultivar 2065 and field B was a three year old stand of the Pickseed® cultivar Leader. The soil on site A was a loam with a pH near 7.4 and 2.0 % organic matter content, whereas on site B it was a clay loam with a pH of 7.5 and 2.5 – 3.0 % organic matter. On both fields irrigation was managed through a centre pivot.

The layout of the experiment followed a strip plot design, where the treatments consisted of tillage and pre-emergence herbicide applications, applied as perpendicular randomized strips (herbicides in one direction and tillage in the other direction), arranged in four blocks with 16 plots each (8 weed control x
This design was well suited to examine interactions between treatment factors and facilitated the application of the tillage treatments (Gomez and Gomez 1984). The weed control treatments consisted of the following:

- Authority® applied at 250 ml/ha; referred to as Authority_L
- Authority® applied at 500 ml/ha; referred to as Authority_H
- tank mix of Authority® at 125 ml/ha and Valtera™ at 105 g/ha; referred to as Authority-Valtera_L
- tank mix of Authority® at 250 ml/ha and Valtera™ at 210 g/ha; referred to as Authority-Valtera_H
- tank mix of Authority® at 125 ml/ha and Velpar® at 500 g/ha; referred to as Authority-Velpar_L
- tank mix of Authority® at 250 ml/ha and Velpar® at 1000 g/ha; referred to as Authority-Velpar_H
- hand weeded
- weedy check

The plots were established in 2014 on April 22 at site A and May 14 at site B, which consisted in marking out the field area, tilling with a cultivator the designated 5 meter wide strips to a depth of 5-8 cm, staking out individual 3.0 by 5.0 meter plots (3.0 by 4.0 m on site B), and in the center of each plot, seeding a 2 meter long shallow furrow with approximately 500 kochia seeds, which had been obtained from a local seed cleaning plant. The herbicides were applied on April 24 at site A and on May 15 at site B, using a motorized CO₂ plot sprayer with a shielded 1.5 m wide boom. The sprayer was equipped with flat fan TeeJet® AIXR 11001 low drift nozzles. The herbicides were applied at a pressure of 275 KPa using a spray volume equivalent to 100 L/ha. The alfalfa had emerged from winter dormancy by mid-April and was actively growing by the time these applications were made.

Control of kochia was assessed by plant counts at two, four, six and ten weeks after the application of the herbicides. Control of other weeds, such as Canada thistle (Cirsium arvense), dandelion (Taraxacum officinale), flixweed (Descurainia sophia), goat’s-beard (Tragopogon dubius), narrow-leaved hawk’s-beard (Crepis tectorum), perennial sow thistle (Sonchus arvensis), prickly lettuce (Lactuca seriola) and curled dock (Rumex crispus), was rated visually along with crop injury. Plot yield was measured by harvesting a 1.2 meter strip along the centre of each plot with a Wintersteiger plot combine. Harvest took place on October 6 on site A and on October 7 on site B. Seed weight was adjusted for moisture content and tested for germination. The germination test was done without scarification at 20 °C for 5 to 7.5 days on samples of 200 seeds from each plot. The field work for this project was done under contract by AqQuest.

The data was subjected to an analysis of variance with main effect interactions as the error terms to reflecting the nature of the design. Where significant main effects were found, Tukey’s multiple comparison test was used to identify treatment differences. A correlation analysis was performed on seed yield and visual ratings of the percent control achieved on weeds other than kochia. All statistical tests were performed with Systat version 13.1.

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1 AgQuest.com
Results and Discussion

At site A no interaction between tillage and weed control treatments was observed, nor was there any tillage effect on kochia counts (fig. 1). There was however a very marked difference in average kochia counts between the weedy check and the weed control treatments. All weed control treatments were effective and resulted in nearly complete control of seeded kochia (fig. 2).

At site B the analysis of variance revealed a significant interaction between tillage and weed control (p=0.003). Consequently the effects of tillage and weed control were examined separately. The weed control treatments exhibited the same pattern irrespectively of tillage, which was consistent with findings at site A (fig. 3-4). Examination of kochia counts for tilled and untilled plots for each weed control treatment at site B showed that the weedy check was the only treatment where tillage had an effect on kochia counts, but the F-test on the comparison of the mean kochia count between tilled and untilled plots was only significant at the 10% alpha level (fig. 5).

Figure 1. The effect of tillage on average kochia seedling counts at site A. Kochia seedlings were counted at 2, 4, 6, and 10 weeks after weed control treatments had been applied.

Figure 2. The effect of weed control treatments on average kochia seedling counts at site A. With the exception of the weedy check differences were not statistically significant.

Figure 3. The effect of weed control treatments on average kochia seedling counts at site B in tilled plots. With the exception of the weedy check differences were not statistically significant.
Crop tolerance to the herbicides was assessed visually and found to be excellent. What appeared to be a minor phytotoxic effect was observed in four plots during the fourth and sixth weeks after the herbicides were applied. The ratings were 10% damage at two occasions and 5% at six occasions. The two 10% ratings were for Authority-Velpar at either rate, but damage for this treatment was limited to only one replication at site A four weeks after application. The 5% phytotoxicity ratings were for Authority at the 500 ml/ha rate on three occasions and for the Authority-Valtera tank mix on two occasions. The symptoms were transient and were observed in only 4 out of 48 herbicide treated plots at four and six weeks after the herbicides were applied. No phytotoxic symptoms were found during the second week or after the sixth week following application of the herbicide treatments.

Seed yield was affected by tillage and weed control treatments. At site A the average yield of the tilled plots was slightly less (6%) than for the untilled plots (fig. 6). This difference was significant at the 5% alpha level (p = 0.044). Average yield differences due to weed control treatments were more pronounced and ranged from 1 kg/ha to 310 kg/ha (fig. 7). A multiple comparison using the relatively conservative Tukey’s test, showed that yields significantly higher than the weedy check were obtained with Authority-Valtera_L (p=0.001), Authority-Valtera_H (p<0.001), Authority-Velpar_L (p<0.001), Authority-Velpar_H (p<0.001) and handweeded (p=0.017). Given that all herbicide treatments were equally effective at controlling kochia (fig. 2) the correlation between control of other weeds (visual ratings) and seed yield was examined. The correlation was positive (Pearson correlation coefficient = 0.599) and scored as highly significant according to Bonferroni’s test (fig. 8).
At site B the effect of tillage was reversed with the average yield of tilled plots 18% higher than the untilled plots, which according to the F-test was significant (fig. 9). However at this site only two of the herbicide treatments resulted in significantly higher yields than the weedy check (fig. 10). They were Authority-Velpar_H (p=0.022) and Authority-Valtera_H (p=0.054). Similarly to site A, seed yields ranged between 468 kg/ha to 676 kg/ha, but there was greater variability within treatments as reflected by the lower $r^2$ value ($r^2 = 0.86$ at site A and 0.79 at site B). The correlation between percent control of other weeds (visual rating) was also positive (Pearson correlation coefficient = 0.429) and statistically significant (fig. 11).

The analysis of variance of the control ratings of other weeds, revealed statistically significant differences at both sites. A Tukey’s test showed that for site A, the tank mixes at the low rate achieved better control than Authority® alone at the low rate (250 ml/ha), but differences were not significant when Authority® was used at the high rate (fig. 12). The picture was similar for site B, were the highest control ratings were also achieved with the high rates of Authority® (fig. 13). Tillage also influenced control ratings, but in opposite directions. At site A tillage resulted in somewhat lower ratings, whereas at site B tilled plots had higher weed control ratings for weeds other than kochia (fig. 14 and 15).

Seed germination, which was tested for each plot (64 samples per site), was not affected by weed control or tillage treatments on either one of the two sites. At site A germination ranged from 86 to 98%, with an average of 93.17% and a standard deviation of 2.20%, whereas at site B germination ranged from 90 to 98% with an average of 95.02% and a standard deviation of 1.87%.
**Figure 8.** Correlation between seed yield and percent control ratings of weeds other than kochia at site A. The Pearson correlation coefficient was 0.599 and was highly significant ($p < 0.001$, Bonferroni test).

**Figure 9.** The effect of tillage on average seed yield at site B. The difference of 95 kg/ha was statistically significant at the 5% alpha level ($p = 0.019$).

**Figure 10.** Average seed yield at site B for weed control treatments with both tillage treatments combined. Yield differences that were statistically significant (Tukey’s test) as compared to the weedy check were Authority-Valtera_H ($p < 0.054$) and Authority-Velpar_H ($p = 0.022$).

**Figure 11.** Correlation between seed yield and percent control ratings of weeds other than kochia at site B. The Pearson correlation coefficient was 0.412 and was highly significant ($p = 0.004$, Bonferroni test).
Figure 12. Weed control ratings at site A of weeds other than kochia, given as percentages of the weedy check ten weeks after application of the herbicide treatments. Letters in common show that the difference was not statistically significant (Tukey’s test).

Figure 13. Weed control ratings at site B of weeds other than kochia, given as percentages of the weedy check ten weeks after application of the herbicide treatments. Letters in common show that the difference was not statistically significant (Tukey’s test).

Figure 14. Weed control ratings at site A of weeds other than kochia, given as percentages of the weedy check ten weeks after the herbicide application. The difference was significant at the 10 % alpha level (F-test, p=0.06).

Figure 15. Weed control ratings at site B of weeds other than kochia, given as percentages of the weedy check ten weeks after the herbicide application. The difference was significant at the 1 % alpha level (F-test, p=0.01).
The results clearly demonstrated that Authority® by itself, or in a tank-mix with either Valtera™ or Velpar®, has the potential to effectively control kochia in established seed alfalfa. The fact that in this trial a known amount of kochia was seeded in each plot prior to the application of the herbicide treatments, provides greater certainty about these findings. Previous work, where kochia control was evaluated based on existing kochia populations, had given mixed results (Howard 2013). At the time we concluded that crop residues could have interfered with the herbicide’s ability to reach the target. In the current study an effort was made to restore the crop residue cover to its original state following the seeding of kochia in the untilled plots, but the amount of crop residues in most plots did not exceed 2 cm in thickness. Given that crop residues present within seed alfalfa fields can vary considerably, a follow-up study may be needed to assess to what extent these residues can interfere with the efficacy of soil applied herbicides.

The tillage by weed control treatment interaction observed at site B was almost entirely due to higher number of kochia seedlings in the tilled weedy check. This was not unexpected because soil disturbance commonly increases germination of annual weeds (Schutte et al. 2013). It also allows better placement of soil applied herbicides by reducing barriers composed of crop residues. Therefore any positive germination effect of tillage may well have been cancelled by increased herbicide efficacy (Mahoney et al. 2014). Results from site A suggest that this may have been the case insofar as there was no significant tillage effect.

The fairly uniform control of kochia achieved with all of the herbicide treatments, may have been influenced by the fact that the kochia had been seeded just one or two days prior to the application of the herbicide. It is likely that control would have been more variable if the products had been applied to kochia ranging from dormant seed to well established seedlings, as would normally be the case in field situations (Monnig and Bradley 2007). In previous work, when Authority® was applied to plots with in-situ kochia populations, control tended to be somewhat inconsistent. Also, in this study none of surviving kochia seedlings, including the ones in the weedy check, were able to develop into mature plants, instead they remained suppressed under the alfalfa canopy for the entire season. Presumably this occurred because the alfalfa was already in full growth by the third week of May, when the kochia emerged.

In the absence of competition from kochia the observed yield differences associated with the herbicide treatments could have been caused by phytotoxic effects of the herbicides on alfalfa or by weed competition from other weeds not sufficiently controlled by the products applied. Since the herbicide treatments didn’t produce any significant visible crop injury it is most likely that yield differences were caused by differences in control of weeds other than kochia. Because these other weeds (mostly dandelion, flixweed, goat’s-beard, narrow-leaved hawk’s-beard and prickly lettuce) were unevenly distributed, meaningful ratings for individual species were not possible, instead they were only rated as a group. When the relationship between control ratings of other weeds and yield was examined through a correlation analysis, it confirmed that competition by other weeds may indeed have been responsible for the observed yield differences (fig. 8 and 11). Consistent with the amount of yield differences between sites, the correlation was strongest where these differences were most pronounced.
It is interesting to note that yield was affected by the tillage operation in opposite ways between the two sites (fig. 6 and 9). On site A, where the tillage was done earlier (April 22 vs May 14) the treated plots yielded less, whereas on site B tillage increased yield. It may be that this was due the soil conditions at the time of the operation, presumably more humid and colder. More detailed work in this area would be beneficial, if tillage is to be developed as a residue and weed management tool in seed alfalfa.

As far as control of other weeds was concerned, the best results were achieved with the high rates of the tank mixes. At site A, where there was a greater variety of weeds present, Authority at the low rate (250 ml/ha) had the lowest control ratings (fig. 12). At the other location the ratings were less variable, but there was a clear separation between high and low rates (fig. 13). It was not unexpected that the tank mixes at the high rate would perform better, because the mixture will control a wider spectrum of weeds and the higher rates will increase persistence and efficacy (Tidemann et al. 2014). However higher rates will increase recropping restrictions, environmental impact and most importantly the cost. A better option would be to increase the number of registered herbicides to cover a broader range of weed species.

The finding that control of other weeds was affected by tillage in a negative or positive manner, depending on the location, most likely had to do with the weed spectrum present at each of these sites. Site A had a greater number of annuals, especially narrow-leaved hawk’s-beard and prickly lettuce, whereas site B had a greater proportion of dandelion and goat’s beard. It is likely that dandelion did not benefit from the tillage disturbance as much as some of the annual weeds. However the differences in control ratings between tilled and untilled plots were small and therefore were of limited practical significance with respect to enhancing herbicide activity.

Germination tests were included as a precautionary measure to detect potential negative effects of the herbicide treatments on seed germination, which is of course very important in the context of seed production. There was no indication in the literature that this may be the case, but then there was no published study where this question had been examined. The results obtained showed that none of the herbicide treatments had any effect on seed germination.

**Conclusion**

Results from this trial support the use of Authority® on established seed alfalfa, used alone or as a tank-mix with either Valtera™ or Velpar®. This trial confirmed previous results showing that these pre-emergence herbicides can be used without any significant risk of crop injury if applied on dormant alfalfa or on alfalfa that has just begun to resume growth after breaking winter dormancy. Authority® effectively controlled kochia at either rate tested, but the tank mixes at the higher rates resulted in the highest yields, presumable because they were more effective at controlling a wider range of weeds. Authority® and Valtera™ would be valuable additions to the fairly limited weed control options currently available to alfalfa seed producers.
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Literature cited


