# Are Intercropped Cover Crops Compatible with Canola Weed Management on the Canadian Prairies?

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## BACKGROUND INFORMATION

### INTRODUCTION

The use of cover crops on the Canadian Prairies is within its infancy and is being driven by early adopters of the practice. The short growing season and limited fall precipitation in the semi-arid climate of Western Canada hinders widespread adoption of fall cover crops[1]. Intercropping is a potential solution by increasing the window for cover crop establishment and growth.

Currently, there is limited information on how cover crops can fit into prairie crop rotations, especially with canola, one of Western Canadas most extensively cultivated crops. Additionally, the use of herbicides to manage weeds in canola introduces complexities for intercropping, making it crucial to assess common herbicide resistance systems for their potential to support the intercropping of cover crop species within canola.

### OBJECTIVES

The objective of the study was to assess the impact of three herbicide resistance systems commonly used with canola hybrids, along with typical herbicide and desiccation application timings, to identify strategies that can support the intercropping of cover crops while maintaining canola productivity.

### MATERIALS AND METHODS

A small plot field experiment was conducted at two sites (Carman, Manitoba and Kernen, Saskatchewan) in 2022 and 2023 to compare three herbicide application timing treatments (pre-emergence only (PRE), pre-emergence and in season (PRE,IS), and a pre-emergence, in season, and desiccant (PRE,IS,D)) for the three herbicide resistance systems utilized with canola hybrids (Liberty Link, Roundup Ready, and Clearfield). Each experiment was conducted using a split-plot design with four replications. Herbicide resistance system was the main plot and application timing was the subplot.

**Table 1.** Growing conditions as described by growing season (April to October) accumulated growing degree days (GDD) and precipitation (mm) for Carman and Kernen in 2022 and 2023. Climate normals are for precipitation are from 1981-2010[2] and from1999-2024 for GDD[3].

| | Carman | | | Kernen | | |
|---|---|---|---|---|---|---|
| | 2022 | 2023 | Normal | 2022 | 2023 | Normal |
| **Growing degree days (GDD)** | 1798.2 | 2096.8 | 1892.0 | 1825.1 | 1950.2 | 1723.1 |
| **Precipitation (mm)** | 451.6 | 269.6 | 441.3 | 150.8 | 211.0 | 277.0 |

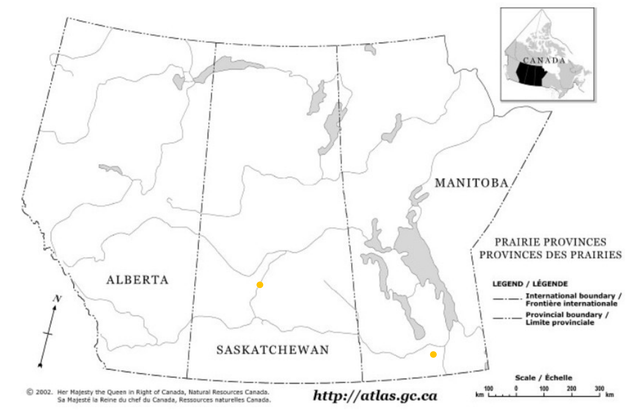



**Figure 1.** Map of the Canadian Prairie provinces[3] with yellow circles indicating Kernen, Saskatchewan and Carman, Manitoba[4].

**SEEDING RATES** Three canola varieties (Liberty Link DKC 82 SCLL, Roundup Ready DK902TF, and Clearfield P508MCL) were seeded to achieve a stand of 110 plants/m$^2$ (445,000 plants/acre). A cover crop mixture was seeded to achieve a stand of 40 plants/m$^2$ at a rate of 3.3 kg/ha in 2022 and increased to a stand of 100 plants/m$^2$ at a rate of 9.0 kg/ha in 2023. The cover crop mixture and canola were seeded in alternate rows on 7.5" spacing in carman and 8" spacing in Kernen.

**Table 2.** Species and seeding rates for the cover crop mixture in 2022 and 2023.

| Cover crop species | Target stand | | Seeding rate | |
|---|---|---|---|---|
| | 2022 | 2023 | 2022 | 2023 |
| | plants/m$^2$ | | kg/ha | |
| **Red clover** | 5 | 15 | 0.252 | 0.756 |
| **White Dutch clover** | 5 | 15 | 0.112 | 0.336 |
| **Subterranean clover** | 5 | 15 | 0.785 | 2.355 |
| **Persian clover** | 5 | 15 | 1.401 | 4.203 |
| **Alfalfa** | 10 | 30 | 0.308 | 0.924 |
| **Italian ryegrass** | 10 | 10 | 0.448 | 0.448 |
| **Mix total** | 40 | 100 | 3.306 | 9.022 |

**HERBICIDES** The pre-emergence only (PRE) treatment was Roundup (glyphosate) applied at a rate of 0.7 L/ac to all plots prior to crop emergence in early May. In-season (IS) applications occurred mid-June (prior to canola bolting) for all three herbicide resistance systems: Liberty (glufosinate) was applicated at 1.0 L/ac, Roundup WeatherMAX (Glyphosate) applied at 0.7 L/ac, and Clearfield Ares (imazamox/imazethapyr) applied at 0.3 L/ac. The desiccant (D) treatment was applied end of August (at 80% seed colour change) and was Reglone Ion (diquat) at a rate of 0.6 L/ac.

### STATISTICAL ANALYSIS

All data was analyzed as a split-plot using the Proc Glimmix procedure of SAS 9.4. Year, location, canola herbicide resistance system, and herbicide application timing were included as fixed effects in the model. Replication was nested in location and was included as a random effect. The normal distribution was used for canola yield, Poisson distribution for cover crop emergence and persistence counts, and a lognormal distribution was used for cover crop biomass. Differences between treatments were separated using LSmeans at the 0.05 significance level for site year.

Herbicide damage ratings were analyzed as a repeated measures using Proc Glimmix of SAS with location, canola herbicide resistance system, and rating as fixed effects in the model with the Kenward-Roger approximation. Rating was set as the repeated effect using the random statement with the sp(pow) structure to account for unequal time interval between ratings. Differences between herbicides and rating intervals were separated using LSmeans at the 0.05 significance level for individual cover crop species at each location.

## RESULTS

### GLOBAL ANOVA

| Sources of variation | Cover crop emergence | Cover crop biomass | Cover crop persistence | Canola yield |
|---|---|---|---|---|
| **Year (Y)** | **<0.0001** | **<0.0001** | - | **<0.0001** |
| **Location (L)** | **0.0024** | **0.0240** | - | **<0.0001** |
| **Herbicide resistance system (HRS)** | 0.5638 | **0.0049** | **0.0021** | **0.0026** |
| **Application timing (AT)** | - | **<0.0001** | **<0.0001** | **0.0120** |
| **Y*L** | **<0.0001** | **<0.0001** | - | **0.0005** |
| **Y*HRS** | 0.1826 | 0.3590 | - | **0.0169** |
| **Y*AT** | - | 0.0549 | - | 0.2243 |
| **L*HRS** | 0.5468 | **0.0002** | - | 0.6440 |
| **L*AT** | - | **<0.0001** | - | 0.1370 |
| **HRS*AT** | - | **0.0040** | **<0.0001** | 0.7600 |
| **Y*L*HRS** | 0.7849 | **0.0034** | - | **0.0413** |
| **Y*L*AT** | - | 0.5919 | - | 0.1307 |
| **Y*HRS*AT** | - | **0.0474** | - | 0.9003 |
| **L*HRS*AT** | - | 0.3186 | - | 0.7120 |
| **Y*L*HRS*AT** | - | **0.0187** | - | 0.6697 |

**Table 3.** F-test probability from the ANOVA of year (2022 and 2023), location (Carman and Kernen), canola herbicide resistance system (Clearfield, Liberty Link, and Roundup Ready) abbreviated as canola, and herbicide application timing (pre-emergence only, pre-emergence and in season, and pre-emergence in season and desiccant) abbreviated as timing, and their interactions for June cover crop counts, post harvest cover crop biomass, cover crop fall persistence counts, and canola yield. Cover crop persistence was analyzed with a reduced model of 2023 data only.

### COVER CROP PERSISTENCE

#### COVER CROP FALL BIOMASS

In 2022, poor cover crop persistence limited cover crop biomass in Carman. In Kernen where some cover crops persisted, the greatest biomass was achieved in the pre-emergence only (PRE) treatment. Cover crop biomass decreased following in-season applications.

In 2023, treatments receiving only a pre-emergence herbicide application had the greatest biomass at both sites. Cover crop biomass also declined with the in-season herbicide application and declined further with the application of a desiccant for all herbicide resistance systems. Moderate cover crop biomass was achieved in the pre-emergence and in-season (PRE,IS) herbicide treatments at both sites. At Carman, Roundup and Clearfield resulted in the greatest biomass while at Kernen Liberty had the most biomass.

When comparing the treatments with the in-season herbicide application there was no difference in cover crop biomass with and without a desiccant, with the exception of Liberty at Kernen in 2022 and both sites in 2023.

#### COVER CROP FALL DENSITY

Cover crop persistence was greater in 2023 than 2022. In 2023, persistence counts follow the same trend as Kernen22, Carman23, and Kernen23 biomass where the pre-emergence only application resulted in the greatest cover crop density which declined with an in-season application and further declined following the application of a desiccant.

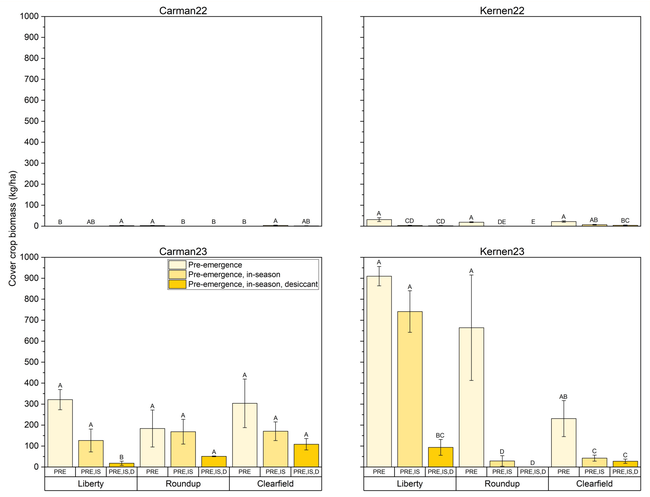



**Figure 2.** The effect of herbicide application timing (pre-emergence only (PRE), pre-emergence and in season (PRE,IS), and pre-emergence in season and desiccant (PRE,IS,D)) on fall cover crop biomass (kg/ha) for three herbicide resistance systems in canola (Liberty Link, Roundup Ready, and Clearfield) seeded with a cover crop mixture at Carman, Manitoba and Kernen, Saskatchewan in 2022 and 2023. Difference in letters indicate significant difference at the P <0.05 significance level. Error bars represent ±1 standard error of the mean.

| Herbicide | Carman22 | Carman23 |
|---|---|---|
| | Plants/m$^2$ | |
| **Pre-emergence** | | |
| Liberty | 0.8 (-13.0) | 19.3 (-102.3) |
| Roundup | 1.3 (-13.8) | 19.5 (-86.8) |
| Clearfield | 0.0 (-12.3) | 15.0 (-120.5) |
| **Pre-emergence and in-season** | | |
| Liberty | 1.5 (-11.0) | 7.3 (-124.5) |
| Roundup | 0.0 (-13.3) | 14.8 (-113.3) |
| Clearfield | 3.0 (-7.3) | 25.5 (-92.5) |
| **Pre-emergence, in-season, and desiccant** | | |
| Liberty | 1.8 (-8.0) | 2.5 (-113.0) |
| Roundup | 0.0 (-17.5) | 10.5 (-110.0) |
| Clearfield | 3.3 (-10.5) | 13.25 (-120.5) |

**Table 4.** Average cover crop persistence at the end of the growing season for Carman22 and Carman23 following three herbicide application timings (pre-emergence only pre-emergence and in season, and pre-emergence in season and desiccant) in three herbicide resistance systems (Liberty Link, Roundup Ready, and Clearfield). All species were combined when counting the total number of plants remaining. Values in parentheses represent departures from emergence values.

### HERBICIDE DAMAGE RATINGS

| Herbicide | Carman 3 DAA | Carman 7 DAA | Carman 14 DAA | Kernen 3 DAA | Kernen 7 DAA | Kernen 14 DAA |
|---|---|---|---|---|---|---|
| | % | | | | | |
| | **Clovers** | | | | | |
| Liberty | 62.5 cd | 79.4 ab | 83.1 a | 66.1 abc | 79.4 a | 64.7 bc |
| Roundup | 29.1 f | 44.7 de | 44.4 de | 7.0 g | 40.6 ef | 79.4 abc |
| Clearfield | 0.0 g | 0.0 g | 0.6 g | 2.5 g | 10.6 g | 35.0 ef |
| | **Alfalfa** | | | | | |
| Liberty | 40.9 d | 61.6 cd | 72.8 cd | 76.0 bc | 90.8 a | 71.8 cd |
| Roundup | 9.1 d | 15.9 d | 22.8 d | 2.6 d | 50.6 d | 89.8 ab |
| Clearfield | 0.0 d | 0.0 d | 0.0 d | 2.0 d | 3.4 d | 47.5 d |
| | **Italian ryegrass** | | | | | |
| Liberty | - | - | - | 52.7 a | 47.0 a | 32.9 a |
| Roundup | - | - | - | 1.6 b | 85.6 a | 100.0 a |
| Clearfield | - | - | - | 2.4 b | 10.8 ab | 85.6 a |

**Table 5.** Herbicide damage ratings by percent injury as determined by the CWSS-SCM rating scale for intercropped cover crop species treated with Liberty, Roundup WeatherMAX, or Clearfield Ares. Ratings were taken 3, 7, and 14 days after application (DAA) in Carman23 and Kernen23. A rating of 0 indicates no damage whereas a rating of 100 indicated complete plant death.

**Table 6.** Canadian Weed Science Society (CWSS-SCM) rating scale for crop tolerance[5]. A rating of 10% of less is considered acceptable injury.

| Phytotoxicity range | Assessment of injury |
|---|---|
| 0-9% | Slight discoloration and/or stunting |
| 10% | Just acceptable |
| 11-30% | Not acceptable |
| >30% | Severe |

#### LIBERTY

Liberty resulted in severe injury to cover crops following application. Bleaching symptoms were visible in alfalfa and slightly in clovers at Carman and Kernen 3 DAA. Wilting and cupping of clover leaves were observed in Carman.
Cover crops were injured to the point where they did not recover in Carman however cover crops did recover in Kernen.

#### ROUNDUP

Roundup resulted in severe injuries to cover crops in Kernen where symptoms of chlorosis and wilting in clovers and alfalfa resulted in severe injury ratings for all cover crop species. Similar symptoms occurred in Carman with chlorosis in clovers resulting in a severe injury rating. A shepherd's crook was visible in alfalfa in Carman, resulting in an injury that was rated as not acceptable.

#### CLEARFIELD

Clearfield was the least damaging herbicide to clovers and alfalfa in the cover crop mixture at both locations. Injury symptoms in the cover crops following Clearfield Ares included slight chlorosis to clovers and alfalfa at Carman, but was rated as an acceptable injury. Chlorosis was prominent to the cover crop species at Kernen and resulted in severe injury ratings for all species.

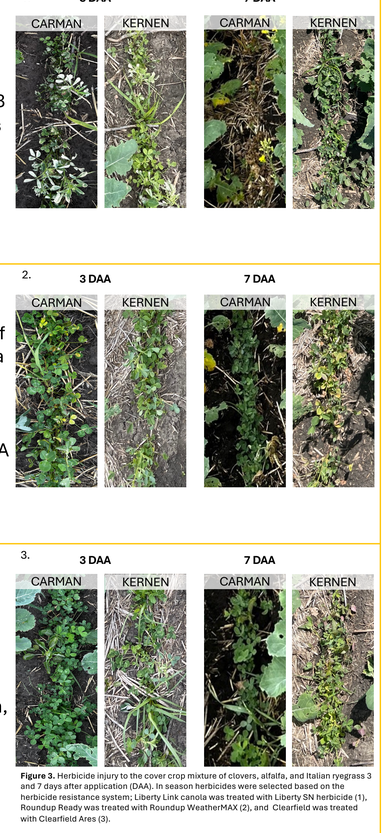



**Figure 3.** Herbicide injury to the cover crop mixture of clovers, alfalfa, and Italian ryegrass 3 and 7 days after application (DAA). In season herbicides were selected based on the herbicide resistance system; Liberty Link canola was treated with Liberty SN herbicide (1), Roundup Ready was treated with Roundup WeatherMAX (2), and Clearfield was treated with Clearfield Ares (3).

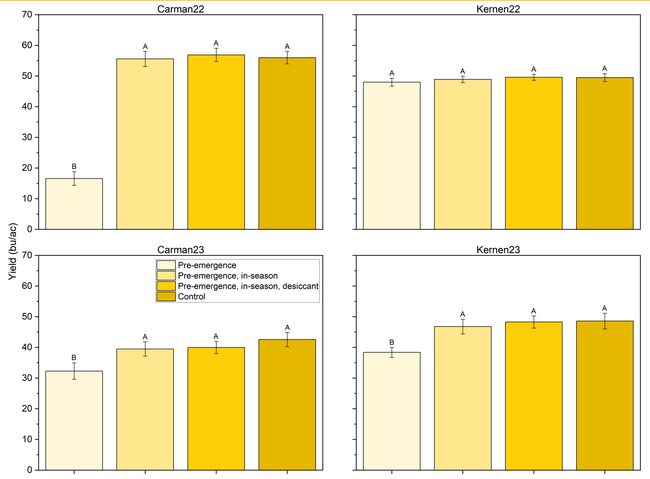
Following in-season application, all herbicides resulted in injury beyond the point of plant recovery at Kernen where Roundup inflicted the most damage followed by Liberty. At Carman the opposite occurred where Liberty was the most damaging followed by Roundup. At both locations Clearfield inflicted the least damage to cover crops, though cover crops were still injured beyond the point of recovery at Kernen.

### CANOLA YIELD

#### CANOLA YIELD

At 3 out of 4 site years, the pre-emergence only (PRE) treatment resulted in the lowest yields. The PRE treatment was statistically lower than treatments receiving in-season herbicide application. The pre-emergence only treatment allowed for the greatest cover crop biomass (Figure 2) and weed biomass, reducing canola yield. In-season herbicides in the PRE,IS and PRE,IS,D treatments provided needed in-crop weed control but had a negative impact on cover crops. However, yield was unaffected by the presence of cover crops in the PRE,IS and PRE,IS,D treatments relative to the no cover crop control treatment.

Overall, the pre-emergence only (PRE) application was associated with lower canola yields. Post emergent herbicides, specifically the in-season application is crucial for maximizing canola yield and the addition of cover crops relative to the control did not negatively impact yields when weeds were controlled.

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#### PERCENT YIELD

To assess the effect of cover crops on canola yield, percent yield relative to the no cover crop control were calculated for the treatments which received the pre-emergence, in-season, and desiccant (PRE,IS,D). There was no statistical difference between the PRE,IS,D treatment with or without intercropped cover crop nor differences between site years.

In 2022, minimal cover crop persistence resulted in no yield penalties, and instead saw slight overyielding compared to the no cover crop control.

In 2023, slight overyielding was also observed at Kernen resulting from minimal cover crop biomass persisting to the fall. In Carman however, greater cover crop biomass in the PRE,IS,D treatments (Figure 2) resulted in a 4% yield penalty to canola averaged across all herbicide resistance systems.

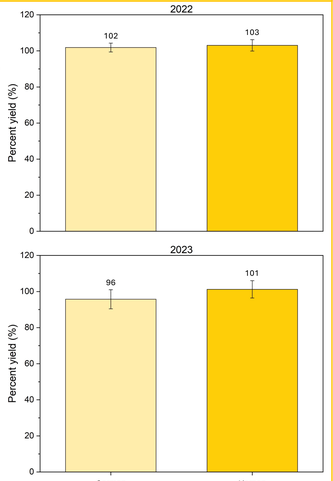


**Figure 5.** Percent yield relative to the no cover crop control (%) for Carman, Manitoba and Kernen, Saskatchewan in 2022 and 2023. Error bars represent ±1 standard error of the mean.

### KEY FINDINGS

**Were cover crops able to establish and persist when intercropped with canola?**
Cover crops were able to establish both years of the experiment. In 2022 cover crop establishment was 13 plants/m$^2$ in Carman and 67 plants/m$^2$ in Kernen. As a result of poor establishment, a minimal amount of cover crops persisted into the fall growing season. In 2023 establishment was greater with the average understory being 124 plants/m$^2$ and 110 plants/m$^2$ in Carman and Kernen respectively. Due to greater establishment, cover crops were able to persist into the fall in the Roundup and Clearfield systems in Carman and the Liberty and Clearfield systems in Kernen.

**Did in season herbicide application timing and desiccant treatments decrease cover crop biomass?**
Cover crop biomass was not statistically different when in-season herbicides or a desiccant was applied. The pre-emergence only (PRE) treatment had the greatest cover crop biomass accumulation. There was moderate cover crop biomass in the pre-emergence and in-season (PRE,IS) treatment. In 2023, the most successful herbicide resistance systems to support cover crop growth was Clearfield and Roundup in Carman whereas in Kernen Clearfield and Liberty were the most successful.

**Did intercropped cover crops decrease canola yield?**
Intercropping of cover crops did not decrease canola yield when weeds were controlled with in-season herbicide applications. Where weeds could not be controlled with in in season herbicide application, yields were reduced. In 2023 a yield penalty of 4% was observed in Carman whereas overyielding occurred in Kernen.

### NEXT STEPS

Further testing is needed with a larger range of cover crop species, cover crop seeding methods and timings, canola varieties, herbicides and application timings, as well as locations to adapt and refine agronomic management strategies for canola and cover crop perforce for cropping systems across western Canada.

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