Flax Herbicide Evaluation

(Adapted from a report by Justice Zhanda, WADO)

Project duration: May 2020 - Sept 2020

Objectives: To compare the efficacy of Authority (standard treatment) to Armezon (experimental treatment) for crop and weed efficacy, and to observe any safety concerns with herbicide combinations.

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Background

Flax (*Linum usitatissimum*) is an important crop known for its value in food and fibre industrial markets around the world. However, flax has a low competitive ability with weeds compared to other crops is recommended to be grown on relatively weed free fields. 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 effectively control weeds and reduce yield loss than employing one control factor alone (Kurtenbach et al., 2019). Preemergence 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 soon after weed emergence to small weeds and flax seedlings, usually results in better control and allow more time for flax recovery from possible herbicide injury than when herbicides are applied to larger weeds and flax later on in the growing season. There is currently a challenge in herbicide options for flax as a result of herbicide resistance. Furthermore, concerns for herbicide injury on flax with the use of different herbicide combinations need to be examined. There is need to investigate possible alternative options, combinations and timing 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 control tough broad leaf weeds and grasses in corn and has potential for use in flax for control of Group 1 resistant grasses due to its suppression effect on grasses (Table 1). Currently, the herbicide is not registered for use in flax but extensive field trials can provide for a pathway to registration and this will benefit flax producers. Therefore, this study seeks to evaluate several herbicides including Authority, Mextrol, Koril, Select and experimental Armezon used alone or tank mixed with compatible herbicides in flax in order to effectively control resistant weeds and reduce yield losses as a result. The study also seeks to evaluate any safety concerns with the use of different herbicide mixes in flax.

Table 1: List of Weeds controlled by Armezon, Authority, Mextrol, Koril and Select

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
Quackgrass					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	
Lambsquarters	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

Adapted from 2019 Manitoba Crop Protection Guide

Materials and methods

The trial was conducted at Melita, Roblin and Arborg in Manitoba, as randomized complete block design with nine herbicide treatments replicated three times. Table 2 shows herbicide treatments. Table 3 summarizes herbicide formulation and treatment description. Ratings for phytotoxicity on flax were taken at two and four after treatment while herbicide injury on weeds was only assessed at two weeks after treatment. Additional data were collected for flax height at 2 weeks after treatment, flax count at four weeks after treatment, top weed species names, weed density at flowering, seed yield and moisture content.

Table 2: Treatments

	RoundUp (Pre-emerge)	Authority (Pre-emerge)	Armezon + Merge	Mextrol 450	Koril	Select + Amigo
1	X					
2	X					
3	X	X				
4	X		X			
5	X	X	X			
6	X	X		X		X
7	X	X			X	X
8	X		X	X		X
9	X		X		X	

Table 3: 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	Treatment
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

Table 4: Spraying information for Arborg, Melita and Roblin site in 2020

Spraying Information	Site		
	Arborg	**Melita**	**Roblin**
Spray Tip	TeeJet AI80015	TeeJet AI8002	BFS Orange AI 01
Water Volume (imp. Gal/ac)	10	10	10
Burnoff	N/A	08-May	29-May
Burnoff Product (Rate)	N/A	Roundup (0.5 L/ac) + Aim (15 ml/ac)	Roundup (0.64L/ac)
Pre-Emerge 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

Agronomic information

Variety:	Neela seeded @ 60lb/ac
Seeding:	May 27
Harvest:	Sep 23
Treatments:	9
Yield:	Sep 23
Moisture:	Sep 23
Previous year's crop:	Barley Silage
Soil Type:	Erickson Loam Clay
Landscape:	Rolling with trees to the east
Seedbed preparation:	Tilled once and then harrowed

Table 5: Fertility Information

	Available	Added	Type
N	66 lb/ac	54 lb/ac	46-0-0
P	47 ppm	10 lb/ac	11-52-0-0
K	612 ppm	-	-

N side banded; P banded with seed

Results and discussion

Roblin

Weed injury percentage was significantly (P=0.001) different among treatments at 2 weeks after application of weed control alternatives at Roblin (Table 5). 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 significantly different. At 2 WAA of treatments, flax injury (47%) was significantly (P<0.001) high when Armezon + Mextrol + Select (treatment 8) were applied post emergence in a single tank mix. All other options resulted in between 0 and 3% flax injury and could be considered to be safe options for the crop in this regard. Further observations made at 4 WAA of the treatment materials found significant (P=0.014) recovery of flax from 47% to 22% for treatment 8 while other alternatives ranged between 0 and 1%. Crop height measurements at 2 WAA of treatments, again, showed that a combination of Armezon + Mextrol + Select applied to flax resulted in significantly (P<0.001) lower height (16 cm) compared to other herbicide options. Although weed injury was only 5% and comparable to 7 other herbicide treatment at 2 WAA, application of Armezon + Mextrol + Select reduced crop height at the same observation period. This might give an indication of negative impact that this combination might have, such as influencing 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 5). 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 May 27 but only received about 5.1 mm of rainfall between May 26 and June 5 (web43.gov.mb.ca/Climate/DailyReport.aspx).

Table 5: GLM Analysis of variance for weed injury, weed density, flax emergence, crop injury, crop height and crop yield at Roblin in 2020

Treatment	Weed Injury (%) 2WAA	Weed Density ppm at flower	Flax Emergence ppm	Crop Injury (%)		Crop Height (cm) 2WAA	Crop Yield (kg/ha)
				2WAA	4WAA		
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
MSE	2.351	0.03	1001.7	0.0056	0.005	24.002	759257
GM	4.671	1.77	150	0	0.034	34	2954

Melita

At Melita, there were significantly (P=0.005) more weed injury percentages with herbicide combinations than single herbicide treatments (Table 6). A combination of Armezon + Bromoxynil + Select caused higher weed injury percentages compared to other herbicide treatments. Higher weed injury percentages for combination treatments involving Authority were probably as a result of adequate rainfall for herbicide activation following application of treatments. Herbicide combinations also caused significant (P=0.004) 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. It is also important to note that although Armezon (in-crop) application alone caused little injury on weeds and flax than when applied in combination with other herbicides at 2WAA, 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 was not significantly different at Melita but the plant stand was more than 300% better than Roblin across all herbicide treatments. This was probably due to differences in soil moisture at crop establishment between the two sites. There were no significant differences in flax seed yield across all treatments and the yields were lower than at Roblin site overall.

Table 6: GLM Analysis of variance for weed injury, weed density, flax emergence, crop injury, crop height and crop yield at Melita in 2020

Treatment	Weed Injury (%) 2WAA	Weed Density ppm at flower	Flax Emergence ppm	Crop Injury (%)		Crop Height (cm) 2WAA	Crop Yield (kg/ha)
				2WAA	4WAA		
1. UTC (no weeding)	*	23a	541			37ab	2473
2. UTC (Hand weeded check)	*	*	537			36ab	2508
3. Authority (pre-seed)	27bc	13ab	520	0d	0b	37ab	2512
4. Armezon (in crop)	7c	21a	567	0d	0b	37ab	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
MSE	4.257	0.07	2881	0.0102	0.001	14.2	50518
GM	7.467	1	522	0.15	0.02	33	2540

Arborg

Weed injury percentage was significantly (P<0.001) high among all combination treatments including Armezon applied in-crop and ranged from 60% to 87% compared with Authority (pre-seed) that only caused 10% injury (Table 7). Treatments 6, 8 and 9 had best weed control with 80, 87 and 85% weed injury at 2 WAA, respectively. It is possible that efficacy of Authority was low as a result of low rainfall within 2 of application of the herbicide. Authority applications require a moderate rainfall of between 10 to 20 mm or equivalent irrigation 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), which was not adequate for activation of the herbicide and could explain the reason why there was only 10% weed injury. Weed density measured at flowering was significantly (P=0.037) different at Arborg. The ideal herbicide option was considered to be the one with the lowest weed density after herbicide treatment relative to other options under consideration. In this regard, weed density was significantly lower in Authority + [Mextrol + Select (in-crop)] (11 ppms) and Armezon + Mextrol + Select (15 ppms). Similar pattern in crop injury recovery as with Melita and Roblin was observed at Arborg with initially high injury percentages at 2 WAA followed by significant (P=0.007) recovery at 4 WAA. Crop height was also significantly (P<0.001) reduced in combination herbicide options especially treatment 8 and 9 that included Armezon + Mextrol + Select and Armezon + Bromoxynil + Select, respectively. Flax plants in these treatments were more than 50% shorter compared to the non-weeded check at 2 WAA. Perhaps Bromoxynil and Mextrol components influenced the reduction in flax height. Flax seed yield was significantly (P<0.001) high in combination herbicides that had Armezon in the mixture and was comparable to the hand weeded check. 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 to reduce the impact on yield but not compromising on weed control.

Table 7: GLM Analysis of variance for weed injury, weed density, flax emergence, crop injury, crop height and crop yield at Arborg in 2020

Treatment	Weed Injury (%) 2WAA	Weed Density ppm at flower	Flax Emergence ppm	Crop Injury (%)		Crop Height (cm) 2WAA	Crop 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
MSE (mean square error) for CV calculations	0.946	0.104	876.200	0.010	0.001	18.620	75721.000
GM	8.061	1.839	300.306	0.645	0.100	32.360	2813.144

Combined site results

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, based on numerical figures available, Armezon + Bromoxynil + Select option caused the highest percentage in weed injury (74%) while other options ranged from 25 to 58% (Table 8). Crop injury at 2 WAA varied significantly (P=0.003) and application of Armezon (pre-seed) + Mextrol + Select (in-crop) caused the highest flax injury (39%) while other herbicide options ranged from 3 to 21%. At 4 WAA there were significant (P=0.023) differences in flax injury as observed at individual site analysis and 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. Height of flax was significantly (P=0.004) different due to different herbicide options applied. Treatments 7, 8 and 9 resulted in significantly shortened flax plants at 2 WAA and the heights were 28, 20 and 25 cm, respectively, compared with hand weeded check that had 42 cm at the same observation period. There were also significant treatment x site interactions in flax plant height (P=0.007), weed density (P=0.015) at 2 WAA and crop yield (P=0.048). Differences in site characterization may have influenced results of these responses to different herbicide options available in this study. Selection of herbicide options to use will likely be based on their performance in a specific geographical area.

Table 8: GLM Combined (Melita, Arborg and Roblin) Analysis of variance for weed injury, weed density, flax emergence, crop injury, crop height and crop yield in 2020

Treatment	Weed Injury (%) 2WAA	Weed Density ppm at flower	Flax Emergence ppm	Crop Injury (%)		Crop Height (cm) 2WAA	Crop 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 summary

Weed species composition differed across the 3 sites under study in 2020 (Table 9). Arborg had predominantly redroot pigweed in treatments 1, 2, 4 and 8 while lambsquarters 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 9: Summary of four major weeds (ranked as most to least) by site after herbicide treatment at flower stage in 2020

Treatment	Site		
	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 (Table 9)

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

Conclusions

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.

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., Dugiud, 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.