The Effect of an Application of Preharvest Roundup on Canada Thistle and Seed Alfalfa

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Canada thistle is a very competitive weed in alfalfa seed fields. Jim Moyer (Moyer et al. 1991) at Lethbridge showed that as Canada thistle density increased alfalfa seed yield decreased. They found that a 17% yield loss occurred in irrigated alfalfa when the number of thistles per square metre increased from zero to two and that 10 plants per square metre reduced yields by 36%. In addition, Canada thistle is a primary noxious weed and therefore, alfalfa seed contaminated with Canada thistle will be severely downgraded. No herbicides are currently registered for the control of Canada thistle in established alfalfa seed fields. In addition, there does not appear to be any new herbicides being developed that would control Canada thistle in alfalfa. Therefore, an integrated approach including prevention, spot spraying, and preharvest treatments need to be developed.

One possible approach is the application of preharvest Roundup (glyphosate). Roundup has been used effectively in other crops as a preharvest spray to control Canada thistle. Forage alfalfa is very sensitive to being killed by Roundup when Roundup is applied in the fall. However, seed alfalfa is at a different physiological stage of development in the fall than forage alfalfa. The tolerance of seed alfalfa to this treatment is unknown. Seed germination and vigour are a serious concern. If Roundup can be used in seed alfalfa to control Canada thistle, growers would benefit from a higher yield in the next year and a reduction in the number of weed seeds that have to be removed during seed cleaning. We decided to test Roundup (glyphosate) as a preharvest treatment to control Canada thistle in alfalfa. If Roundup is going to be effective as a preharvest treatment in alfalfa seed production more knowledge is required in three areas, seed quality, alfalfa regrowth, and Canada thistle regrowth.

Methods and Materials

A preliminary experiment was started at the Melfort Research Farm in 1994 and four experiments were initiated in 1995, two at the Melfort Research Farm and two in commercial alfalfa seed fields in Arborfield and Pilger. All small plots were sprayed with a bicycle sprayer using compressed air. The small plots were 3.66 m wide and 6 or 7 metres long, depending on the experiment. One cultivar, Beaver, was used in the tests at Melfort. Rangelander was used at Arborfield and Beaver was used at Pilger. Roundup was applied in September. The seed harvested in October was tested for germination and emergence. The following spring and summer, regrowth and flowering were measured and seed yields were determined in October one year after spraying.

Reglone (diquat) and glufosinate ammonium (Harvest or Liberty) were used as desiccant checks. The chemicals tested were applied to the alfalfa at specific development stages as the alfalfa seed matured. Glufosinate ammonium was applied at the recommended stage of development, when approximately 60 to 75% of the pods had began to change colour from green to brown (Moyer et al. 1996). Glufosinate was applied when 60 to 70% of the pods had began to change colour from green to brown. Diquat was applied when at least 80 to 90% of the pods had changed colour as recommended on the product label. Glyphosate was applied when 60 to 70% of the pods had started to change colour unless a specific stage of development is given as in Table 8. The control plots were sprayed with water. Alfalfa was harvested once it had finished ripening. Consequently, all the treatments were not harvested at the same time.

Canada Thistle Control

Two tests were established to examine the effect of Roundup on Canada thistle in seed alfalfa. The tests were at different locations, Arborfield and Pilger. Both tests were placed on Canada thistle patches in commercial alfalfa seed fields. At Arborfield the Rangelander was in its fifth year of production and the Beaver at Pilger was in its forth year of seed production. Five rates of Roundup 0, 220, 440, 660, and 880 g a.i. ha^{-1} (0, 0.25, 0.5, 0.75, and 1 L $acre^{-1}$) were applied at Arborfield on September 4, 1995. Six rates of Roundup 0, 220, 440, 660, 880 and 1100 g a.i. ha^{-1} (0, 0.25, 0.5, 0.75, 1 and 1.25 L $acre^{-1}$) were applied at Pilger on September 5, 1995.

Seed Quality and Alfalfa Regrowth

In 1994, a preliminary experiment was conducted at Melfort testing the effects of diquat, glufosinate ammonium and Roundup applied before harvest. The diquat was applied at 400 g a.i. ha^{-1} (2 L $acre^{-1}$) and the glufosinate ammonium was applied at 375, 450 and 525 g a.i. ha^{-1} (2.5, 3 and 3.5 L $acre^{-1}$). The Roundup was applied at 880 and 1246 g a.i. ha^{-1} (1 and 1.4 L $acre^{-1}$). This stand of Beaver was in its fifth year of seed production in 1994. These treatments were reapplied to the same plots in 1995.

In 1995 a test was conducted at the Melfort Research Farm to examine the effect of different rates of Roundup on alfalfa plant survival and alfalfa seed germination. Roundup was applied at 0, 440, 880, 1320 and 1760 g a.i. ha^{-1} (0, 0.5, 1, 1.5 and 2 L $acre^{-1}$). Two checks, diquat and glufosinate ammonium, were used. This stand of Beaver was in its first year of seed production in 1995. This experiment was repeated in 1996 at a new site.

In 1995 a test was conducted at the Melfort Research Farm to examine the effect of applying Roundup at different times as the alfalfa matures, on alfalfa plant survival and alfalfa seed germination. Two rates of Roundup, 880 and 1760 g a.i. ha^{-1} (1 and 2 L $acre^{-1}$) were applied at four stages of crop development, 1, 26, 51 and 76% pod turn. Pod turn refers to the percentage of pods in the plot that have begun to change colour. The actual dates of application were August 21, September 1, 8

and 14. Three checks, a nonsprayed check, diquat and glufosinate ammonium, were used. This stand of Beaver was in its first year of seed production in 1995. This experiment was repeated in 1996 at a new site.

Testing Seed Germination and Emergence

The germination tests on the seed harvested in 1994 were conducted by an accredited lab at Newfield seeds in Nipawin, Saskatchewan. They used the methods and procedures set out by the C.D.A. for seed testing. The rest of the germination tests were carried out at the Melfort research farm by placing 50 seeds on two filter papers in a petri dish. Approximately 3.5 ml of water were added and the lid was placed on top of the petri dish. The petri dishes were then placed in a germination chamber. To help break seed dormancy the temperature was kept between 3 and 5 C for three days before the temperature was raised to 20 C. The germinated, hard and dead seeds were counted after seven days.

The emergence tests were carried out on the 1994 harvested seed in a green house in the fall to simulate spring like temperatures. The other emergence tests were carried in growth chambers. A temperature program was set up to reflect the normal daily fluctuations that the seed would be exposed to during germination in the late spring in Saskatchewan. The max daily temperature was 24 C and the minimum daily temperature was 12 C. The seed was place 2 to 3 cm below the soil surface. The potting soil was a mixture of eight parts peat, three parts tropical soil,, three parts perlite, two parts sand, and one part topsoil. The top soil was not sterilized so that any soil borne organisms that would affect seed emergence would be present in the soil mixture while the seed was emerging. Emergence was rated every seven days for at least 42 days. When the field establishment test was conducted (Table 3) seed was planted in small plots 1.4 m by 7 m using a plot size, Fabro seed drill. The row width was 7 inches and a double disk type opener was used. The seed was placed 1.5 to 2.5 cm below the soil surface at a seeding rate of 7 kg ha. The test was planted on May 29 at the Melfort Research Farm.

Results and Discussion

Canada Thistle Control

Canada thistle control varied between the two locations, Arborfield and Pilger. At Arborfield the 200 g a.i. ha^{-1} (0.25 L $acre^{-1}$) rate controlled 70% of the Canada thistle (Table 1). The higher rates did not improve control of the Canada thistle. The response of the Canada thistle to the increasing rates of Roundup was cubic. However, from a biological point of view a quadratic response curve may reflect reality better than a cubic response curve. As the rate of Roundup increased the vegetative growth decrease (Table 1). Therefore, the competitiveness of the alfalfa would decrease as the rate of Roundup increased. This may explain the lack of an increase in Canada thistle control as the rate of Roundup increased above 220 g a.i. ha^{-1}.

At Pilger the 200 g a.i. ha^{-1} (0.25 L $acre^{-1}$) rate controlled 51% of the Canada

thistle (Table 2). The control for most of the rates was erratic and none of the rates provided acceptable control of the Canada thistle. There was a statistically significant linear response to increasing the rate of Roundup. We are not sure why the control was different between the two locations.

Seed Quality

Seed quality was first examined by measuring the seed germination in each experiment started in 1995. The roundup did not affect seed germination and these results were reported in last years annual report (May et al. 1996). Germination tests are currently being conducted on the five experiments sprayed in the fall of 1996.

Seed emergence tests were conducted to increase our confidence that Roundup did not effect seed quality. None of the Roundup treatments had any affect on seed emergence (Tables 3 and 4). The growth stages of the emerged seedlings were recorded. No treatment delayed plant development when compared with the other treatments. These results indicate that the treatments did not affect seedling emergence or development in growth chambers.

To ensure that these results would apply to seedling emergence in the field, a test was planted on the Melfort research station using seed harvested from the experiment that examined the effect of applying Roundup at different stages of development. The Roundup did not affect the vegetative growth and plant density of the alfalfa when measured near the end of the growing season (Table 5). In conclusion we found no evidence to suggest that Roundup had any affect on the germination, emergence or growth of alfalfa seed.

Alfalfa Regrowth

Alfalfa regrowth was very inconsistent. The alfalfa regrowth in the experiment sprayed in 1994 was reduced by the Roundup in the early spring of 1995 (Table 6). However, by the beginning of July the Roundup treatments had similar amounts of vegetative growth as the other treatments. The seed yield was not affect by the Roundup treatments. When this experiment was repeated regrowth in the early spring of 1996 was severely reduced (Table 6). The vegetative growth of the Roundup treatments never recovered during the growing season. The yield from the lowest rate of Roundup (880 g a.i. ha^{-1} or 1 L $acre^{-1}$) was 200 kg ha^{-1} less than the control.

When we examined the effect of different rates of Roundup on the regrowth of alfalfa, we found that the vegetative regrowth was reduced as the rate of Roundup was increased (Table 7). On May 28 the growth decreased linearly as the rate of Roundup increased. By July 4, the vegetative growth of the 440 g a.i. ha^{-1} (0.5 L $acre^{-1}$) rate of Roundup started to catch up to the control. By July 28 there was little difference between the control and 440 g a.i. treatment. However, most of the seed set occurs in July. The Roundup treatments had a similar effect on the amount of bloom in the alfalfa stand. The yield was reduced as the rate of Roundup increased. The yield of the 440 g a.i. ha^{-1} (0.5 L $acre^{-1}$) was 58% of the control and

the 880 g a.i. ha^{-1} (1.0 L $acre^{-1}$) was 29% of the control. The high rate of Roundup (1760 g a.i. ha^{-1} or 2.0 L $acre^{-1}$) did a very good job of suppressing alfalfa growth and yields. However, when the plants were not disturbed for the entire summer the plants appeared to recover.

The maturity of the alfalfa affected the regrowth of the alfalfa when the 880 g a.i. ha^{-1} (1.0 L $acre^{-1}$) rate was used but not when the (1760 g a.i. ha^{-1} or 2.0 L $acre^{-1}$) rate was used (Table 8). Yield was not affected at either rate. When the 880 g a.i. rate was applied at 1% pod turn there was more regrowth than at the other stages of maturity. As in the other experiments as the rate of Roundup increased the vegetative growth and yield decreased.

In the two experiments established on producer fields the same trends can be observed (Tables 1 and 2). The vegetative growth and yield decreased as the rate of Roundup increased. All these results suggest that applications of Roundup before seed harvest can significantly reduce vegetative growth and seed yields in the following year.

We can conceive two ways of using Roundup in alfalfa seed yields. The first way is the last year of seed production. This would alow the producer to get a head start on talking out his alfalfa and starting his thistle control. A 2 L $acre^{-1}$ rate stopped the growth of the alfalfa for most of the season. This approach has potential. Experiments should be set up in alfalfa fields that are in there last year of seed production to evaluate the effectiveness of preharvest Roundup applications.

The second way is to use Roundup at low rates while the alfalfa crop is still in production. The results from these experiments suggest that the risk of reducing seed yields are quite high. However, the yields were low in the two experiments set up on thistle patches. Growers may want to use preharvest Roundup on their worst Canada thistle patches to try to slow the spread of the Canada thistle. I suspect that the Roundup is being taken up by the regrowth at the base of alfalfa plant. Therefore, one possible solution to the problem of reduced growth and yields may be to apply the Roundup with a wick to the top of the canopy. We hope this would apply Roundup to the thistles without applying the Roundup to the green growth at the base of the plant. A wick treatment was included in the three experiments placed on Canada thistle patches in the fall of 1996. The results next summer will be interesting.

Three conclusions can be drawn from the work completed up to this point. Seed quality has not been reduced by preharvest applications of Roundup. Next, the Roundup did not consistently control the Canada thistle. Last, using high rates of Roundup in the last year of seed production may be more feasible at this point than low rates of Roundup applied to a stand that is staying in production.

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Table 1. The effect of glyphosate on seed yields in 1996 when applied preharvest to seed alfalfa in 1995 near Arborfield when 90% of the pods have turned colour.

	Yield	Vegetative Growth %			Flowering	Alfalfa	Canada thistle	Canada thistle
Glyphosate g a.i. ha^{-1}	(kg ha^{-1})	May 29	June 27	July 31	% of plants flowering	plants m^{-2}	plants m^{-2}	% control
0	68.4	100	100	100	100	7	9	0
220 g a.i. ha^{-1}	49.1	22.5	96	94	89	8	6	70
440 g a.i. ha^{-1}	25.4	7	63	83	48	7	7	66
660 g a.i. ha^{-1}	20.8	4	29	66	31	8	3	75
880 g a.i. ha^{-1}	14.8	5	21	65	24	8	6	65
Response to glyphosate								
Linear	**	**	**	**	**	NS	*	**
Quadratic	NS	**	NS	NS	NS	NS	NS	**
Cubic	NS	**	**	NS	NS	NS	NS	*
Pr>F	0.001	0.0001	0.0001	0.001	0.0001	0.70	0.08	0.0001
CV	38	6	12	12	25	18	40	21

** Significant at $P<0.01$, * Significant at $P<0.05$; NS, not significant.

Table 2. The effect of glyphosate on seed yields in 1996 when applied preharvest to seed alfalfa in 1995 near Pilger when 60 to 70% of the pods have turned colour.

	Yield	Vegetative Growth %			Alfalfa	Canada thistle	Canada thistle
Glyphosate g a.i. ha^{-1}	(kg ha^{-1})	July 5	July 25	Aug 14	plants m^{-2}	plants m^{-2}	% control
0	77.0	100	100	100	4	11	0
220 g a.i. ha^{-1}	69.3	98	73	71	4	7	51
440 g a.i. ha^{-1}	47.8	66	60	68	4	8	39
660 g a.i. ha^{-1}	64.9	48	56	53	4	8	30
880 g a.i. ha^{-1}	45.3	25	49	50	4	9	44
1100 g a.i. ha^{-1}	46.6	29	46	53	3	6	50
Response to glyphosate							
Linear	**	**	**	**	NS	NS	**
Quadratic	NS	NS	NS	**	NS	NS	NS
Cubic	NS	NS	NS	NS	NS	NS	**
Pr>F	0.06	0.0001	0.003	0.0001	0.96	0.38	0.001
CV	29	26	25	16	35	49	37

** Significant at $P<0.01$, * Significant at $P<0.05$; NS, not significant.

Table 3. The emergence of seed after a desiccant was applied preharvest to seed alfalfa when 60 to 70% of the pods have turned colour in 1994 and 1995.

	1994				1995			
	Germination (%)	Emergence (%) (greenhouse)			Germination (%)	Emergence(%) (growth cabinet)		
days after planting		14	28	61		14[z]	28[y]	57[x]
control	35 *c*[w]	18	22	25	43	28	26	27
diquat	44 *ab*	17	19	23	39	24	21	22
glufosinate ammonium 375 g a.i. ha^{-1}	40 *bc*	19	22	26	30	22	19	20
glufosinate ammonium 450 g a.i. ha^{-1}	37 *bc*	12	18	21	38	20	18	18
glufosinate ammonium 525 g a.i. ha^{-1}	49 *a*	16	20	22	38	21	18	19
glyphosate 880 g a.i. ha^{-1}	37 *bc*	15	19	21	32	19	16	17
glyphosate 1246 g a.i. ha^{-1}	37 *bc*	12	16	18	38	19	17	18
Pr>F	0.03	0.53	0.73	0.53	0.40	0.21	0.10	0.09
CV	18	50	38	33	23	28	30	29

[z] All the plants were at the cotyledon or one unifoliate stage of development.
[y] The plants were at various stages of development, a unifoliate leaf, one trifoliate leaf and two or more trifoliate leaves. Most of the plants had one or more trifoliate leaves
[x] All plants had at least two trifoliate leaves on them by this time.
[w] *a-c* Values within a column followed by the same letter are not different at $P \leq 0.05$ (experimentwise error) by protected LSD.

Table 4. The emergence of seed after a desiccant was applied preharvest to seed alfalfa when 60 to 70% of the pods have turned colour in 1995

	Emergence % (growth cabinet)			Germination %	Hard Seed %
days after planting	14[z]	28[y]	64[x]		
control	13	13	13	66	33
diquat	17	16	15	68	31
glufosinate ammonium	17	17	18	69	32
glyphosate 440 g a.i. ha^{-1}	16	17	16	58	42
glyphosate 880 g a.i. ha^{-1}	15	16	17	64	37
glyphosate 1320 g a.i. ha^{-1}	17	16	16	64	37
glyphosate 1760 g a.i. ha^{-1}	24	22	22	56	44
Pr>F	0.48	0.53	0.29	0.80	0.77
CV	40	38	30	22	38

[z] All the plants were at the cotyledon or one unifoliate stage of development.
[y] The plants were at various stages of development, one unifoliate leaf, one trifoliate leaf and two or more trifoliate leaves. Most of the plants had two or more trifoliate leaves
[x] All plants had at least two trifoliate leaves on them by this time.

Table 5. The establishment of alfalfa in 1996 using seed that was subjected to the preharvest application of a desiccant as the alfalfa crop matured in 1995

Chemical	Desiccation [y]	Vegetative growth [z]	Plant Density	Seed germination	Hard seed
	% pod turn	%	Plants m^{-2}	%	%
control	100	90	18	73	27
diquat	90	93	22	70	37
glufosinate ammonium 450 g a.i. ha^{-1}	76	93	21	63	29
glyphosate 880 g a.i. ha^{-1}	1	91	21	57	44
glyphosate 880 g a.i. ha^{-1}	26	83	16	60	41
glyphosate 880 g a.i. ha^{-1}	51	85	19	62	38
glyphosate 880 g a.i. ha^{-1}	76	91	22	69	31
glyphosate 1760 g a.i. ha^{-1}	1	84	19	60	39
glyphosate 1760 g a.i. ha^{-1}	26	88	19	64	36
glyphosate 1760 g a.i. ha^{-1}	51	90	18	63	36
glyphosate 1760 g a.i. ha^{-1}	76	85	18	57	43
Pr>F		0.76	0.76	0.86	0.86
CV		10	26	23	39

[z] The percentage of total growth compared to the plot with the most vegetative growth in each replication.
[y] Stage of development at which the seed crop was desiccated.

Table 6. The seed yield and growth of alfalfa in 1995 and 1996 after desiccants were applied preharvest to seed alfalfa when 60 to 70% of the pods have turned colour in 1994 and 1995.

	1995			1996			
	Yield (Kg ha^{-1})	Vegetative Growth		Yield (Kg ha^{-1})	Vegetative Growth		
		May 25	July 5		May 28	June 14	July 4
control	184*b*	100*a*	100	331*a*[z]	100*a*	100*a*	100*a*
diquat	370*a*	90*ab*	98	277*a*	73*bc*	96*ab*	91*ab*
glufosinate ammonium 375 g a.i. ha^{-1}	323*a*	89*ab*	90	276*a*	84*ab*	93*b*	84*b*
glufosinate ammonium 450 g a.i. ha^{-1}	344*a*	93*ab*	93	253*a*	61*c*	85*c*	80*b*
glufosinate ammonium 525 g a.i. ha^{-1}	336*a*	95*ab*	95	343*a*	78*bc*	100*a*	88*ab*
glyphosate 880 g a.i. ha^{-1}	339*a*	81*b*	93	108*b*	5*d*	20*d*	55*c*
glyphosate 1246 g a.i. ha^{-1}	342*a*	64*c*	89	54*b*	5*d*	10*e*	35*d*
Pr>F	0.0003	0.007	0.08	0.001	0.0001	0.0001	0.0001
CV	19	13	6	35	20	6	12

[z] *a-e* Values within a column followed by the same letter are not different at $P \leq 0.05$ (experimentwise error) by protected LSD.

Table 8. The effect of glyphosate on seed yields in 1996 when applied preharvest at different rates and maturities to seed alfalfa in 1995 when 60 to 70% of the pods have turned colour.

Chemical	Desiccation [y]	Yield (kg ha^{-1})	Vegetative Growth %					
	% pod turn		May 31		June 14	July 4		July 28
control	100	544	100		100	100		100
diquat	90	656	100		96	99		100
glufosinate ammonium 450 g a.i. ha^{-1}	76	639	90		100	100		100
glyphosate			880 g a.i. ha^{-1}	1760 g a.i. ha^{-1}		880 g a.i. ha^{-1}	1760 g a.i. ha^{-1}	
	1	197	24	6	31	65	17	45
	26	200	7	5	16	37	30	46
	51	176	9	4	19	44	16	44
	76	205	6	3	15	36	23	54
Response to pod turn								
Linear		NS	**	NS	*	**	NS	NS
Quadratic		NS	**	NS	NS	NS	NS	NS
Cubic		NS	**	NS	NS	NS	NS	NS
Glyphosate Rate								
0 g a.i. ha^{-1}		544			99			100
880 g a.i. ha^{-1}		238			30			58
1760 g a.i. ha^{-1}		151			10			36
Response to Rate								
Linear		**			**			**
Quadratic		**			**			NS
CV		19	12		29	22		

[y] Stage of development at which the seed crop was desiccated.
** Significant at $P<0.01$, * Significant at $P<0.05$; NS, not significant.