FINAL REPORT

Project Title: Corn Agronomy Project	
Date: March 26, 2018	
Project Start Date: April 1, 2014	**Project End Date: March 31, 2018**
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<u>Researcher and Staff</u>:

Project Leader: Dr. Yvonne Lawley, Department of Plant Science, University of Manitoba

Project Collaborators:

Dr. Don Flaten, Department of Soil Science, University of Manitoba
Dr. Paul Bullock, Department of Soil Science, University of Manitoba
Dr. Derek Brewin, Department of Agribusiness an Agricultural Economics
Dr. Lana Reid, Agriculture and Agri-Food Canada, Ottawa

Applicant* and Co-funders: Manitoba Corn Growers Association*, Western Grains Research Foundation

Background and Objectives:

The development of short season corn varieties that are suitable for corn grain production in Manitoba and favorable corn grain prices have driven an increase in corn acres and expanded the growing area for corn in Manitoba. Major breeding efforts are underway by private breeding companies to develop short season corn that is better adapted to prairie growing conditions. Agronomic best management practices and recommendations that are specific to crop rotations, soil types, and the environmental conditions of Manitoba are needed to enhance the success of current and new corn growers. Important agronomic issues to address in Manitoba in the short term include: crop rotation, residue management, phosphorus fertilization, corn row spacing, and improvements to the corn heat unit systems.

This research project has engaged and established a network of scientists at the University of Manitoba to work on corn agronomy issues. In a short period of time, we have learned much about how to adapt and optimize corn agronomy for Manitoba growing conditions. We have also identified some research questions that warrant further study, such as the evaluation of corn heat units in Manitoba. Several graduate students will be involved with this research project. The training they have received in corn agronomy has already begun to make an important contribution to the corn industry as they graduate and have begun their careers in Manitoba.

The research objectives for this project were to:

1. Identify the best crops to grow prior to corn in a rotation
2. Evaluate fertilization strategies for corn grown after canola
3. Conduct an economic analysis of optimal crop rotations involving corn
4. Identify optimum corn residue management strategies
5. Evaluate fertilization strategies for alternative tillage systems for corn production
6. Evaluate the corn heat unit system for Manitoba

<u>Activities and Major Findings by Project Objective</u>:

Objective 1: Identify the best crops to grow prior to corn in a rotation

Dr. Yvonne Lawley and Dr. Navneet Brar (PDF)

The recent increase in high yielding short season corn hybrids may increase corn acreage in Manitoba and improve crop diversity in existing rotations currently dominated by canola and wheat. However, corn grain yield is influenced by crop rotation due to its association with arbuscular mycorrhizal fungi (AMF) for nutrient and water uptake. Abundance of AMF in soil is influenced by inclusion of crops that host mycorrhizal (soybean, wheat, corn) or non- host crops (canola) grown in a rotation. To understand effects of preceding crop on corn grain yield and growth, two-year rotation studies were initiated at University of Manitoba Ian N. Morrison Research Farm, near Carman, Manitoba in 2014-15, 2015-16 and 2016-17. Corn, canola, soybean and wheat were grown in sequence year 1 in a randomised complete block design as preceding treatment crops. Corn was grown as a test crop in sequence year 2. Test crop corn plants at V6 and silking stage were sampled for plant biomass and phosphorus (P) uptake. Corn root samples at the same stages were collected for assessment of AMF colonization. In spite of similar spring soil test Olsen P levels in all preceding crop treatments, early vegetative growth (V6) of the corn test crop was affected in all the three years. Corn plants after canola were shorter and had the lowest biomass and P uptake at V6 stage compared to all other treatments in all three years of the study. Similarly, AMF colonization of corn roots was lowest after canola at the V6 stage in two of the three years. In contrast, V6 corn plants were taller and had the highest biomass and P uptake following soybean in 2015 and following corn and soybean in 2016 and 2017. Despite these early season differences, there was no reduction in corn grain yield following canola in any year of the study.

Major Findings

- Growing host mycorrhizal crops in a rotation not only increased early corn growth but also promoted early colonization of mycorrhiza on corn roots.
- Presence of non-host in a cropping system not only decreased biomass as well as P uptake but also delayed mycorrhizal colonization to silking stage.

- Preceding crops did not affect the grain yield of following corn crop. However, corn following canola had a 1-3 day delay in silking compared to other preceding crops. This delayed corn grain dry down following canola compared to wheat. Thus having the potential to increase grain drying costs.
- Early vs late season response. No difference in corn yields following preceding crop even though early difference in corn growth to silking stage was present.

Objective 2: Crop rotation and P fertilization

Dr. Don Flaten and Magda Rogalsky (MSc student)

This crop rotation study evaluated corn response to spring side banded P and Zn fertilizer when corn followed canola versus soybean. Treatments included a control (no starter) and two rates of P (30 and 60 kg P_2O_5 ha^{-1}) in the form of monoammonium phosphate (MAP, 11-52-0) or MicroEssentials® SZ (MESZn, 12-40-0-10-1) side banded (5 cm to the side and 2.5 cm below the seed) during corn planting in the spring of 2015 and 2016. Preceding crop did not have any influence on mycorrhizal colonization of corn roots (total, arbuscular, hyphal, vesicular). However, application of P suppressed total and arbuscular colonization of corn roots by 5 and 4% respectively, relative to the unfertilized control. Side banded fertilizer increased early season biomass by up to 110% compared to the unfertilized control, with the largest increases in corn following canola. Concentration and uptake of P in early season biomass increased as the P rate increased, and was greatest for the high rate of MAP and MESZn treatments. Zinc concentrations in plant tissue were highest for the unfertilized control and MESZn treatments, regardless of the preceding crop. Zinc uptake was significantly greater with application of starter fertilizer compared to the unfertilized control, especially in corn grown after canola. Silking date was advanced by 3-7 days with application of starter fertilizers. At harvest, all starter fertilizer treatments reduced grain moisture by 2-3% in corn following canola only, and there was a 10% yield increase in grain yield with the high rate of MAP compared to the control, regardless of preceding crop.

Major Findings:

- Starter fertilizer benefits are greatest when corn is planted after canola;
- Starter fertilizer placed in close proximity to the seed at planting in our northern corn production system allowed the corn plants to have excellent access to P.
- Corn growers can realize the benefits of accelerated maturity, increased grain yields and reduced grain moisture at harvest, resulting in increased net returns;
- Accelerated maturity and lower grain moisture allow farmers to harvest short-season hybrids 3 to 7 days earlier, further reducing their risk against fall frost damage and potentially poor harvesting conditions;
- Accelerated maturity and lower grain moisture enables corn growers to grow longer-season, higher-yielding corn hybrids at the same level of risk as shorter season hybrids grown without starter fertilizer;

- Side-banded P at planting is agronomically superior to precision fall deep-banding for corn, keeping in mind that our fall deep-band placement was deeper compared to most common fall applications in MB;

Objective 3: Economic Analysis of optimal crop rotations involving corn

Dr. Derek Brewin, Hazel Sakulanda (MSc Student), and Liting Yi (MSc Student)

Using Manitoba Agricultural Services Corporation (MASC) data from 2008 to 2012, Anastasia Kubinec calculated the average impact on yields of crops grown in various rotations in the 2014 edition of Yield Manitoba. One of her tables is reprinted below as Table 1. It shows the impact of the crop choice in the previous year on various crop yields, relative to the 2008-2012 average for that seeded crop. For example, looking at the first column of Table 1, winter wheat planted into the stubble of a previous winter wheat crop yielded 78% of the average winter wheat yield. A 22% drop from average yields. Winter wheat planted into canola stubble yielded 104% of the average yield. Continuously cropping of the same species has a significant negative impact on yield for all of the crops listed.

Table 1. Relative Yield Response (per cent of 2008-2012 average) of Manitoba crops sown on previous crops (stubble >120 acre). (Source: Kubinec)

	Crop Planted									
Previous Crop	**Winter Wheat**	**Spring Wheat**	**Barley**	**Oat**	**Canola**	**Flax**	**Field Pea**	**Soybean**	**Sunflower**	**Grain Corn**
Winter Wheat	78	74	106	100	97	107	107	101	97	87
Spring Wheat	86	85	98	101	104	104	103	103	101	100
Barley	83	89	84	93	100	96	101	100	97	99
Oat	76	90	86	82	92	95	97	99	100	93
Canola	104	102	103	104	85	88	92	101	95	95
Flax	102	98	110	97	104	73	101	96	98	NSD
Field Pea	NSD	100	104	98	104	124	NSD	NSD	NSD	NSD
Soybean	NSD	106	106	105	98	100	NSD	95	92	103
Sunflower	NSD	99	102	96	NSD	NSD	NSD	99	88	99
Grain Corn	NSD	NSD	101	106	104	NSD	NSD	107	112	87
Yield (bu/ac)	*65*	*47*	*62*	*95*	*34*	*20*		*32*	*1521lb*	*95*

It is a regular practice for farmers to estimate the returns of different crops at spring seeding time and Manitoba Agriculture puts out a yearly budget tool to look at the average returns and costs of most of the major crops. Over the years canola often looked like the highest return per acre. Lately corn and soybeans have been leaders. However, the implications of previous crops need to be taken into consideration as planting decisions are made if the wrong rotation can lower yield by as much as 22%.

As part of her thesis for a Masters in Agribusiness, Hazel Sakulanda began with Manitoba Agricultures budgets from 2016 and set out to explore the implications of these yield connections through as many as five years of different crops grown in rotation. She used five year average prices from MASC. Sakulanda focused on the five largest crops grown in rotation in Southern Manitoba. Using five year average prices and yields and 2016 costs she came up with Table 2, which shows the average returns of the five most common crops grown in Southern Manitoba. In that table the average yields are used, and corn comes out as the best return per acre. However, if that single simple budget was used every year to choose the best returns corn might be planted on corn. That choice would have a negative impact on yield of 13% as indicated in Table 1 (corn grown on corn stubble gets 87% of the average yield).

Table 2. Average Net Returns (2012-16) for 5 Crops Grown in Southern Manitoba.
(Source: Sakulanda, Manitoba Agriculture, and MASC)

	Sp. Wheat	Oats	Canola	Soybean	Corn
Total Operating Costs ($ per acre)	$201.36	$161.53	$256.98	$196.66	$315.88
Market Price ($ per bu.)	$6.40	$2.98	$10.89	$10.48	$4.85
Average yield (bu. per acre)	55	100	40	35	115
Net returns ($ per acre)	$150.64	$136.47	$178.62	$170.14	$241.87

Taking the yield impacts of Table 1 into effect, Sakulanda considered over 3,800 combinations of five, four, and three year rotations. The top five are shown in Table 3 along with some other rotations to give you the relative changes rotations can make. No three year rotations were in the top five although canola, soybeans and corn had the 9th highest average return. All of the top ten rotations contained corn and soybeans. Four of the top ten had wheat and two of the top five included canola.

Table 3. Rank of Average Net Returns for Various Rotation Options.
(Source: Sakulanda, Manitoba Agriculture, and MASC).

	Rotations by year					Average Return $/ac
Rank	Year 1	Year 2	Year 3	Year 4	Year 5	
1st	Soybean	Corn	Soybean	Corn		$ 227.21
2nd	Canola	Corn	Soybean	Corn		$ 216.11
3rd	Corn	Soybean	Corn	Soybean	Corn	$ 215.64
4th	Canola	Soybean	Corn	Soybean	Corn	$ 214.34
5th	Sp. Wheat	Corn	Soybean	Corn	Soybean	$ 207.64
1204th	Sp. Wheat	Canola	Sp. Wheat	Canola		$ 176.86
1795th	Corn	Corn	Corn	Corn	Corn	$ 169.36
3821st	Canola	Canola	Canola	Canola	Canola	$ 113.28
3874th	Sp. Wheat	Sp. Wheat	Sp. Wheat	Sp. Wheat	Sp. Wheat	$ 97.84

The economic impact of continuous cropping is clear. Continuous corn crops average $57 per acre less than soybeans and corn grown in rotation. Continuous canola earns $64 per acre less than canola and wheat grown in rotation and continuous wheat earns $79 less. Soybeans' impact on other crops is also clear. Even though it is the third most profitable crop in average budgets, its positive impact on other crops makes it a very profitable choice within rotations. Soybeans were part of all of the top ten rotations.

As we have shown in other work, the prices of corn are highly variable and may affect the optimal rotation as we move forward. To check this impact Sakulanda adjusted the prices in her optimal budgets using the past 13 years of annual prices. In 10 of 13 years corn and soybeans remained as the most profitable rotation choice. In 3 of the 13 years the highest earning rotation contained canola.

Future Questions

In the future we hope to update these results with more recent rotation impact data from MASC, and look at more regionally realistic rotations. As Sukalanda's work shows, the economic impact of rotations will be very important. But these results could vary greatly across regions and when prices of different crops are not moving together. As important to price, yield and location, we also need to keep track of changing cropping options in the face of climate changes and variety improvement as well as evolving strategies for nutrient and pest management.

Objective 4: Identify optimum corn residue management strategies.

Dr. Yvonne Lawley and Patrick Walther (MSc student)

The impact of different tillage equipment to manage corn residue was evaluated based on soil temperature, soil moisture, and the response of a soybean test crop. Field trials were conducted over a three year period (2014-2016). The experiments were set up as on-farm trials in four locations in Manitoba on sandy soils. The trials were randomized and replicated in farmer's fields. Four tillage practices were compared: 1) conventional double disc; 2) vertical till high disturbance; 3) vertical till low disturbance; 4) strip till (See pictures of treatments in Appendix 1). Residue management treatments occurred in the spring with the exception of the Winkler site where treatments occurred in the fall. Soil temperature and moisture were recorded hourly at 5 and 30cm depths. Soybean emergence, flowering, and maturity were observed three times a week during these critical growth stages. Soybeans were harvested using commercial combines and calibrated weigh wagons. Fuel consumption and horsepower requirements were measured to compare the equipment included in the study. These measurements were made in collaboration with PAMI.

Surface residue cover varied significantly among corn residue management treatments, ranging from 29 to 65% (see Pictures of treatments in Appendix 1). Around the time of planting, daily surface soil temperature at 5cm varied among treatments only during the peak and low temperature points of the day. Overall, all tillage treatments grouped together in contrast with the undisturbed soil treatment between strip till rows (Appendix 1). Soil temperature trends were not always consistent between site-years. Planting and rolling operations seemed to have influence on maximum and minimum soil temperature patterns (Appendix 1, Figure 5). Another way to look at the effect of residue cover on soil temperature throughout the soybean emergence period is to calculate cumulative soil temperature above the threshold temperature of 10^{o}C. During soybean emergence, soil temperature at planting depth (5cm) showed no differences among treatments in total accumulated, as well as daily accumulated soil temperature above 10°C at any site-year.

Previous studies have shown that residue cover can also influence soil moisture at planting. However, in this study only two out of four site-years had higher moisture contents over a longer period of time in the un-tilled part of strip till. At planting, all treatments at all sites had the minimal volumetric soil moisture threshold of 0.096 m^{-3} required for soybean emergence. Despite differences in absolute soil temperature and moisture between residue management treatments, no significant differences in soybean emergence and final plant stand were observed in three out of four site years (Appendix 1, Figure 6). At harvest, soybean grain yield was not statistically different among the corn residue management treatments ($p=0.6267$, CV 6.7%).

Economic analysis showed time and cost savings for strip till. For the analysis, costs due to management practices such as seeding rate and crop protection were kept the same among treatments. Revenue calculated from soybean yields were also the same due to a lack of statistical differences between treatments in the experiments. Thus, differences in economic return are driven by the cost of the tillage systems compared. Total costs for corn residue management treatments were: double disc (32.25 $/ac, including 2 passes), vertical till high disturbance (31.7 $/ac, including 2 passes), vertical till low disturbance (29.72 $/ac, including 2 passes) and strip till (19.31 $/ac, only one pass required). Using the average farm size for Manitoba of 1134 ac, strip till could save the farmer $11,805 compared to vertical till and $14,674 compared to double disc per year. Furthermore, strip till as a one pass system practiced across an average farm of 1134 acres, showed time savings of 1.1 to 3.7 days compared to vertical till and double disc, respectively.

This research project has provided information that was not previously available to help corn growers in Manitoba evaluate residue management practices in side by side replicated field scale experiments. The results of this study indicate that farmers have many tools that will allow them to manage corn residue and grow a successful crop after corn in Manitoba. Both vertical tillage and strip tillage show promise as alternatives to managing corn residue with a double disc in Manitoba. However, when interpreting the findings of this study it is important to note that all the site-years were conducted on sandy soils. Further research on heavy clay soils is still needed.

Objective 5: Evaluate fertilization strategies for alternative tillage systems for corn production

Dr. Don Flaten and Magda Rogalsky (MSc student)

This residue management study evaluated corn response to fall banded and spring side banded P fertilizer in strip-tillage and conventional tillage. Treatments included a control (no P), two rates of P (30 and 60 kg P_2O_5 ha^{-1}) in the form of MAP, applied either in the fall as a deep band (10-13 cm deep) with a strip-till unit or in the spring as a side band with a corn planter. At Carman in 2015 and 2016, spring side banded P treatments increased early season biomass by up to 103% compared to the unfertilized controls. Spring side banded P treatments consistently increased early season P concentration in plant tissue and P uptake at all site-years, relative to the unfertilized control. Banded P treatments reduced days to silking by 2-3 d compared to the unfertilized control. At harvest, banded P treatments reduced moisture by 1-2 g kg^{-1} at both site-years in 2016. Spring side band P treatments increased grain yield by an average of 467 kg ha^{-1} relative to the unfertilized control and out-yielded the fall deep banded treatments by 470 kg ha^{-1}, regardless of the tillage treatment.

Major Findings

- Fall strip tillage systems for corn production can provide the soil conservation benefits of reduced tillage compared to conventional tillage, without an agronomic penalty.
- Starter fertilizer placed in close proximity to the seed at planting in our northern corn production system allowed the corn plants to have excellent access to P.
- Corn growers can realize the benefits of accelerated maturity, increased grain yields and reduced grain moisture at harvest, resulting in increased net returns;
- Accelerated maturity and lower grain moisture allow farmers to harvest short-season hybrids 3 to 7 days earlier, further reducing their risk against fall frost damage and potentially poor harvesting conditions;
- Accelerated maturity and lower grain moisture enables corn growers to grow longer-season, higher-yielding corn hybrids at the same level of risk as shorter season hybrids grown without starter fertilizer;
- Side-banded P at planting is agronomically superior to precision fall deep-banding for corn, keeping in mind that our fall deep-band placement was deeper compared to most common fall applications in MB.

Objective 6: Evaluation of corn heat unit system for Manitoba

Dr. Paul Bullock, Justice Zhanda (MSc student), Dr. Lana Reid

The purpose of this study was to identify a heat unit with a consistent accumulation from planting to various stages of grain corn phenological development. This was a field-based study located adjacent to Agriculture and Agri-Food Canada's grain corn yield trials at eight locations (six in Manitoba and two in southern Alberta). Five corn hybrids with varying corn heat unit (CHU) ratings (2200, 2275, 2550, 2600 and 2700) were grown in plots alongside the yield trials. Each phenology plot was photographed multiple times daily with a time-lapse camera. A portable weather station at each site monitored weather conditions hourly. The 2550, 2600 and 2700 hybrids were grown at 7 of the 8 locations 2015 and all eight locations in 2016. The 2200 and 2275 hybrids were grown at all 8 locations in 2016.

Daily values were calculated at each study site from the air temperature data for several heat units, including CHU, General Thermal Index (GTI), two different Growing Degree Day (GDD) indices and the Beta Function (BF) index. For each heat unit, accumulated daily values were calculated from planting until the observed date of several vegetative and reproductive growth stages as determined with the camera images or from on-site observation.

The relationship between CHU rating and relative maturity (RM) rating for the grain corn hybrids in the most recent provincial grain corn trials were also assessed. The study also investigated the impact of cold night temperatures on heat unit accumulation to physiological maturity (PM).

Study Results:

- The differences in heat unit accumulation to any phenological development stage tested did not differ significantly ($P > 0.05$) among the five corn hybrids.
- All hybrids accumulated more CHU to reach PM than suggested by their CHU ratings. On average, an additional 300 CHU above the rating was required to reach PM.
- The coefficient of variation (CV) for accumulated index values was greatest at emergence and the V2 stage but declined in subsequent phenological stages. At PM, all thermal indices had a CV of 10.5% or less, with GTI consistently showing the numerically lowest CV (<5%) for all hybrids.
- The relationship between relative maturity rating and corn heat unit rating is very strong, especially for hybrids with 72-76-day RM rating and 2200-2500 CHU, which are normally considered the most suitable hybrids for the Prairies.
- More frequent cold night temperature exposure resulted in reduced total CHU accumulation from planting to PM for one of the hybrids but had inconsistent effects on CHU accumulation for the other hybrids.
- GTI accumulation from planting to PM was relatively unaffected by cold night temperatures.

Discussion:

- The lack of significant difference in heat unit accumulation to any phenological stage across 5 hybrids with differing CHU rating is cause for concern. Even more concerning is the additional CHU above rated values required by the hybrids to achieve PM and the large variability in accumulated CHU between locations. Thus, climatic values of long-term growing season CHU accumulation are not an accurate means to determine which hybrids are suitable for production in a given area. Additional site-years of study, especially for early maturing hybrids is required to draw stronger conclusions with statistical significance.
- The study indicated that accumulated GTI is a potentially better alternative heat unit for selection of corn hybrids suitable to specific regions in cold temperature areas such as the Canadian Prairies. The accumulated GTI values had a relatively low CV between locations that was not affected by variation in the occurrence of cold nights. In order to implement this change, new grain corn hybrids would need to be rated in GTI units and climatic risk maps for GTI accumulation would need to be developed.
- Contrary to popular belief, exposure to cold nights did not increase the heat units required for corn to reach PM and, for one hybrid, it reduced the accumulated CHU.

Objective 7: Evaluate corn row spacing to optimize corn yield and fall dry down.

Dr. Yvonne Lawley, Dr. Navneet Brar (PDF)

Row spacing is an important agronomic management practice for corn production. Although the standard row spacing for corn is 30 inches, studies in other corn growing regions have identified corn hybrid responses to narrow, wide, and twined rows. Given the environmental and hybrid interactions observed in these studies, it is important to evaluate optimal row spacing in Manitoba using the short season hybrids and inbreds that are being developed for this shorter growing season environment. A row spacing by population experiment was conducted at University of Manitoba's research farm near Carman, MB in 2016 and 2017.

In 2016, treatments included in the experiment included five plant population densities (20000, 26000, 32000, 38000, and 44000 seeds/ac) compared at two row-spacing (15-inch and 30-inch) for two hybrids (DKC27-55 and DKC 30-07). A large storm in mid-July created extensive damaged to the experiment. Many of the corn plants were snapped and thus changed the plant densities. To learn what we could from this experiment the focus was changed to look at the relationship between treatments and corn snap. Corn snap increased with increasing plant population and was higher at 15 inch row spacing than at 30 inch spacing (Appendix 2, Figure 6).

In 2017, the experiment treatments were adjusted to compare two row spacing at 22 and 30 inches for the same two hybrids (DKC27-55 and DKC 30-07), and a higher range of plant populations was evaluated (26000, 32000, 38000, and 44000, and 55000 seeds/ac). Corn yields were highest for the target plant population of 38,000 plants/ac (Appendix 2, Figure 7), but was not influenced by row spacing in 2017. Further study is required to confirm the results from 2017.

Highly Qualified Personal Training:

With the expansion of corn in Manitoba and with industry planing for continued growth in this crop across the prairies, there is an immediate need for more students to be trained in corn agronomy research. This project has been successful at training undergraduate students, graduate students, and research technicians in corn agronomy research methods as well as applied economic research methods. Four of the graduate student that have completed their degrees are now employed. Three of the graduate students currently have jobs working in agronomy research in Manitoba. The skills gained by graduate and undergraduate students during this project bring much needed research experience in corn agronomy with them to their future careers to contribute to many areas of the agricultural sector in Manitoba. The skills that research technicians have gained in corn agronomy research will allow for continued training of graduate and undergraduate students through their mentoring of future students at the University of Manitoba.

MSc Graduate Students and Post Doctoral Fellows

- Magda Rogalsky, M.Sc. graduate student (April 2015 – August 2017)
- Patrick A. Walther, M.Sc. graduate student (January 2015 – May 2017)
- Justice Zhanda, M.Sc. graduate student (April 2015 – August 2017)
- Hazel Sakulanda, M.Sc. graduate student (April 1, 2015 to September 2016)
- Liting Yi, M.Sc. graduate student (November 1, 2017 to March 31, 2018)
- Navneet Brar, PDF (February 2015 to October 2017)

Undergraduate Research Assistants

- Megan Bourns, Matheus Castello (May 2016 – August 2016)
- Thomas Cuddy (May 2015-Aug 2015)
- Gregory Sawatzky (May – Aug 2016)
- Caitlin Spellman (May – Aug 2017)
- Kapilan Panchendrabose (June – Sept 2017)
- Joyce Almonte (June – Sept 2017)
- Gillian McIvor (June – Sept 2017)

Technicians

- Mike Cardillo, (half-time, May 2015 – September 2015)
- Marliese Peterson, (half-time, May 2016 – September 2016)
- Eric Wallace (half-time, 2014-15)
- Stephanie Dheilly (half- time 2016-18)

Extension of Research Project Results

There has been great interest in the corn agronomy project and we have taken advantage of the many opportunities available to us to communicate the results of our research to a variety of audiences including farmers, agronomists, scientists, and economists locally, nationally, and internationally. Communication formats have ranged from newsletters and magazine articles, to poster and oral presentations at scientific conferences. During the time frame of the project, farmers and agronomists started actively engaging on Twitter as a source for learning about current agronomy research projects in Manitoba. Some of the graduate students working on this project explored ways to communicate their research activities on Twitter and enlightened their advisors of the opportunities with this new medium for communicating along the way.

Master of Science thesis, available with open access at the links provided:

- Rogalsky, M. 2017. Phosphorus Beneficial Management Practices for Corn Production in Manitoba. http://hdl.handle.net/1993/32462
- Walther, P. A., 2017. Corn (Zea mays L.) residue management for soybean (Glycine max L.) production: On-farm experiment. https://mspace.lib.umanitoba.ca/handle/1993/32331
- Zhanda, J. 2017. Assessing Thermal Indices for Modeling Grain Corn Phenological Development on the Prairies. http://hdl.handle.net/1993/32367
- Hazel Sakulanda. 2017. Optimal rotations with considerations for corn in southern Manitoba. http://hdl.handle.net/1993/32897

Conference Presentations:

- Manitoba Agronomists Conference, Winnipeg, Dec 2015 & Dec 2016 (posters)
- CropConnect Conference, Winnipeg, Feb 2015, 2016 & Feb 2017 (oral, poster & oral, respectively)
- Tri-Society Conference, Phoenix, Arizona, Nov 2016 (posters and oral)
- Tri-Society Conference, Tampa, Florida, Oct 2017 (oral)
- MSSS conference, Winnipeg, Feb 2016 and Feb 2017 (poster and oral)
- 70th Northeastern Corn Improvement Conference, Ottawa, Feb 2017 (orals)
- Saskatchewan Soils and Crops Workshop, Saskatoon, SK, Mar 2017 & 2018 (Oral)
- CSA-CSH joint conference, Montreal, July 2016 (oral)
- CPS-CSA joint conference, Winnipeg, Jun 2017 (oral)
- Sakulanda, H. & D.G. Brewin. (2015). Optimal Rotations using Corn in Southern Manitoba. NAREA/CAES Joint Annual Meeting. Newport, RI. June 28-30, 2015.
- Brewin, D.G. & H. Sakulanda. (2017). Economics of Crop Rotations in Manitoba. Canadian Association of Farm Advisors Management. Niverville, MB. November 2, 2017.
- IAAE Tri-Annual Meeting. Vancouver, BC. July 28- August 2, 2018.

Field Days and Meetings:

- Sneak Peak field tour at Carman Research Station Aug 2015
- MB Corn Growers Field Tour, University of Manitoba Carman Research farm, July 2016
- AGVISE Soil Fertility Seminars at Portage la Prairie (Mar 2016 & Mar 2017), plus Granite Falls, MN; Hankinson, ND; Grand Forks, ND (Jan 2018)
- Portage la Prairie Field Day, Jul 2015 (Paul Bullock and Justice Zhanda)
- Roblin Field Day, July 2015 and 2016(Justice Zhanda)
- Corn Agronomy Research meeting with MCGA board members and staff in 2015 and 2016
- Nielsen Seeds Corn Production Meeting, Jan 2018, Virden, MB

Newsletters or Magazine Articles:

- articles in the Apr 2016 and Jan 2018 MB Corn Growers Association newsletters
- feature article in Oct 2017 Country Guide magazine
- feature article in Mar 2018 Top Crop Manager

Manuscripts:

Zhanda, J., Bullock, P.R., Zvomuya, F., Shaykewich, C.F., Reid, L., Lawley, Y. and Flaten. D.N. Assessing Thermal Indices for Modeling Grain Corn Phenological Development on the Canadian Prairies. Canadian Journal of Plant Science (submitted, March 2018)

Four additional manuscripts and one economics working paper based on MSc thesis are in preparation.

Acknowledgements

This project was funded by the Manitoba Corn Growers Association, Western Grains Research Foundation, and by the Agri-Food Research and Development Initiative (ARDI) under the Canada-Manitoba Growing Forward 2 Initiative. The use of equipment brand names and crop variety names in this report do not represent endorsement by the researchers or funders of this project.

<u>Appendix 1:</u> Corn Residue Management

Figure 1: Conventional tillage with double disc. Two sets of concave discs following after each other to assure a good mixture of residue into the soil. Surface residue coverage after two passes was 30%. Photo Credit: Patrick A. Walther

Figure 2: Vertical till high disturbance (6° disc angle, concave disc). The angle of the disc creates much more soil disturbance than in vertical till low disturbance. Surface residue coverage after two passes was 27%. Photo Credit: Patrick A. Walther

Figure 3: Vertical till low disturbance (0° disc angle). Some soil movement is observable when compared to the area of undisturbed soil to the right. Surface residue coverage after two passes was 65%. Photo Credit: Patrick A. Walther

Figure 4: Strip till uses tillage in only a small strip zone and leaves the area in-between the shanks untilled. This unit consists of two fertilizer carts for granular (white) and liquid (turquoise) fertilizer placement. Surface residue coverage after two passes was 4% in the strip, 95% between the strips and 63% when analysed over the entire area. Photo Credit: Patrick A. Walther

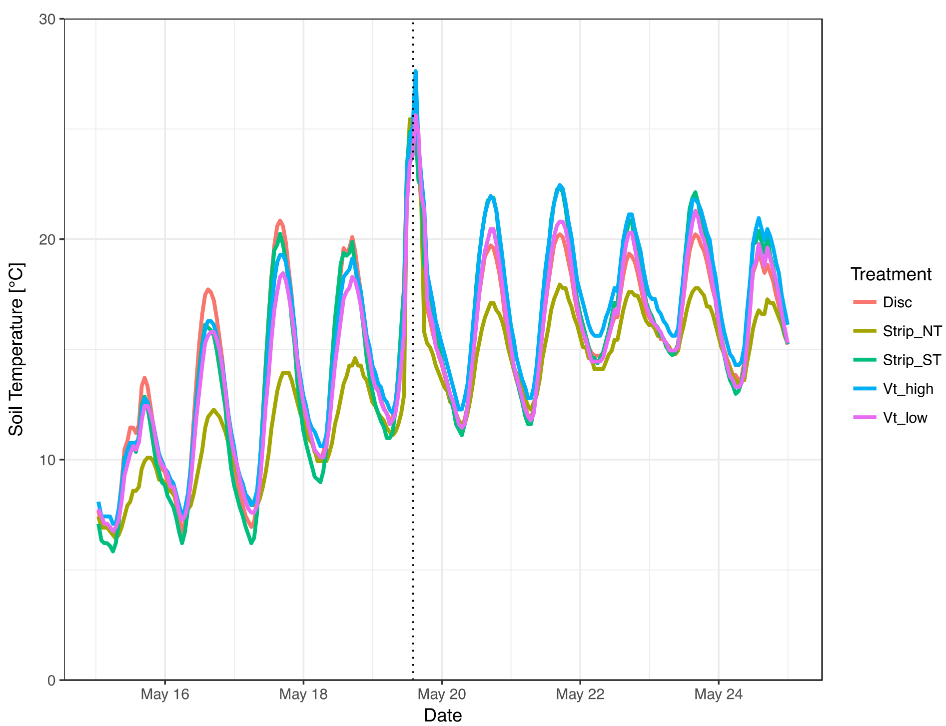

Figure 5: Soil temperature at 5cm depth in MacGregor 2016 before and after planting (May 19th 2016, see dotted line) of treatments double disc (Disc), strip till between row (Strip_NT), strip till in row (Strip_ST), vertical till high disturbance (Vt_high) and vertical till low disturbance (Vt_low).

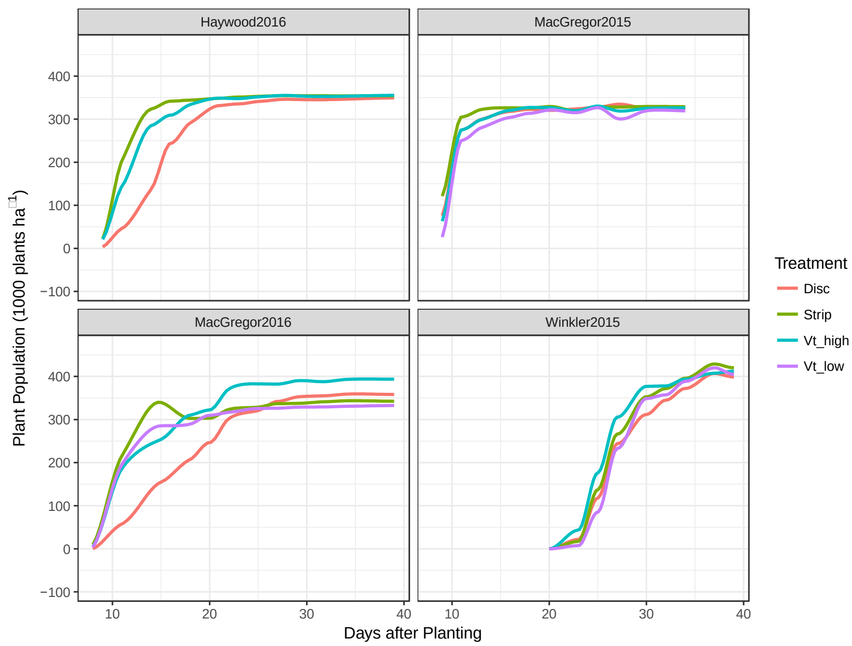

Figure 6: Soybean emergence and final plant stand following corn residue management treatments using double disc (Disc), strip till (Strip), vertical till high disturbance (Vt_high) and vertical till low disturbance (Vt_low) in Haywood 2016, MacGregor 2016, MacGregor 2015 and Winkler 2015.

Appendix 2: Corn Row Spacing and Plant Population

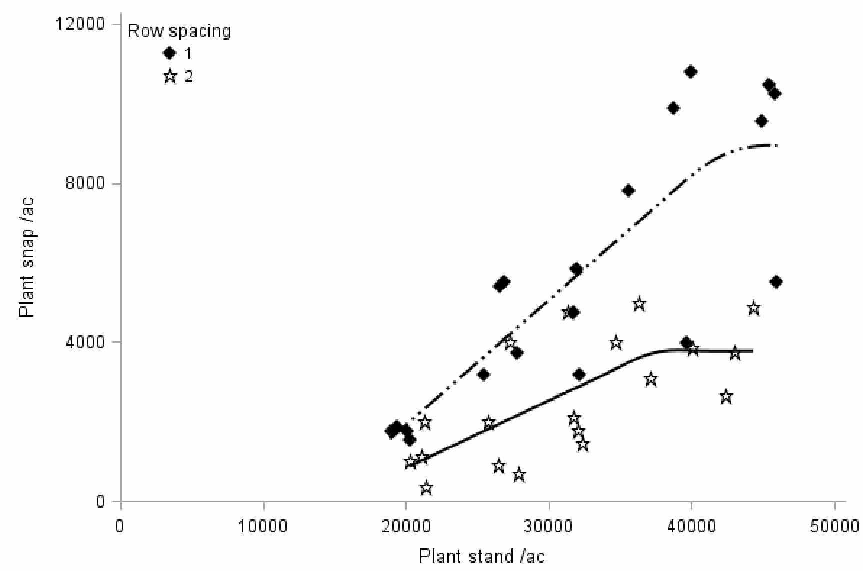

Figure 7: The relationship between plant stand and plant snap when planted in 15-inch (solid diamond) and 30-inch (star) row spacing after a July wind storm at Carman, MB 2017..

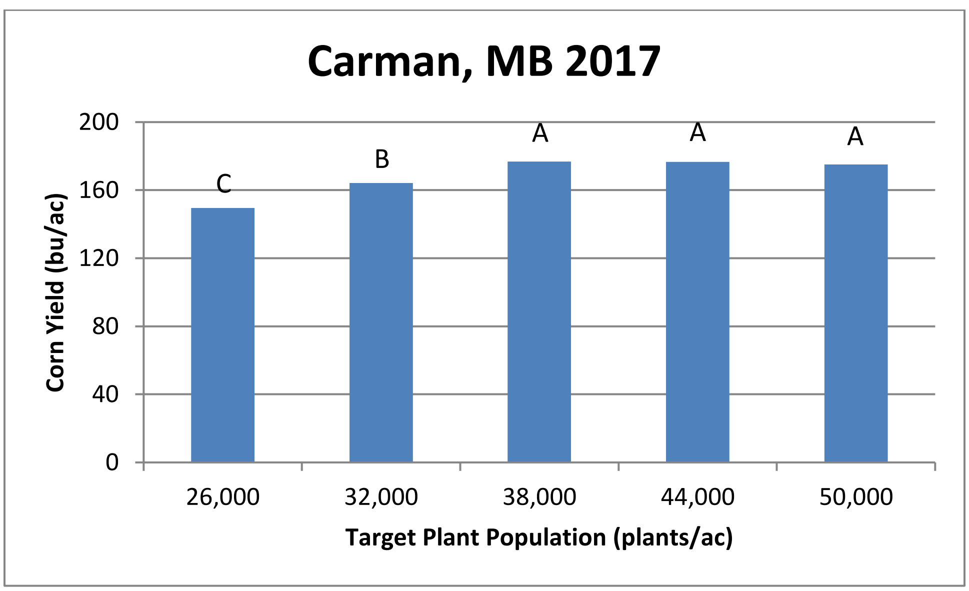

Figure 8: The relationship between target plant population and corn grain yield at Carman, Manitoba in 2017.