2024 Final Report

for the

Saskatchewan Oilseeds Development Commission

Canola Agronomic Research Program

Project Title: Evaluating the efficiency of glufosinate and clethodim in varying water qualities in combination with water conditioners in canola.

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Project Identification

1. **Project Title:** Evaluating the efficiency of glufosinate and clethodim in varying water qualities in combination with water conditioners in canola
2. **Project Number:** CARP ADOPT 2023.453
3. **Producer Group Sponsoring the Project:** Saskatchewan Oilseeds Development Commission
4. **Project Location(s):**

Western Applied Research Conservation, Scott, SK

5. **Project start and end dates (month & year):** April 10, 2024 to March 1, 2025
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Objectives and Rationale

7. **Project objectives:**

To evaluate the efficiency of glufosinate and clethodim chemistries in varying water qualities coupled with the use of water conditioners. This trial will look at the efficacy and ensure proper water quality combined with Group 1 and 10 chemistries when spraying to optimize all applications. This trial will show the importance of testing water sources to increase use efficiency. This trial is to compare the activity of Group 1 and 10 chemicals, at half and full rates, in hard, soft, and RO water with the use of a water conditioner, and when one would be necessary. This trial will also evaluate the ROI of a water conditioner compared to a higher rate of the chemistry applied in varying water conditions.

8. **Project Rationale:**

The use of hard water in spraying operations, through previous research, has shown that hard water conditions can reduce the efficacy of weak acid herbicides such as glufosinate and clethodim. It has been shown that although the solubility of weak acidic herbicides is higher in alkaline pH's, the absorption through the leaf cuticle is increased in more acidic spray water solutions. Research has shown that glufosinate efficacy can be reduced by 10-12% when dropping the pH of spray water from 9 to 4 (Daramola, et.al., 2022). The alkalinity of the spray water was found to dissociate the herbicide molecules and reduce the effectiveness on weeds and the presence of glufosinate in the weed tissues. In a similar study, the addition of ammonium sulphate (AMS) to reduce the carrier water pH from 9 to 4 reduced weed biomass. It was also found that increasing the hardness of the spray water negatively influenced glufosinate efficacy and resulted in 20% reduced control in giant ragweed and 17% less control in palmer amaranth (Devkota & Johnson, 2016). Water hardness and sediments have also been shown to impact the efficiency of glufosinate and clethodim in solution. Inorganic and organic matter, sediments and charged cations will bind to the herbicide molecules instead and reduce their performance. Water conditioners have been used as adjuvants to overcome the ionic reactions that occur in hard spray water. Common nitrogen-containing substances have been used as successful water conditioners, AMS being the most studied (Mirzaei, et.al., 2023).

Saskatchewan producers are in a constant struggle to find water sources that are suitable for pesticide applications, and therefore sometimes use water of inadequate qualities. Producers commonly use the water that is available to them for spraying, surface waters like sloughs or dugouts or well water from underground aquifers are the more common sources of spray water. Using water that is too hard can lead to inefficient and wasteful applications. Weak acid herbicides are affected the most in hard water conditions. Five main cation minerals affect the hardness of water and are especially antagonistic to pesticide applications. Most underground waters in Saskatchewan contain three of them, calcium, magnesium, and sodium. It is suggested that water should be treated if the harness is over 250 to 350 ppm calcium carbonate (Storrie, 2019). Electrical conductivity (EC) is also used as a good baseline for comparing to ppm for water hardness and since there is a large variance in EC for each of the main water sources, it is extremely important to test the water used for spraying to understand how it will affect the efficacy of the pesticide application. There is a 200-2000 EC variance recorded in slough and dugout water and a 700-4000 EC difference for common aquifer types in Saskatchewan, showing that water quality differs between each producer and area and needs to be accounted for in spray applications (Government of Saskatchewan, 2023). By demonstrating to producers, the difference in chemical efficacy when using different water types, chemical rates, and water conditioners, they will be able to apply this understanding to their operations to reduce product waste and increase pesticide activity. In July 2023, Crop Diagnostic School was held in Indian Head, Saskatchewan, with AAFC, IHARF and the Saskatchewan Ministry of Agriculture. One of the demonstrations showcased the antagonism of different water qualities mixed with glyphosate in jars. Due to the high interest in this station, SaskCanola expressed interest in pursuing a small plot demonstration similar to the jar test.

Methodology and Results

9. Methodology:

This trial was seeded with an area-specific, high-yielding glufosinate tolerant canola variety. The canola was seeded through the seed row, and at the same time, area-specific wheat was seeded as weeds in the midrow bands. A seeding rate of 115 seeds/m^2 was used for the canola, along with a seeding rate of 150 seeds/m^2 for wheat. This demonstration was set up in a randomized complete block design (RCBD) with 12 treatments (Table 1). The treatments consisted of a full rate and half rate of clethodim (Centurion) and glufosinate (Liberty 150 SN) in three different water types. There were three different types of water used in this trial, all water was sourced from the same well, reverse osmosis (RO) water, soft water, and hard water. The water samples were sent to AgVise for spray water quality testing. Each water and chemical combination also had a water conditioner (Amigo) and no water conditioner added.

Table 1. Treatment list for "Evaluating the efficiency of glufosinate and clethodim in varying water qualities in combination with water conditioners in canola" in Scott, SK in 2024.

TRT #	Water Type	Clethodim Rate	Glufosinate Rate	Water Conditioner
1	RO Water	50 ml/acre	1.35 L/acre	No
2	RO Water	77 ml/acre	1.62 L/acre	No
3	RO Water	50 ml/acre	1.35 L/acre	Yes
4	RO Water	77 ml/acre	1.62 L/acre	Yes
5	Hard Water	50 ml/acre	1.35 L/acre	No
6	Hard Water	77 ml/acre	1.62 L/acre	No
7	Hard Water	50 ml/acre	1.35 L/acre	Yes
8	Hard Water	77 ml/acre	1.62 L/acre	Yes
9	Soft Water	50 ml/acre	1.35 L/acre	No
10	Soft Water	77 ml/acre	1.62 L/acre	No
11	Soft Water	50 ml/acre	1.35 L/acre	Yes
12	Soft Water	77 ml/acre	1.62 L/acre	Yes

This trial was seeded on May 27th, 2024, with a Fabro knife opener drill with 10-inch row spacing. Emergence was recorded on June 10th, 2024, 14 days after seeding. A fertilizer blend of 69-17-6-8 was placed in the sideband at 180 lbs/ac. A pre-seed herbicide application of Glyphosate 540 at 1L/ac and Aim at 35 mL/ac was conducted on May 26th, 2024. The treatments listed in Table 1 were applied on June 24 at the 5-6 leaf stage. An in-crop application of Cotegra at 280 mL/ac was done on July 11th, 2024. Crop and weed counts were done by counting 4 x 1 meter row lengths per plot, only in treatment 2. Counts took place on the day of application (June 24th) and 14 days after application (DAA) on July 11th. The pH and alkalinity of the spray water were measured with pH strips before and after chemical addition. Crop phytotoxicity ratings were conducted 7, 14 and 21 DAA using the Canadian Weed Science Society (CWSS) evaluation of herbicide efficacy scale where ratings <60% were considered poor, 60-69% were considered not acceptable, 70-79% considered suppression, 80% considered acceptable control, 81-90% considered good to very good control and 91% to 100% considered very good to excellent control (Figure 1). Yields were determined from cleaned harvested grain samples and corrected to 10.0% moisture content. Protein and oil content were measured using a CropScan 3000X Whole Grain NIR Analyzer. Daily weather was collected by an Environment Canada on-site weather station. Long-term weather data was collected from Environment Canada (1985-2014).

Activity Range	Description of Control	Suggested Interval size
91-100%	Very Good to Excellent	2%
81-90%	Good to Very Good	5%
80%	Just Acceptable	
70-79%	Suppression	5%
60-69%	Not Acceptable	5%
< 60%	Poor	10%

- **80% or better is considered acceptable control**

Figure 1. Canadian Weed Science Society (CWSS) evaluation of crop tolerance scale.

Data Analysis

The data was analyzed using R (ver. 2023.12.0+369; RStudio Team, 2023) to assess the effect of water quality on liberty efficacy in canola; including weed control, yield, and grain quality. A linear mixed-effects model was applied with water quality, liberty and clethodim rate, and adjuvant as the fixed effect and replicate as the random effect. All models were evaluated for assumptions of normality and homogeneity of variance. When these assumptions were not met, data were log-transformed. Analysis of variance (ANOVA) was performed to identify significant differences at $p < 0.05$. Post-hoc pairwise comparisons of means were conducted using estimated marginal means (EMMs) via the emmeans package in R, with the Sidak adjustment for multiple comparisons. There was a sprayer application error on plot 101 (treatment 1) which greatly reduced weed control; therefore this plot was excluded from the analysis for the phytotoxicity ratings.

Weather Data

The spring growing conditions for 2024 were cooler and wetter than the long-term average for May and June (Table 2). The months of May and June received 74.2 and 112 mm of precipitation respectively as fairly regular rain events throughout the entire month. As a result, there were adequate moisture conditions throughout seeding and in the early part of the growing season. The temperatures in May and June were slightly below average at 9.8 and 13.3 °C, respectively. In turn, growing degrees days for May and June were also below average at 154.5 and 232.5 days, respectively. As a result, crops experienced slow early-season growth. Conditions changed in July with increased temperatures which allowed for vigorous plant growth. However, extreme temperatures were frequent in July with maximum daily temperatures above 25 °C for 17 days. These high temperatures coincided with flowering for most crops, which may have impacted seed development. Additionally, July was also quite dry, receiving only 26.7 mm, which is well below the long-term average. The month of August was comparable to the long-term average temperature and precipitation. Overall, the growing season was slightly above the average long-term temperature and precipitation. The first part of the growing season (May and June) was cooler but received consistent and abundant precipitation, but conditions changed in July with high temperatures and minimal precipitation.

Table 2. Mean monthly temperature, precipitation and growing degree days accumulated from April 2024 to August 2024 at Scott, SK.

Year	April	May	June	July	August	Average/Sum	% of Long-term Average
			Temperature (°C)				
2024	5.7	9.8	13.3	18.9	17.4	13.0	103%
Long-term^z	3.8	10.8	14.8	17.3	16.3	12.6	
			Precipitation (mm)				
2024	22.1	74.2	112.0	26.7	42.8	277.8	111%
Long-term^z	24.4	38.9	69.7	69.4	48.7	251.1	
			Growing Degree Days				
2024	58.8	154.5	232.5	417.7	385.1	1248.4	101%
Long-term^z	44.0	170.6	294.5	380.7	350.3	1240.1	

^{z}Long Term Average (1985-2014)

10. Results

Soil Test Results

Soil samples were collected in the spring of 2024 at two depths of 0-6 and 6-24 inches to determine residual soil nutrient levels (Table 3). Lab results from Agvise displayed low nitrate levels in the soil, with only 17 lbs/ac in the first 6 inches and a combined 29 lbs/ac from the topsoil to 24 inches deep. Phosphate and potassium levels were high, at 16 ppm and 219 ppm, respectively. The sulphur levels were observed at a medium concentration of 22 lbs/ac within the first 6 inches while they were high at depth according to the AgVise soil report interpretation. Organic matter was relatively adequate at 4.0%. While the soil pH was slightly acidic at 5.4 in the top 6 inches and neutral at depth.

Table 3. Soil nutrient concentrations and characteristics for Scott, SK., 2024.

		Soil Depth	
		0-6"	**6-24"**
Nitrate	lb/ac	17	12
Phosphorus	ppm	16	--
Potassium	ppm	219	--
Sulfur	lb/ac	22	102
Organic Matter	%	4.0	--
pH		5.4	7.8
Cation Exchange Capacity	meq	14.6	--

Water Test Results

Water tests for each water quality were collected and sent to AgVise for Spray Water Analysis before product application occurred. Each water test sample was taken mid-stream, in a clean glass jar after the water was run for a minute. The results listed in Table 4 exhibit a generally neutral water pH in RO water while being slightly more basic in both the soft and hard water samples. As anticipated, the analysis revealed a high sodium content, consistent with the characteristics typically associated with soft water. The analysis of the hard water sample revealed elevated concentrations of minerals, including calcium, magnesium, and iron, with its hardness value significantly higher than the other samples. The RO water analysis expressed low levels of ions, minerals and electrical conductivity (EC). Soft water had the second highest level of recorded ions and minerals, although displaying the highest EC. In conclusion, the water quality analysis provided valuable insights into the distinct characteristics of each water type, which will inform the appropriate selection of products for application.

Table 4. Water test results for "Evaluating the efficiency of glufosinate and clethodim in varying water qualities in combination with water conditioners in canola" in Scott, SK in 2024.

		RO Water	**Soft Water**	**Hard Water**
pH		6.8	8.2	8
Sodium	ppm	37	1317	143
Calcium	ppm	0.01	6	496
Magnesium	ppm	0.02	4.5	310
Potassium	ppm	0.01	6.2	10
Iron	ppm	0.01	0.09	0.01
Electrical Conductivity (EC salts)	mmho/cm	0.17	4.4	3.3
Hardness (CaCO3 equivalent)	ppm CaCO3	0	34	2538
Sodium Adsorption Ratio (SAR)		-	99.19	1.24

The treatment solutions were tested before and after the addition of the prescribed products. Each water type and treatment combination were evaluated by a pH strip, showing pH and alkalinity (Table 5). Treatments were grouped by water type and the presence or absence of a water conditioner. Generally speaking, the addition of glufosinate and clethodim with or without a water conditioner lowered the pH of the solution to become more acidic. The largest difference in pH change was observed in both hard and soft water before the addition of the treatments and after. Generally, the addition of a water conditioner to both hard and soft water resulted in a lower pH compared to the treatments without a water conditioner. Pictures were taken of the product solutions before application to provide a visual representation of the difference in treatments (Figures 2 & 3). It was observed that treatments without the use of a water conditioner remained transparent and clear. In contrast, treatments with the water conditioner generally became translucent and cloudy. When both chemical rates and a water conditioner were used with RO and soft water types the treatments became extremely cloudy. In comparison, treatments with hard water were only slightly more translucent than those without a water conditioner. These observations highlight the impact of water conditioners on solution clarity and pH, emphasizing their role in modifying the chemical environment of herbicide treatments.

Table 5. pH and alkalinity of each water type with and without water conditioner before and after the addition of product treatments for "Evaluating the efficiency of glufosinate and clethodim in varying water qualities in combination with water conditioners in canola" at Scott, SK in 2024.

		pH		
TRT #	**Treatment**	**Before**	**After**	**Alkalinity**
1, 2	RO Water; No Water Conditioner	6.2	<6.2	0
3, 4	RO Water; Water Conditioner	6.2	<6.2	0
5, 6	Hard Water; No Water Conditioner	8.4	6.8	180
7, 8	Hard Water; Water Conditioner	8.4	<6.2	40
9, 10	Soft Water; No Water Conditioner	8.4	6.8	180
11, 12	Soft Water; Water Conditioner	8.4	<6.2	120

Figure 2. Visual representation of treatments varying water quality, water conditioners, and herbicide rates (glufosinate and clethodim) arranged before application at Scott, SK in 2024. The treatments are displayed in bottles and listed in order from left to right as follows: 5, 9, 2, 6, 10, 3, 7, 11, 4, 8, and 12.

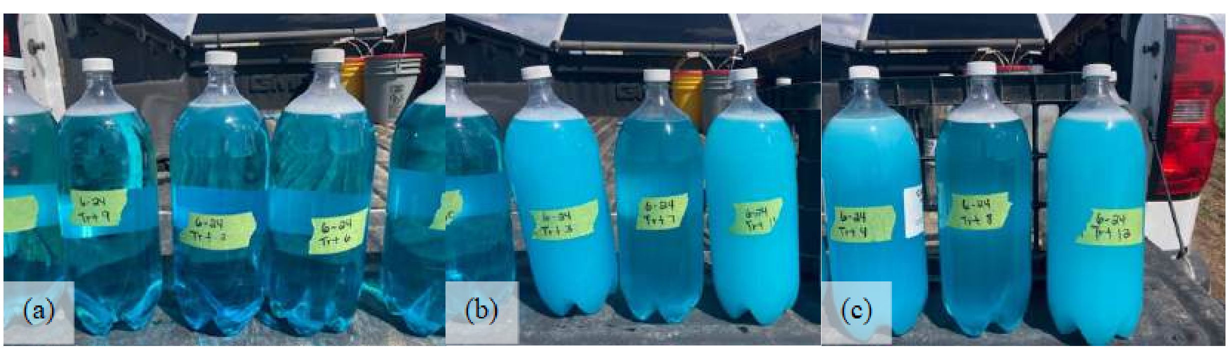

Figure 3. Visual representation of treatments varying in water quality, water conditioners, and herbicide rates (glufosinate and clethodim) arranged prior to application at Scott, SK, in 2024.
(a) Treatments 5, 9, 2, 6, and 10: no water conditioner applied. Treatments 5 and 9 received a half rate of glufosinate and clethodim, while treatments 2, 6, and 10 received a full rate. The water quality order is reverse osmosis (RO), hard, and soft, respectively.
(b) Treatments 3, 7, and 11: all received a half rate of glufosinate and clethodim with water conditioner. Water quality order from left to right is RO, hard, and soft.
(c) Treatments 4, 8, and 12: all received a full chemical rate with water conditioner. Water quality order is RO, hard, and soft, respectively.

Canola & Weed Counts

Plant stands were recorded on the day of application (DOA, July 5) and again 14 days after application (DAA, July 11). Counts were taken from treatment 2 (full-rate herbicides with RO water and no water conditioner) within 1m × 1m rows. As shown in Figure 4, canola plant counts increased slightly following the in-crop herbicide application, possibly due to reduced weed competition or favourable growing conditions after treatment. In contrast, the wheat seeded as weeds in the midrow bands experienced a significant decline after the full herbicide rate was applied, demonstrating the treatment's effectiveness. This pattern was consistent across other treatments, where visual assessments showed a noticeable reduction in weed pressure, as reflected in the phytotoxicity ratings presented below. Additionally, no major crop injury symptoms were observed in the canola following application, suggesting good herbicide tolerance. Additional plant count data can be found in Table A1 (Appendix A).

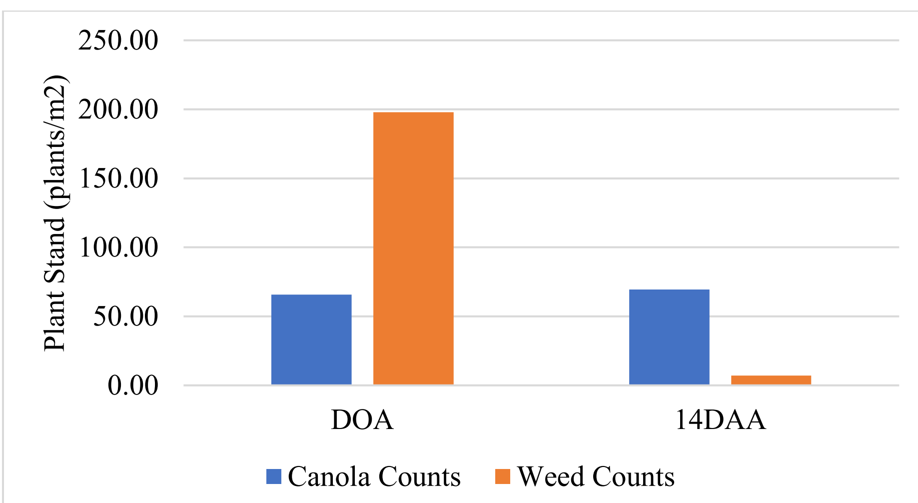

Figure 4. Plant stand (plants/m^2) of crop and weed counts on the DOA and 14 DAA for "Evaluating the efficiency of glufosinate and clethodim in varying water qualities in combination with water conditioners in canola" at Scott, SK in 2024.

Phytotoxicity

Phytotoxicity ratings indicated high levels of weed control across all collection dates, with all treatments exceeding the CWSS 80% control threshold (Figure 1; Figure 5). Early on, the lowest efficacy ratings were observed in treatments 5, 6, and 7 (hard water at all herbicide rates without a water conditioner) and treatment 9 (soft water with a low herbicide rate and no water conditioner), all at 94% efficacy. By 14 DAA, most treatments reached 98% efficacy, while treatments 1 and 9 increased to 97%, and treatment 5 remained the lowest at 96%. Since all treatments achieved 98% control by 21 DAA, statistical analysis was not conducted due to the lack of variation.

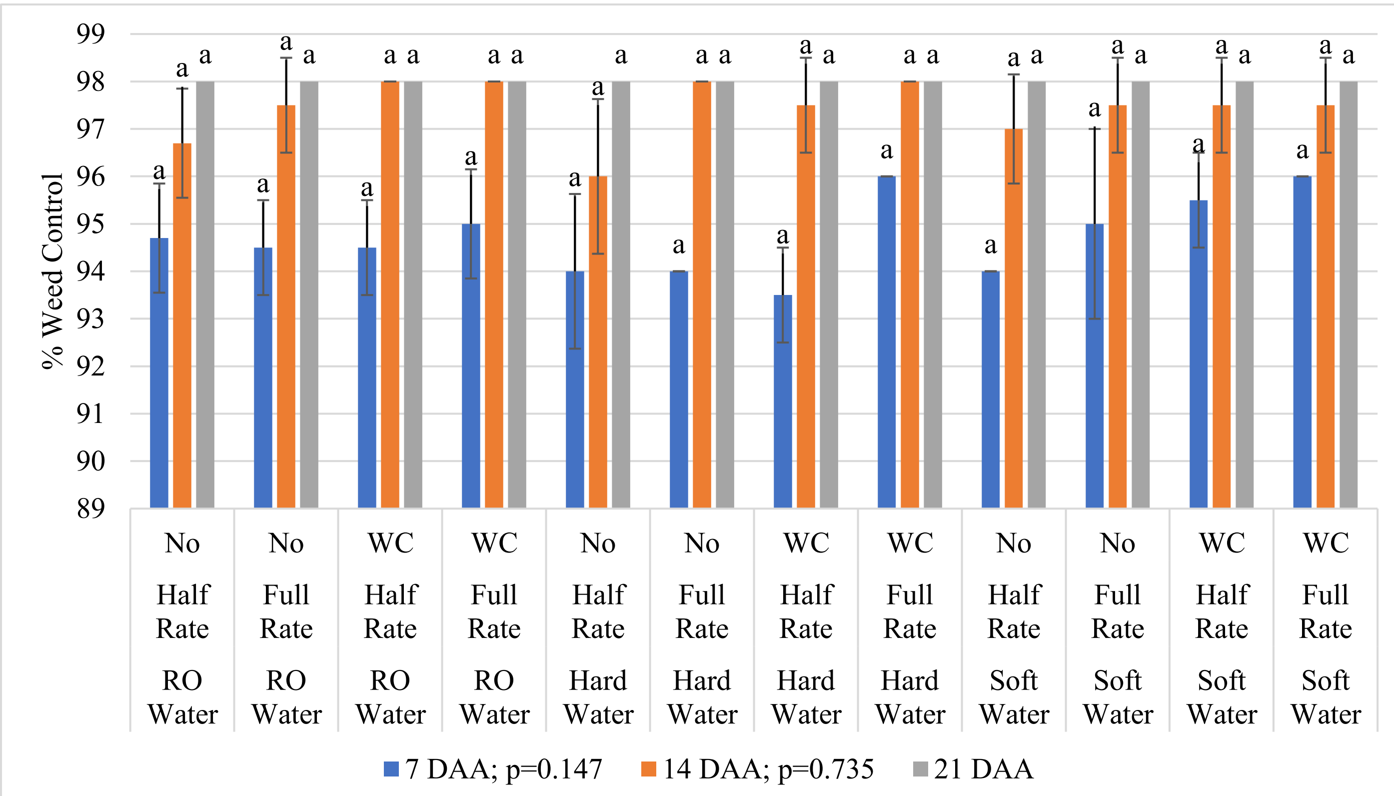

Figure 5. Percent (%) weed control phytotoxicity ratings for herbicide rate, water type and presence or a water conditioner (WC) for "Evaluating the efficiency of glufosinate and clethodim in varying water qualities in combination with water conditioners in canola" at 7, 14 and 21 days after application (DAA) at Scott, SK in 2024.

Although some differences in herbicide efficacy were observed, all treatments provided acceptable to excellent weed control, with no significant differences detected at 21. However, statistical analysis at 7 and 14 DAA indicated that the herbicide rate and the presence of water conditioners influenced weed suppression (Table A2; Appendix A). At 7 DAA, both herbicide rate (p=0.022) and water conditioner (p=0.019) were statistically significant factors. Full rates of Liberty resulted in statistically greater weed control when compared to the half rate (Figure 6; Table A3; Appendix A). While the addition of a water conditioner further improved herbicide efficacy over its absence. (Figure 7; Table A4; Appendix A). These trends continued at 14 DAA, where herbicide rate (p=0.029) and water conditioner presence (p=0.025) remained significant, suggesting that the recommended rate and products provide more rapid and sustained weed suppression. Overall differences between weed control although significant are low and the practical impact remains limited.

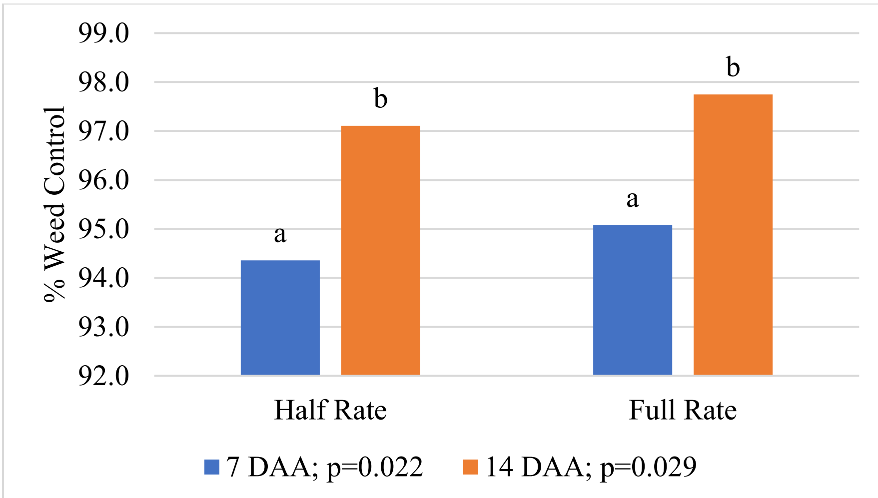

Figure 6. Phytotoxicity ratings at 7 and 14 DAA comparing the interaction between half and full Liberty and Centurion rates for "Evaluating the efficiency of glufosinate and clethodim in varying water qualities in combination with water conditioners in canola" at Scott, SK in 2024.

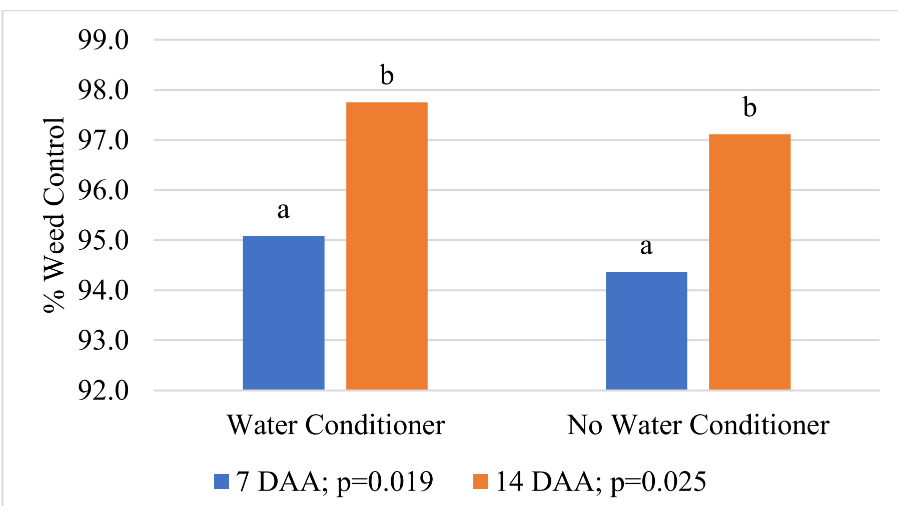

Figure 7. Phytotoxicity ratings at 7 and 14 DAA comparing the presence of a water conditioner for "Evaluating the efficiency of glufosinate and clethodim in varying water qualities in combination with water conditioners in canola" at Scott, SK in 2024

Yield

No statistical trends or relationships were observed between the yields of the treatments (p = 0.461). The lowest-yielding treatment, which included a water conditioner, a full herbicide rate, and reverse osmosis (RO) water (treatment 4), yielded 40.4 bu/ac, 2.1 bu/ac lower than the highest-yielding treatment. Treatment 6 was the highest-yielding treatment at 42.5 bu/ac and used no water conditioner, a full herbicide rate, and hard water. No significant differences were found between water qualities, herbicide rates, or the presence of the water conditioner. Treatments with half rates of the applied herbicide generally exhibited median yields, as observed in both the highest and lowest-yielding treatments. For supplementary yield data, refer to Table A2 in Appendix A.

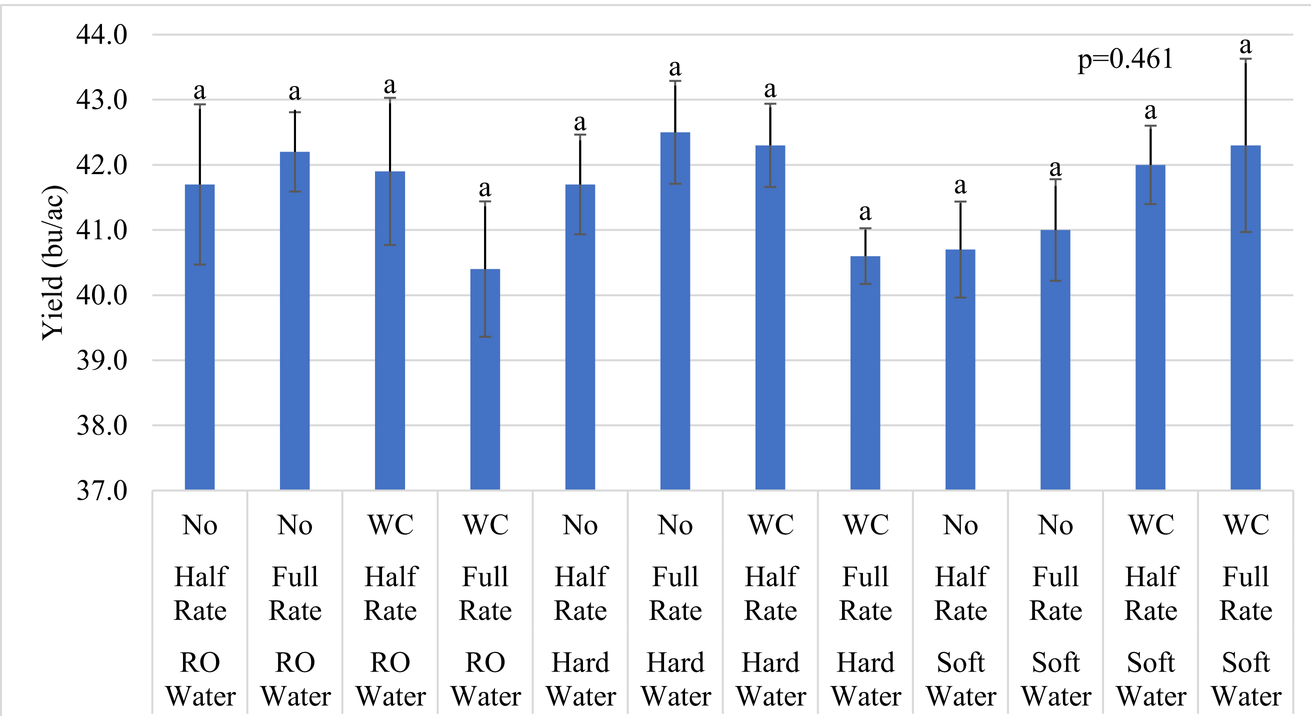

Figure 8. Yield results for herbicide rate, water type or the presence of a water conditioner (WC) for "Evaluating the efficiency of glufosinate and clethodim in varying water qualities in combination with water conditioners in canola" at Scott, SK in 2024.

Grain Quality

There were no large overlying statistical trends affecting seed protein (p = 0.902) or oil content (p = 0.241) (Appendix X). Although protein content varied slightly (Figure A1, Appendix A), it remained fairly consistent, ranging between 21% and 22.6%. Oil content exhibited slightly more variation, with a 2% difference observed. Oil and protein contents are inversely related, with the highest and lowest values typically observed in opposite treatments. This is a common phenomenon, as plants often allocate resources in a trade-off between producing either oil or protein, particularly under varying environmental conditions or management practices. A significant interaction was observed between herbicide rate and the presence of a water conditioner (p = 0.032) (Figure 9; Table A5, Appendix A). On average, the addition of a water conditioner to full herbicide rate treatments increased oil content, while it decreased oil content in half-rate treatments.

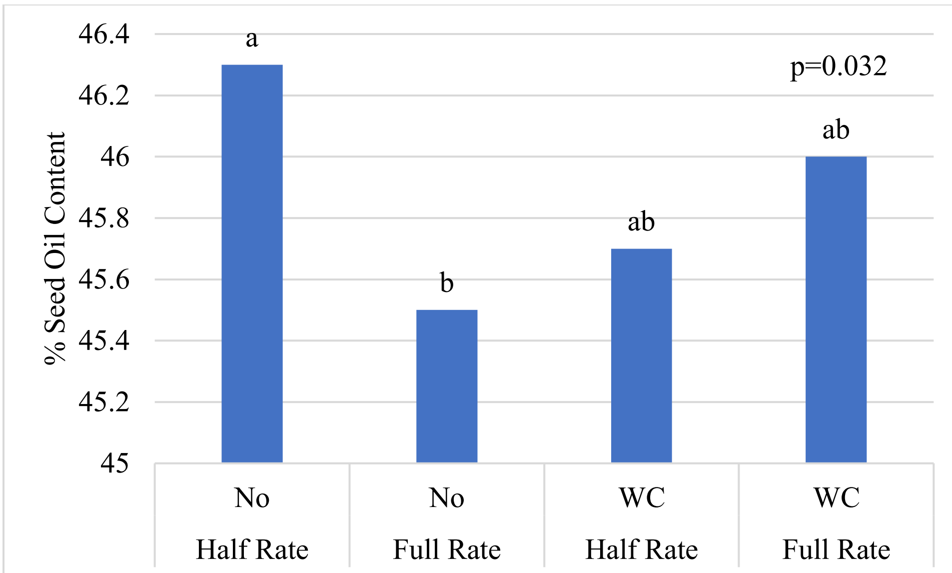

Figure 9. Seed oil content effect by herbicide rate and the presence of a water conditioner (WC) for "Evaluating the efficiency of glufosinate and clethodim in varying water qualities in combination with water conditioners in canola" at Scott, SK in 2024.

11. Conclusions and Recommendations

The study examined the effects of water quality, herbicide rate, and the presence of a water conditioner on plant growth, herbicide efficacy, and seed composition in canola. Results indicated that while water quality, herbicide rate, and water conditioner had minimal impact on seed yield, herbicide efficacy was significantly influenced by both the herbicide rate and the presence of a water conditioner. Weed control was generally high across all treatments, with all treatments being rated above acceptable control by the first assessment and 98% weed control across all treatments by 21 days after application. Although seed protein contents did not exhibit strong statistical trends, seed oil content was affected by the addition of a water conditioner in full herbicide rate treatments. Herbicide treatments did not influence plant stands, but weed pressure was notably reduced. Water quality analysis revealed distinct characteristics of RO, soft, and hard water, providing valuable information for selecting the appropriate herbicide products. The findings suggest that adhering to the recommended rates of glufosinate, clethodim, and a water conditioner improves the consistency of weed control and suppression. While water quality had minimal impacts on herbicide efficacy in this study, it did influence the pH and clarity of the treatment solutions. This highlights the importance of understanding water quality, as it can affect the application and efficacy of herbicides and other products in different environmental conditions.

11. Acknowledgements

Project funding was provided by the Saskatchewan Oilseed Development Commission. This trial was led by Koralie Mack and Jessica Enns. Statistical analysis was done by Alex Waldner. Data collection was assisted by all of the permanent and part-time summer staff at Western Applied Research Corporation.

12. Appendices

Appendix A. Supporting data tables and figures for “Evaluating the efficiency of glufosinate and clethodim in varying water qualities in combination with water conditioners in canola” at Scott, SK in 2024.

Table A1. Canola and weed counts on the day of application (DOA) and 14 days after application (DAA) in treatment 2 for “Evaluating the efficiency of glufosinate and clethodim in varying water qualities in combination with water conditioners in canola” at Scott, SK in 2024.

Canola Counts		**Weed Counts**	
DOA	**14DAA**	**DOA**	**14 DAA**
----------------- Plants/m^2 -----------------			
65.75	69.49	197.83	7.14

Table A2. Combined data means and statistical analysis for "Evaluating the efficiency of glufosinate and clethodim in varying water qualities in combination with water conditioners in canola" at Scott, SK in 2024.

Treatment (Water Type/ Herb. Rate/ Water Conditioner)	**Phytotoxicity** 7 DAA		14 DAA		21 DAA		**Yield**		**Seed Oil**		**Seed Protein**	
	---------- % ----------						-- bu/ac --		-- % --		-- % --	
[1] RO Water/ Half Rate/ No WC	95	a	97	a	98	a	41.7	a	45.9	a	22.2	a
[2] RO Water/ Full Rate/ No WC	95	a	98	a	98	a	42.2	a	45.9	a	22.0	a
[3] RO Water/ Half Rate/ Yes WC	95	a	98	a	98	a	41.9	a	46.0	a	22.0	a
[4] RO Water/ Full Rate/ Yes WC	95	a	98	a	98	a	40.4	a	46.6	a	21.1	a
[5] Hard Water/ Half Rate/ No WC	94	a	96	a	98	a	41.7	a	47.1	a	21.7	a
[6] Hard Water/ Full Rate/ No WC	94	a	98	a	98	a	42.5	a	45.2	a	22.6	a
[7] Hard Water/ Half Rate/ Yes WC	94	a	98	a	98	a	42.3	a	45.7	a	21.8	a
[8] Hard Water/ Full Rate/ Yes WC	96	a	98	a	98	a	40.6	a	45.9	a	21.9	a
[9] Soft Water/ Half Rate/ No WC	94	a	97	a	98	a	40.7	a	45.8	a	21.8	a
[10] Soft Water/ Full Rate/ No WC	95	a	98	a	98	a	41.0	a	45.5	a	21.8	a
[11] Soft Water/ Half Rate/ Yes WC	96	a	98	a	98	a	42.0	a	45.4	a	22.1	a
[12] Soft Water/ Full Rate/ Yes WC	96	a	98	a	98	a	42.3	a	45.4	a	21.8	a
	---------- Pr > F (p-value) ----------											
Overall F-test	0.147		0.735		-		0.461		0.241		0.902	
Water (W)	0.1439		0.738		-		0.8284		0.105		0.8063	
Rate (R)	**0.022**		**0.029**		-		0.575		0.35		0.7964	
Adjuvant (A)	**0.019**		**0.025**		-		0.9764		0.817		0.3648	
W x R	0.411		0.258		-		0.6833		0.123		0.2199	
W x A	0.389		0.601		-		0.1025		0.392		0.5719	
R x A	0.156		0.087		-		0.0905		**0.032**		0.2145	
W x R x A	0.147		0.735		-		0.461		0.241		0.9023	

Table A3. Phytotoxicity (% weed control) and herbicide rate interaction at 7 and 14 DAA for "Evaluating the efficiency of glufosinate and clethodim in varying water qualities in combination with water conditioners in canola" at Scott, SK in 2024.

	Phytotoxicity (% Weed Control)			
Herbicide Rate	7 DAA		14 DAA	
Half Rate	94.4	a	97	a
Full Rate	95.1	b	98	b
	p-value	0.022	p-value	0.029

Table A4. Phytotoxicity (% weed control) and water conditioner interaction at 7 and 14 DAA for "Evaluating the efficiency of glufosinate and clethodim in varying water qualities in combination with water conditioners in canola" at Scott, SK in 2024.

Phytotoxicity (% Weed Control)				
Water Conditioner	7 DAA		14 DAA	
Yes	95.1	a	98	a
No	94.4	b	97	b
	p-value	0.019	p-value	0.025

Table A5. Seed oil content (%), herbicide rate and water conditioner interaction for "Evaluating the efficiency of glufosinate and clethodim in varying water qualities in combination with water conditioners in canola" at Scott, SK in 2024.

Herbicide Rate	**Water Conditioner**	**Seed Oil (%)**	
Half Rate	No	46.3	a
Full Rate	No	45.5	b
Half Rate	Yes	45.7	ab
Full Rate	Yes	46.0	ab
		p-value	0.032

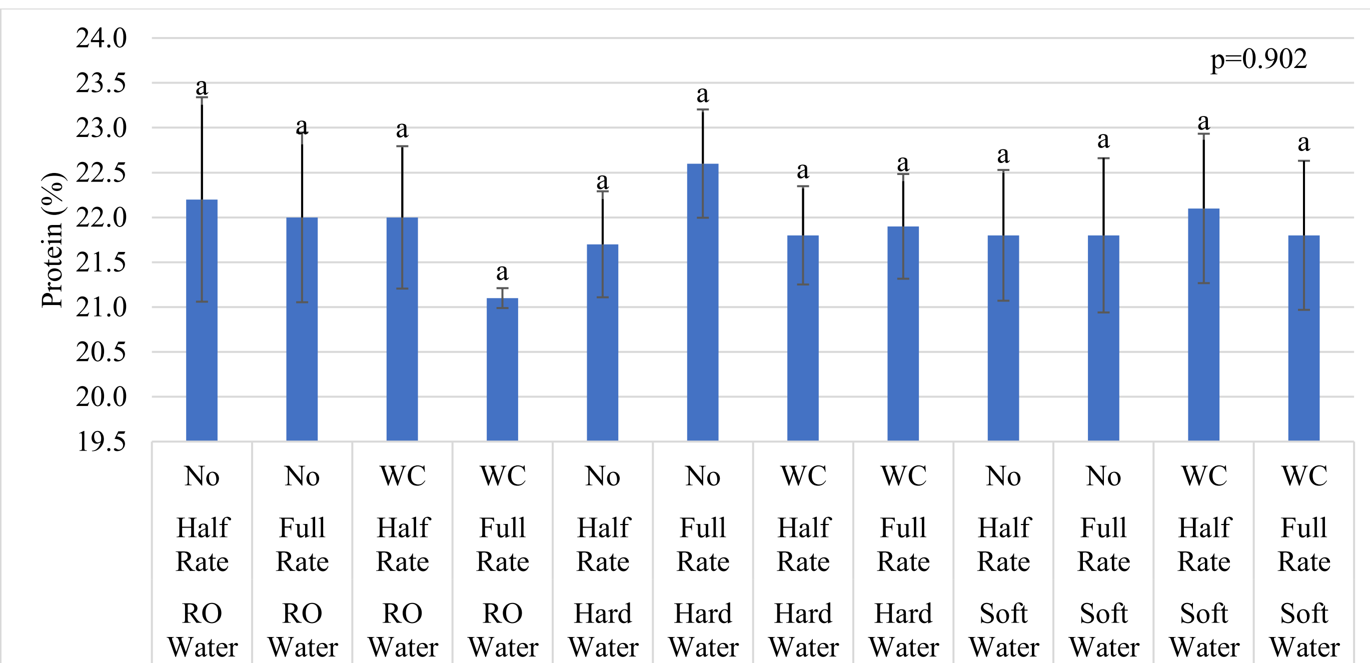

Figure A1. Seed protein values (%) for all treatments in "Evaluating the efficiency of glufosinate and clethodim in varying water qualities in combination with water conditioners in canola" at Scott, SK in 2024.

13. Abstract

This study examines the interactions between the full and half rates of both glufosinate and clethodim in a tank mix with and without a water conditioner across varying water qualities. A high-yielding glufosinate- tolerant canola variety was seeded in the seed row alongside wheat in the mid-row bands seeded as weeds. Herbicide efficacy was evaluated through phytotoxicity ratings, weed counts, yield, and grain quality analysis. Visual assessments of the treatment solutions after mixing revealed significant differences in the opacity of the solutions. All treatments experienced a pH drop, with a more pronounced decrease with the addition of a water conditioner. Phytotoxicity ratings at 7, 14, and 21 days after application (DAA) showed that all treatments exceeded acceptable weed control levels by the first assessment. Early on, the lowest efficacy was identified in treatments with hard water and no water conditioners or soft water with no water conditioner and low herbicide rates. By 21 DAA, all treatments had achieved 98% weed control. Overall, full herbicide rates enhanced weed control at 7 ($p=0.022$) and 14 ($p=0.029$) DAA, while water conditioner addition also significantly enhanced control ($p=0.019$; $p=0.025$). However, the actual phytotoxicity variance between herbicide rates and water conditioner was extremely low. No statistical yield trends were detected, but an interaction between herbicide rate and water conditioner influenced seed oil content, higher herbicide rates with a water conditioner significantly increased the seed oil content ($p=0.032$), while half rates reduced it. Overall, the results suggest that adhering to the recommended rates of glufosinate, clethodim, and a water conditioner improves the consistency of weed control and suppression. While water quality did not have a significant impact on herbicide efficacy in this study, it did influence the pH and clarity of the treatment solutions. This highlights the importance of understanding water quality, as it can affect the application and effectiveness of herbicides and other products in different environmental conditions.

14. **Finances**

Expenditure Statement

	Year 1	Total
Salaries and Benefits		
- Students - Postdoctoral/Research Associates - Technical/Professional Assistants	$ 3,250.00	$ 3,250.00
Consultant Fees & Contractual Services	$ 4,750.00	$ 4,750.00
Rental Costs		
Materials and Supplies	$ 2,500.00	$ 2,500.00
Project Travel - Field Work - Collaborations/consultations		
Other - Field Day - Administration - Miscellaneous	$ 1,500.00	$ 1,500.00
Total	$12,000.00	$12,000.00

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