PROJECT DETAILS

- **Title**: Harrington seed destructor evaluation at field scale in Alberta
- **Funders:** Alberta Canola
- **Research program:** Agriculture Funding Consortium
- **Principal investigator:** Breanne Tidemann
- **Collaborators/additional investigators:** Hugh Beckie, Troy Lucyshyn, Neil Harker
- **Year completed:** 2020

Final report

Background

Herbicide resistant weeds incidence and frequency continues to increase across the Canadian Prairies (Beckie et al. 2020). At the same time, discoveries of new herbicide modes of action that could manage resistant weed species have been declining in frequency (Duke 2012). This leaves a shortage of herbicide management options for many weed species, and increases selection pressure for resistance to those herbicides which are still effective. As a result there is increasing focus on non-herbicide methods of managing weeds in Canada as well as globally.

In Australia, there has been development and adoption of a weed management method known as harvest weed seed control (HWSC). This method focuses on managing weeds expelled from combine harvesters in the chaff fraction so as to prevent additions to the weed seed bank (Walsh et al. 2013). There are a number of methods of HWSC including narrow windrow burning, chaff lining/tramlining, chaff collection, bale direct systems, and physical impact mill systems. Expert opinion expects physical impact mills to be the most likely method of HWSC to be adopted on a large scale in western Canada due to reduced requirements for additional management, no requirement for burning or towing, and high levels of efficacy. There are a number of physical impact mills now on the market including the iHSD (integrated Harrington Seed Destructor, produced by deBruin), the Seed Terminator, the Seed Control Unit (Redekop Manufacturing) and the WeedHOG.

However, HWSC is not effective on all weeds. For weeds to be managed via HWSC methods they must be retained at the time of harvest, at a height from which the harvester can collect them (Walsh et al. 2013). For problematic weeds in Australia such as annual ryegrass or wild radish, these conditions are met. Problematic Canadian weeds vary in their suitability for HWSC (Burton et al. 2016, 2017; Beckie et al. 2017, Tidemann et al. 2017B). As an example, volunteer canola and cleavers are expected to make good targets for HWSC methods while the low levels of seed retention until crop harvest are a concern for species such as wild oat (*Avena fatua* L.) (Walsh et al. 2018). While efficacy evaluations of the Harrington Seed Destructor (expected to be representative of most of the physical impact mill systems) have been conducted on Canadian weeds

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(Tidemann et al. 2017A), field scale evaluations of the HSD have not been completed/published in Canada or in North America to date. The tow-behind Harrington Seed Destructor is now an obsolete version of the physical impact mills, however results are expected to be representative of other cage/hammer mill systems (Seed Terminator, and Seed Control Unit). The results would likely overestimate efficacy of the WeedHOG, which is based on a different mill system and tends to show lower levels of efficacy on processed weeds.

Objectives and deliverables

The original objective was to evaluate the efficacy of the Harrington Seed Destructor on weeds in Alberta and determine if efficacy varies by cropping system and management choices. The short term objective was to determine the effect of the Harrington Seed Destructor on weed populations in Alberta. The long term objective was to determine if the Harrington Seed Destructor is a viable weed management option in Alberta, and which cropping systems and practices it is suited for.

Planned deliverables:

The primary deliverable was knowledge on if the HSD was effective on weeds in Canadian cropping systems. In addition there are plans for a scientific manuscript, as well as presentations at conferences, grower meetings, agronomy updates, etc.

20 producer fields were identified within an approximately 50 km distance from Lacombe (Figure 1) where there was, at a minimum, a large patch of a problematic weed. The goal was to select producers starting in canola, wheat and peas with swathed and straight cut harvest timings in wheat and canola. Because of logistics, we struggled to find producers within a reasonable area who were swathing wheat. However, the desired crops were found at the start of the project and then rotations were allowed to vary as per farm rotation. Crop rotations and harvest system of each of the 20 fields is presented in Table 1.

In each field the size of the weed patch was scouted. That area was then broken into six plots. This allowed for 3 replicates of an untreated/regular harvest to be implement and 3 replicates of a Harrington Seed Destructor harvest to be implemented in each field, although the size of the plots/replicates varied by field. Prior to the initial harvest, weed counts were conducted across the entire trial area, by species, to determine what populations were there at harvest. The first harvest was conducted in fall of 2017. All 20 fields were successfully harvested.

In spring of 2018 pre-spraying seedling counts were conducted in all 20 fields. To determine weed densities 20 quadrats per plot were counted with weeds identified and counted by species. A smaller (10 quadrats per plot) pre-harvest survey was conducted in fall of 2018. In fall of 2018, 19 out of 20 fields were harvested. One field

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was seeded to hemp and due to harvest challenges with that crop we did not combine with the HSD in that field that year.

In spring of 2019 pre-spraying seedling counts were again conducted in all 20 fields. Weed densities were determined by species through 20 quadrat counts, as above. A final pre-harvest survey was again conducted in fall of 2019. All 20 fields were harvested with expected treatments in fall of 2019.

In spring of 2020 final pre-spraying seedling counts were conducted in all fields using 20 quadrat counts per plot. In addition to emerged seedling counts, 15 4" diameter soil cores were sampled to a depth of 2" in each plot to evaluated weed seedbank densities. Soil cores were washed through a series of sieves to reduce the overall size of the sample without losing any weed seeds. Samples were then processed through a clipper cleaner into two fractions. One where large seeded weeds could be removed by hand, with a focus on wild oat or other large weeds with dormancy, and the other that required growth time in a growth chamber to identify weeds. We had hoped to process the samples through washing and hand removal of weeds only, and had worked at building a protocol to allow us to do so. However, the soil that we tested the protocol with did not have as high of a sand content as the soil in our seedbank samples from our producer fields. This posed a problem for small seeded weeds such as chickweed which is nearly impossible to separate by hand from sand. As a result we have had to revert to the grow out method of evaluating species in the soil seedbank. Each sample is grown out by plot, and is grown under controlled growth conditions for 3 weeks in a growth chamber. As weeds emerge they are identified to species and removed. After the three week period samples are placed in a freezer for 3 weeks. After the freezing period they are removed from the freezer, the soil is mixed/disturbed, and they are placed under grow lights in a temperature controlled room. Emerged seedlings are again identified to species and removed. If a third grow out is required, that is conducted after an additional freezing period.

Unfortunately, due to the extended time required to process each sample through the seedbank grow out method, this data collection is ongoing. We had hoped to bypass this lengthy process by using the washing method. We can successfully use this method for wild oats but not for smaller seeded weeds when sand content is high. The overall seedbank information is therefore not completed. Results of the seedbank analysis will be completed and analyzed later at which time those results will be forward on to the funding agencies to complete the final report.

Statistical analysis: Top weeds were identified out of each field, to allow for summary of a simply massive amount of data. This was based on the top 5 weeds in the field that were present at a density of more than 50 m-2. Data were analyzed using generalized linear mixed models ANOVA in SAS 9.4. Distributions were selected based on Akaike's Corrected Information criterion and an examination of the residuals. Analysis was conducted

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across all fields for total number of weeds counted in the spring of 2020 (seedling emergence count). For top weeds, analysis was conducted across all fields in the spring of 2020 that were associated with that weed as a top weed using treatment as a fixed effect and rep nested in field ID as a random effect. In addition an ANOVA was conducted by field for each top weed where treatment was a fixed effect and replicate was a random effect. We are in the midst of also doing a multivariate analysis, however, unresolved problems with my SAS program and computer hardware have not allowed me to complete that analysis in time for this report. Details of that analysis will be included with the results of the soil seedbank measurements.

Results, discussion and conclusions

The first result that needs to be highlighted is that all 20 producers' fields remained in the project for the entire duration of the project. This is quite unusual when it comes to producer field projects, particularly when a trial is set up in their fields, and their fields aren't being used for just a survey. We did have a few bumps in the road (one field out of the trial for one harvest due to growing hemp, a producer not spraying any weed control in the HSD trial area so we could "really test that machine", etc.) but all fields were maintained as part of the project for the entire duration. This is exciting and gives us a large database of data to work with.

The initial ANOVA analysis results show limited significant differences between the check and the HSD treatments. There are, however, also some interesting trends to highlight, as well information and understanding to be gained from future multivariate analyses as well as the data collected from the seedbank samples.

Focussing on the measurement of total weed densities, there was no significant difference between the check treatment and the HSD treatment when analyzed across fields. In fact, the mean densities were quite similar (225 vs 228 m-2). Although we would have hoped to have seen a difference, it's not surprising that we did not considering this is analyzed across all weed species. This project intentionally included species that were expected to be good targets for HWSC as a result of their measured or observed seed retention, as well as species that were not expected to be good targets based on height or seed retention, in order to be able to demonstrate a difference and an impact that is species specific. When analyzed across fields there were only 3 fields with significant differences between treatments, none of which were as a result of decreased weed densities in the HSD treatment. Possible reasons that we may see increased weed densities in the HSD treatment will be discussed later.

Cleavers was the most common top weed in the study, ranking as a top weed in 15/20 fields. In only two fields was there a measured significant difference between treatments. One where the HSD had higher densities than the untreated, and one where densities were significantly reduced. However, interestingly, cleavers

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densities were numerically lower in 10/15 fields. Cleavers was a weed that was expected to be reduced in densities from the HSD treatments, based on measured seed retention values (Tidemann et al. 2017B). It is possible that with additional years under HSD treatment, some of the numerical reductions in densities would become statistically significant. Weed densities, being highly variable in producer fields, can be difficult to differentiate statistically. It is also worth noting that cleavers densities in spring of 2020 were very high in all fields compared to previous years. The weather in 2020 proved to be good "cleavers weather" which may also impact our ability to differentiate between the untreated and the HSD treatments. Overall I would have expected higher control of this species, which leads me to question the high densities overall in 2020, and the potential to measure differences in future years. The seedbank densities of cleavers will be a valuable component to this comparison.

Wild oat/volunteer cereals was one of the next most common top weeds, ranking as a top weed in 14/20 fields. Volunteer cereals were combined with wild oats. Seedling counts were taken in the spring, prior to farmers applying an in-crop herbicide. In some cases herbicide applications were made when the wild oat/volunteer cereals were only one leaf and incredibly difficult to identify without digging up every plant, and even then if the seed is lost it is incredibly difficult. As a result, due to time constraints and a need for efficiency, the volunteer cereals and wild oats have been combined for analysis to remove any possibility of incorrect data from misidentification. The majority of these weeds are believed to be wild oat. Across all fields where wild oat was a top weed there was no significant difference between the untreated and the HSD treatments. There were four fields were there were significant differences in wild oat densities between the HSD and the untreated; in 2 cases wild oat densities were reduced with the HSD and in 2 they were increased. When looking at numeric means wild oat densities were only reduced in 6/14 fields where it was a top weed. Limited efficacy on wild oat was expected from the HSD, due to early seed shed in this species (Tidemann et al. 2017B). An interesting observation is that in field 12, where wild oat densities were significantly reduced by the HSD, we observed high levels of seed retention in the wild oat plants in the field at harvest in 2017. It's possible that increased seed retention is a biotype feature of that wild oat population which allowed for the HSD to be more effective. This is a hypothesis only, as wild oat biotypes have not been examined for differences in seed retention to date. Overall, limited impact on this species in terms of seedling numbers is not unexpected, although it is disappointing. The seedbank numbers and the ability to do a full population comparison will be important to finalizing these results.

Volunteer canola was also a top weed in 14/20 fields. There were no significant differences between the untreated and the HSD treatments across fields or in any fields. Even numerically there were only 4/14 fields where volunteer densities were lower in the HSD treatments. This is frankly very surprising based on the seed retention of volunteer canola (Tidemann et al. 2017B), suggesting that it would make a very good target for

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HWSC. The seedbank samples may provide important information here. It is possible that when seedbank densities are high, a limited number of individuals are able to germinate and emerge. However, when seedbank densities are reduced, each individual has a higher probability of germinating because of better seed-soil contact, more 'safe-sites', and more niche availability. It will be very interesting to compare the seedbank numbers to the emerged seedling densities. If seedbank densities also reflect limited impact on canola densities, it will be important to determine why. In theory canola meets all the criteria for a good target for HWSC (good seed retention, excellent height of seed retention, easily combined), so identifying why we weren't able to measure an impact is important. It's possible that volunteer canola is shattering out when the header contacts it and is dropped to the soil prior to entering the combine, or that it is being expelled in a non-chaff fraction. These questions will be determined/strengthened after the seedbank analysis is complete.

Chickweed was a top weed in 13/20 fields. There was no significant difference between the HSD treatment and the untreated check across fields or in any of the 13 fields. This is unsurprising. Chickweed is a very low growing weed and produces many of it's seeds under the crop cutting height. It is unlikely that many retained seed can be collected due to the low height of production. Chickweed is another weed that was quite abundant in spring of 2020, apparently appreciating the weather conditions that were received early in the growing season.

Hempnettle was a top weed in 7/20 fields. There was no significant reduction in hempnettle densities across or in any of the 7 fields. However, in field 2, there is no test of difference between the treatments possible. Two replicates of the HSD treatment had no hempnettle counted. As a result there was only one replicate of the HSD treatment with a density value. As there is no variance to the measured density for that treatment (only one measured value) an ANOVA is not possible. Numerically, the HSD treatment had fewer hempnettle plants than the untreated check. Including field 2, there were lower hempnettle densities in 5/7 fields with hempnettle as a top weed, suggesting there may be some efficacy on this species. Expected efficacy on this species was unknown – seed retention has not been measured, but appeared likely to be conducive to control with HWSC.

Sowthistle was also a top weed in 7/20 fields. There were no significant reductions in sowthistle densities compared to the untreated across fields or in any of the fields. There was only one significant difference between the HSD and the untreated in field 8 and it did not result in a reduction in densities in the HSD treatment. Numerically there is no trend towards reduced populations in the HSD treatments. Sowthistle was expected to be a poor target for the HSD based on limited seed retention (Beckie et al. 2018) so it is not surprising to not measure a larger impact on this weed based on seedling counts alone.

Wild buckwheat was identified as a top weed in 4/20 fields. While there were no significant reductions in density across or within any of the fields, it is interesting to note that in all comparisons the buckwheat density

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was numerically lower in the HSD treatment. Most of these numeric differences were very minor, however. Buckwheat is expected to be a good target for HWSC based on high seed retention (Burton et al. 2016, 2017). This will be another species that will be interesting to determine the seedbank densities and complete a population density analysis.

Green foxtail, field violet, storksbill and cornspurry/field horsetail were all top weeds in 2/20 fields, but there were no significant differences in control in the HSD vs the untreated for any of them. There was a numeric trend to reductions in density of storksbill, although as mentioned previously the difference was not significant. Cornspurry and field horsetail are combined, again due to risk of misidentification at the early seedling stage. It is unlikely that the HSD would have significant effects on these species as they are typically lower growing species, or do not reproduce by seed (field horsetail). It is possible that green foxtail would make a better target in other locations where it has been known to grow taller, as seed retention has been measured to be quite high at harvest (Burton et al. 2016, 2017).

White cockle, shepherd's purse, willowherb, lambsquarters, dandelion and toadflax were all top weeds in 1/20 fields. Only shepherd's purse showed a significant difference between the HSD and untreated check, with a reduced seedling density in the HSD treatment. Some of the species (white cockle, toadflax, and dandelion) are unlikely to make good targets due to biennial/perennial natures.

While we would have hoped to see more dramatic reductions in weed seedling populations after 3 years, there are a number of factors that could have limited efficacy. The first being dormancy – large seedbanks of species that have dormancy may make it difficult to determine efficacy of the HSD in such a short timeframe. However, it was simply uneconomical to do a longer term study at this point. In addition, the 2018 harvest was interrupted by early snowfall which could also have caused additional weed seed loss, reducing efficacy substantially in the second year of the study. I am not at this point willing to say that the HSD did not work, particularly without analyzing the seedbank data. A weed population is made up not only of the plants we see growing above the surface, but also of those individuals that remain in the seedbank. Once the seedbank data is completed a population density analysis will occur. In addition the multivariate analysis that we are working on will allow us to compare cropping systems in addition to the straightforward treatment effects looked at in the ANOVA's. This analysis will be conducted on the seedling growth, as well as on the entire population density (seedling plus seedbank numbers). The seedbank data is not available to present at this point, but having to resort to growing out the samples with limited controlled growth facilities greatly extended the time needed to collect the data. Of course the soil seedbank sampling only occurred at the end of the study which gives no time to adapt to the change in protocol without it impacting the timeline and available results at the time of this report. An updated final report will be provided with a report and discussion of entire population density once it is completed. One factor that would have been nice to include more

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frequently in the studying is swathing at harvest. Swathing of cereals is quite limited in the Lacombe area, as we discovered when trying to set up the project. We were able to find fields/systems that included swathing at least once in the rotation 9 times and a few additional that included swathing twice. This should give us lots to work with for pulling out any advantage to incorporating swathing for management with the HSD.

Benefits to the industry

In the short-term, with current data the HSD is showing limited benefit for western Canadian producers. However, this may change significantly once the seedbank data, and a full population density analysis are completed. If we are able to show a benefit of the machine on entire weed density then we can explain expected efficacy levels to producers and they can determine whether the additional tool makes sense in terms of on-farm investment. If we do not show a benefit of the machine on weed density after the population analysis then we will have saved farmers from investing in a machine that is unlikely to work in western Canadian conditions.

This is difficult to determine without having completed the full population analysis. If the project is successful there is a very large market for uptake of HWSC methods in western Canada. At this time uptake of HWSC methods has already begun to slowly occur since the initiation of the study in 2017. There were 4 impact mill units running in Saskatchewan as of harvest 2020, and a Canadian manufacturer has entered the HWSC game. Anecdotal and informal discussion suggests there will be at least 7 units running in Saskatchewan as of harvest 2021, with a few additional producers being interested in potentially purchasing impact mills as well. The economic impact of herbicide resistant weeds in Alberta was estimated at $17/acre in the last Alberta HR survey. Impact mills may provide a way to help manage those weeds and that economic cost to producers. These benefits to the industry will also be updated after the seedbank data is completed.

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