9.0 Pre-harvest herbicide and desiccation options for straight-combining canola: Effects on plant and seed dry-drown, yield and seed quality

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Objectives

- The project objectives were to evaluate the effectiveness of pre-harvest herbicide/desiccant applications for assisting plant and seed dry-down for the two dominant herbicide systems (Liberty Link® and Roundup®). The options and relative performance for Clearfield® canola would presumably be similar to Liberty Link® canola.

Methods

Field trials were completed during each of three growing seasons (2017, 2018, and 2019) at four locations (Indian Head, Melfort, Scott, and Melita). The treatments were two hybrids (LL versus RR) and four pre-harvest application options plus an untreated control for each hybrid. In 2017, the two hybrids were L233P LL and 45M35 RR. In 2018 and 2019, L233P was replaced with L255PC in hopes that it would be more similar to 45M35 with respect to crop development throughout the season and maturity date. The ten treatments that were evaluated are described in Table 9a below. Timing of the pre-harvest treatments were targeted for 60-75% seed colour change (glyphosate and saflufenacil) or approximately 90% seed colour change (glufosinate ammonium and diquat); however, the actual crop stages varied to some extent due to differences between hybrids, logistic considerations and weather. For all products, excluding glyphosate applied alone (where lower application volumes were permitted but not required), the minimum solution volume was 187 l/ha (20 U.S. gallons per acre). Treatment 7 (RR – glufosinate ammonium) was not included at the 2017-Melfort site due to a misinterpretation of the protocol. Overall, the wide range of environmental conditions combined with a certain amount of variation in treatment application and harvest timing provided a robust evaluation of the treatments.

Table 9a: Treatment list for Canola Pre-harvest Application Study (CARP 2017.9).

Treatment Name	
1) LL – untreated	**6)** RR – untreated
2) LL – glyphosate (890 g ai/ha) ^{Z}	**7)** RR – glufosinate ammonium (408 g ai/ha) ^{Y}
3) LL – saflufenacil (50 g ai/ha) ^{Z}	**8)** RR – saflufenacil (50 g ai/ha) ^{Z}
4) LL – glyphosate (890 g ai/ha) + saflufenacil (50 g ai/ha) ^{Z}	**9)** RR - glyphosate (890 g ai/ha) + saflufenacil (50 g ai/ha) ^{Z}
5) LL – diquat (40 g ai/ha) ^{Y}	**10)** RR – diquat (40 g ai/ha) ^{Y}

LL – glufosinate ammonium tolerant; RR – glyphosate tolerant; ^{Z} 60-75% seed colour change; ^{Y} 90% seed colour change

Seeding was generally completed within the first three weeks of May with canola direct-seeded into cereal stubble, target seeding rates ranging from 120-125 seeds m^{-2}, and row spacing ranging from 24-30 cm. Plot size varied across locations depending on seeding equipment and other site-specific considerations. With the exception of 2017-Melfort where no herbicides were applied, weeds were controlled using registered pre-emergent and in-crop herbicides. At Indian Head and Melita, conventional canola herbicide options (i.e. Edge, Lontrel, Muster, etc.) were utilized while, at Scott and Melfort in 2018 and 2019, each variety was sprayed with its partner in-crop herbicide (i.e. glyphosate or glufosinate ammonium). Insecticides were only applied if necessary while foliar fungicides were applied preventatively to reduce the risks of sclerotinia stem rot at all locations except Melita where no foliar fungicides were applied. Harvest dates varied with site-year; however, all treatments were harvested on the same date for individual hybrids and, in most cases, both varieties were harvested on the same date. The intent was to give the earlier pre-harvest applications (glyphosate and saflufenacil) a minimum of 14 days to affect crop dry-down while also harvesting within 14 days of the later applications (i.e. diquat and glufosinate ammonium); however, actual timings of operations varied. The challenge was to find the right balance between giving the pre-harvest applications enough time to work while also harvesting the plots early enough that treatment effects (i.e. differences in whole plant and seed moisture content) would still be evident. In many cases, this meant harvesting when some plots were still relatively tough/green; however, in some, the canola dried down rapidly and harvest was completed relatively early after the treatment applications (i.e. 10 days at Melita 2019). In other cases, cold, wet late-season weather delayed maturity, treatment applications and harvest; thus diminishing our ability to detect treatment differences (i.e. Melfort 2019).

Various data were collected to provide explanatory background information and assess treatment effects on both plant/seed dry-down and grain quality. As an indicator of overall site establishment and variability, plant densities were estimated by counting plants in two separate 1 m sections of crop row per plot. These measurements were completed in the spring, after emergence was complete, and the values were converted to plants m^{-2}. Visual stem dry-down ratings were completed prior to harvest where the front and back of each plot was rated on a scale of 0-100 where a rating of 100 indicated that the plants, focusing on the stems, visually appeared to be completely dried down. These values were very subjective and, therefore, of somewhat limited practical value. Whole plant moisture at combining was determined by harvesting all of the above-ground biomass from a minimum of 1 m of crop row within 24 hours of combining, determining both the fresh and dry weights, and calculating percent (wet basis) gravimetric water content [(fresh weight - dry weight)/fresh weight)]. At Indian Head, these samples were collected from unharvested crop rows while, at the other sites, the plots were smaller so samples were collected prior to combining where the entire plot areas were harvested. Seed moisture content was measured in a similar manner and using the same formula as opposed to using electronic meters. The rationale for using gravimetric water content for the seed was that we expected the values to occasionally fall outside of the testable limits of approximately 5.5-15%. While this approach generally worked well, there were cases where the absolute values were unusually low and it appeared that either some drying had occurred between sampling and fresh weight determination or the samples were not completely dried before dry weight determination (i.e. seed moisture and Scott and Melfort in 2017). This was also observed for the whole plant moisture measurements to a certain extent. Seed yields were corrected for dockage and to a uniform moisture content of 10%. Seed weight was determined by counting a minimum of 500 seeds using automated seed counters, weighing the counted seeds to the nearest 0.00 g, and calculating g/1000 seeds. Green seed was assessed by crushing 500 seeds per plot, counting any distinctly green seeds, and converting the values to percent green seed. Daily temperatures and precipitation amounts were compiled from the nearest Environment Canada weather station or Manitoba Agriculture weather stations in the case of Melita site.

Exploratory statistical analyses and basic evaluation of the data confirmed that the results varied by site-year due to factors such as hybrid, weather, timing of operations, and the specific methods/equipment used for plant and seed moisture determination. As such, it was difficult to group site-years in a meaningful manner that would be advantageous over simply analyzing each site-year individually. While this approach creates challenges for summarizing the results in a simple and precise manner, it would be inappropriate to compare values directly across site-years for many variables and misleading to simply average data across sites given the high variability and, at times, contrasting results. Log and arcsine transformations were explored for the percentage data; however, none consistently improved model convergence and therefore the original, untransformed values were analyzed and summarized for simplicity. Data were analyzed using the Mixed procedure of SAS with the effects of treatment (hybrid x pre-harvest treatment) considered fixed and replicate effects considered random. Individual treatment means were separated using Fisher's protected LSD test. Additional contrasts were used to compare the control treatments to all treated plots (untreated versus treated) and individual pre-harvest herbicide/desiccant products directly to their respective control treatments, averaged across canola herbicide systems where applicable. For the most part, overall treatment effects and differences between individual means were considered significant at $P \le 0.05$; however, for the contrasts, actual p-values are provided but sites where $P \le 0.10$ were considered responsive when summarizing and interpreting these results.

Results

Crop establishment:

Plant populations were measured and analyzed for supplemental background information and could not be affected by the pre-harvest herbicide/desiccant applications as these treatments had not yet been applied when the measurements were completed. Overall F-test results are provided with the individual treatment means in Table 9b. Seeding rates were adjusted for seed size and germination with the objective of achieving similar plant populations for both hybrids. Although the overall densities varied widely from site-to-site, the overall F-test was not significant at 10/12 site-years indicating that plant populations were similar regardless of treatment in the vast majority of cases. The exceptions were Indian Head-2017 and Melita-2017 where the responses were mainly due to generally lower plant densities with the RR compared to the LL hybrid.

Visual stem dry down and whole plant moisture content:

At Melita (Table 9c), visual stem dry-down ratings varied in 2017 and 2019 ($P < 0.001$), but not in 2018 where all values were rated as 100% (i.e. completely dried down) and not statistically analyzed. For both RR and LL canola in 2017 and 2019 at Melita, diquat led to the highest visual dry-down ratings. The remaining options generally resulted in intermediate values but the specific results varied to some extent. For whole plant moisture content, treatment effects were highly significant in 2017 and 2019 (P <0.001-0.032) but only marginally so in 2018 ($P = 0.079$). For LL canola at Melita, diquat provided the most consistent benefit, followed by glyphosate while whole plant moisture content with saflufenacil applied alone was always similar to the control. For RR canola at Melita, whole plant moisture content values were variable and the only significant effect of interest was a reduction with diquat in 2017.

Seed dry down and yield:

Unlike most agronomy studies, we were not particularly interested in effects on seed yield; however, data were statistically analyzed and summarized nonetheless to provide background information on overall productivity and, in certain cases, the relative harvestability of individual treatments. To be clear, none of the products that were evaluated should impact yield if used according to label directions and harvest is completed within a reasonably timely manner; however, treatment effects did occasionally occur in the current project. Yield differences between hybrids could be reasonably expected but pre-harvest treatment effects would indicate either improper timing (i.e. reduced yield when applied too early) or differences in harvest loss resulting from variation in crop dry-down (i.e. green crop more difficult to feed into combine and thresh. We monitored for pod shattering but no substantial losses or treatment differences were ever noted. At Melita (Table 9d), there was no effect on yield in 2017 or 2018 (P = 0.070-0.422) but in 2019 the effect was significant (P = 0.001). The observed differences at Melita 2019 were difficult to explain and are attributed to a combination of hybrid effects and naturally occurring variability. The overall F-tests indicated treatment effects for seed moisture in 2017 and 2019 (P = 0.012-0.033) but not 2018 (P = 0.264) (Table 9d). Specifically, for LL canola at Melita, the only notable effect on seed moisture content was a significant reduction with diquat in 2019. For the RR canola, both glufosinate ammonium and diquat reduced seed moisture in 2017 but no individual options had a significant impact in either 2018 or 2019.

Seed quality:

Seed size is an important yield component and, similar to what occurs with swathing too early, applying pre-harvest herbicides or desiccants ahead of the recommended crop stage could conceivable lead to smaller seeds and subsequently lower yields. We would not generally expect any such impact when products are applied according to the label recommendations. Results for this variable are presented in Table 9e for Melita.

The other seed quality component that was assessed and potentially expected to be affected by the pre-harvest treatments was distinctly green seed. At Melita (Table 9e), the overall F-test for green seed was significant in all three years (P <0.001-0.054) and the specific nature of the treatments was also consistent. In all three years, values for all LL treatments were similar to one another; however, for the RR treatments, percent green seed was always significantly higher with diquat than either the control or any other pre-harvest options.

Table 9b. Treatment means and tests of fixed effects for plant density at Melita from 2017-2019. Means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test; *P* ≤ 0.05).

Treatment[z]	**2017**	**2018**	**2019**
	----Plant Density (plants m^{-2})----		
1) LL – Control	37.8 bc	34.7 a	87.6 a
2) LL – Glyphosate	34.7 cd	43.0 a	74.6 a
3) LL – Saflufenacil	43.5 abc	35.2 a	77.2 a
4) LL – Safl + Glyph	56.0 a	40.9 a	80.3 a
5) LL – Diquat	50.8 ab	38.9 a	78.2 a
6) RR – Control	20.7 de	53.9 a	73.6 a
7) RR – Gluf. Amm.	15.0 e	42.0 a	73.1 a
8) RR – Saflufenacil	19.2 e	42.5 a	69.9 a
9) RR – Safl + Glyph	13.0 e	50.8 a	74.6 a
10) RR – Diquat	19.2 e	52.8 a	70.0 a
S.E.M.	5.76	6.16	6.19
LSD [x]	14.25	ns	Ns
Pr > *F* (p-value)	**<0.001**	0.230	0.640

[z]Pre-harvest herbicide/desiccant treatments were not yet applied at the time of these measurements; only differences between hybrids may be logically explained by anything other than background variability and experimental error

Table 9c. Treatment means and tests of fixed effects for final visual stem dry-down ratings and whole plant gravimetric moisture content at Melita, Manitoba. The treatments were pre-harvest/desiccation options for glufosinate ammonium (LL) and glyphosate (RR) tolerant canola. Means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test; *P* ≤ 0.05).

Treatment	**MT-2017**	**MT-2018**	**MT-2019**	**MT-2017**	**MT-2018**	**MT-2019**
	-- Visual Stem Dry-Down Ratings (0-100)[Z] --			----- Whole Plant Moisture Content (%)[Y] -----		
1) LL – Control	71.3 cd	100	42.5 ef	30.4 a-d	12.2 a	24.4 abc
2) LL – Glyphosate	88.8 ab	100	37.5 f	21.6 d	14.5 a	29.1 a
3) LL – Saflufenacil	71.3 cd	100	37.5 f	31.2 ab	16.2 a	28.5 a
4) LL – Safl + Glyph	83.8 b	100	57.5 cde	25.1 bcd	14.5 a	24.9 ab
5) LL – Diquat	91.3 ab	100	73.8 abc	21.8 cd	9.2 a	15.3 cde
6) RR – Control	67.5 d	100	57.5 cde	36.1 a	8.5 a	16.1 b-e
7) RR – Gluf. Amm.	90.0 ab	100	81.3 ab	28.2 a-d	8.1 a	18.4 cde
8) RR – Saflufenacil	82.5 bc	100	65.0 bcd	33.9 ab	6.2 a	8.7 e
9) RR – Safl + Glyph	86.3 ab	100	52.5 def	30.7 abc	9.2 a	16.8 b-e
10) RR – Diquat	97.5 a	100	85.0 a	26.5 bcd	8.3 a	12.0 de
S.E.M.	5.23	–	6.57	3.06	2.59	0.31
LSD [X]	12.34	–	18.87	8.89	ns	0.91
Pr > *F* (p-value)	**<0.001**	–	**<0.001**	**0.032**	0.079	**<0.001**

[Z] Final ratings completed at harvest [Y] Gravimetric water content of above-ground plant material (including grain) at harvest

Table 9d. Treatment means and tests of fixed effects for seed moisture content and yield at Melita, Manitoba. The treatments were pre-harvest/desiccation options for glufosinate ammonium (LL) and glyphosate (RR) tolerant canola. Means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test; *P* ≤ 0.05).

Treatment	MT-2017	MT-2018	MT-2019	MT-2017	MT-2018	MT-2019
	---------- Seed Moisture Content (%)[Z] ----------			--------------- Seed Yield (kg/ha)[Y] ---------------		
1) LL – Control	8.7 abc	5.0 a	10.0 a	3584 a	2219 a	3060 bc
2) LL – Glyphosate	8.1 bcd	4.9 a	9.4 abc	3496 a	2123 a	2993 cd
3) LL – Saflufenacil	8.2 bcd	5.0 a	9.9 ab	3502 a	2088 a	3065 bc
4) LL – Safl + Glyph	8.5 a-d	5.0 a	9.7 ab	3689 a	2171 a	3140 bc
5) LL – Diquat	8.1 bcd	4.8 a	7.4 d	3648 a	2025 a	2818 d
6) RR – Control	9.5 a	5.0 a	9.0 abc	3613 a	2145 a	3196 bc
7) RR – Gluf. Amm.	7.8 cd	5.1 a	8.0 cd	3524 a	2278 a	3443 a
8) RR – Saflufenacil	9.1 ab	4.9 a	8.5 bcd	3436 a	2248 a	3225 ab
9) RR – Safl + Glyph	8.7 abc	4.8 a	8.9 abc	3304 a	2237 a	3242 ab
10) RR – Diquat	7.5 d	4.9 a	8.2 cd	3577 a	2127 a	3209 bc
S.E.M.	0.43	0.08	0.63	122.4	77.2	92.6
LSD [X]	1.13	ns	1.45	ns	ns	230.7
Pr > *F* (p-value)	**0.033**	0.264	**0.012**	0.070	0.422	**0.001**

[Z] Gravimetric water content of canola seed at harvest [Y] Corrected for dockage and to 10% seed moisture content

Table 9e. Treatment means and tests of fixed effects for seed weight and percent distinctly green seed at Melita, Manitoba. The treatments were pre-harvest/desiccation options for glufosinate ammonium (LL) and glyphosate (RR) tolerant canola. Means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test; *P* ≤ 0.05).

Treatment	MT-2017	MT-2018	MT-2019	MT-2017	MT-2018	MT-2019
	--------- Seed Weight (g/1000 seeds) ---------			----------------- Green Seed (%) -----------------		
1) LL – Control	3.28 a	2.25 b	2.28 b	0.3 bc	0.3 bc	0.1 b
2) LL – Glyphosate	3.21 a	2.27 b	2.21 b	0.1 c	0.3 c	0.4 b
3) LL – Saflufenacil	3.20 a	2.25 b	2.29 b	0.1 c	0.7 ab	0.5 b
4) LL – Safl + Glyph	3.18 a	2.28 b	2.24 b	0.4 bc	0.4 abc	0.2 b
5) LL – Diquat	3.21 a	2.31 b	2.15 b	0.1 c	0.5 abc	0.3 b
6) RR – Control	3.24 a	2.57 a	2.59 a	0.9 b	0.2 c	0.3 b
7) RR – Gluf. Amm.	3.21 a	2.59 a	2.57 a	0.7 bc	0.2 c	0.2 b
8) RR – Saflufenacil	3.27 a	2.57 a	2.64 a	0.5 bc	0.3 c	0.2 b
9) RR – Safl + Glyph	3.27 a	2.58 a	2.60 a	0.2 bc	0.2 c	0.2 b
10) RR – Diquat	3.29 a	2.52 a	2.62 a	1.9 a	0.7 a	1.1 a
S.E.M.	0.073	0.037	0.084	0.24	0.13	0.14
LSD [X]	Ns	0.091	0.153	0.71	0.38	0.42
Pr > *F* (p-value)	0.864	**<0.001**	**<0.001**	**< 0.001**	**0.054**	**0.004**