

Evaluating Herbicide Efficacy in Flax

Project duration

2020-2021

Collaborators

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Objectives

The purpose of this project is –

- 1) To compare efficacy of standard herbicide (Authority) treatments to experimental herbicide (Armezon) treatments in controlling weeds in flax.
- 2) To determine any safety concerns from the use of herbicide combinations.

Results

Roblin site

Weed injury was different among herbicide treatments after two weeks of application (2 WAA) at Roblin (Table 1). Application of Authority as a pre-seed injured 73% of the sampled weeds compared to 43% observed for a tank mix of Armezon + Bromoxynil + Select applied in-crop. High efficacy of Authority applied prior to seeding could have been as a result of activation by rainfall following herbicide application.

All other herbicide options, including Armezon applied in-crop alone were not effective, with only 5 to 8% weed injury at 2 WAA and were not different from each other in terms of efficacy.

Flax injury was high both at 2 (47%) & 4 (22%) WAA when Armezon + Mextrol + Select (treatment 8) were applied post emergence in a single tank mix. All other herbicide treatments proved to be safe at Roblin site.

A combination of Armezon + Mextrol + Select applied to flax resulted in lower plant height compared to other herbicide options. This might influence flax development and ultimate yield in the long term. On the other hand, a tank mix of Armezon + Bromoxynil + Select resulted in crop height that was not significantly different from treatments 1, 3, 4 and 5 and is acceptable compared to treatment 8 (Table 1). Therefore, Armezon + Bromoxynil + Select applied in-crop and Authority applied pre-seed could be better options when considering herbicide injury percentages and crop height impact. There were no significant yield differences observed regardless of herbicide treatment applied but numerically, in-crop application with Armezon achieved the highest seed yield of 4041 kg ha⁻¹.

Overall high coefficient of variation for weed injury was as a result of treatment 9 (Armezon + Bromoxynil + Select) and 3 (Authority pre-seed), which had lots of variation. Flax emergence lower than expected due to excessively dry conditions at crop establishment. The site was seeded on the 27th of May but only received about 5.1 mm of rainfall between the 26th of May and the 5th of June (<https://web43.gov.mb.ca/Climate/DailyReport.aspx>).

Table 1. Effect of different herbicide treatments on weed injury, weed density, flax emergence, crop injury, crop height and yield at Roblin.

Treatment	Weed Injury (%) 2 WAA	Weed Density at flower (pl/m ²)	Flax Emergence (pl/m ²)	Crop Injury (%)		Plant height (cm) 2 WAA	Yield (kg/ha)
				2 WAA	4 WAA		
1. UTC (no weeding)	*	51	155	*	*	39abc	3097
2. UTC (Hand weeded check)	*	*	149	*	*	44a	1939
3. Authority (pre-seed)	73a	53	134	0b	0b	40ab	2976
4. Armezon (in crop)	8c	72	136	0b	0b	35bcd	4041
5. Authority + Armezon	5c	52	158	3b	0b	37abcd	3141
6. Authority + [Mextrol + Select (in crop)]	5c	60	150	3b	0b	31cd	3110
7. Authority + [Bromoxynil + Select (in crop)]	5c	41	157	2b	0b	30d	3013
8. Armezon + Mextrol + Select	5c	68	146	47a	22a	16e	2418
9. Armezon + Bromoxynil + Select	43b	62	180	3b	1b	33bcd	2864
P value (treatment)	0.001	0.573	0.794	<0.001	0.014	<0.001	0.320
Coefficient of Variation (%)	33	10	21	85.8	196.2	14	29

Melita site

At Melita, herbicide combinations resulted in greater weed injury than in single herbicide treatments (Table 2). Higher weed injury for combination treatments involving Authority were probably as a result of adequate rainfall for herbicide activation following application.

Herbicide combinations also caused greater reduction in weed densities compared to Armezon or Authority applied alone. Overall, weed density was lower at Melita compared to Arborg and Roblin, which could be due to site specific differences.

Table 2. Effect of different herbicide treatments on weed injury, weed density, flax emergence, crop injury, crop height and yield at Melita.

Treatment	Weed Injury (%) 2WAA	Weed Density at flower (pl/m ²)	Flax Emergence (pl/m ²)	Crop Injury (%)		Plant height (cm) 2WAA	Yield (kg/ha)
				2WAA	4WAA		
1. UTC (no weeding)	*	23a	541			37a	2473
2. UTC (Hand weeded check)	*	*	537			36ab	2508
3. Authority (pre-seed)	27bc	13ab	520	0d	0b	37a	2512
4. Armezon (in crop)	7c	21a	567	0d	0b	37a	2376
5. Authority + Armezon	45bc	6bc	473	10cd	0b	34ab	2762
6. Authority + [Mextrol + Select (in crop)]	78ab	4c	500	20bc	0b	31bc	2490
7. Authority + [Bromoxynil + Select (in crop)]	92a	4c	537	10cd	2b	32abc	2603
8. Armezon + Mextrol + Select	72ab	4c	506	43a	8a	26cd	2596
9. Armezon + Bromoxynil + Select	93a	5c	524	37ab	10a	24d	2526
P value (treatment)	0.005	0.003	0.627	0.001	0.008	0.002	0.699
Coefficient of Variation	28	26	10	68.4	140.7	11	9

Armezon (in-crop) application alone caused little injury on weeds and flax than when applied in combination with other herbicides. It did not have a negative impact on flax height compared to combination herbicides. Crop injury recovery was observed at 4 WAA of combination herbicides involving Armezon, which explains the ability of flax to recover in the short term after herbicide treatment.

Flax emergence did not differ among treatments and overall Melita site had good stand establishment. This was probably due to adequate soil moisture at crop establishment stage. There were no significant differences in flax seed yield across all treatments.

Arborg site

Weed injury was high among all combination treatments including Armezon applied in-crop at Arborg site. It ranged from 60% to 87% compared with Authority (pre-seed) that only caused 10% injury (Table 3). It is quite possible that Authority was not effective due of low rainfall received within two weeks of application. Authority applications require a moderate rainfall of between 10-20 mm within 10 to 14 days for proper activation. During the 2-week period from application of Authority, Arborg site only received 3.8 mm rainfall (<https://web43.gov.mb.ca/Climate/DailyReport.aspx>), which was not adequate for its activation.

Table 3. Effect of different herbicide treatments on weed injury, weed density, flax emergence, crop injury, crop height and yield at Arborg.

Treatment	Weed Injury (%) 2WAA	Weed Density at flower (pl/m ²)	Flax Emergence (pl/m ²)	Crop Injury (%)		Plant height (cm) 2WAA	Yield (kg/ha)
				2WAA	4WAA		
1. UTC (no weeding)	*	96a	264	*	*	42ab	1889e
2. UTC (Hand weeded check)	*	*	313	*	*	47a	3553a
3. Authority (pre-seed)	10b	93ab	293	8	12ab	35bc	2217de
4. Armezon (in crop)	60a	109a	304	13	13ab	20d	2574cd
5. Authority + Armezon	67a	104ab	317	13	7c	32c	3198ab
6. Authority + [Mextrol + Select (in crop)]	80a	11c	279	12	6c	46a	3007bc
7. Authority + [Bromoxynil + Select (in crop)]	78a	68abc	315	17	8bc	22d	3052b
8. Armezon + Mextrol + Select	87a	15bc	315	28	15a	17d	2944bc
9. Armezon + Bromoxynil + Select	85a	70a	277	23	13ab	19d	3116ab
P value (treatment)	<0.001	0.037	0.29	0.242	0.007	<0.001	<0.001
Coefficient of Variation	12	17	10	15.2	25.7	13	10

Weed density at flower differed among different treatments. Weed density was lower in Authority + {Mextrol + Select (in-crop)} and Armezon + Mextrol + Select herbicide combinations.

Similar pattern in crop injury recovery was observed at Arborg site as at Melita and Roblin sites. Crop recovered significantly at 4 WAA. Authority in combination with Armezon or Mextrol & Select resulted in less crop injury at 4WAA.

Crop height was reduced in treatments 4, 5, 7, 8 & 9. It looks like Armezon alone or in combination with bromoxnil did have its effect on flax height.

Flax seed yield was higher in combination herbicide treatments. Overall, flax yield ranged from 1889 kg ha⁻¹ to 3553 kg ha⁻¹, with the lowest being the non-weeded check as expected. Although it caused significantly high percentage in weed injury during the first 2 WAA, the MCPA component in Mextrol with Armezon + Mextrol +Select appeared to have reduced

flax seed yield. Probably application rates of the Mextrol component might need to be revised so as to reduce the impact on yield but not compromising on weed control.

Combined site analysis

A combined site analysis conducted to determine performance of herbicide treatments across different environments found no significant differences in efficacy on weed injury, weed density at flowering stage and flax emergence. However, Armezon + Bromoxynil + Select combination caused the highest weed injury while other treatments ranged from 25 to 58% (Table 4).

Crop injury at 2 and 4WAA varied significantly and application of Armezon (pre-seed) + Mextrol + Select (in-crop) caused the highest flax injury (39% & 15%, respectively). There were also significant recoveries from herbicide injury within the 2-week period from the initial observation. The impact of treatments 8 and 9 were not significantly different on crop injury at 4 WAA.

Flax height was significantly affected due to different herbicide options applied. Treatments 7, 8 and 9 resulted in shortened flax plants at 2 WAA. There were also significant treatment x site interactions in flax plant height, weed density at 2 WAA and crop yield. Site differences may have influenced results of this study. Selection of herbicide options to use will likely be based on their performance in a specific geographical area.

Table 4. GLM Combined (Melita, Arborg and Roblin sites) analysis of variance for weed injury, weed density, flax emergence, crop injury, crop height and crop yield during 2020 testing.

Treatment	Weed Injury (%) 2WAA	Weed Density at flower (pl/m ²)	Flax Emergence (pl/m ²)	Crop Injury (%)		Plant height (cm) 2WAA	Yield kg/ha
				2WAA	4WAA		
1. UTC (no weeding)	*	57	320	*	*	39ab	2486
2. UTC (Hand weeded check)	*	*	333	*	*	42a	2667
3. Authority (pre-seed)	37	53	315	3c	4b	37abc	2568
4. Armezon (in crop)	25	67	336	4c	4b	31bcd	2997
5. Authority + Armezon	39	54	316	9bc	2b	34abcd	3034
6. Authority + Mextrol + Select (in crop)	54	25	309	12bc	2b	36abc	2869
7. Authority (pre-seed) + Bromoxynil + Select (in crop)	58	38	336	9bc	3b	28cde	2889
8. Armezon (pre-seed) + Mextrol + Select (in crop)	54	29	322	39a	15a	20e	2653
9. Armezon + Bromoxynil + Select (in crop)	74	46	327	21b	8ab	25de	2835
P value (treatment)	0.647	0.058	0.821	0.003	0.023	0.004	0.876
P value (Site)	0.22	0.202	0.159	0.291	0.208	<0.001	0.392
P value (Site x Treatment)	0.015	0.075	0.481	0.056	0.082	0.007	0.048

Weed species composition differed across all the three sites (Table 5). Arborg had predominantly redroot pigweed in treatments 1, 2, 4 and 8 while lambs quarters was only present in treatment 1 and 2. At Melita, biennial wormwood was predominant in treatments 1, 3, 4 and 6 while volunteer wheat appeared in more than 50% of the treatments. At Roblin, volunteer canola was predominant in all treatments followed by green foxtail.

Table 5. Summary of four major weed species (ranked as most to least) by site after herbicide treatment at flower stage.

Treatment	Arborg	Melita	Roblin
1	RRP> C> D> LQ	BW> D> VW> CT	C> GF> LQ> SP
2	RRP> D> C> LQ	D>W	C> GF> LQ> D
3	WB> D	BW> VW> WB> K	C> GF
4	RRP> C> WB> D	BW> D> WB> VW	C> GF
5	D> WB> RRP	WB> CT> VC> BW	C> GF> D
6	C> D> RRP> WB	BW> VW> WO> VW	C> GF> D
7	D	D> VW> RRP> BW	C> GF> SP
8	RRP> C> D	WB> BW	C> GF> LQ

Key RRP – Redroot pigweed, C – volunteer canola, D – Dandelion, WB – Wild Buckwheat, LQ – Lambs quarters, BW – Biennial Wormwood, WO – Wild Oat, K – Kochia, VW – Volunteer Wheat, CT – Canadian Thistle, GF – Green foxtail, SP – Shepherd’s purse

Project Findings

Interestingly there were no flax injuries with Authority + Mextrol option but Armezon in combination with Mextrol caused injuries. Based on these preliminary findings, this combination should be avoided in real farm situations unless if further studies with reduced applications rates of Mextrol can prove otherwise. Armezon on its own did not seem to show crop injury, but it stunted the height of flax, which could reduce seed yield. Arborg was the only site that showed yield loss based on herbicide use in general. At this site, Armezon showed yield loss both in sole use, and in combination with Mextrol. The study will be conducted again in 2021 before recommendations can be made available for registration of Armezon in flax. There might be need to consider reducing Mextrol application rates when used in combination with Armezon in order to address crop injury concerns.

Background / References / Additional Resources

Flax (*Linum usitatissimum*) is an important crop known for its value in food and fiber industrial markets around the world. However, flax has a low competitive ability with weeds compared to other crops. Various weed management strategies that include; competitive varieties, early seeding, increased seeding rates and the use of pre- and post-emergence herbicides can help to control weeds and reduce yield losses than using only one control method (Kurtenbach et al., 2019). Pre-emergence weed control is crucial in flax to reduce yield loss since flax is a weak competitor with weeds (Berglund and Zollinger, 2007).

Post-emergence weed control, if done timely, usually results in better weed control and allow more time for flax recovery from possible herbicide injury. There is currently a challenge in herbicide options for flax as a result of herbicide resistance. Furthermore, herbicide injury concerns after the use of different herbicide combinations need to be examined. There is need to investigate possible alternative options, herbicide combinations and timings of application for control of both broad leaf weeds and grasses.

Armezon® herbicide, which is classified as Group 27, is an effective tank-mix option that is currently registered as a post-emergence herbicide for the control of tough broad leaf weeds and grasses in corn and has potential for use in flax for control of Group 1 resistant grasses (Table 6). Currently, the herbicide is not registered for use in flax but extensive field trials can provide data for registration. Therefore, this study is evaluating several herbicides including Authority, Mextrol, Koril, Select and experimental Armezon used alone or tank mixed with

compatible herbicides to see their effectiveness in weed control and protecting yield losses. The study also aims to assess any safety concerns with the use of different herbicide mixes in flax.

Table 6. List of weeds controlled by Armezon, Authority, Mextrol, Koril and Select herbicides.

Weeds Controlled	Herbicide Name				
	Armezon	Authority	Mextrol	Koril	Select
	Herbicide Group				
	27	14	4 + 6	6	1
Barnyard Grass	S				C
Foxtail Green	S				C
Foxtail Yellow	S				C
Quack grass					C
Volunteer Cereals					C
Wild Oats					C
Wild Buckwheat		C	C	C	
Night-flowering Catchfly			C		
Chickweed	S				
Cleavers		S			
Cocklebur			C	C	
Dandelion					
Flixweed			C		
Hemp-nettle					
Kochia	C	C	C	C	
Lambs quarters	S	C	C	C	
Round leaved Mallow					
Wild Mustard	C		C	C	
Red Root Pigweed	C	C	S	C	
Russian Thistle	S		C	C	
Shepherds Purse			C		
Annual Smartweed	S		C	C	
P. Sow thistle			TG		
Stinkweed			C	C	
Canada Thistle			TG		
Vol. Canola	C		C	C	

C – Control, S – Suppress, TG – Top growth

References

Berglund, D. R. and Zollinger, R. K. 2007. *Flax Production in North Dakota*. North Dakota Extension Service, North Dakota State University 58105: A-1038.

Kurtenbach, M. E., Johnson, E. N., Gulden, R. H., Duguid, S., Dyck, M. F., Willenborg, C. J. 2019. *Integrating Cultural Practices with Herbicide Augments Weed Management in Flax*. *Agronomy Journal* **111 (4): 1904-1912**. <https://doi.org/10.2134/agronj2018.09.0593>.

Materials and Methods

The trial was conducted at Melita, Roblin and Arborg sites in Manitoba, as randomized complete block design with the following nine herbicide treatments replicated three times:

1. UTC (no weeding)
2. UTC (Hand weeded check)

3. Authority (pre-seed) @ 100 ml/acre
4. Armezon (in crop) @ 15 ml/acre + Merge @ 0.25L/100L water
5. Authority (pre-seed) + Armezon (in crop)
6. Authority (pre-seed) + (Mextrol 450 @ 0.5L/acre + Select @ 100 ml/acre + Amigo in crop)
7. Authority (pre-seed) + (Bromoxynil @ 0.49L/acre [Koril] + Select @ 100 ml/acre)
8. Armezon + (Mextrol 450 + Select + Amigo)
9. Armezon + (Bromoxynil + Select)

Herbicide treatments were applied using a calibrated CO₂ backpack sprayer. Herbicide formulation and treatment description is summarized in Table 7.

Table 7. Herbicide formulation and treatment description for flax herbicide trial in 2020

Trade name	Chemical	App. Rate g a.i./L	Field Rate ml/ac	Water Vol. Rate gal/ac	Treatments
Armezon	Topramezone	336	15	10	4,5,8,9
Merge	Adjuvant		0.25L/100L	10	3,4
Authority	Sulfentrazone	480	100	10	3,5,6,7
Mextrol	MCPA + Bromoxynil	225 + 225	500	10	6,8
Koril	Bromoxynil	235	490	10	7,9
Select	Clethodim	252	100	10	6,7,9,9
Amigo	Surfactant		0.5L/100L	10	6,8

Plot management varied from site to site. Summary of site description, agronomic management followed, spray information and assessment dates are presented in Tables 8 and 9.



Flax herbicide trial at Arborg site.

Table 8. Spraying information for Arborg, Melita and Roblin sites.

Spraying information	Arborg	Melita	Roblin	
Spray Tip	TeeJet AI80015	TeeJet AI8002	BFS Orange AI 01	
Water Volume (imp. Gal/ac)	10	10	10	
Burnoff	NA	08-May	29-May	
Burnoff Product (Rate)	NA	Roundup (0.5 L/ac) + Aim (15 ml/ac)	Roundup (0.64L/ac)	
Pre-emerg app date	22-May	08-May	29-May	
In-crop app date	13-Jun	04-Jun	25-Jun	
Assessments				
Crop Injury	2WAA	26-Jun	18-Jun	08-Jul
	4WAA	13-Jul	02-Jul	22-Jul
Weed Injury date	2WAA	26-Jun	26-Jun	08-Jul
Weed count date at flower		13-Jul	02-Jul	27-Jul
Crop height date	2WAA	13-Jul	20-Jul	22-Jul

Table 9. Characterization and Agronomy information for Arborg, Melita and Roblin sites.

Description	Arborg	Melita	Roblin
Research Group	PESAI	WADO	PCDF
Legal Land Location	NW 16-22-2 E1	SE 26-3-27 W1	NE 20-25-28 W1
Soil Series	Fyala heavy clay	Newstead Loam	Erickson clay loam
Stubble	wheat	spring wheat	silage barley
Field Prep	harrowed	harrowed, no till	harrowed, no till
Soil Test N-P-K (lbs/ac)	112-22-380	35-18-900	66-92-1224
Fertilizer App		108-35-20-8-2 Zn	
N-P-K-S-Zn (lbs/ac)	50(B)-20 (SB)-0	(SB)	54-10-0 (SB)
Seeder Type	disc drill	Knife drill	disc drill
Rows and Spacing (inches)	8 (7.5)	6 (9.5)	5 (9.5)
Seed Date	21-May	08-May	27-May
Seed Depth	0.75"	0.5"	0.5"
Fungicide/Insecticides	NA	NA	NA
Desiccation Product	Reglone	Reglone	Reglone
Harvest Date	08-Sep	24-Aug	04-Sep
Growing Season Meteorology information (Seed Date - Harvest Date)			
GGDs actual Base 5°C	1403	1380	1157
GGDs normal	1242	1313	1141
Precipitation actual	195	168	225
Precipitation normal	252	272	215

GDD – growing degree days, B – broadcast, SB – side banded, NA – not applicable