2021 and 2022 Annual Report

Soybean and Pulse Agronomy Lab

Department of Plant Science
University of Manitoba

Kristen P. MacMillan
kristen.macmillan@umanitoba.ca
@kpmacmillanUM

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Research Team

Brodie Erb (Technician)
Ishan Samaranayake (Technician)
Sharlene MacCoy (Summer student 2022)
Brett Van Niew Amerongen (Summer student 2022)
Soham Gulati (Summer Student 2021)

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About the Soybean and Pulse Agronomy Lab

The Soybean and Pulse Agronomy team led by Kristen P. MacMillan focuses on soybean, dry bean and pea agronomy and cropping systems. Our Mission is to study and develop best management practices for soybean and pulse cropping systems that optimize agronomy, profitability, and sustainability for farmers in Manitoba and western Canada through applied agronomic research, extension, and teaching. Established in 2017 and renewed in 2023, this program is a unique collaboration between the Manitoba Pulse & Soybean Growers and the University of Manitoba that arose in response to the growth of soybean acres, steady dry bean production, re-emerging interest in peas and the overall demand for applied research. Focused specifically on grain legumes, our applied research addresses production questions, evaluates cropping systems, extends knowledge, and brings an applied professional to the classroom. This annual report is a summary of the Soybean and Pulse Agronomy lab's research trials in Manitoba in 2021 and 2022. It has been developed as a reference for farmers, crop advisors and industry members and is meant to provide a concise summary of each experiment and working area.

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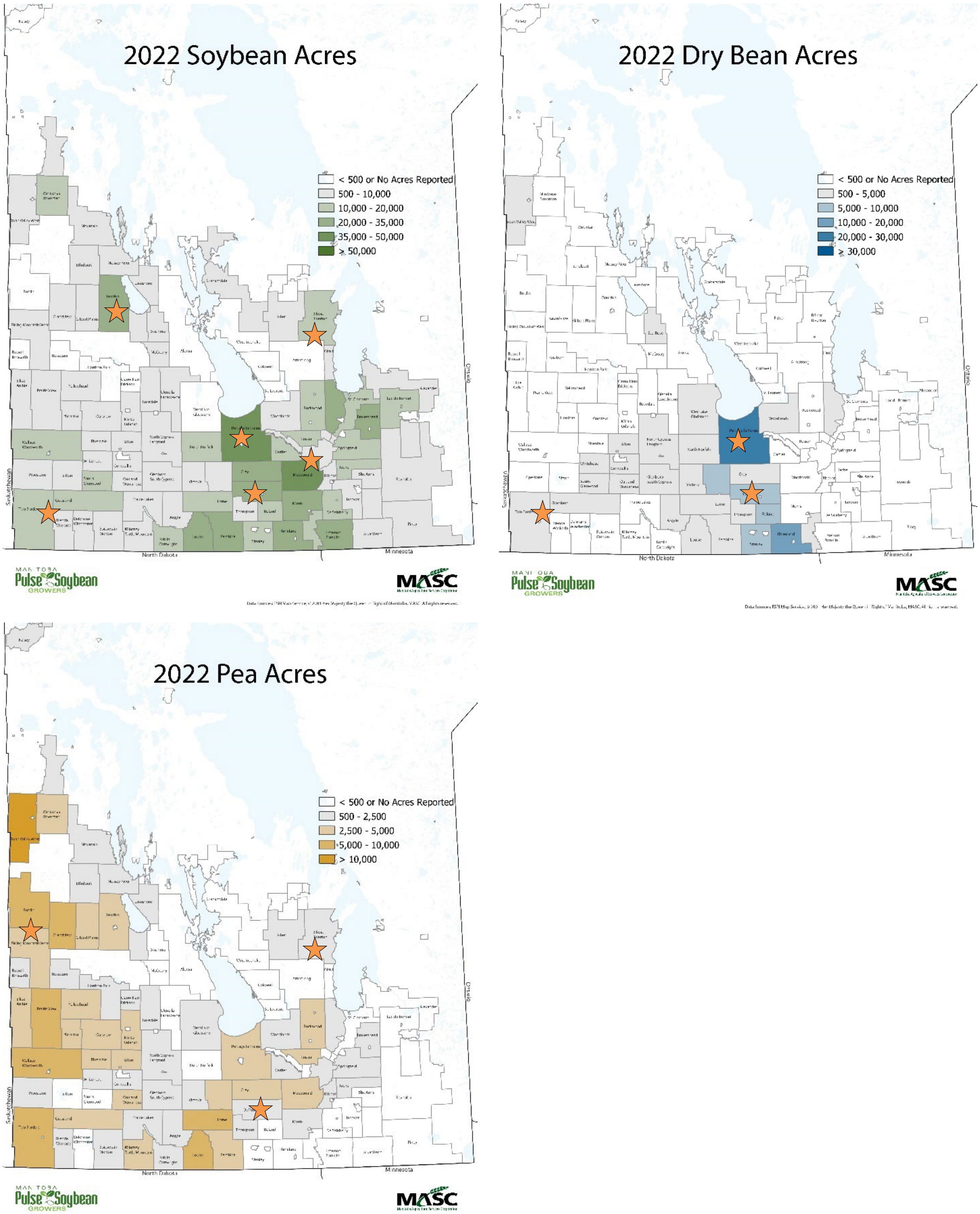

Figure 1. Soybean, dry bean, and field pea acre distribution by municipality in Manitoba and locations of research trials in the soybean and pulse agronomy research lab (maps developed by Manitoba Pulse & Soybean Growers with data from Manitoba Agricultural Services Corporation).

Collaborating Partners

The soybean and pulse agronomy research lab would like to thank the following organizations and teams for their contribution to our research in 2021 and 2022 and for making province-wide research possible:

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We would also like to recognize our farm and industry partners who have provided seed and inputs for crop management or product for testing:

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Corteva agriscience
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Western Harvest
NutriAg
BrettYoung
Seine River Seed Farm
Dekalb
Durand Seeds Inc.
Clearview Acres Ltd.

Soybean Iron Deficiency Chlorosis (IDC) and Yield

(Oak Bluff, MB • 2017-2022)

Introduction

In areas of soybean fields where iron deficiency chlorosis occurs, **yield is reduced by 1.5-2.8 bu/ac for each 0.1-unit increase in IDC score, on average.** New work is underway to understand if varieties we choose for IDC also yield well in non-IDC areas of the field.

Iron deficiency chlorosis (IDC), better known visually as “yellow soybeans”, is a soybean production challenge that reduces yield in Manitoba and throughout the prairies. Soil factors such as calcium carbonate content, salinity, nitrates and excess moisture can prevent the uptake of plant available iron to soybean plants, leading to yellowing of upper foliage. Variety selection is the most effective management option. To help farmers and agronomists choose varieties with IDC tolerance, Manitoba Agriculture (MB Ag) coordinates a variety evaluation trial at an IDC susceptible site near Winnipeg. The soybean and pulse agronomy research team has harvested the trial since 2017 to build our knowledge base on variety selection as a management tool.

The first objective of this project is to examine the relationship between IDC score and soybean yield in Manitoba. The data produced quantifies the yield impact of yellow soybeans and demonstrates the value of variety selection in managing this production challenge.

A second objective began in 2021 to understand if paired yield data from IDC and non-IDC field sites could improve variety selection in spatially variable IDC prone fields.

Figure 1. The variety evaluation trial at the IDC site and non-IDC site located within the same field at Oak Bluff, MB in 2022.

Materials and Methods

Each year, 80-96 varieties (entries) are seeded in 1m-rows with 3 replicates on an IDC susceptible site near Oak Bluff, MB that is very high in $CaC0_3$ (Table 1a). From late June through mid-July, corresponding to V1 through R1, each row is evaluated for IDC score according to a scale that ranges from 1-5 (Fig. 2). Three ratings are collected each year. A lower score is better – meaning greater tolerance to iron chlorosis. At harvest, the rows are hand harvested for yield and linear regression analysis is conducted for the rating scores and yield data. All ratings were correlated to yield; the overall average rating is used for linear regression.

Beginning in 2021, a second trial with the same varieties was seeded at a separate site within the same field that is less susceptible to iron deficiency chlorosis (Fig. 1). This trial was also rated for IDC and harvested for yield.

Figure 2. IDC rating scale from left to right: 1 = healthy, green, 2 = some yellowing, 3 = interveinal chlorosis, 4 = dead tissue evident, 5 = stunted growing point.

Results (Obj. 1)

In 2017, IDC scores of entries ranged from 1.5 to 2.9 (Table 2) and there was a significant linear relationship between IDC rating and soybean yield (Fig. 3). For each 1-unit increase in IDC score, approx. 27.7 bu/ac of soybean yield is lost or for each 0.1-unit increase in IDC score, approx. 2.8 bu/ac of soybean yield is lost.

In 2018, IDC scores of entries ranged from 1.6 to 2.1 and there was no significant linear relationship between IDC (data not shown). The occurrence and severity of IDC in the trial was low compared to other years.

In 2019, IDC scores in the variety evaluation trial ranged from 1.5 to 2.3. Unfortunately, due to a wet fall, saturated field conditions and geese damage, we could not harvest the trial.

In 2020, IDC scores of entries ranged from 1.5 to 2.8 and there was a significant linear relationship between IDC rating and soybean yield (Fig. 3). For each 1-unit increase in IDC score, soybean yield was reduced by 24.4 bu/ac or for each 0.1 unit increase in IDC score, yield was reduced by 2.4 bu/ac.

In 2021, IDC scores in the variety evaluation trial ranged from 1.6-2.4 and there was a significant linear relationship between IDC score and yield (Fig. 3). For each 1-unit increase in IDC score, soybean yield was reduced by 14.6 bu/ac or for each 0.1 unit increase in IDC score, yield was reduced by 1.5 bu/ac.

In 2022, IDC scores of entries ranged from 1.3 to 4.2 and there was a significant linear relationship between IDC score and soybean yield (Fig. 3). For each 1-unit increase in IDC score, soybean yield was reduced by 21.3 bu/ac or for each 0.1 unit increase in IDC score, soybean yield was reduced by 2.1 bu/ac.

Table 1. Soil characteristics of the soybean iron deficiency chlorosis (IDC) variety evaluation field near Oak Bluff, MB.

		Salinity (mmho/cm, 0-6”, 6-12”)	**Calcium Carbonate Content**	**Nitrate N** (lbs/ac, 0-12”)	**Soil pH** (0-6”)	**IDC Risk**
2017		0.46	n/a	36	7.8	High
2018		0.43, 0.55	7.8%	149	8.3	High-Very high
2020		0.36, 0.35	6.7%	89	8.2	High
2021	IDC site	0.42, 0.27	5.3%	95	8.2	High
	Non-IDC site	0.81, 0.67	1.3%	153	7.2	Moderate

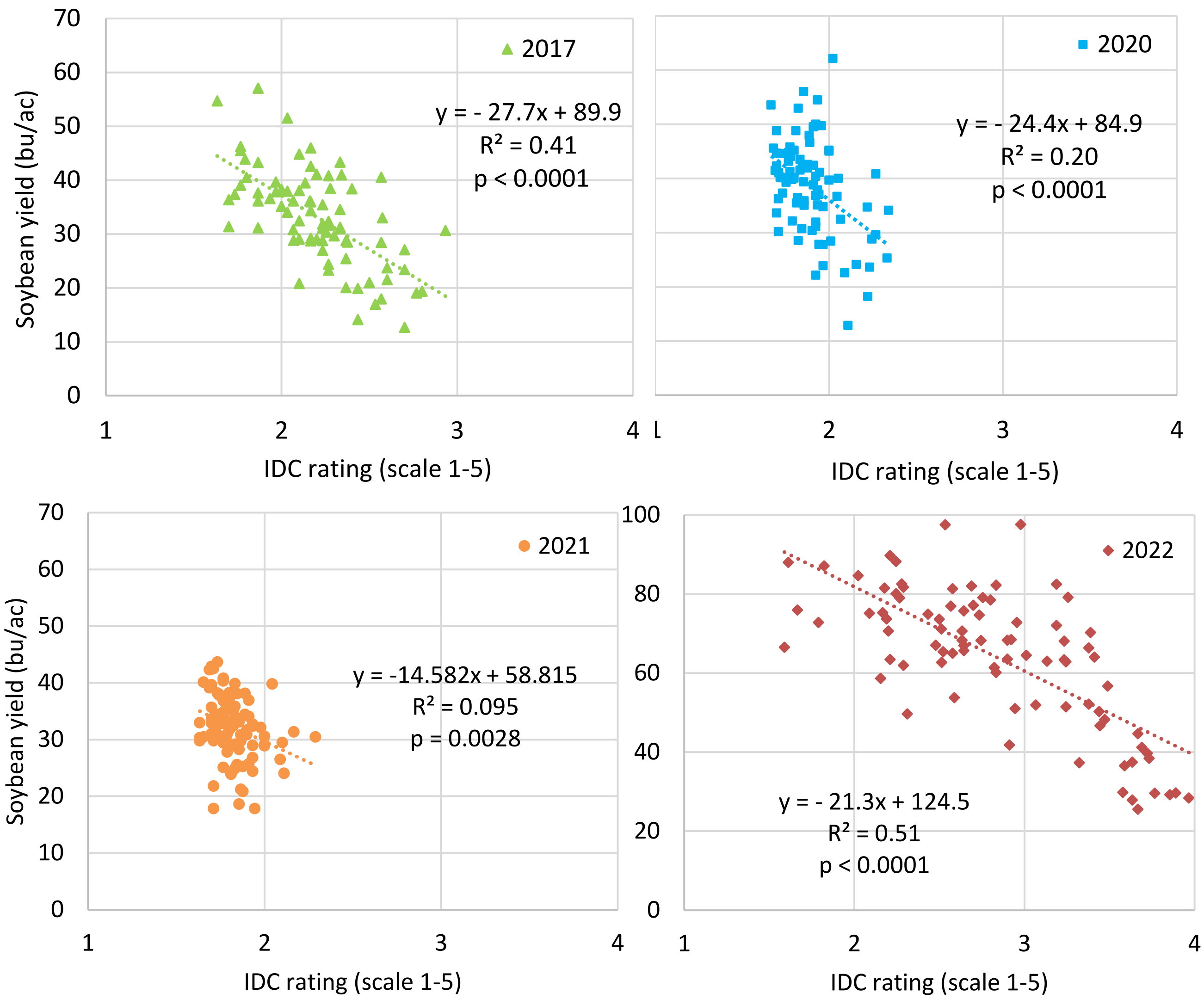

Figure 3. Effect of average IDC score on soybean yield from the variety evaluation site in 2017, 2020, 2021 and 2022 (each data point is the mean of 3 replicates).

Discussion and Conclusions (Obj. 1)

The occurrence and severity of iron deficiency chlorosis varies by year. In areas of soybean fields where IDC symptoms occur and persist, the yield impact can be significant and is likely one of the most yield limiting factors for soybean production in Manitoba.

In 4 out of 5 years, a significant linear relationship between overall IDC score and soybean yield was characterized. In areas of the field where IDC occurs, soybean yield is estimated to be reduced by 15-28 bu/ac for each 1-unit increase in IDC score, or 1.5-2.8 bu/ac for each 0.1-unit increase.

It is important to note that overall, long-term average IDC scores reported for soybean varieties typically range from 1.5 to 2.6, so the effect of a 1-unit difference is substantial. It is more relevant if we consider that for each 0.1 unit that IDC score increases, soybean yield is reduced by 1.5-2.8 bu/ac, on average. Therefore, in areas of a field where IDC occurs, a variety rated 1.7 would be expected to yield 6-11 bu/ac more, on average, than a variety rated 2.1.

In North Dakota, yield loss associated with IDC is estimated at 9 to 19 bu/ac per 1.0 unit increase in IDC score at the 5-6 leaf stage, depending on the year (Franzen and Goos 2016). This is lower than our Manitoba estimates and could be related to the range of IDC scores assigned by evaluators or indicative that the impact of IDC on yield is more severe in Manitoba.

The occurrence of IDC within a field can be highly variable and related to heterogenous soil factors that interact with available moisture. In a survey of 53 farmers and agronomists, the frequency of IDC occurring varies from every year to 1 in 4. When IDC does occur, the majority responded that only 10-25% of a field is affected. This annual and spatial variability makes precision management both an opportunity and a challenge.

Table 2. Summary of mean iron deficiency chlorosis (IDC) scores (scale 1-5) and yields for all entries in each year of the variety evaluation trial near Oak Bluff, MB (2017-2022).

Year	Variable	Mean	Range
2017	IDC rating 1 June 19	1.9	1.5-2.4
n = 80	IDC rating 2 June 22	2.0	1.5-2.5
	IDC rating 3 June 29	2.0	1.6-2.4
	IDC rating 4 July 5 @ V4	2.2	1.7-2.7
	IDC rating 5 July 10 @ V5, R1	2.2	1.6-2.9
	IDC rating overall average	2.1	1.6-2.6
	Yield (bu/ac)	33	13-57
2018	IDC rating 1 June 25 @ V2	1.8	1.6-2.1
n = 96	IDC rating 2 July 3 @ V3	1.8	1.6-2.1
	IDC rating 3 July 9 @ R1	1.8	1.6-2.1
	IDC rating overall average	1.8	1.7-2.0
	Yield (bu/ac)	46	30-65
2019	IDC rating 1 June 26 @ V2	1.8	1.5-2.3
n = 89	IDC rating 2 July 3 @ V3	1.8	1.6-2.3
	IDC rating 3 July 11 @ V4, R1	1.8	1.6-2.1
	IDC rating overall average	1.8	1.6-2.2
	Yield (bu/ac)	not available	
2020	IDC rating 1 June 25 @ V2	1.9	1.7-2.3
n = 80	IDC rating 2 July 2 @ V3	1.9	1.7-2.5
	IDC rating 3 July 10 @ V4	1.9	1.6-2.4
	IDC rating overall average	1.9	1.7-2.3
	Yield (bu/ac)	38	13-62
2021	IDC rating 1 June 22 @ V2	1.9	1.6-2.3
n = 92	IDC rating 2 June 28 @ V3	1.8	1.6-2.4
	IDC rating 3 July 6 @ V5, R1	1.8	1.6-2.2
	IDC rating overall average	1.8	1.6-2.3
	Yield (bu/ac)	32	18-44
2022	IDC rating 1 June 14 @ V1	2.6	1.5-3.7
n = 85	IDC rating 2 June 28 @ R1	3.1	1.8-4.1
	IDC rating 3 July 12 @ R3	2.8	1.3-4.2
	IDC rating overall average	2.8	1.6-4.0
	Yield (bu/ac)	64	26-98

New for 2021 and 2022 (Obj. 2)

We began evaluating variety performance in IDC and non-IDC soil conditions in the same field beginning in 2021. We wanted to answer the question, do varieties that we choose for IDC also yield well in non-IDC areas of the field? **The overall aim of this data collection is to determine the information required to optimize variety selection in spatially variable fields (Fig. 4) where IDC occurs in only a portion of the field.** This concept has been adapted from Helms et al. 2010 who identified a yield drag associated with IDC tolerance.

Currently, there are two types of information available to farmers and agronomists to make variety selection choices for IDC prone fields – 1) IDC scores evaluated from an IDC site and 2) yield from separate high yielding variety trial sites. Since we have recently characterized the significant linear relationship between IDC score and yield (Fig 2.), we can confirm that IDC scores are suitable for choosing varieties for IDC areas. Farmers and agronomists are encouraged to choose varieties with a low IDC score and high yield. However, since the yield data currently available are from separate fields across the province, there is the confounding effect of environment. To eliminate this, we established an additional trial in the IDC testing field with the same varieties but on a non-IDC part of the field (i.e. where soil carbonates are much lower). Yield was collected from both trials/sites and related to IDC score from the IDC trial.

Preliminary data from 2021 and 2022 suggests that IDC score from the IDC site and yield from the non-IDC site is either not correlated or negatively correlated (in a similar fashion that IDC score and yield from the IDC site is negatively correlated). This means that choosing a variety based on IDC score generally does not negatively affect its yield performance in non-IDC areas of the field. However, there is greater variability that warrants further investigation. We will continue to explore how this additional information on variety performance may improve our variety selection for spatially variable fields.

Figure 4. Soybean iron deficiency chlorosis (background) often occurs in only portions of a field.

To demonstrate, Table 3 includes a dataset of 10 varieties that were common in both test years (Table 3). Based on current available data, variety 2, 4, 7, 8 or 9 would likely be chosen for an IDC prone field (low IDC score, high yield). With the new data, we can evaluate the yield of each variety in an IDC and non-IDC area of the same field. Based on this data, variety 3 and 9 yielded highest on the IDC site, variety 4 and 8 yielded highest on the non-IDC site and variety 4 had the highest average yield. This information can now be applied to multiple scenarios where the % of a field affected by IDC varies.

Table 3. Comparison of IDC score and yield data to choose soybean varieties for IDC prone fields.

	Current data from Variety Guide		New data from paired IDC and non-IDC field trials (average of 2021 and 2022)			
Variety	IDC Score	Yield (% of check)	IDC Score	IDC yield (bu/ac)	Non-IDC yield (bu/ac)	Average yield (bu/ac)
1	1.7	95	1.9	52	49	51
2	**1.8**	**111**	2.2	52	53	52
3	2.0	99	2.4	**67**	60	**64**
4	**1.7**	**107**	1.9	**64**	**76**	**70**
5	2.3	78	2.9	26	39	33
6	2.0	103	2.5	49	60	54
7	**1.8**	**106**	2.0	60	54	57
8	**1.8**	**103**	2.2	59	**71**	**65**
9	**1.7**	**106**	1.7	**65**	58	62
10	1.8	97	1.8	63	65	64

For example, if 25-75% of a field is affected by IDC, identifying the overall best varieties (high yielding on IDC and non-IDC sites) is almost equally effective as planting two different varieties for IDC and non-IDC areas of the field, while saving additional time and labour associated with variable cultivar planting. An additional year of study will provide more insight and further analysis on a common set of varieties will be conducted.

To read more about soybean iron deficiency chlorosis, visit "Yield impact of yellow soybeans" or "Iron deficiency chlorosis".

References

Helms, T.C., R.A. Scott, W.T. Schapaugh, R.J.Goos, D.W. Franzen and A.J. Schlegel. 2010. Soybean iron-deficiency chlorosis and yield decrease on calcareous soils. Agron. J. 102:492-498.

Franzen, D. & R. J. Goos. 2016. How Much Does IDC Reduce Soybean Yield? https://www.ag.ndsu.edu/cpr/soils/how-much-does-idc-reduce-soybean-yield-05-12-16

Figure 5. Soybean variety rated 2.8, 3.6 and 3.2 for IDC score in 2022.

Effect of simulated hail damage on soybean yield and maturity

(Portage la Prairie and Minto, MB • 2015-2018)

Introduction

Susceptibility of crops to hail damage depends on plant type, growth stage and hail severity but can result in stem breakage, leaf defoliation, stand reduction, stem bruising, direct loss of yield components and/or secondary effects such as increased susceptibility to lodging and pests. In Manitoba, approx. 5% of crop acres are affected annually, equating to about 4,900 field claims for crop hail damage (Wilcox 2017). On average from 2009-2018, most hail events occurred from July 1 to August 31 and in soybeans specifically, the greatest losses from hail claims occur from V7 to V10, which coincides with flowering and pod fill (Wilcox, personal communication). There were some notable hail events that occurred in western Manitoba in 2013 and 2014 where farmers expressed concerns over hail adjusting procedures. In 2016 alone, there was a record 10,500 field claims for hail damage, affecting 13% of annual crop acres in Manitoba (Wilcox 2017). While soybeans have been grown in Manitoba since the early 2000s, acres steadily increased to 2017 when a record 2.2M acres were seeded (MASC). The surge of the soybean industry surpassed our ability to produce regional information. The data currently used by the Canadian Crop Hail Association and local crop insurance providers to assess hail damaged soybeans is based on data from the United States. Discrepancies between current data and how soybeans recover from hail in Manitoba fields is evident.

The overall objective of this research is to quantify the effect of simulated hail damage on soybean yield and maturity in Manitoba and produce data for western Canada. Specifically, we aim to predict soybean yield loss by level of defoliation and node removal at different growth stages under Manitoba growing conditions. To achieve this objective, two experiments separately evaluating defoliation (exp 1) and stem breakage (exp 2) were conducted at Portage la Prairie and Minto, MB from 2015 to 2018 for a total of 5 site-years. Unfortunately, 3 site-years were lost due to actual hailstorms (July 16, 2016 in Minto, August 15, 2016 in Portage la Prairie and June 14, 2018 in Minto). Results of Experiment 1 are reported in the 2019-2020 Annual Report.

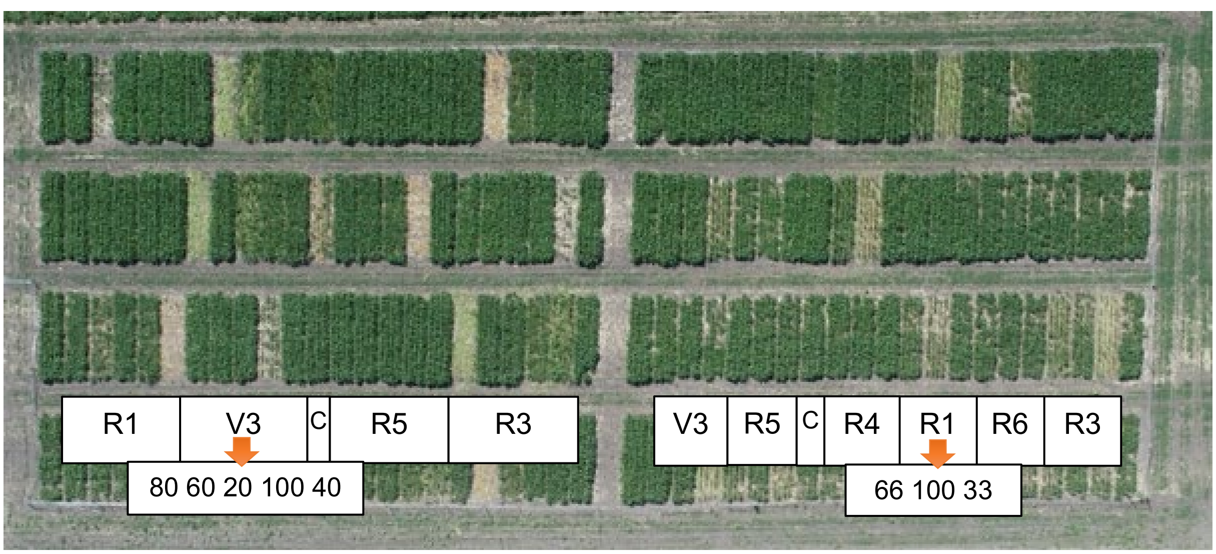

Figure 1. Soybean node removal (L) and defoliation (R) experiments at Portage 2018. Plot labels given for Replicate 2 (third from the top).

Experiment 2: Soybean yield response to node removal (stem breakage) in Manitoba

Objective

To determine the effect of node removal at various growth stage/timings and severity levels on soybean yield and produce region-specific crop insurance data.

Soybean yield loss at 100% stem breakage during V3 is higher than previously reported and this is the first report of an 8–14 day maturity delay.

Materials and Methods

Trial management and simulated hail treatments
Experiments were located at the Agriculture and Agri-Food Canada research station in Portage la Prairie and the Ag Quest research station near Minto, MB and took place from 2015-2018. Soil type at both locations was clay loam and environmental conditions were warm and dry with 41-61% of normal growing season precipitation (127 to 172mm). Experiments were seeded between May 19 and 29 at 200,000 or 210,000 seeds/ac with a plot drill into tilled cereal or corn residue. Row spacing ranged from 20 to 30.5 cm (8 to 12 in). The soybean varieties DK 23-60 RY (MG 00.3) and DK 24-10 RY (MG 00.5) were used at Minto and Portage, respectively. Plots were maintained weed-free using primarily glyphosate but also included hand weeding, Edge granular and Pardner herbicides in some years. At Portage 2017, two insecticide applications were made to control soybean aphid at 250 aphids/plant. For the simulated hail treatments at each timing/growth stage, the total number of main stem nodes (excluding the cotyledonary node) was determined by counting nodes on 10 plants/plot. The average number of main stem nodes/plant was then multiplied by 0.20, 0.40, 0.60 and 0.80 to determine the number of main stem nodes that would be removed by manually cutting with garden trimmers. Nodes were counted from the uppermost node on the main stem downwards until the number of nodes to be cut was reached and then a single cut was made to the main stem. For 100% node removal, each plant was clipped above the cotyledonary node.

Experimental design and statistical analysis
A 2-way factorial experiment with a control in a split arrangement of an RCBD (main plot = timing/growth stage, sub plot = severity/level of node removal) with 4 replicates was tested at 5 site-years/environments. Node removal took place during 5 growth stages (V3, R1-R2, R3, R4 and R5) and 5 severity levels (20, 40, 60, 80 and 100% of main stem nodes) plus a shared control (0), for a total of 26 treatments (5 timings x 5 severity levels + 1 shared control = 26 treatments). The number of observations for each treatment was unbalanced (Table 1: not all timing x severity combinations were present in each site-year).

Table 1. Number of observations (n) per treatment.

	% Node removal/stem breakage					
Timing	**0**	**20**	**40**	**60**	**80**	**100**
V3	20	20	20	20	20	20
R1-R2		20	20	20	20	20
R3		16	16	16	16	16
R4		8	8	8	8	8
R5		12	12	12	12	12

Statistical analysis

Analysis of variance (ANOVA) on the full model was performed using Proc GLIMMIX, with site-year, severity and timing as fixed effects and block(site-year) and timing*block(site-year) as random effects. Residuals were assessed for normality, outliers, and homogeneity of variance. Putative outliers were reviewed and removed if necessary. Due to several significant effects, the percent sums of squares (%SS) was obtained through Proc Mixed method=type 3 to assess the contribution to variance of each factor. Because the objective of the research was to obtain soybean yield loss and maturity data by node removal severity for multiple growth stages relevant to Manitoba and western Canada, data from each site-year were pooled and separate analyses were conducted for each node removal timing (growth stage). For these analyses, severity and site-year were treated as fixed effects and block(site-year) as a random effect. Residuals were assessed for normality, outliers and homogeneity of variance. Putative outliers were reviewed and removed if necessary.

To predict yield loss across all severity levels for each node removal timing (growth stage), the % severity factor was partitioned into linear, quadratic and lack of fit components and tested for significance. Since non-linear responses were detected, Proc IML was used to obtain the appropriate coefficients for a polynomial and an exponential model. Efron's Pseudo R2 were estimated to select the best fit non-linear equation. Plots were created for predicted values of the regression equation and LS means (+/- SE) from the study were then overlaid.

Results and Discussion

Overall soybean yield in the control treatments ranged from 47-71 bu/ac among site-years, which is above the provincial average yield of 36 bu/ac. Both locations would be considered highly productive.

The three-way analysis of variance of data obtained for yield, yield loss and maturity are shown in Table 2. In the full model analysis of yield, all main effects and interactions were significant. To account for differences in overall yield among site-years, yield was converted to yield loss [(% yield loss = yield of treatment / yield of control) x 100)], and because relative differences between treatments were similar among site-years (Muro et al. 2001; Bueckert et al. 2011; Owen et al. 2013). Converting yield to yield loss eliminated the effect of site-year and site-year interactions accounted for little variation overall.

Table 2. Summary of three-way analysis of variance for soybean yield, yield loss and maturity (5 site-years in Minto and Portage la Prairie, MB from 2015-2018).

	Yield		**Yield loss**		**Maturity**	
	Pr > F	% SS	Pr > F	% SS	Pr > F	% SS
Site-year	<.0001	7.7	0.7080	0.4	<.0001	66.1
Timing	<.0001	6.1	<.0001	6.3	<.0001	3.2
Site-year x Timing	0.0452	0.8	0.0044	1.0	<.0001	6.8
Severity	<.0001	67.5	<.0001	72.2	<.0001	7.9
Site-year x Severity	<.0001	2.1	<.0001	1.3	<.0001	6.8
Timing x Severity	<.0001	5.5	<.0001	6.0	0.0018	0.7
Site-year x Timing x Severity	<.0001	2.9	<.0001	3.1	0.0005	1.5

Yield loss and yield loss equations

Severity (% main stem node removal) accounted for most of the variation in soybean yield loss (72%), followed by the timing of node removal (6%) and the interaction between severity and timing (6%). All other factors explained ≤ 3% of the variation in yield loss (Table 2). It is well known in crop hail research that the effect of hail damage varies by growth stage. Therefore, to further elicit the effect of timing (crop growth stage) and produce data for crop insurance purposes, data were handled separately for each timing and agrees with separating severity and growth stage for a range of crops reported (Muro et al. 2001; Conley et al. 2009; Bueckert et al 2011; Owen et al. 2013). This also allows investigation of the high-level 3-way interaction, whereby the severity x site-year interaction can be evaluated for each timing.

Table 3. Analysis of variance for the effect of severity, site-year and their interaction on soybean yield loss by growth stage/timing (Minto and Portage la Prairie, 2015-2018).

	V3	**R1-R2**	**R3**	**R4**	**R5**
			Pr > F		
Severity	<.0001	<.0001	<.0001	<.0001	<.0001
Site-year	0.3891	0.9849	0.1957	0.3169	0.3631
Severity x Site-year	<.0001	0.0056	0.1308	0.3310	0.3334

The following discussion focuses on soybean yield response by growth stage that node removal occurred (Table 3 and Fig. 2.). The effect of node removal on yield loss was consistent among environments at R3, R4 and R5 (no interaction between severity and site-year). At V3 and R1-R2, however, there was variability in the observed yield loss response among site-years (data not shown). This variability is attributed to the range in yield loss observed at 100% node removal during V3 (Fig. 1, 29-86% yield loss) and 80% node removal during R1 (19-51% yield loss). Crop recovery may be difficult to estimate during those growth stages for those specific severity levels and is likely dependent on environmental conditions following crop damage.

Figure 2. Variability in soybean re-growth between site-years following 100% node removal during V3 on August 10, 2017 (left) compared to August 8, 2018 (right) at Portage la Prairie.

The best fit regression models for soybean yield loss at each growth stage are presented in Fig. 2 and explain 71-96% of the variation in yield loss. Four out of the five growth stage timings resulted in an exponential yield response to node removal severity, whereby as severity increases, yield loss increases more sharply.

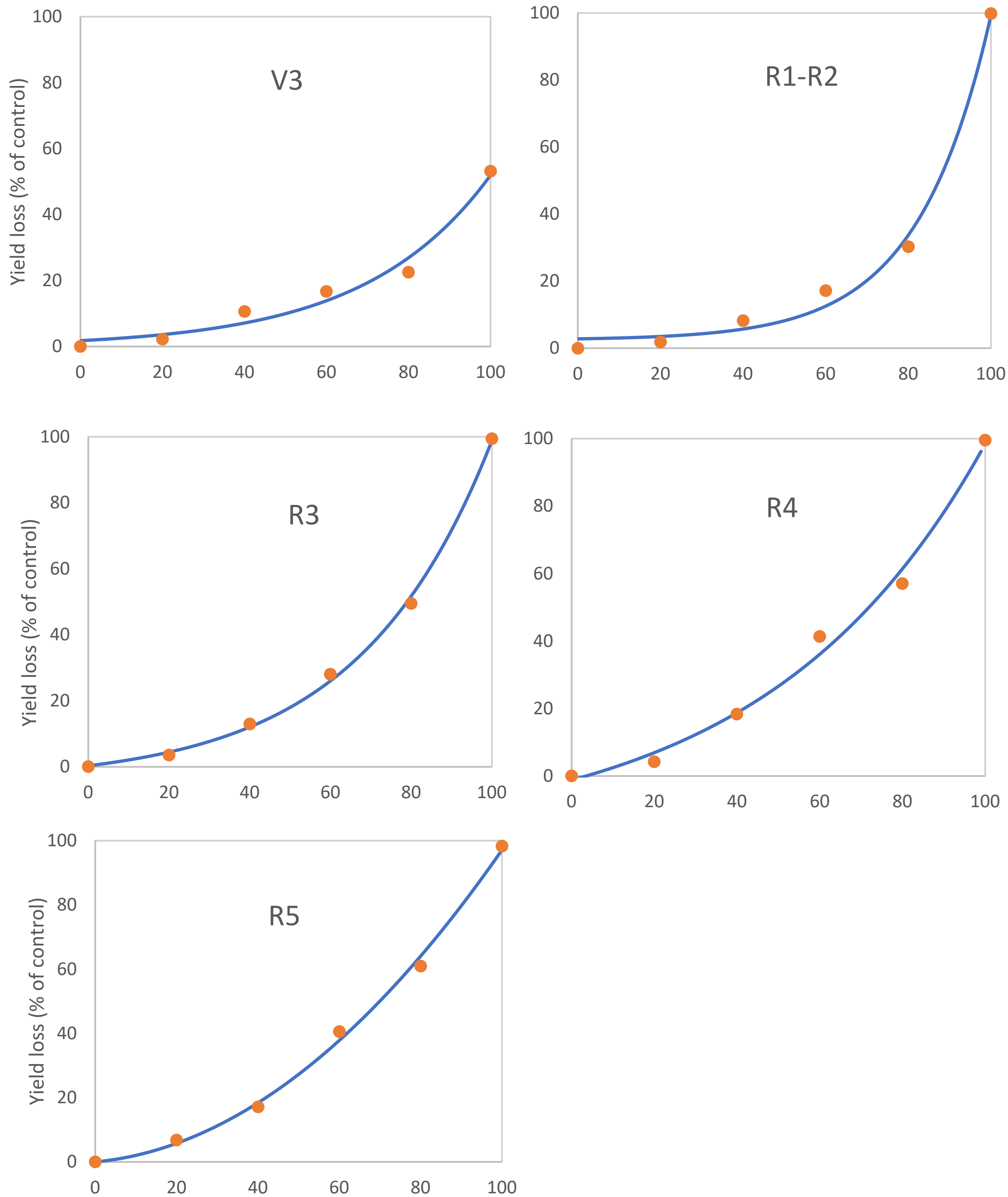

Figure 2. The relationship between soybean yield loss and % node removal at five growth stages in Manitoba averaged across 5 site-years (2015-2018).

At growth stage V3, soybean was the most tolerant to high levels of node removal and was the only growth stage timing to recover from 100% node removal. The average yield loss when 80% of main stem nodes above the cotyledon were removed was 23% and is similar to values currently reported in Iowa (Licht et al. 2016). However, the average yield loss when 100% of main stem nodes are removed was 53% which is greater than values currently reported (38%). Generally, soybeans compensate well for leaf loss during vegetative growth and early flower due to rapid leaf re-growth (Board and Kahlon 2011) and new growth from axillary buds, but our data demonstrates that crop recovery is region specific.

At R1-R2 (flowering), soybean is no longer able to recover following 100% node removal. Yield loss observed for all other severity levels is consistent with observations from other regions.

At R3 (early pod), soybean yield loss observed in our study from 60 and 80% node removal is 20-30% lower than values currently reported for Iowa (Licht et al. 2016) and Nebraska (Klein and Shapiro 2011) and represents the greatest deviation between yield loss values among regions. This may be due to the distribution of yield components (pods and seeds) among main stem nodes, whereby, more pod and seed development occurs on the lower portion of the stem in short-season cultivars or environments.

During R4 (full pod) and R5 (early seed), soybean was most sensitive to node removal with 41-61% yield loss occurring when 60-80% of main stem nodes are removed. To our knowledge, this is the first study to report a yield loss relationship for R4 and R5 since node removal/stem breakage from growth stage R4 onward is considered direct loss. At this point in soybean reproductive development, pods and seeds are formed sufficiently to allow quantitative evaluation of yield loss. During R4 and R5, the effect of node removal severity was consistent among site-years and the yield loss models were similar across severity levels. Thus, suggesting that these crop loss models may be combined and used by crop hail adjustors in place of direct loss measurements which offers two immediate benefits – time efficiency and accuracy, since pods are often detached from the stem and found loose on the ground following a hailstorm.

Table 4. Mean soybean yield loss (%) by node removal severity for each growth stage averaged across 5 Manitoba site-years.

Node removal severity	V3	R1-R2	R3	R4	R5
	% Yield loss				
0%	0e	0e	0e	0e	0e
20%	2.2e	1.9e	3.5e	4.2e	6.8e
40%	10.6d	8.2d	12.9d	18.4d	17.1d
60%	16.7c	17.1c	28.0c	41.3c	40.5c
80%	22.5b	30.3b	49.5b	57.0b	60.9b
100%	53.1a	99.9a	99.4a	99.6a	98.3a

Days to full maturity (R8)

All main effects and interactions influenced soybean days to R8 full maturity (Table 2). The most important factor was site-year, accounting for 66% of the variation in soybean maturity. In the separate analyses by growth stage/timing, the effect of severity on crop maturity varied by site-year (data not shown).

During V3, all levels of node loss significantly delayed soybean maturity compared to the control (Fig. 3). Soybean maturity was delayed by 6-8 days at 40-80% severity and 14 days, on average, when 100% of nodes were removed (Fig. 4). In Manitoba, soybeans progress from physiological maturity to full maturity in about 7 days (range 4-12) therefore a maturity delay of 7 days or greater would be expected to pose a significant agronomic risk to soybeans in Manitoba. The magnitude of maturity delay was 7 days or greater at 4 out of 5 site-years.

During R1, soybean maturity was delayed by 2-6 days on average across severity levels from 20-80%. The magnitude of maturity delay varied from 0 to 11 days among site-years with 2 out of 5 site-years resulting in an agronomically significant delay of 7 days or greater at the highest severity level (80%).

From R3 through R5, the interaction between the effect of severity and site-year becomes clearer and differentiated by site (data not shown). There were no differences in soybean maturity among node loss treatments during the study years at Portage. At Minto, however, soybean maturity was delayed by 5-12 days when 60-60% of nodes were removed. Thus, the risk of hail-damaged soybeans not reaching maturity before fall frost is greater in shorter season regions of Manitoba.

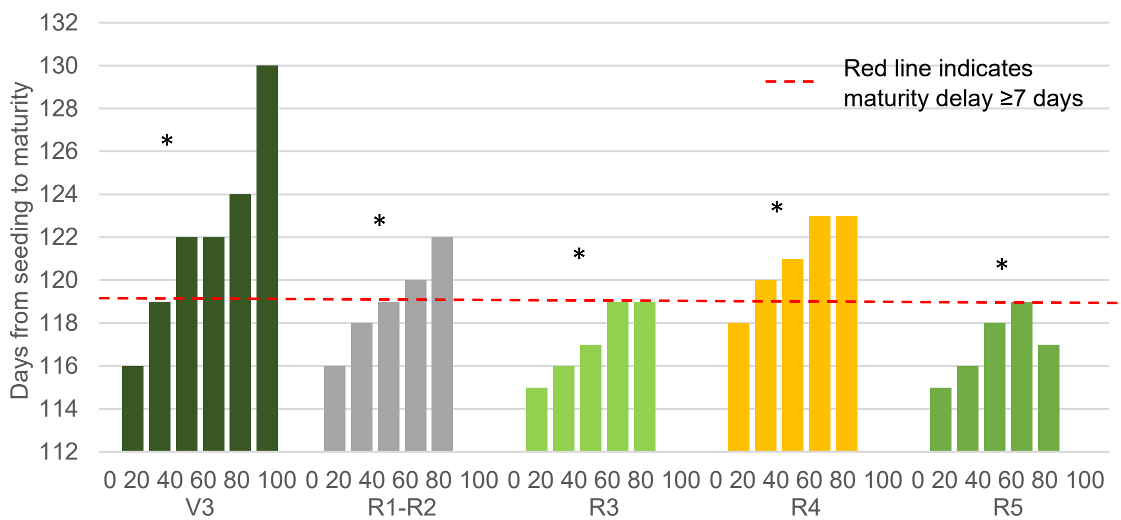

Figure 3. The effect of main stem node removal on soybean maturity at each growth stage and severity level based on 5 site-years in Manitoba (2015-2018).

Conclusions

This study provides the first comprehensive dataset quantifying the impact of node removal/stem breakage on soybean yield and maturity in Manitoba and western Canada. Results indicate that the response of short-season soybean in western Canada to node removal is different compared to southern growing regions (Table 5). Current data appears to be overestimating yield loss in some instances during R3 while the greatest discrepancy occurs during V3 when 80-100% of main stem nodes are removed. The economic loss in yield (23-53%) is substantially higher than current data suggests, and we are the first to document the maturity risk, which equates to an 8 to 14 day delay in reaching R8. Equations for the soybean yield responses in Fig. 2, will be made available to farmers, agronomists and crop insurance adjusters.

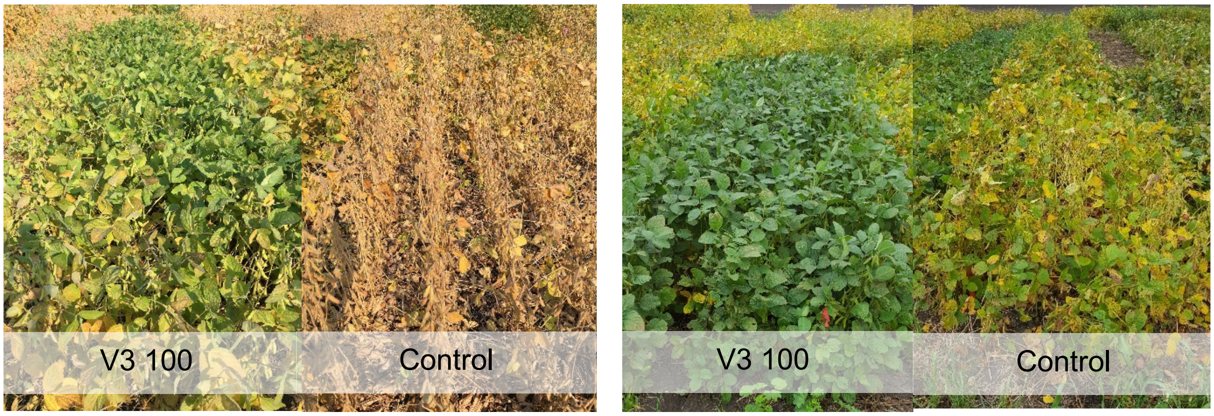

Figure 4. Soybean maturity following 100% node removal during V3 compared to the control at Portage on Sept. 12, 2017 (left) vs. Minto on Sept.10, 2015 (right).

Table 5. Difference between new soybean yield loss data and current data used by crop insurance providers for each growth stage and defoliation level in Manitoba.

	V3	R1	R3	R4	R5	
20	-3.8	-5.3	-5.1			
40	-4.5	-9.7	-9.4			<5%
60	-1.8	-7.8	-12.6	Data not previously reported.		5-10%
80	3.7	-1.8	-12.1			>10%
100	13.8	4.6	-1.1			

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Development of an Integrated Weed Management (IWM) Package to Mitigate and Manage Glyphosate-Resistant Weeds in Soybean

(Portage la Prairie, MB • 2019-2022)

The soybean and pulse agronomy team collaborated with **Dr. Charles Geddes**, Weed Scientist at AAFC Lethbridge on two experiments* as part of a prairie-wide study to develop an IWM strategy for soybean. Overall, four experiments were conducted under both weedy and weed-free conditions to determine how agronomic practices impact the ability for soybean to compete with and withstand competition from weeds and reduce selection pressure for glyphosate resistance while mitigating yield loss induced by weed competition in the Canadian prairies.

- Soybean cultivar and planting date (Exp 1*)
- Crop sequence, residue management and planting date (Exp 2*)
- Row spacing, target density and fall rye cover cropping (Exp 3)
- Plant spatial arrangement based on growth habit (Exp 4)

Preliminary results of this study reported here are adapted from Dr. Geddes' article "Supporting Soybeans in the War on Weeds" and the technical report provided to project funders.

Variety Selection

Experiment 1 assessed the impact of soybean cultivars and planting dates (early vs. mid vs. late) at three locations (Lethbridge, Saskatoon, and Portage la Prairie) over two years (2019 and 2020). Genotype by environment interactions suggest the optimal soybean genetics in one region will differ from those in another. However, across all six site-years of research, the highest-yielding soybean varieties under weed-free conditions within each location also tended to have the highest yield under weed competition. This is good news for soybean farmers because it suggests that breeding efforts aimed at improving soybean yield have not compromised the traits that lead to a competitive crop.

✓ **Grow a regionally adapted, high yielding soybean variety.**

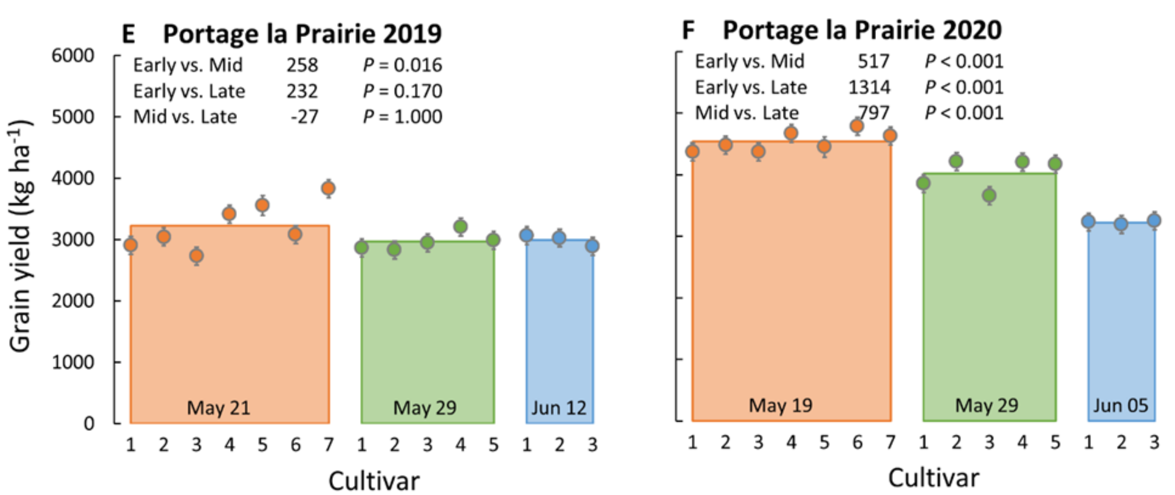

Figure 1. Soybean grain yield in the absence of weed interference for different cultivars ranging in phenotypic and morphological traits planted at early vs. mid vs. late planting dates. Bars indicate overall means for all cultivars planted on the date indicated near the x-axis. Circles indicate cultivar means while error bars indicate ± SEM. Single degree-freedom estimates show differences between planting date means.

Planting date

Different soybean varieties planted early (May 13-22), mid (May 23-June 1) or late (June 2-11) in exp. 1 demonstrated that the impact of planting date on weed competition varies among locations and depends on the timing of weed pressure. For example, about 18% greater soybean yield loss was observed due to weeds emerging after an early planting date compared with mid or late planting dates in one of two years in Lethbridge. In Saskatoon, however, about 20-30% greater yield losses were observed in both years when planting later, while differences among seeding dates were absent in Portage la Prairie. Meanwhile, soybean yield under weed-free conditions was maximized with early planting overall (Fig. 1).

In exp. 2, soybean yield losses were greater when soybeans were planted early compared with mid in two of three environments. Weed density and biomass were also greater in early-planted soybeans compared with mid in all three environments. These results suggest that the impact of soybean planting date on weed competition varies depending on the timing of weed emergence within the field, which is often related to heat and moisture.

- ✓ **Weed density and biomass can be greater in early-planted soybeans (May 13-22), but yield potential is generally greater, so attention to timely and effective in-crop weed management is important.**

Row spacing

Experiment 3 and 4 evaluated the effect of soybean row spacing on weed-free yield, weed density and biomass and yield loss due to weed interference. All six site-years of exp. 3 were completed between 2020 and 2022, five of which have been analyzed (Fig. 2). Narrow (7.5-10") row soybean yielded greater than wide (24-30") rows by 24% on average in three (Lethbridge 2020, Lethbridge 2021, Carman 2022) of five site-years. Narrow rows also resulted in lower yield loss (24%) due to weeds than wide rows (39%) in Lethbridge 2021, but no other site-year.

All six site-years of exp. 4 were completed between 2020 and 2022, five of which have been analyzed. In general, higher weed-free yields were observed when soybean was planted in narrow (7.5-10") rows compared with medium (15-18") or wide (24-30") row spacing.

- ✓ **Narrow row spacing generally results in greater yield and less weed interference.**

Lethbridge, AB - 2020

Target density (plants/ac)	Row spacing 27"	18"	9"
80,000	28 e	33 de	28 e
160,000	40 cd	37 c-e	52 a
240,000	42 b-d	43 a-d	51 ab
320,000	36 c-e	45 a-c	40 b-d

Carman, MB - 2021

Target density (plants/ac)	Row spacing 30"	15"	7.5"
80,000	39 a-c	35 bc	46 a
160,000	38 a-c	37 a-c	44 a-c
240,000	42 a-c	35 bc	43 a-c
320,000	42 a-c	34 c	46 ab

Indian Head, SK - 2021

Target density (plants/ac)	Row spacing 24"	16"	10"
80,000	.	30 a	29 a
160,000	35 a	33 a	35 a
240,000	36 a	34 a	37 a
320,000	35 a	35 a	35 a

Lethbridge, AB - 2021

Target density (plants/ac)	Row spacing 27"	18"	9"
80,000	29 d	32 b-d	36 a-d
160,000	28 d	41 ab	34 a-d
240,000	30 cd	44 ab	41 ab
320,000	40 a-c	44 a	42 ab

Carman, MB - 2022

Target density (plants/ac)	Row spacing 30"	15"	7.5"
80,000	43 e	45 e	58 a-d
160,000	54 b-e	48 de	63 ab
240,000	59 a-c	46 e	66 a
320,000	53 b-e	49 c-e	65 a

Figure 2. Weed-free soybean yield (bu/ac) in response to row spacing and target plant density at five site-years across the soybean cultivar factor. Within site-year, different letters indicate significant difference based on Tukey's HSD (α = 0.05).

Seeding rate

Experiment 3 showed that increasing soybean target densities from current recommendations (160,000 plants/ac) could make the soybean crop more tolerant of weed competition. For example, soybean yield losses were lowest when targeting a very high density of 320,000 plants/ac in Carman, while in Lethbridge, yield losses were lowest at 240,000 plants/ac. Current recommendations for soybean target densities (160,000 plants/ac) resulted in similar yield loss to that of half (80,000 plants/ac) of the recommended target density. These results suggest that higher soybean densities could help to maintain soybean yield when competing with problematic weeds. Under weed-free conditions, soybean yield also tended to increase with increasing target density.

- ✓ **Maintain the recommended target density or increase to make the soybean crop more competitive against weeds.**

Cover cropping

Planting soybeans in narrow (7.5-9 inch) rows into a fall rye cover crop terminated with the pre-plant burndown herbicide halved mid-season weed biomass, compared with wide (24-30”) row soybeans without a cover crop. This result was observed all five site-years analyzed and suggests that both fall rye cover cropping and narrow soybean rows could interact to help improve the competitive ability of soybeans grown in the Canadian prairies. The shoulder season fall rye cover crop did not have a negative impact on soybean yield in any site-year.

Integrated weed management

Overall, the first three years of this prairie-wide research project have started to uncover which agronomic tools could aid weed management programs in soybean production. However, the efficacy of many of these cultural weed management tools varied depending on the location and interactions among practices were common. This means that the weed management strategies discussed above should be implemented in combination to achieve the greatest benefit.

Integrated weed management principles suggest that the use of multiple diverse weed management practices can add up, leading to reduced selection pressure for resistance to a single weed control tool (such as herbicides). It is noted that many of these options require additional investment, which can be difficult to pencil out if the economics of the farming operation are considered only on a year-to-year basis. Rather, proactive investment in the form of IWM takes a longer-term focus on the health of farming systems, suggesting that a small investment today could help prevent the necessity for large investments down the road.

- ✓ **Adopt multiple cultural weed management tools together to increase the chances of one or more tools contributing positively to yield and weed management.**

Effect of Weed Control Timing on Soybean Yield

(Carman, MB • 2022-continuing)

Early weed interference reduces soybean yield, yet weedy fields are a common occurrence across Manitoba each year. Development of herbicide resistant weeds is increasing and reducing the efficacy of current herbicide programs, but overall, increased attention to timely and effective weed control is warranted. The average critical weed free period (CWFP), which defines the duration of time that soybean must be kept weed free to prevent yield loss, extends from seeding up to V4 (approx. 30 days after emergence) as studied in Ontario (Van Acker 2001). Intensive studies evaluating various cultural and integrated weed management strategies to shorten the CWFP (Rosset and Gulden 2019) and reduce selection pressure have recently been conducted in Manitoba (Geddes et al., page 17). Strategies such as narrow row spacing, high seeding rate and preceding fall rye cover crop can increase crop competitiveness thereby reducing weed biomass and selection pressure from applied herbicides. Additionally timely herbicide management is important to maximize yield potential.

In North Dakota, delaying herbicide weed control from pre-emerge until VC to V1 or V2-V4 reduces soybean yield by 5% and 8%, respectively, compared to maintaining the crop weed-free (Endres and Ostlie 2011-2014). This type of generalized data on the impact of weed control timing on soybean yield typically resonates well with farmers and agronomists.

The objective of this trial is to quantify the yield impact of weed control timing in Manitoba soybeans. This trial was initiated at Carman in 2022 and will continue at multiple locations in 2023.

To determine the effect of weed control timing on yield, soybeans will be seeded using current best management practices (mid-May seeding date, narrow row spacing,180-200,000 seeds/ac) and following a pre-seed burn-off (or tillage) in all treatments, in-crop weed control timing will be incrementally delayed. The experimental design is an RCBD with 4 replicates.

Treatment list:

1. Weed-free control
    - Pre-seed burn off + pre-emerge residual + post emergent herbicide application (approx. 4 weeks after seeding, soybean at V3)
2. Weedy check
    - Pre-seed burn off or tillage only (no in-crop herbicide)
3. Early weed control
    - Pre-seed burn off or tillage + first herbicide app when weeds reach 2-4” in height (approx. 2 and 5 weeks after seeding, soybean at VC and V4)
4. Late weed control
    - Pre-seed burn off or tillage + first herbicide app when weeds reach 4-6” in height (approx. 3 weeks after seeding, soybean at V1)
5. Rescue weed control
    - Pre-seed burn off or tillage + first herbicide app when weeds reach 8+” in height (approx. 4 weeks after seeding, soybean at V3)

At Carman 2022, soybeans were seeded June 5 at 180,000 seeds/ac on 7.5” rows. The weed community consisted of green foxtail, volunteer cereals, lambsquarters, redroot pigweed and wild buckwheat.

Table 1. Herbicide treatment descriptions for Carman 2022.

Treatment	Pre-seed[x]	Pre-emerge[y]	In-crop glyphosate[z]	Stage	Weed ht.	Cost ($/ac)
1. Weed-Free	✓	✓ June 8	✓ July 5	V3	4-10”	$75
2. Weedy	✓					$19
3. Early	✓		✓ June 22, July 13	VC, V4	4”, 4”	$57
4. Late	✓		✓ June 28	V1	6”	$38
5. Rescue	✓		✓ July 5	V3	10”	$38

[x] Pre-seed: Roundup WeatherMAX (0.67 L/ac) applied June 4
[y] Pre-emerge: Heat LQ (30 mL/ac) + Zidua SC (60 mL/ac) + Merge adjuvant (0.3 L/100 L solution)
[z] In-crop: Roundup WeatherMAX at 0.67 L/ac
Cost ($/ac) = herbicide product + spray operation (excludes the initial pre-seed glyphosate pass)

Figure 1. Effect of weed control timing on soybean yield (bu/ac) at Carman 2022.

At one site-year, soybean yield in the weed-free control was 74 bu/ac and was reduced by 4-7% as initial herbicide timing was delayed from pre-emerge to when weeds were 4-6” in height (Fig. 1). Based on an average soybean yield of 45 bu/ac and price of $18/bu in 2022, a 4-7% yield reduction associated with delayed weed control results in reduced revenue of $32 to $57/ac. This offsets the additional cost of the weed-free control program, which is $18 or $37/ac higher than a two or three-pass glyphosate program (Table 1), respectively. The 2022 Manitoba growing season was favorable for soybeans, with normal to above normal rainfall that was generally well distributed. The provincial average yield of 45 bu/ac is a record. Yield loss due to delayed weed control may be greater in years when soil moisture is limiting.

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Soybean Late Planting Study Contributes Data for Extended AgriInsurance Soybean Seeding Deadlines

Media Bulletin – Manitoba
May 20, 2022
AGRIINSURANCE SEEDING DEADLINE FOR SOYBEANS EXTENDED

Manitoba Agriculture and the Manitoba Agricultural Services Corporation (MASC) are announcing the extension of the AgriInsurance seeding deadlines for soybeans starting in 2022.
The full coverage seeding deadlines for soybeans are now June 8 in Soybean Area 1 and June 4 in Soybean Areas 2 and 3. In addition, soybean growers in these areas will now be eligible for insurance if planting occurs in the five days following the full-coverage seeding deadline. However, coverage will be reduced by 20 per cent. The full-coverage seeding deadline for Soybean Area 4 continues to be May 30 with no extended seeding deadline coverage. These changes are permanent and will be part of the AgriInsurance contract going forward.

These changes were made in consultation with the Manitoba Pulse and Soybean Growers Association after a review of available data and agronomic considerations such as growing season length and the use of varieties that are more adapted to Manitoba conditions since the seeding deadlines were last considered. These changes are not expected to materially change the risk to the AgriInsurance program and therefore there is no change to premiums as a result.

MASC is not considering seeding deadline extensions for other crops at this time. The final spring seeding deadline for many major crops is June 20. AgriInsurance contract holders who are unable to seed by June 20 due to wet conditions are eligible for Excess Moisture Insurance.

For a full list of MASC seeding deadlines, visit www.masc.mb.ca/seeding-deadlines.

Table 1. Soybean seeding deadlines in Manitoba as of May 20, 2022 (Source: MASC).

Crop	Seeding Deadline (Full Coverage)		Extended Seeding Period (20% Reduced Coverage)		
Soybeans	Soybean Area 1	**June 8**	Soybean Area 1	**June 9 – June 13**	*Previously June 6 and June 7-11*
	Soybean Area 2	**June 4**	Soybean Area 2	**June 5 – June 9**	*Previously May 30 and May 31-June 4*
	Soybean Area 3	**June 4**	Soybean Area 3	**June 5 – June 9**	*Previously May 30 and May 31-June 4*
	Soybean Area 4	**May 30**	Soybean Area 4	**None**	*No change*

Results of the Soybean Late Planting Study that took place from 2015-2017 in Morden, Carman and Arborg, MB have been reported here:

MacMillan K.P. and R.H. Gulden. 2020. Effect of seeding date, environment and cultivar on soybean seed yield, yield components and seed quality in the Northern Great Plains. Agronomy Journal: 112;1666-1678. doi.org/10.1002/agj2.20185

MPSG. 2019. Yield and maturity of late-seeded soybeans in Manitoba. Pulse Beat Sci. Ed (3).

MacMillan, K.P. 2018. "Yield and maturity of late-seeded soybean in Manitoba". Pulse Beat (83) p32-33.

Soybean Seeding Depth Evaluation

Soybean yield was maximized by seed depths ranging from 0.75–1.75 inches, with 1.25 inches producing the greatest yield, on average. There was no benefit to chasing moisture and seeding soybeans deeper than 1.75 inches.

DRY CONDITIONS OVER the past few years have enticed farmers to drive soybean seed deeper than usual (>2 inches) to connect with soil moisture. The current recommendation to seed soybeans between 0.75–1.5 inches deep is based on guidelines from other regions and the range of seed depths reported by farmers and agronomists is much wider. Understanding the yield impact of soybean seed depth under Manitoba conditions became a clear priority.

The objective of this study was to identify the optimum seeding depth for soybeans in Manitoba, through evaluation of plant density, nodulation, root rot, pod height, maturity and yield.

Seeding depths ranging from 0.25–2.25 inches were tested at Arborg (clay soil) and Carman (loam soil) from 2017 to 2019 in small-plot field trials. All trials were seeded into tilled stubble, except at Arborg in 2017 which was seeded into tilled fallow. Growing conditions were drier than normal across all site-years, with cumulative May and June precipitation at 40–87% of normal. Although soil moisture was not measured, moist soil was often observed to be at 1.25 inches or deeper at the time of seeding.

Soybean seed depths of 0.5–2.25 inches resulted in maximum plant density, with plant stands ranging from 140–170,000 plants/ac, on average. Shallow seeding (0.25 inches), on the other hand, significantly reduced plant stands to 81,000 plant/ac, on average. Shallow seeded soybeans were subject to moisture fluctuations at the soil surface, which resulted in desiccation and failed germination. Deep seeded soybeans (2.25 inches) produced an acceptable plant stand but emergence was delayed, increasing risk of soil pathogens and pests,

and seedlings showed signs of stress, including hypocotyl swelling, loss of cotyledons and chlorosis.

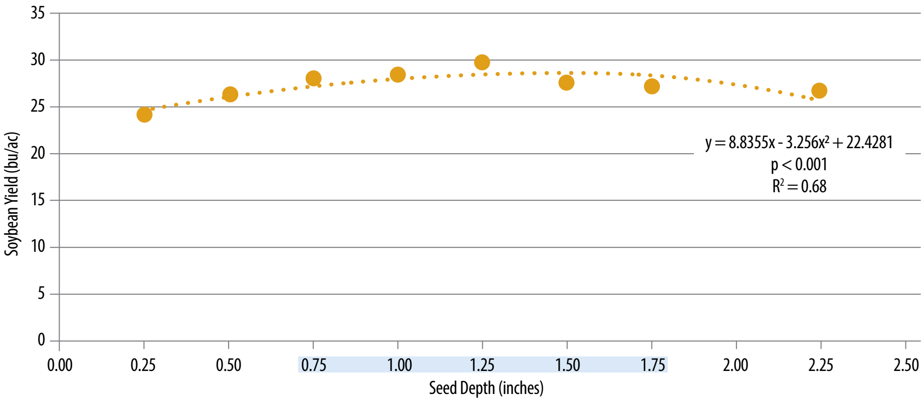
The seed depth range that maximized yield was 0.75–1.75 inches, with yield maximization at 1.25 inches (Figure 1). Shallower and deeper seeding reduced yield by 19% and 10%, respectively. Shallow seeding was more detrimental than deep seeding, likely due to dry conditions. Yield loss from non-optimal seed depth in this study was likely due to delayed emergence, reduced plant stand and reduced seedling vigour (e.g., hypocotyl swelling, chlorosis and loss of cotyledons).

To answer questions posed by farmers and agronomists, pod height, days to maturity, nodulation and root rot were all evaluated. Pod height was significantly influenced by seed depth and environment, although environment had a greater influence. Seed depths of 0.5–2.25 inches produced the highest pods (3.5–3.9 inches, on average), while shallow seeding significantly reduced pod height (3.1 inches, on average). Soybean maturity was influenced by environment but not seed depth. There was no effect of seed depth on nodulation nor root rot.

Overall, soybeans should be seeded within the optimal range of 0.75–1.75 inches, adjusting within this range depending on soil moisture, soil type, equipment and management practices.

This study provides evidence that even under dry conditions there is no benefit to chasing soil moisture beyond 1.75 inches.

Figure 1. Relationship between soybean seed depth and soybean yield based on six site-years in Manitoba (Arborg and Carman from 2017–2019). Seed depths of 0.75–1.75 inches maximized yield.



PRINCIPAL INVESTIGATOR Kristen P. MacMillan, University of Manitoba

MPSG INVESTMENT $84,000

CO-FUNDER Growing Forward 2

DURATION 3 years

Refining Soybean Seeding Window Recommendations

The window to seed soybeans in Manitoba is flexible throughout the month of May. Soybean yields did not differ among May 1–24 seeding dates, but yields were reduced by 15%, on average, when seeding was delayed until May 31–June 4.

Emerged soybean seedlings from the very early seeding window (April 28–May 6) exposed to a late spring frost.

THE TRADITIONAL RECOMMENDATION has been to plant soybeans when soil temperatures have warmed to at least 10°C, or from May 15–25 in Manitoba. However, previous Manitoba-based research found that late April to early May planting dates corresponding with soil temperatures of 6.0–10.6°C produced similar and, in one case, greater soybean yields than those seeded at the traditionally recommended time.

The purpose of the current study aimed to update soybean seeding date recommendations across a wider range of environments, using defined calendar dates. Over three years (2017–2019), experiments were established at Arborg, Carman, Dauphin and Melita. Four seeding windows were tested: *very early* (April 28–May 6), *early* (May 8–14), *normal* (May 16–24) and *late* (May 31–June 4), using the short-season variety, S007-Y4 (MG 00.5), and mid-season variety, NSC Richer (MG 00.7). Soybeans were seeded into soil temperatures as low as 0°C.

There were no differences in soybean yield when planted throughout May 1 to 24 (Figure 1). Yield was reduced by 15%, on average, when seeding was delayed until May 31 to June 4. These results indicate that the soybean seeding window is flexible during the first three weeks of May in Manitoba.

At four of 11 site-years, yield was maximized by seeding very early (April 28–May 6), but yield was significantly reduced by this very early seeding at one site-year. At five of 11 site-years, yield was maximized during the early seeding window (May 8–14).

These results highlight the risks related to seeding soybeans too early in Manitoba. Cold soil temperatures within the first 48 hours of seeding can result in chilling injury, reduced or delayed emergence and increased susceptibility to soil-borne pathogens. There is also the risk of exposure to spring frost, which can kill or injure emerged seedlings. The coldest soil temperatures occurred during the very early seeding window at Melita in 2019 (0°C), at Melita in 2017 (1.1°C) and at Arborg in 2018 (5.8°C). At those site-years, yield was reduced by 13–19% during the very early seeding window (April 28–May 6). Late killing spring frosts occurred on May 19, 2017 and June 2, 2019, that may have negatively impacted emerged seedlings and yield from the very early seeding window.

In these experiments, soybean seed protein averaged 31.9%, 13% moisture basis (range: 26.5–35.1%). The effect of seeding window on seed protein was significant overall, but this depended on the environment. At eight out of 11 site-years, protein was the same among seeding dates. Late seeding produced greater protein than during the very early or early seeding windows at two out of 11 site-years. We need to gain a greater understanding of how genetic, management and environmental factors interact and affect soybean protein and other quality factors in Manitoba before altering our farming practices to manage protein.

Based on the results of this study, seeding soybeans during the second week of May generally maximized soybean yield in Manitoba while reducing the risks associated with cold soil and late spring frost. However, the optimal time to seed soybeans can vary by region and from year to year. Each planting season, avoid seeding into soil temperatures below 8°C, ensure there is no cold rain or snow in the forecast for the first 24–48 hours after planting and aim to seed within two weeks of the last expected spring frost to establish a strong plant stand, maximize yield and minimize risk.

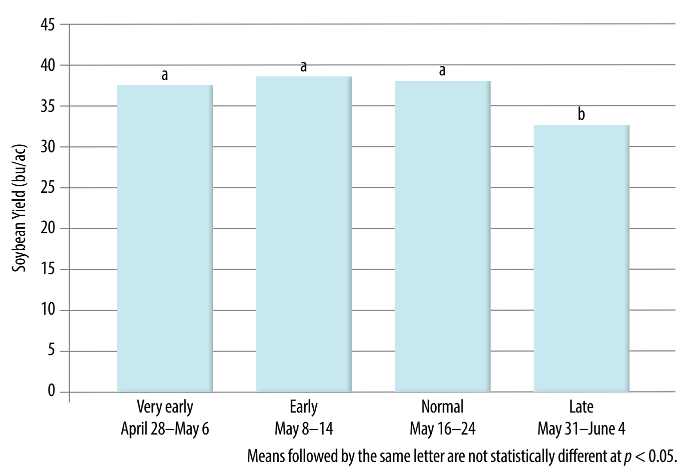


Figure 1. Soybean yield by seeding window among Arborg, Carman, Dauphin and Melita environments from 2017–2019.

PRINCIPAL INVESTIGATOR Kristen P. MacMillan, University of Manitoba

MPSG INVESTMENT $169,400

CO-FUNDER Growing Forward 2

DURATION 3 years

Evaluating Dry Bean Inoculants

The Primo GX2/N Charge inoculant significantly improved dry bean nodulation and yield at Melita in 2020 and 2021 while no difference was observed at Carman from 2019-2021. The BOS peat inoculant was no different from the non-inoculated check.

Dry bean roots with nodulation.

OBSERVATIONS OF NODULATION and lack of consistent yield response in N fertilizer studies has led to a re-evaluation of the contribution of biological N fixation to the N requirements of dry bean. Inoculation with effective rhizobia may improve N fixation and reduce N fertilizer use, however, commercial inoculants are not widely available nor commonly applied. Dry bean association with rhizobia can be highly specific and vary by both environment and variety. This apparent specificity and the overall low acreage of dry beans are limitations to inoculant development.

The objective of this research was to determine if any recently available dry bean inoculants improve nodulation and yield in pinto (Windbreaker and Vibrant), navy (T9905) and black beans (Eclipse), compared to non-inoculated, non-fertilized checks.

From 2019-2021 at Carman and Melita, inoculant products evaluated were BOS self-adhering peat inoculant and Primo GX2 granular inoculant (later re-formulated and named N Charge), both containing *Rhizobium leguminosarium* biovar *phaseoli*. Residual soil nitrate-N ranged from 12-76 lbs/ac (0-24"). At flowering, dry bean nodulation was scored on a rating scale of 0-4, where 0 = no nodules, 1 = ≤5 nodules/plant, 2 = 6-10 nodules/plant, 3 = 11-20 nodules/plant and 4 = >20 nodules/plant.

At Carman in 2019, there were no significant effects of inoculant on nodulation incidence, score nor yield for pinto and black beans. Navy beans were unharvestable due to poor establishment.

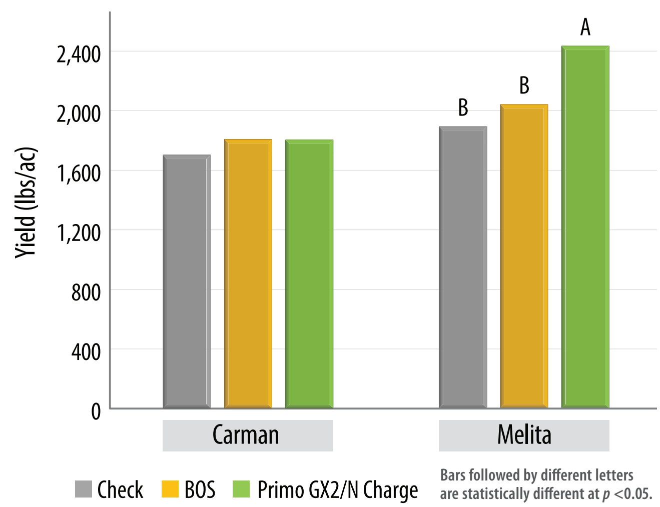
At Carman and Melita in 2020 and 2021, inoculant products had the same effect across all three bean market classes, indicating that specificity among market classes is not an issue for inoculant products. Among market classes, 77-80% of bean plants developed N-fixing nodules. On average, the granular Primo GX2/N Charge inoculant resulted in more nodulated plants than the check and was similar to the BOS product.

At Carman in 2020 and 2021, nodulation scores were relatively low (1.2 on a scale of 0-4), which may be due to the site's low soil pH (≤6.0 in 0-6" depth). At this location, nodulation score and yield were the same for all treatments.

At Melita in 2020 and 2021, however, the Primo GX2/N Charge inoculant resulted in significantly greater nodulation scores (3.2) than both the BOS inoculant (2.7) and the untreated check (1.6), which were similar to one another. This in turn resulted in a significantly greater yield for beans treated with Primo GX2/N Charge inoculant, which improved yield by 543 lbs/ac (29% more than the check).

This research is continuing to test more dry bean inoculant options for Canadian farmers as products become available. Results from this research are being reviewed in conjunction with N fertility trials to update N management recommendations for dry beans in Manitoba.

Figure 1. Pinto, navy and black bean yield (lbs/ac) response to inoculant at Carman and Melita (2020 and 2021).



PRINCIPAL INVESTIGATOR Kristen P. MacMillan, University of Manitoba

DURATION 3 years

MPSG INVESTMENT $140,000

Optimizing Nitrogen Rates for Pinto and Navy Beans

Dry bean yield matched maximum yield at the lowest rate of N fertilizer applied which was 35 lbs N/ac and equivalent to 60-90 lbs total N/ac as a combination of fertilizer and soil residual-N. However, the economic optimum scenario was not applying N fertilizer at all.

DRY BEANS ARE relatively poor nitrogen (N) fixers, producing less than 45% of their N requirement, on average, through biological N fixation. Currently, commercial inoculants are not easily accessed nor commonly applied. As a result, dry beans are typically fertilized like a non-legume crop. Application of N fertilizer at a rate of 70 lbs N/ac is common practice, though recommendations vary by region.

Nitrogen uptake rates in dry beans range from 3.9-4.7 lbs N required per cwt of seed, meaning a 2,000 lb/ac dry bean crop would require 78-90 lbs N/ac. This nitrogen may be derived from a combination of residual soil N, biological N fixation and N fertilizer. This experiment evaluated N fertilizer rates while a follow-up companion study has been evaluating inoculant options.

Five rates of N fertilizer (0, 35, 70, 105 and 140 lbs N/ac) were compared in Windbreaker pinto beans and T9905 navy beans at Carman and Portage la Prairie from 2017 to 2019. Nitrogen was applied as spring broadcasted urea and incorporated prior to planting dry beans. Non-inoculated dry beans were planted on 15-inch rows into tilled wheat stubble. Residual N levels among site-years ranged from 23-56 lbs N/ac (0-24” depth).

The 2017 to 2019 growing seasons were dry and warm. This lack of soil moisture may have influenced N dynamics throughout this study, reducing mineralization, inhibiting nodule development and promoting root exploration to access deep N (>24”).

Nodulation was low overall, which is not surprising since beans were not inoculated, and sites did not have recent dry bean history. At flowering, dry bean nodulation was evaluated on a scale of 0-4, with 4 being >20 nodules per plant and 0 being no nodules present. Pinto beans had slightly greater nodulation than navy beans (0.6 vs. 0.4). Nodule development in this study is a result of native rhizobia populations since beans were not inoculated. As N fertilizer rate increased, dry bean nodulation score decreased.

Yield response to nitrogen rate did not vary with market class. Dry bean yield was only significantly increased over the 0 N control at the greatest rate of 140 lbs N/ac, which boosted yield by 17% (Figure 1). The yields of the other N rates were no different from the control. However, yield was maximized at the lowest rate of N applied (35 lbs N/ac), which was equivalent to 60-90 lbs of total N/ac (as a combination of N applied and soil residual N).

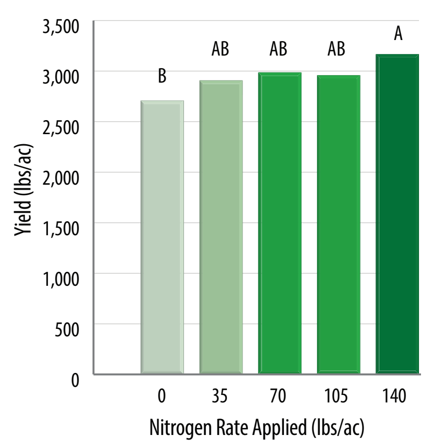
Which N rate was the most economical? Across multiple N cost and bean pricing scenarios, the return on investment was statistically similar for all rates of N application. This indicates that the economic optimum practice in these experiments was not applying N at all.

Yield from the 0 N control was exceptional, averaging 2700 lbs/ac and resulting in 83% of maximum yield. Total N uptake in the 0 N control was estimated to be 64-169 lbs N/ac. Residual soil N would have only provided 23-56 lbs N/ac, resulting in a deficit of 8-131 lbs N/ac. Soil samples were taken post-harvest and found residual N levels in the 0 N control ranging from 20-60 lbs N/ac. This post-harvest surplus indicates N requirements of dry beans were met through a combination of biological N fixation, mineralization and accessing deep nitrogen sources.

Emerging guidelines from this research suggest that full fertilization to meet N requirements may not be necessary in Manitoba and that biological N fixation is contributing to the N requirements of dry bean. In this study, non-fertilized, non-inoculated beans resulted in 83% of maximum yield. Applying the highest rate of N maximized yield but was not economical. Applying N fertilizer at a rate of 35 lbs/ac or to reach 70 lbs/ac of total N (including soil residual N) matched maximum yield without reducing nodulation.

Results from this research are being reviewed in conjunction with inoculant evaluation research and on-farm N fertility trials to revisit N management recommendations for dry beans in Manitoba. Future work will measure biological N fixation in current varieties.

Figure 1. Dry bean yield (lbs/ac) response to nitrogen rate (lbs/ac) at Carman and Portage (2017-2019) averaged across pinto and navy bean market classes.



Bars followed by different letters are statistically different at $p < 0.05$.

PRINCIPAL INVESTIGATOR Kristen P. MacMillan, University of Manitoba

MPSG INVESTMENT $77,000

CO-FUNDERS Growing Forward II

DURATION 3 years

On-Farm Evaluation of Nitrogen Rates in Dry Beans

on-farm network
PARTICIPATORY • PRECISE • PROACTIVE

Not applying nitrogen was the economical decision at four out of five on-farm trials. Dry bean nodulation was excellent in these on-farm trials even though inoculant was not applied.

AS APPLIED SMALL-PLOT research was investigating optimum nitrogen (N) rates, complementary on-farm trials were established to determine the effects of different N fertilizer rates on dry bean nodulation and yield at the field-scale.

From 2019 to 2021, MPSG's On-Farm Network conducted five trials testing a range of N fertilizer rates in non-inoculated dry bean fields. The selected fertilizer rates were specific to each farm, ranging from 0-140 lbs N/ac (Table 1). Residual soil nitrate-N levels ranged from 20-70 lbs N/ac.

At flowering, nodulation was scored on a rating scale where 0 = no nodules, 1 = ≤5 nodules/plant, 2 = 6-10 nodules/plant, 3 = 11-20 nodules/plant and 4 = >20 nodules/plant. Dry beans in these trials were not inoculated, yet they had good to excellent nodulation ratings (>3.5) at all locations where ratings were collected.

Even though inoculation is not common practice for dry beans in Manitoba, native soil rhizobia populations appear to be associating effectively with dry beans. This leads us to question how much biologically fixed N is contributing to dry bean N nutrition. Similar to results from the small-plot research, as the applied N rate increased, nodulation scores decreased by 0.5-2 points in on-farm trials.

Three of the five on-farm trials did not produce a yield response to increasing N rate (Figure 1). At one trial in 2020, yield was reduced at the greatest N rate (105 lbs N/ac applied) which has been attributed to prolonged vegetative growth and delayed maturity. In these four on-farm trials, the most economical decision was to not apply additional N.

In 2021, however, there was a significant yield increase of 151 lbs/ac with 70 lbs N/ac applied compared to the 0 N control. This yield response is economical if the cost of N is less than $1.00/lb and bean prices are more than 50 cents/lb. Nitrate in the top 12" was stable over the growing season at this trial, indicating that there may have been a limited contribution of mineralized-N to dry bean N nutrition. July rainfall was 7% of normal at this location and was expected to have reduced the contribution of mineralized-N, leading to a positive yield response to fertilizer-N.

Farmers are encouraged to dig up their dry bean roots at flowering to evaluate nodulation in their fields. Identifying if nodules are present and actively fixing N (indicated by a pink/red colour inside the nodule) is the first step in making future N management decisions.

Table 1. Descriptions of the five On-Farm Network trials investigating nitrogen fertilizer rates in dry beans.

	2019		2020		2021
R.M.	Norfolk Treherne	Rhineland	Boissevain Morton	Norfolk Treherne	Norfolk Treherne
Variety	T9905	Windbreaker	CDC Blackstrap	Vibrant	Vibrant
Nitrogen rates tested (lbs N/ac)	0, 70, 140	0, 40, 70, 140	40, 70, 100	0, 35, 70, 105	0, 35, 70
Residual nitrate-N (0-24") (lbs N/ac)	20	58	n/a	34	70
Nodulation score in 0 N check strips (0-4 scale)	3.5	3.9	n/a	3.6	4.0
Yield response to fertilizer rate?	No	No	No	Yes, decrease	Yes, increase

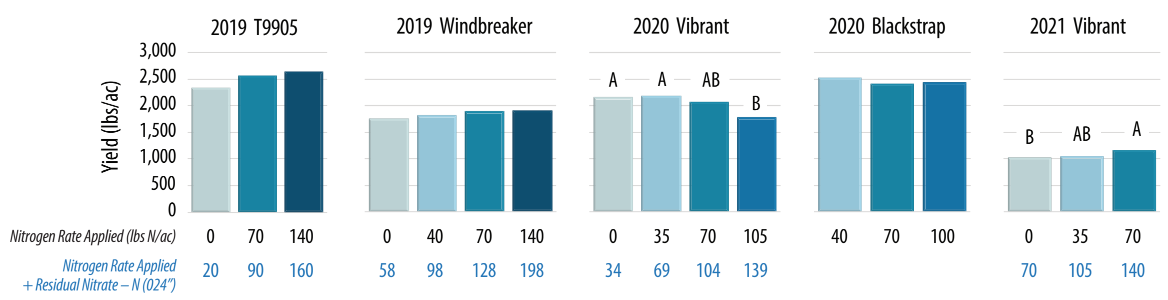


Figure 1. Dry bean yield response to nitrogen fertilizer rates at five On-Farm Network trials.

Within each on-farm trial, bars with different letters are statistically different at $p < 0.05$.

PRINCIPAL INVESTIGATOR Manitoba Pulse & Soybean Growers On-Farm Network

MPSG INVESTMENT $23,930

CO-FUNDERS Canadian Agricultural Partnership

DURATION 3 years

Preceding Crop and Residue Management Effects on Dry Beans

Pinto beans can be grown successfully following a range of crops (wheat, corn, canola or dry beans) and under direct seed conditions in Manitoba with no penalties to plant stand nor yield.

CROP SEQUENCE WITHIN a rotation can influence yield through various agronomic factors, such as nutrient cycling, residue, soil moisture and pest pressure. Farmers in Manitoba seed dry beans most commonly following wheat > corn > canola > dry beans and oats.

According to MASC data from 2011 to 2020, 23% of navy bean acres were planted into spring wheat stubble, 29% into canola stubble, 10% into navy bean stubble and 15% into corn stubble, and relative navy bean yield produced by those previous crop types was 111%, 89%, 91% and 111%, respectively. There is currently no research data available for Manitoba on the effect of preceding crop and residue management on dry bean yield and productivity. The objective of these experiments was to determine the effect of preceding crop type and residue management on dry bean production.

From 2017 to 2020, experiments were established at Carman and Portage la Prairie on land that had not seen dry beans in at least five years. Windbreaker pinto beans were planted into four crop residues (wheat, canola, corn and pinto beans) that had been split into tilled and direct seed treatments.

Preceding crop did not affect pinto bean yield in these experiments, with bean yield ranging from 2908–3041 lbs/ac among preceding crop type, suggesting that there is flexibility in where to place dry beans in a crop rotation. In two out of six site-years, at Carman in 2018 and 2019, direct-seeded pintos yielded 10–17% greater than those seeded into tilled stubble (Figure 1). Pinto beans at Carman may have benefitted from some moisture conservation associated with direct seeding as the soil texture at that site is lighter.

Overall, pinto beans seeded into tilled residue resulted in a slightly higher plant population (74,000 plants/ac) than direct-seeded beans (70,000 plants/ac). Pinto beans seeded into canola stubble (76,000 plants/ac) resulted in a higher plant population than corn stubble (68,000 plants/ac) overall, but the trend was not consistent among environments. All plant populations were near the target plant stand of 70,000 plants/ac. An important finding is that bean plant stands following corn were similar in both direct seed and tilled treatments since corn residue management can be challenging. Seeding equipment varied by environment, but all sites used double- or single-disc openers and seeding took place between the preceding corn rows to avoid root balls. Minimal hair pinning occurred in corn stubble but was sometimes a problem where wheat residue was not standing or well distributed.

Crop residue and tillage treatments influenced grassy weed control. Grass weed density was lower when beans followed corn (13 plants/ft^2) compared to beans following wheat (47 plants/ft^2). In all preceding crop types, grass weed density was lower in direct seeded pintos (24 plants/ft^2) compared to pinto beans seeded into tilled residue (43 plants/ft^2). In fields where grassy weeds are a problem, especially herbicide-resistant populations, consideration of where pinto beans occur in rotation and how residue is managed can help reduce weed competition and selection pressure.

Root rot severity was the greatest in pinto beans following pinto beans and lowest in beans following corn. Environment accounted for the greatest range in root rot severity. Fields with a long history of bean production or fields prone to wetness are likely to see more significant effects of root rot. It is possible that the dry growing season conditions (39–69% normal precipitation) and lack of dry bean field history resulted in lower disease levels. White mould was not a yield-limiting factor in these experiments.

Throughout this study, dry conditions were favourable for yield and highlighted the resilience of pinto beans to direct seed conditions when residue management and seeding equipment facilitate good crop establishment.

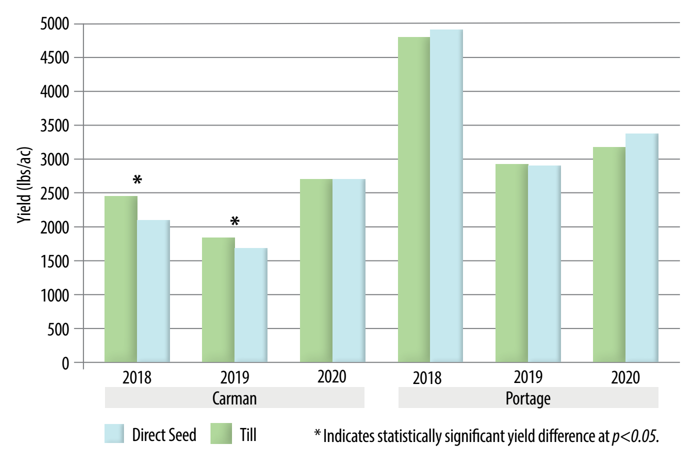


Figure 1. Average pinto bean yield (lbs/ac) by tillage system at Carman and Portage la Prairie, MB from 2018–2020 (n=48).

PRINCIPAL INVESTIGATOR Kristen P. MacMillan, University of Manitoba

MPSG INVESTMENT $121,800

CO-FUNDER Growing Forward 2

DURATION 4 years

Growth and Development of Dry Bean and Yellow Pea in Manitoba

Ishan Samaranayake, Brodie Erb and Kristen P. MacMillan
Soybean and Pulse Agronomy Research Lab @kpmacmillanUM
Department of Plant Science, University of Manitoba

Overview

- First characterization of dry bean and yellow pea phenology in Manitoba.
- In dry bean, a new node is developed every 3-4 days from VC through to R1. Navy bean generally reaches reproductive stages 2-6 days after pinto bean. At R1, pinto bean has 7-10 nodes and navy bean has 5-10 nodes.
- In pea, two key developmental stages that coincide with scouting and management decisions are V4-5 (herbicide) and R2 (fungicide). On average, these stages occur 26 and 50 days after seeding, respectively.
- The average and range of days after seeding is presented since cultivar, environment and agronomic practices can affect phenology.

Data Collection

- From the control plots of our applied dry bean and pea agronomy studies, the growth stage of dry beans and yellow peas was recorded every 3-7 days beginning at emergence.
- Data was collected from 6 site-years for dry beans (Carman and Melita 2020-2022) and 11 site-years for peas (Carman and Arborg 2018-2022)
- Varieties sometimes varied by site-year. The pinto bean variety was Windbreaker (2020) or Vibrant (2021 and 2022) and the navy bean variety was T9905. These dry bean varieties are upright vines, indeterminate. Yellow pea varieties were AAC Carver, CDC Amarillo and AAC Chrome.
- The average days and accumulated growing degree days (GDD) from seeding are the average of at least 3 site-years (not all growth stages were captured in each site-year).

Acknowledgements

Core funding for the soybean and pulse agronomy research program is provided by Manitoba soybean, dry bean and pea farmers through the Manitoba Pulse & Soybean Growers.

DRY BEAN (*Phaseolus vulgaris*)

		VC	V2-3	V4-5	V8	R1	R2	R3	R4	R5	R6	R7	R8	R9
		Unifoliate	Unrolled trifoliate leaves			Beginning bloom	Beginning pod	50% bloom	Full pod	Beginning seed	50% seed	Full seed	Beginning maturity	Full maturity
Pinto bean	Days after seeding	**14**	**25**	**32**	**43**	**47**	**51**	**55**	**61**	**63**	**69**	**77**	**80**	**89**
		(10-17)	(17-31)	(24-35)	(38-49)	(42-50)	(47-55)	(51-59)	(55-66)	(56-70)	(62-73)	(70-86)	(77-83)	(84-97)
	GDD	177	336	419	547	651	739	809	861	920	940	1079	1151	1265
Navy bean	Days after seeding	**14**	**24**	**33**	**45**	**52**	**55**	**61**	**63**	**65**	**75**	**76**	**83**	**93**
		(10-17)	(19-28)	(28-35)	(42-49)	(45-56)	(47-62)	(55-66)	(56-70)	(59-73)	(69-78)	(70-83)	(77-90)	(85-104)
	GDD	177	306	429	615	718	825	862	920	928	1056	1094	1209	1337

YELLOW PEA (*Pisum sativum L.*)

	V2-3	V4-5	V8	R1	R2	R3	R4	R5	R6	R7	Harvest
	Node development			Flower bud	Beginning bloom	Flat pod	Full pod	Beginning maturity	Mid maturity	Full maturity	
Days after seeding	**20**	**26**	**37**	**43**	**50**	**55**	**67**	**71**	**80**	**86**	**99**
(range)	(17-21)	(20-34)	(27-46)	(39-46)	(41-56)	(48-64)	(61-72)	(62-77)	(73-90)	(78-97)	(86-133)
Accumulated growing degree days from seeding	214	274	405	543	629	692	856	930	1052	1133	

For complete descriptions of growth stages, refer to the Manitoba Pulse & Soybean Growers "Dry bean growth staging guide" and the "Field pea growth staging guide", available at www.manitobapulse.ca
Growing degree day data accessed from Manitoba Agriculture weather stations (https://web43.gov.mb.ca/climate/DailyReport.aspx) and plant development illustrations created with BioRender.com

Pea Response to Preceding Crop, Residue Management and P Fertilizer

(Carman and Roblin, MB • 2020-2024)

Introduction

Opportunities for pea production in Manitoba are expanding with initiatives and investments such as Protein Industries Canada, the Protein Highway and the Manitoba Protein Advantage. Several new pea protein facilities have been built in Manitoba to source yellow peas from Manitoba farmers. It is our mission to support these opportunities by conducting pea agronomy research that will develop best management practices to improve the productivity and profitability of pea production in Manitoba.

This experiment will test three management practices: crop sequence, residue management and phosphorus (P) fertilizer use and placement. We will compare peas seeded into tilled vs. direct seed wheat and canola stubble, and within each of those residue-tillage combinations, we will compare side-band P, seed-placed P and no starter P.

Currently, those management practices vary widely among farmers and there is no local research informing us on how they affect pea yield, quality and profitability. In Manitoba, most commonly peas are grown in rotation on wheat (30%) and canola (35%) stubble and phosphorous is applied to approximately 83% of pea acres, most frequently as monoammonium phosphate (88%) applied at the time of planting (Stratus Ag Research 2015). Seed-placed (51%) and side or mid-row banding (47%) applications are the most common phosphorus placements with growers applying an average of 23 lb. P_2O_5/ac. Decisions on phosphorus fertilizer rate are often based on historically used rates (56%), calculations based on nutrient balance (24.6%) and soil test results (27%).

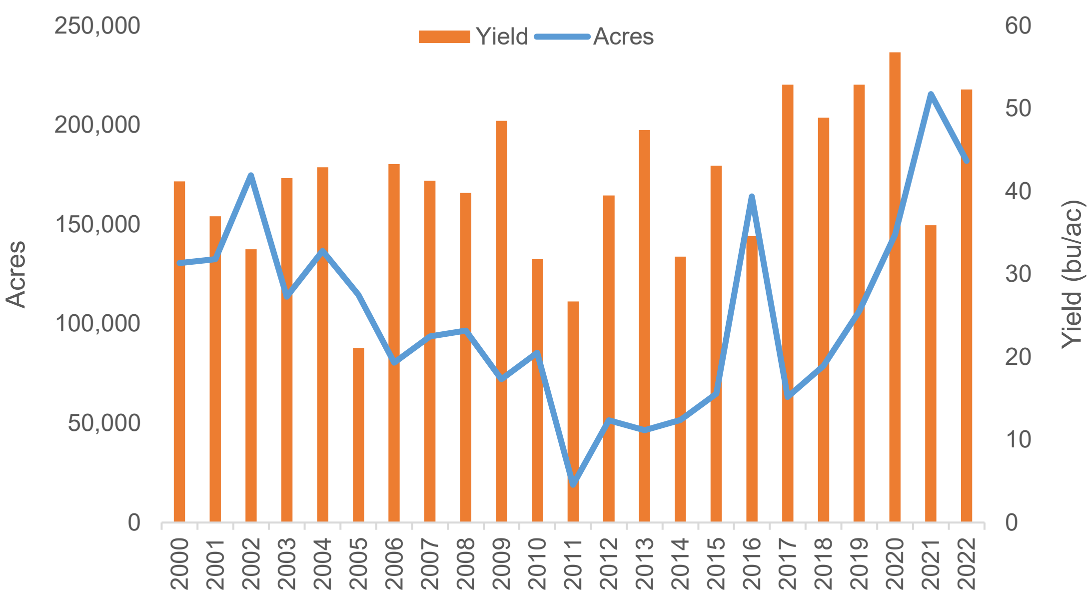


Figure 1. Yellow pea cultivated acres and yield in Manitoba from 2000-2022 (MASC 2023). Since 2011, pea acreage in Manitoba has trended upwards.

Experimental Design

The experiment is a three-way multifactorial arranged in a RCBD design with four replicates at two Manitoba locations: Carman and Roblin, MB. The treatment list is as follows:

Trt	Residue Type	Residue Management	P Fertility Strategy
1	Wheat stubble	Tilled	None
2	Wheat stubble	Tilled	Seed-placed
3	Wheat stubble	Tilled	Side-banded
4	Wheat stubble	Direct seed	None
5	Wheat stubble	Direct seed	Seed-placed
6	Wheat stubble	Direct seed	Side-banded
7	Canola stubble	Tilled	None
8	Canola stubble	Tilled	Seed-placed
9	Canola stubble	Tilled	Side-banded
10	Canola stubble	Direct seed	None
11	Canola stubble	Direct seed	Seed-placed
12	Canola stubble	Direct seed	Side-banded

Materials and Methods

A two-year study is being conducted in Carman, MB and Roblin, MB from 2020-21, 2021-2022 and 2022-2023 for a total of 6 site-years. The preceding crops, wheat and canola, were seeded in year one of the experiment and managed according to best current practices. Tillage was performed using a rototiller in the tilled treatments after harvest in either the fall or spring prior to pea planting in year two. In year two, AAC Carver field peas were seeded at 400,000 seeds/ac (99 seeds/m^2) into each preceding crop-residue management treatments between May 1 and May 16 on 7.5” (Carman) or 9” (Roblin) row spacing. Three different phosphorus (P) fertilizer application strategies were implemented amongst the crop-residue management treatments resulting in twelve total treatments. Phosphorous fertilizer strategies included none, 20 lbs P_2O_5/ac starter P as monoammonium phosphate (MAP) into the seed row, and applying 20 lbs P_2O_5/ac starter P as MAP in a side-banded configuration approx. 2” away from the seed. All site-years managed weeds using a pre-seed herbicide application followed by one or two in-crop herbicide applications (Table 1 and 2). In 2022, fungicide applications were made at R2 at both trial locations using Headline EC (pyraclostrobin Grp 11) to control Mycosphaerella/Ascochyta blight complexes. Insecticide was applied in Carman and Roblin 2022 at R2 to control pea aphids that had reached economic thresholds using Movento (spirotetramat) and Lagon 480E (dimethoate) respectively. Field pea harvest occurred between August 3 and August 22 using a Wintersteiger plot combine. Growing season mean daily temperature was above the long-term average in Carman for both years and below the long-term average in Roblin for both years. In Carman, growing season precipitation was lower than the long-term average for both years. In Roblin, growing season precipitation was lower than average in 2021 and higher in 2022 (Table 3).

Table 1. Soil characteristics, applied fertilizer and weed control for Carman 2021 & 2022.

	Carman 2021				Carman 2022			
	Wheat, tilled	**Wheat, direct**	**Canola, tilled**	**Canola, direct**	**Wheat, tilled**	**Wheat, direct**	**Canola, tilled**	**Canola, direct**
Nitrate-N (0-24”, lbs/ac)	55	74	77	96	20	28	18	34
P2O5-P (0-6”, ppm)	10	8	13	10	14	13	11	12
K2O (0-6”, ppm)	220	188	236	205	255	272	274	278
S2O4 (0-24”, lbs/ac)	30	30	46	41	36	30	33	29
Soil OM %	3.4	3.4	3.2	3.5	5.1	5.1	5.0	3.9
Soil pH (0-6”, 6-24”)	5.3, 7.3	5.3, 7.4	5.2, 6.8	5.2, 7.2	5.6, 6.0	5.4, 6.2	5.4, 6.2	5.5, 6.2
Soluble Salts (0-6”, 6-24”, mmho/cm)	0.2, 0.2	0.1, 0.3	0.2, 0.2	0.2, 0.3	0.2, 0.2	0.1, 0.2	0.1, 0.2	0.1, 0.2
Soil Series & Texture	Rignold sandy clay loam and Deadhorse clay loam				Rignold sandy clay loam			
P Fertilizer	20 lbs P_2O_5/ac on P treatments applied as MAP							
Weed Control	Heat Complete (saflufenacil grp 14, pyroxasulfone grp 15, and glyphosate grp 9) pre-seed, Odyssey Ultra NXT (imazamox grp 2, imazethapyr grp 2, and sethoxydim grp 1) in-crop							

Table 2. Soil characteristics, applied fertilizer and weed control for Roblin 2021 and 2022.

	Roblin 2021				Roblin 2022			
	Wheat, tilled	**Wheat, direct**	**Canola, tilled**	**Canola, direct**	**Wheat, tilled**	**Wheat, direct**	**Canola, tilled**	**Canola, direct**
Nitrate-N (0-24”, lbs/ac)	Not available				227	227	161	140
P2O5-P (0-6”, ppm)					37	39	37	39
K2O (0-6”, ppm)					510	523	489	622
S2O4 (0-24”, lbs/ac)					164	169	208	151
Soil OM %					6.4	6.1	6.5	6.7
Soil pH (0-6”, 6-24”)					7.6, 7.9	7.6, 8.0	7.6, 7.8	7.6, 7.8
Soluble Salts (0-6”, 6-24”, mmho/cm)					0.4, 0.7	0.5, 0.8	0.5, 0.7	0.4, 0.5
Soil Texture					Erickson Series, clay loam			
P Fertilizer	20 lb/ac on P treatments applied as MAP							
Weed Control	Authority 480 (sulfentrazone grp 14) pre-seed, Viper ADV (imazamox grp 2 and bentazon grp 6) in-crop							

Table 3. Summary of mean daily temperature and precipitation in Carman and Roblin (2021 and 2022).

	Mean daily temperature (°C)						Precipitation, mm					
Site	**May**	**June**	**July**	**Aug**	**M-A**		**May**	**June**	**July**	**Aug**	**M-A**	
Carman21	10.7	18.3	20.2	18.7	17.1	↑	27	103	17	78	226	↓
Carman22	10.9	17.6	19.2	19.3	16.8	↑	99	35	83	49	265	↓
LTA-Carman	11.6	17.2	19.4	18.5	16.7		70	96	79	75	319	
Roblin21	9.3	17.7	20.1	16.6	15.9	↓	50	62	37	83	233	↓
Roblin22	9.9	15.2	18.2	17.9	15.3	↓	132	77	111	25	345	↑
LTA-Roblin	9.3	21.4	24.1	23.5	19.6		53	83	72	66	273	

LTA = long term average (1981-2010), ↑ ↓ = +/- 10% of normal
Data sources: Manitoba Agriculture and Environment Canada

Results and Discussion

Statistical analyses of data from year 1 and year 2 of this 3-year study have not been conducted. General observations and trends are included here until the final year of data has been collected in 2023 followed by data analysis.

Figure 2. Pea plots at Carman22 on June 28, 2022 and July 7, 2022**.**

Plant Density

Plant counts were taken 4 to 5 weeks after planting at V5 to V6 pea plant staging. In Carman21 pea establishment was reduced following canola (55 plants/m^2) compared to wheat (82 plants/m^2) but was similar between residue management treatments (Figure 2). Canola residue also reduced plant establishment at Roblin21, though to a lesser degree.

Table 4. Plant population and establishment by site-year for phosphorus fertility treatments.

	Carman21 (plants/m^2)	**Carman22** (plants/ m^2)	**Roblin21** (plants/ m^2)	**Roblin22** (plants/ m^2)	**% est.**
No P fertilizer	71	81	87	86	71-87
Seed-placed P	69	74	78	88	69-88
Side-banded P	66	81	87	82	66-87

The current plant stand recommendation to optimize yield in Manitoba of 75-86 plants/m^2 (MPSG). Treatments generally were within 10% of this range, except for peas following canola at both sites in 2021 and peas that received P fertilizer at Carman21 (Table 4).

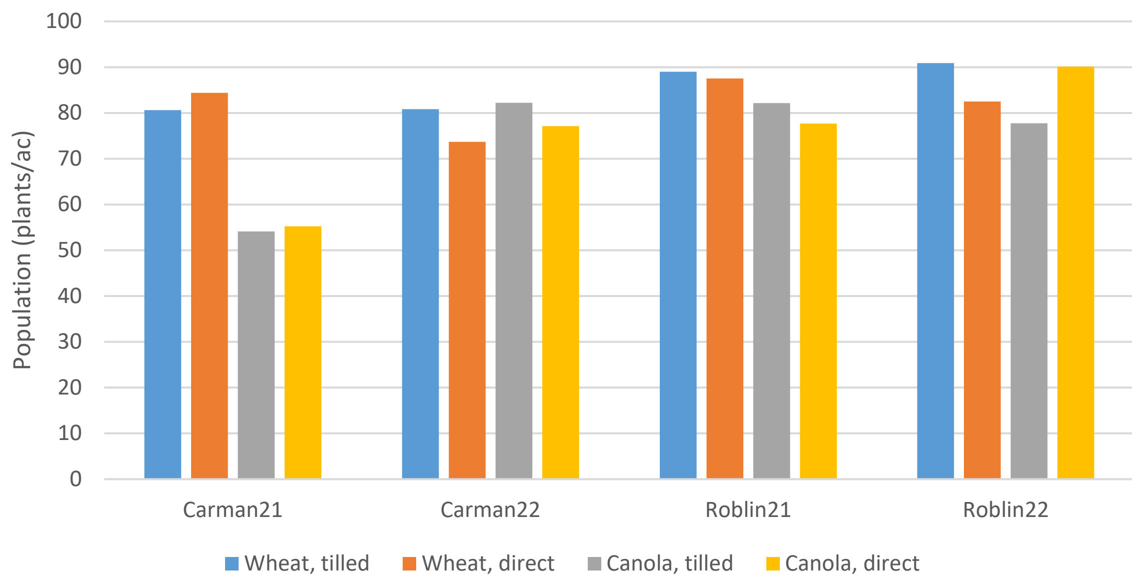


Figure 2. Plant population and percent establishment by site-year for crop-residue treatments.

Plant Biomass at R1

Plant biomass was taken at R1 at Carman21 (Figure 3) only and was 19% greater for peas in direct-seeded treatments compared to tilled.

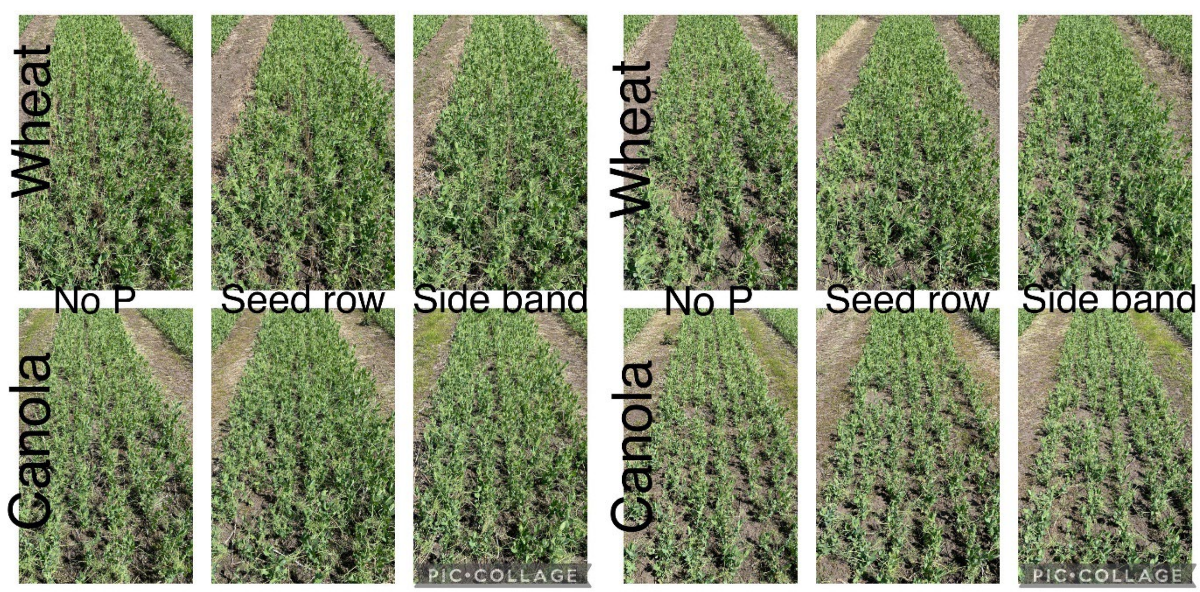


Figure 3. Visual differences in early season pea biomass between direct seed (L) and tilled treatments (R) and between wheat (top) and canola (bottom) stubble at Carman June 23, 2021.

Weed Community at In-Crop Herbicide Timing (V3-V5)

Weed communities were observed and surveyed prior to the first in-crop herbicide pass (June 1 to June 13). In Carman, there is suspected Group 1 & 2 resistant green and yellow foxtail as well as high weed seed banks in the soil. As such, it is the likely reason for more abundant overall weed counts in the Carman sites as well as greater grassy weed proportions within all treatments compared to Roblin. The most abundant weeds at the Carman sites include green foxtail, volunteer canola and wild buckwheat. At Roblin, wild oats, volunteer canola and lamb's quarters were most abundant. Weed density and proportion were observed to be variable amongst site-years. Weed populations were fully controlled after the initial herbicide pass for all site-years.

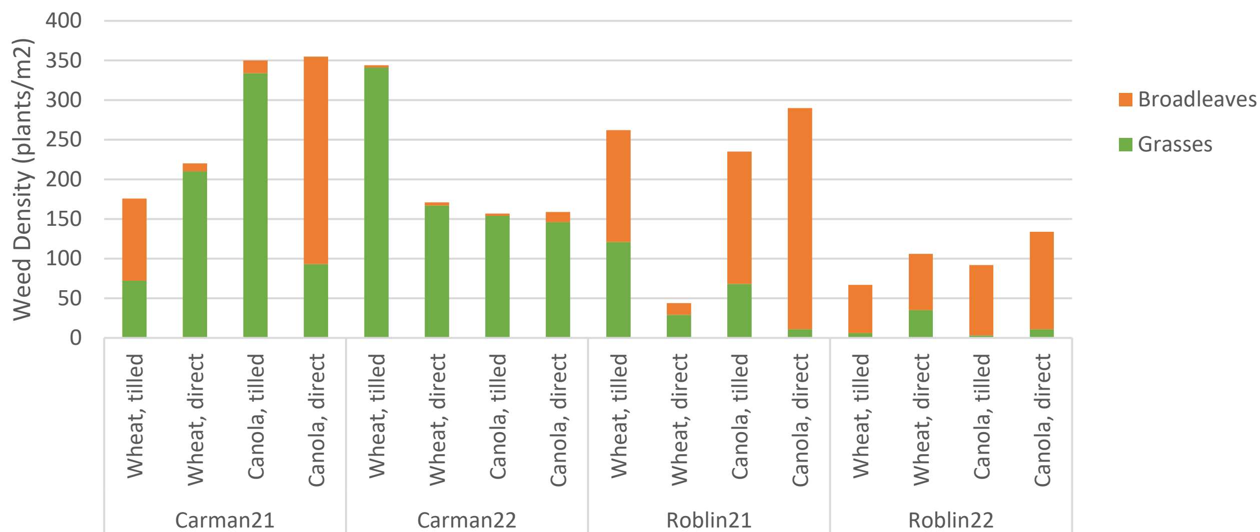


Figure 4. Grass and broadleaf weed density in each residue-tillage combination amongst all four site-years.

Root Rot Incidence and Severity (V4-V5)

Peas grown on canola residue had higher incidence and severity of root rot caused by *Fusarium sp.* in 2022 and overall we observed higher root rot severity in 2022 compared to 2021, likely due to more growing season precipitation. However, overall severity was relatively low for all site-years. No other treatment interactions were observed.

Table 5. Effect of preceding residue on root rot severity and incidence for each site-year.

	Wheat Residue		**Canola Residue**	
	Incidence (%)	**Severity** (1-7)	**Incidence** (%)	**Severity** (1-7)
Carman21	21	1.3	23	1.3
Carman22	86	2.9	88	3.1
Roblin21	1	1.0	1	1.0
Roblin22	37	1.4	48	1.6

Figure 5. Pea root rot symptoms in Carman22 on July 1, 2022 in rep 4. Top-left: wheat, tilled treatment (plot 411). Top-right: wheat, direct treatment (plot 401). Bottom-left: canola, tilled treatment (plot 403). Bottom-right: canola, direct treatment (plot 409).

Foliar Disease Incidence and Severity at R2

Mycosphaerella and Ascochyta blight complexes were observed and rated in field peas at R2 between June 30 and July 18. Disease ratings were similar among treatments in all site-years. Disease ratings were higher in 2022 (higher precipitation) but overall, very low across site-years. Ratings ranged from 1.3-1.9 on a scale of 1-7 (Table 6).

Table 6. Foliar disease incidence and severity for each site-year.

	Incidence (%)	**Severity** (1-7)
Carman21	34	1.3
Carman22	95	1.9
Roblin21	36	1.4
Roblin22	53	1.6

Days to Maturity (DTM)

No differences in days to maturity (R7) were observed between treatments for any site-years. However, the site-years varied widely. At Carman, peas matured 9-12 days earlier than Roblin and in 2022, peas matured 7-8 days later than 2021, likely due to higher growing season precipitation.

Table 7. Average days to maturity (DTM) of field pea for each site-year.

	DTM
Carman21	80
Carman22	87
Roblin21	91
Roblin22	99

Yield

Field pea yield response to preceding crop, residue management and P fertilizer strategy and their interactions varied by site-year. Statistical analysis will elucidate these effects. For now, a summary of observations within each site-year are described.

At Carman21, preceding crop residue influenced pea yield. Peas grown on canola stubble yielded 31 bu/ac compared to 45 bu/ac for peas grown on wheat stubble. In canola stubble, direct-seeded peas out-yielded peas in the tilled system. In wheat-tilled treatments, peas that had seed-placed P yielded 9-10 bu/ac higher than other P fertility strategies. This effect was also evident at Carman22, where seed-placed P also improved yield by 6-14 bu/ac in wheat-tilled treatments than other P fertility methods.

At Carman22, pea yields were higher overall, ranging from 58 to 72 bu/ac and the effects of stubble type, residue management, P fertilizer and their interactions were less clear.

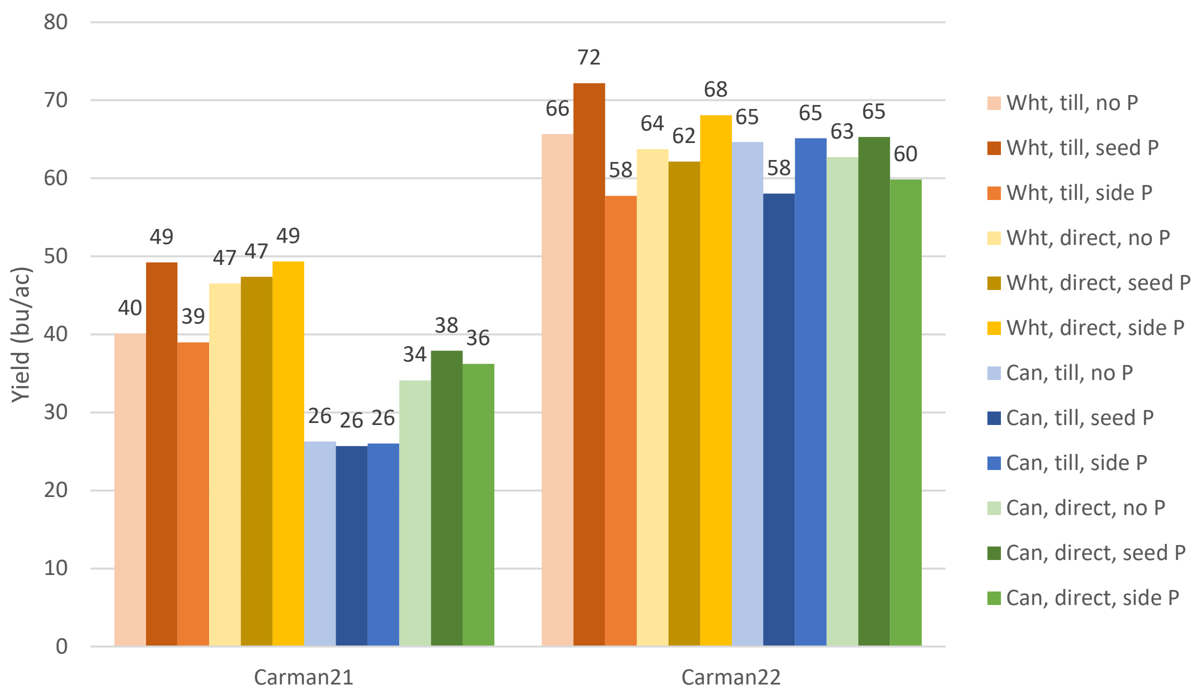


Figure 6. Pea grain yield at Carman21 and Carman22 by treatment.

At Roblin21, pea yielded 21-26 bu/ac overall. Interestingly, there may be a negative yield response to seed-placed P in tilled systems by about 2 bu/ac on average compared to side band or no P (Figure 7). In direct seed systems, however, pea yield was similar or increased with starter P application.

At Roblin22, tilled canola residue improved pea yield on average by approximately 11.5 bu/ac compared to direct seeded canola residue. In both tilled wheat and canola systems, pea yield responded favorably to side-band P application. In direct seeded wheat residue systems, pea yield decreased with either seed-placed or side-band P application by 12-15 bu/ac.

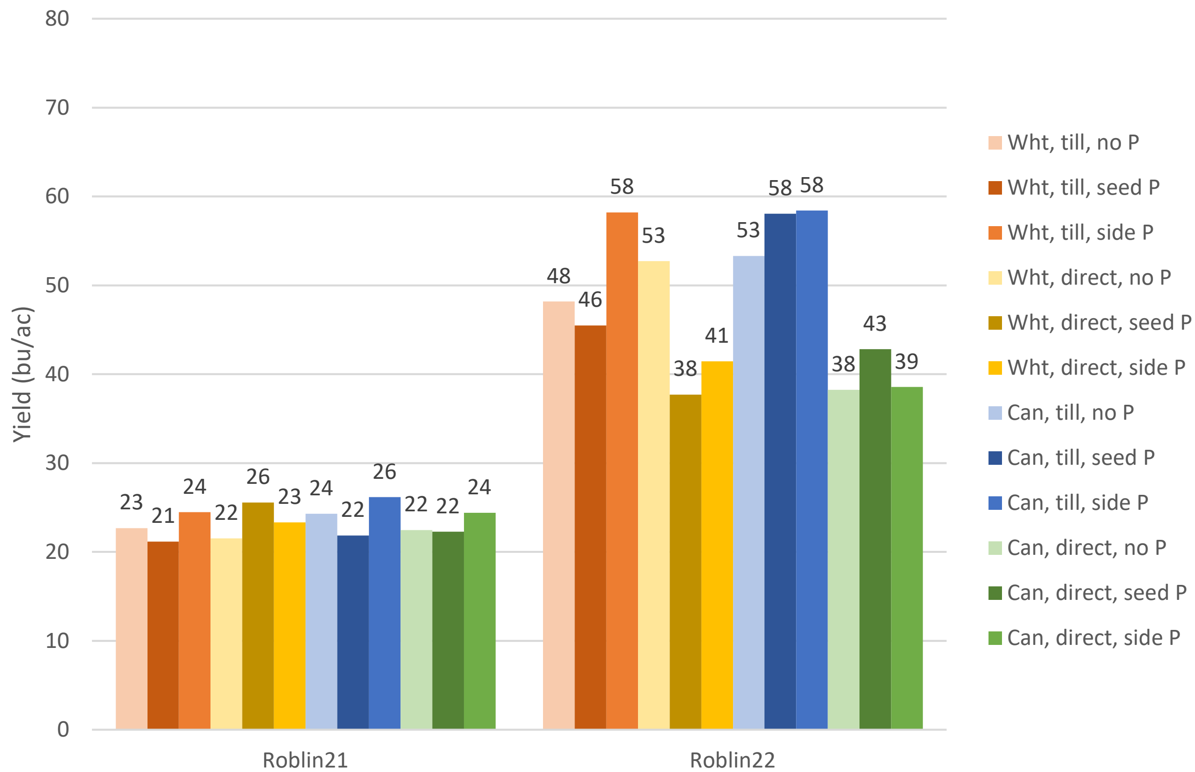


Figure 7. Pea grain yield at Roblin21 and Roblin22 by treatment.

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Effect of Yellow Pea Cropping Intensity on *Aphanomyces euteiches* and Crop Yield

(Carman, MB • 2021-continuing)

Objective

Determine the effect of crop rotation length on pea root rot caused by *Aphanomyces euteiches*, grain yield and cropping system productivity.

Materials and Methods

A ten-year study examining three crop rotation lengths (3, 5, and 7 years) plus control rotations without pea, was established at Carman, MB in 2021 on a sandy clay loam soil with no known pea history. The crop rotation is fully phased, meaning that each crop is present in each year as to minimize year-year variability and to allow for continuous data collection. Data from the 3-year rotation will be available in 2024, followed by the 5-year rotation in 2025 and the first full comparison of all three crop rotation lengths will occur in 2027. All crops are managed according to current best management practices. The experimental design is a randomized complete block with 4 replicates. Plot size is 24 m^2.

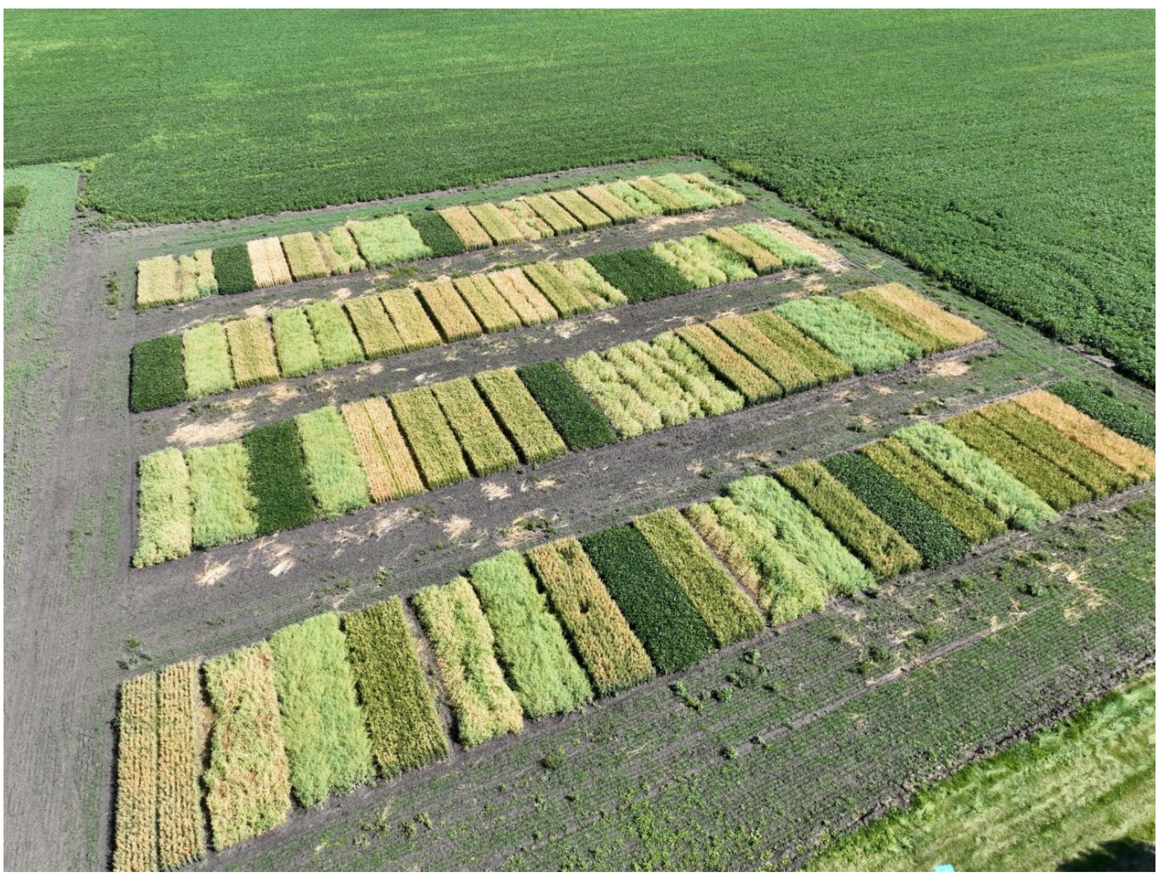

Figure 1. Long-term yellow pea crop rotation study comparing 3-, 5- and 7-year rotation intervals of yellow pea at Carman, MB on August 16, 2022. Rotation crops include wheat, canola, soybean and oats.

Table 1. Yield (bu/ac) of rotational crops in 2021 and 2022.

		Carman21		Carman22	
Treatment	**Phase**	**Crop**	**Yield** (bu/ac)	**Crop**	**Yield** (bu/ac)†
3 year	1	Wheat	43	Pea	54
	2	Pea	32	Canola	36
	3	Canola	12	Wheat	56
5 year	1	Wheat	41	Pea	50
	2	Pea	31	Canola	38
	3	Canola	14	Oat	138
	4	Oat	86	Soybean	58
	5	Soybean	19	Wheat	53
7 year	1	Wheat	37	Pea	54
	2	Pea	30	Canola	38
	3	Canola	16	Oat	143
	4	Oat	84	Soybean	61
	5	Soybean	18	Wheat	51
	6	Wheat	39	Canola	32
	7	Canola	14	Wheat	51
Control 1	Excludes peas	Soybean	22	Wheat	46
Control 2	Cereals only	Wheat	35	Barley	66
Average crop yield across treatments within year †		Wheat	39	Wheat	51
		Pea	29	Pea	52
		Canola	14	Canola	36
		Oat	85	Oat	140
		Soybean	19	Soybean	60

† Long-term average crop yields in the Dufferin municipality: 50.1 bu/ac wheat, 24.6 bu/ac peas, 36.7 bu/ac canola, 34.9 bu/ac soybean, 98.7 bu/ac oats and 65.8 bu/ac barley (MASC, 1993-2022).

Preliminary results and discussion

We do not expect to see differences in pea productivity among crop rotation treatments until year 4 (2024) when the 3 yr. crop rotation will be repeated for the first time. Pea yields were below average in 2021 following drought and above average in 2022 (Fig. 2). Pea root rot ratings were low in both years of study, ranging from 1.0 to 1.4 on a scale of 1-7 (Fig. 3). The field that the experiment has been established on has not grown peas in at least the previous 10 years. Comparatively, in annual field surveys conducted by Agriculture and Agri-Food Canada and the Manitoba Pulse & Soybean Growers, the mean severity of root rot has ranged from 2.9 to 4.2 on a scale of 0-9 from 2018-2022. Soil and root samples are submitted each year to Dr. Syama Chatterton at AAFC Lethbridge for detection and quantification of *Aphanomyces* pathogen levels using DNA extractions. Root and soil samples from 2021 and 2022 were negative for *Aphanomyces euteiches*.

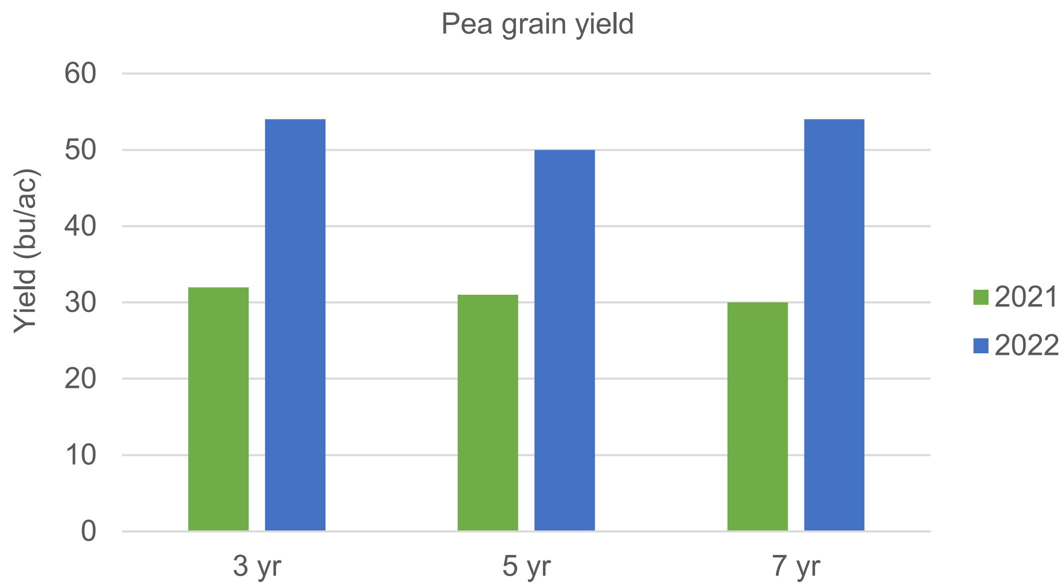

Figure 2. Effect of crop rotation length on pea grain yield in year 1 and 2 of the study. No effect observed since crop rotations treatments will not take effect until year 4 (2024).

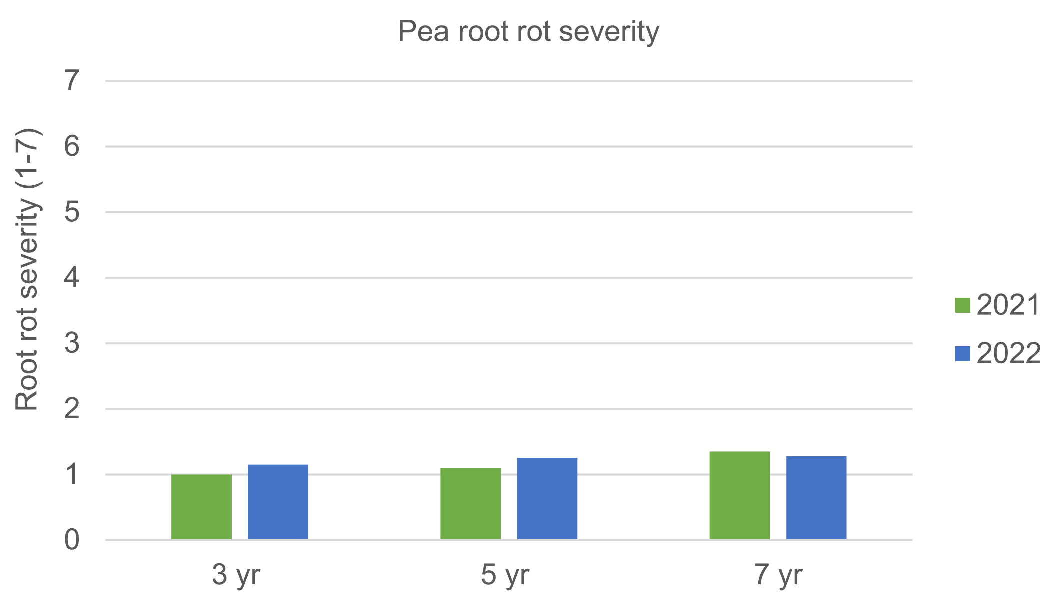

Figure 3. Effect of crop rotation length on pea root rot severity in year 1 and 2 of the study. No effect observed since crop rotations treatments will not take effect until year 4 (2024).

Intercropping with Soybeans and Peas in the Interlake

(Arborg, MB • 2021)

Intercropping is the practice of seeding, growing and harvesting 2 or more crops together. The concept is to utilize crop combinations that complement one another through mechanisms such as resource use efficiency, potentially resulting in over-yielding and greater profitability compared to monocropping. Careful consideration needs to be given to how the crops are seeded, managed, harvested and separated. The most common intercrop grown commercially in Manitoba is pea-canola. Beginning in 2019, we started to test pea-canola, soybean-flax, pea-flax and pea-oat intercrop combinations at Arborg, MB. For each intercrop combination, 2-3 seeding rate ratios were tested and compared to pea, soybean, canola, flax and oat monocrops.

To assess the productivity of intercrops compared to their component crops grown in monoculture, the land equivalent ratio (LER) is used. LER is a ratio of the individual crop yields from the intercrop divided by the respective monocrop yield. It is desirable to achieve a LER > 1 which indicates over-yielding (more land would be required to produce the same yield with individual monocrops compared to the intercrop). Gross and marginal revenues are also calculated because seasonal growing conditions and market prices are important variables that affect the productivity, yield and economic return of cropping in a given year.

Objectives

1. Gain experience in intercropping: observe and evaluate agronomic performance of intercropping compared to monocrops.
2. Evaluate yield, land equivalent ratio (LER) and profitability of intercropping compared to monocrops.
3. Overall, start a knowledge base on if and how intercrops can be utilized in cropping systems in the Interlake and Manitoba.

Materials and Methods

The intercropping trial was seeded into tilled wheat residue on May 12, 2021 at Arborg, MB with a plot seeder on 9" row spacing. All intercrops were seeded in the same, mixed row except soybean-flax where soybean was seeded down the mid-row fertilizer tube to achieve row separation (4.5"). Soil type at the research site is a heavy clay (Fyala series) and background soil test levels were 122 lbs N/ac and 32 ppm P_20_5. Specific agronomic practices used for each intercrop treatment are listed in Tables 2 and 3.

Table 1. Seasonal growing degree days, crop heat units, precipitation, and temperature at Arborg in 2021.

	May	June	July	August	May-August
Growing degree days*	163 (80%)	412 (122%)	502 (116%)	397 (103%)	1475 (108%)
Crop heat units*	298 (81%)	626 (110%)	739 (104%)	618 (96%)	2282 (100%)
Precipitation, mm*	19 (36%)	39 (51%)	11 (20%)	116 (147%)	186 (69%)
Mean daily temperature, °C†	9.5 (10.0)	18.7 (15.8)	21.2 (18.6)	17.8 (17.5)	16.8 (15.5)

*% of normal at Arborg
†Long-term average daily temperature in Arborg (climate.weather.gc.ca, 1981-2010)
Sources: https://web43.gov.mb.ca/climate/SeasonalReport.aspx

Project funding provided by Prairies East Sustainable Agriculture Initiative

PESAI

Summary

This was the third year of experimenting with intercropping in the Interlake region of Manitoba. Treatments included three seeding rate combinations of pea-canola, soybean-flax, pea-flax and pea-oat compared to pea, canola, flax, soybean and oat monocrops. Results of the 2021 experiment including treatment descriptions, agronomic practices, yield, gross and marginal revenues and general observations are listed in Table 2 and 3. The pea-oat intercrop was sampled for total dry matter and forage nutrient analysis (Table 4). The 2021 growing season at Arborg was exceptionally dry with 69% of normal growing season precipitation (Table 1) compared to 70% of normal precipitation in 2020 with only 36% of normal growing precipitation occurring in the months of May through July. During this period, the drought assessment in the Bifrost-Riverton municipality was classified as D4 giving it a 50+ year event distinction. Drought compounded with high grasshopper pressure to all treatments throughout the months of June and July resulted in crop failure and mostly negative marginal revenues (Fig. 2). Due to low crop yields overall, LER values are inflated. We plan to continue testing intercrops in 2022 with supplemental irrigation to allow for evaluation under normal precipitation. A synopsis of the 2019 and 2020 results is available in our 2019-2020 annual report. Across 3 years of study, pea-canola intercrop has been the most consistent over-yielder.

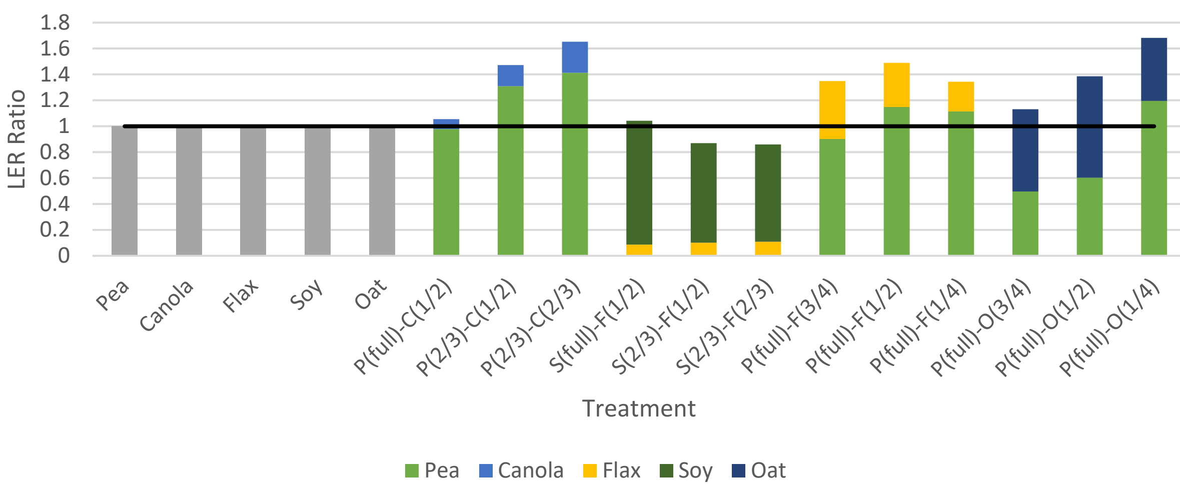

Figure 1. Average total Land Equivalent Ratio (LER) for each intercrop treatment composed of each partial LER crop component (n=3) at Arborg, MB in 2021.

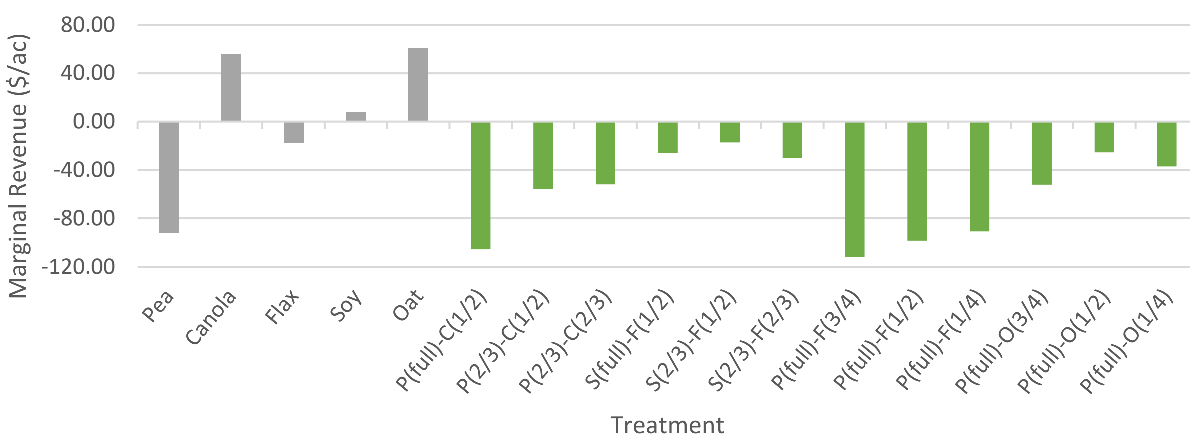

Figure 2. Average marginal revenue of monocrop and intercrop treatments at Arborg, MB in 2021.

Table 2. Seeding rates, varieties, seed depth, plant stand, plant height, yield and profit of intercrop treatments in 2021 at Arborg, MB.

No.	Treatment	Crop	Seed rate strategy	Variety	Seeding rate (seeds/m²)	Plant stand* (plants/m²)	Height (cm)	Yield † (bu/ac)	Land Equivalent Ratio ¥	Gross ‡ revenue ($/ac)	Marginal revenue ‡ ($/ac)
1	Pea	Pea	Full	CDC Amarillo	100	85	33.0	1.5	1.0	$19.47	-$92.21
2	Canola	Canola	Full	5545 CL	108	39	73.0	9.4	1.0	$170.01	$55.46
3	Flax	Flax	Full	CDC Glas	700	235	39.9	3.1	1.0	$70.78	-$17.86
4	Soybean	Soybean	Full	NSC Watson	49	47	31.2	8.6	1.0	$128.76	$7.98
5	Oats	Oats	Full	Souris	355	181	42.9	17.8	1.0	$111.01	$61.01
6	Pea-canola	Pea Canola	Full 1/2	CDC Amarillo 5545 CL	100 54	83 17	32.7 52.1	1.5 0.7	1.05	$31.83	-$105.46
7	Pea-canola	Pea Canola	2/3 1/2	CDC Amarillo 5545 CL	67 54	64 12	32.1 56.9	2.0 1.5	1.47	$53.08	-$55.50
8	Pea-canola	Pea Canola	2/3 2/3	CDC Amarillo 5545 CL	67 72	62 25	31.8 61.9	2.1 2.3	1.65	$68.24	-$51.81
9	Soy-Flax	Soybean Flax	Full 1/2	NSC Watson CDC Glas	49 350	48 79	26.0 46.9	8.2 0.3	1.04	$129.29	-$26.09
10	Soy-Flax	Soybean Flax	2/3 1/2	NSC Watson CDC Glas	33 350	32 61	30.0 48.4	6.6 0.3	0.87	$106.04	-$17.24
11	Soy-Flax	Soybean Flax	2/3 2/3	NSC Watson CDC Glas	33 467	27 81	28.2 48.6	6.4 0.3	0.86	$104.29	-$29.82
12	Pea-Flax	Pea Flax	Full 3/4	CDC Amarillo CDC Plava	100 525	83 176	30.2 34.8	1.4 1.4	1.35	$49.11	-$111.97
13	Pea-Flax	Pea Flax	Full 1/2	CDC Amarillo CDC Plava	100 350	81 118	31.3 38.3	1.7 1.1	1.49	$46.56	-$98.29
14	Pea-Flax	Pea Flax	Full 1/4	CDC Amarillo CDC Plava	100 175	86 53	34.1 37.8	1.7 0.7	1.34	$37.83	-$90.69
15	Pea-Oat	Pea Oat	Full 3/4	CDC Amarillo Souris	100 266	71 138	27.6 37.0	0.7 11.3	1.13	$80.09	-$52.14
16	Pea-Oat	Pea Oat	Full 1/2	CDC Amarillo Souris	100 178	81 87	28.4 44.0	0.9 13.9	1.39	$98.87	-$25.39
17	Pea-Oat	Pea Oat	Full 1/4	CDC Amarillo Souris	100 89	81 66	29.1 48.4	1.8 8.6	1.68	$77.27	-$37.11

*Optimum plant stands for monocrops: peas (7-8 plants/ft² or 70-80 plants/m²), canola (5-7 plants/ft² or 50-70 plants/m²), flax (37-56 plants/ft² or 396-599 plants/m²), soybean (4 plants/ft² or 40 plants/m²) and oats (18-23 plants/ft² or 194-248 plants/m²).

† Long-term average crop yields in the Bifrost-Riverton municipality: 36.6 bu/ac peas, 30.0 bu/ac canola, 17.8 bu/ac flax, 31.0 bu/ac soybean and 87.6 bu/ac oats (MASC, 1993-2021).
2021 average crop yields in the Bifrost-Riverton municipality: 17.8 bu/ac peas, 18.2 bu/ac canola, 8.2 bu/ac flax, 25.1 bu/ac soybean and 46.4 bu/ac oats (MASC, 2021).

‡ Profit margins were calculated as follows: *Gross revenue ($/ac)* = Yield x Market price
Marginal revenue ($/ac) = Gross revenue – Seed – Fertilizer – Pesticide – Separation ($0.25/bu)
(Market prices from Manitoba Agriculture 2021 Costs of Production: $13.00/bu peas, $18.00/bu canola, $23.00/bu flax, $15.00/bu soybean and $6.25/bu oats)

¥ Land equivalent ratio (LER) = $\frac{\text{yield of intercrop species 1}}{\text{yield of monocrop species 1}} + \frac{\text{yield of intercrop species 2}}{\text{yield of monocrop species}}$

Table 3. Seeding depth, weed control, fertility and general notes/observations of intercrop treatments in 2021 at Arborg, MB.

No.	Treatment	Crop	Seed rate	Depth	Herbicides/weed control*	Fertilizer applied†	General notes and observations
1	Pea	Pea	Full	1.5”	Pre-emerge: Authority In-crop: hand-weeded	15 lbs/ac P_2O_5	Sprayed with Silencer 120 EC 3 times to control grasshoppers. First pea aphid recorded June 17. Pea aphids counts reached economic threshold, but did not exceed it at flowering. Harvested August 26.
2	Canola	Canola	Full	0.75”	Pre-emerge: None In-crop: hand-weeded	38 lbs N/ac 15 lbs/ac P_2O_5 15 lbs S/ac	Sprayed with Silencer 120 EC 3 times to control grasshoppers. Sclerotinia disease risk very low. Harvested September 8
3	Flax	Flax	Full	0.75”	Pre-emerge: Authority 480 In-crop: hand-weeded	15 lbs/ac P_2O_5	Sprayed with Silencer 120 EC 3 times to control grasshoppers. Harvested September 8
4	Soybean	Soybean	Full	1”	Pre-emerge: Authority 480 In-crop: hand-weeded	15 lbs/ac P_2O_5	Sprayed with Silencer 120 EC 3 times to control grasshoppers. Soybean IDC assessment values were very low. Harvested September 23.
5	Oats	Oats	Full	1.5”	Pre-emerge: None In-crop: hand-weeded	15 lbs/ac P_2O_5	Sprayed with Silencer 120 EC 3 times to control grasshoppers. Harvested August 26.
6	Pea-canola	Pea Canola	Full 1/2	0.75”	Pre-emerge: None In-crop: hand-weeded	15 lbs/ac P_2O_5	Sprayed with Silencer 120 EC 3 times to control grasshoppers. First pea aphid recorded June 17. Pea aphids counts reached economic threshold, but did not exceed it at flowering. Harvested September 1.
7	Pea-canola	Pea Canola	2/3 1/2	0.75”		15 lbs/ac P_2O_5	
8	Pea-canola	Pea Canola	2/3 2/3	0.75”		15 lbs/ac P_2O_5	
9	Soy-Flax	Soybean Flax	Full 1/2	0.75”	Pre-emerge: Authority 480 In-crop: hand-weeded	15 lbs/ac P_2O_5	Sprayed with Silencer 120 EC 3 times to control grasshoppers. Flax generally matured about 25 days earlier than soybeans. Harvested September 23. Would be useful to desiccate prior to harvest to improve harvest-ability and reduce soybean seed coat damage.
10	Soy-Flax	Soybean Flax	2/3 1/2	0.75”		15 lbs/ac P_2O_5	
11	Soy-Flax	Soybean Flax	2/3 2/3	0.75”		15 lbs/ac P_2O_5	
12	Pea-Flax	Pea Flax	Full 3/4	1”	Pre-emerge: Authority 480 In-crop: hand-weeded	15 lbs/ac P_2O_5	Sprayed with Silencer 120 EC 3 times to control grasshoppers. First pea aphid recorded June 17. Pea aphids counts reached economic threshold, but did not exceed it at flowering. Harvested September 1.
13	Pea-Flax	Pea Flax	Full 1/2	1”		15 lbs/ac P_2O_5	
14	Pea-Flax	Pea Flax	Full 1/4	1”		15 lbs/ac P_2O_5	
15	Pea-Oat	Pea Oat	Full 3/4	1.5”	Pre-emerge: None In-crop: hand-weeded	15 lbs/ac P_2O_5	Sprayed with Silencer 120 EC 3 times to control grasshoppers. First pea aphid recorded June 17. Pea aphids counts reached economic threshold, but did not exceed it at flowering g. Crops generally matured within four days of each other. Harvested August 26.
16	Pea-Oat	Pea Oat	Full 1/2	1.5”		15 lbs/ac P_2O_5	
17	Pea-Oat	Pea Oat	Full 1/4	1.5”		15 lbs/ac P_2O_5	

Figure 3. Pea-Canola treatment (plot 201) taken on July 8, 2021.

Figure 4. Soybean-Flax treatment (plot 204) taken on July 8, 2021.

Figure 5. Pea-Flax treatment (plot 205) taken on July 8, 2021.

Figure 6. Pea-Oat treatment (plot 203) taken on July 8, 2021.

Table 4. Forage nutrient analysis of oat monocrop and pea-oat intercrop from Arborg 2021. Samples were collected on July 8, 2021 at pea flowering (R2) and oat heading (inflorescence).

	Feed Basis	Oat	Full pea, ¾ oat	Full pea, ½ oat	Full pea, ¼ oat
Acid Detergent Fibre (%)	As Fed	27.98	26.85	27.97	20.63
Calcium (%)	As Fed	0.26	0.50	0.60	0.49
Crude Protein (%)	As Fed	13.28	14.78	14.13	11.54
Digestible Energy (Mcal/kg)	As Fed	2.65	2.71	2.66	2.01
Dry Matter (%)	As Fed	91.35	91.32	91.41	68.51
Magnesium (%)	As Fed	0.22	0.29	0.35	0.26
Metabolizable Energy for Cattle (Mcal/kg)	As Fed	2.20	2.25	2.21	1.67
Moisture (%)	As Fed	8.65	8.68	8.59	6.49
Net Energy for Gain (Mcal/kg)	As Fed	0.85	0.89	0.85	0.65
Net Energy for Lactation (Mcal/kg)	As Fed	1.37	1.40	1.37	1.04
Net Energy for Maintenance (Mcal/kg)	As Fed	1.40	1.44	1.40	1.06
Neutral Detergent Fibre (%)	As Fed	54.44	46.35	47.49	32.36
Non Fibre Carbohydrates (%)	As Fed	13.75	20.32	19.91	17.20
Phosphorus (%)	As Fed	0.19	0.18	0.18	0.14
Potassium (%)	As Fed	1.82	1.93	1.74	1.34
Sodium (%)	As Fed	0.75	0.51	0.54	0.29
Total Digestible Nutrients (%)	As Fed	60.21	61.38	60.29	45.54
Relative Feed Value	Dry Matter	101.33	121.33	116.67	96.75
Total Dry Matter (lbs/ac)	Dry Matter	1834	785	1097	903

Intercropping with Soybeans and Peas in the Interlake

(Arborg, MB • 2022)

Intercropping is the practice of seeding, growing and harvesting 2 or more crops together. The concept is to utilize crop combinations that complement one another through mechanisms such as resource use efficiency, potentially resulting in over-yielding and greater profitability compared to monocropping. Careful consideration needs to be given to how the crops are seeded, managed, harvested, and separated. The most common intercrop grown commercially in Manitoba is pea-canola. Beginning in 2019, we started to test pea-canola, soybean-flax, pea-flax and pea-oat intercrop combinations at Arborg, MB. For each intercrop combination, 2-3 seeding rate ratios were tested and compared to pea, soybean, canola, flax and oat monocrops.

To assess the productivity of intercrops compared to their component crops grown in monoculture, the land equivalent ratio (LER) is used. LER is a ratio of the individual crop yields from the intercrop divided by the respective monocrop yield. It is desirable to achieve a LER > 1 which indicates over-yielding (more land would be required to produce the same yield with individual monocrops compared to the intercrop). Gross and marginal revenues are also calculated because seasonal growing conditions and market prices are important variables that affect the productivity, yield and economic return of cropping in a given year. Evaluating intercrops on LER alone can be misleading when monocrop yields are exceptionally low.

Objectives

1. Gain experience in intercropping: observe and evaluate agronomic performance of intercropping compared to monocrops.
2. Evaluate yield, land equivalent ratio (LER) and profitability of intercropping compared to monocrops.
3. Overall, start a knowledge base on if and how intercrops can be utilized in cropping systems in the Interlake and Manitoba.

Materials and Methods

The intercropping trial was seeded into canola stubble on June 08, 2022 at Arborg, MB with a plot seeder (R tech double disc) on 9” row spacing. All intercrops were seeded in the same, mixed row except soybean-flax where soybean was seeded down the mid-row fertilizer tube to achieve row separation (4.5”). Soil type at the research site is a heavy clay (Fyala series) and background soil test levels were 260 lbs N/ac and 19 ppm P_20_5. Specific agronomic practices used for each intercrop treatment are listed in Tables 2 and 3. The experimental design is a RCBD with 3 replicates.

Table 1. Seasonal growing degree days, crop heat units, precipitation, and temperature at Arborg in 2022 (in brackets, % of normal GDD, CHU and precipitation and long-term daily average† temperature).

	May	June	July	August	May-August
Growing degree days*	176 (86%)	333 (99%)	503 (116%)	470 (122%)	1484 (109%)
Crop heat units*	295 (80%)	545 (96%)	741 (104%)	702 (110%)	2285 (100%)
Precipitation, mm*	112 (211%)	116 (149%)	186 (308%)	39 (49%)	454 (168%)
Mean daily temperature, °C	10.4 (10.0)	16.1 (15.8)	21.2 (18.6)	20.2 (17.5)	17.0 (15.5)

†Long-term average daily temperature in Arborg (climate.weather.gc.ca, 1981-2010)
Sources: https://web43.gov.mb.ca/climate/SeasonalReport.aspx

Summary

This was the fourth year of experimenting with intercropping in the Interlake region of Manitoba. Treatments included three seeding rate combinations of pea-canola, soybean-flax, pea-flax and pea-oat compared to pea, canola, flax, soybean and oat monocrops. Results of the 2022 experiment including treatment descriptions, agronomic practices, yield, gross and marginal revenues, and general observations are listed in Table 2 and 3. The pea-oat intercrop was sampled for total dry matter and forage nutrient analysis (Table 4). **The 2022 growing season at Arborg was exceptionally wet with 168% of normal growing season precipitation (Table 1) compared to 69% of normal precipitation in 2021.** Due to high precipitation in May, the trial was seeded on June 8 and seeds were placed shallower. Overland flooding due to frequent rain after seeding resulted in some seeds being moved with flood water and overall reduced plant stands. Twelve plots were lost, and ten treatments were affected (one treatment was lost, full pea, ¼ flax) due to flooding from June 11 to June 27, 2022. In addition, canola plant stand was significantly reduced due to flea beetle damage. Crop yields were below average for pea, canola, and soybean while flax and oat yields were above average.

In 2022, the LER values for most of the intercropped treatments, except pea-flax, are greater than 1 indicating that they over-yielded their mono-cropped counterparts (Fig 1.). With high commodity prices, all crops produced positive marginal revenue. Marginal revenue was highest for monocrop oats and pea-oat intercrops, followed by monocrop flax and monocrop peas.

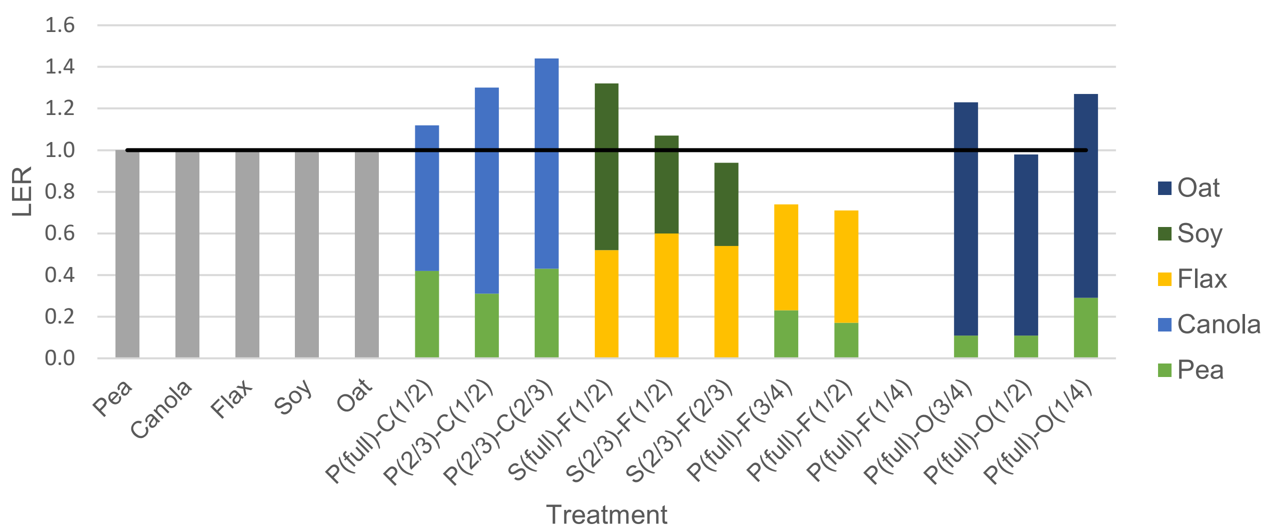

Figure 1. Average total Land Equivalent Ratio (LER) for each intercrop treatment composed of each partial LER crop component (n=2 or 3) at Arborg, MB in 2022.

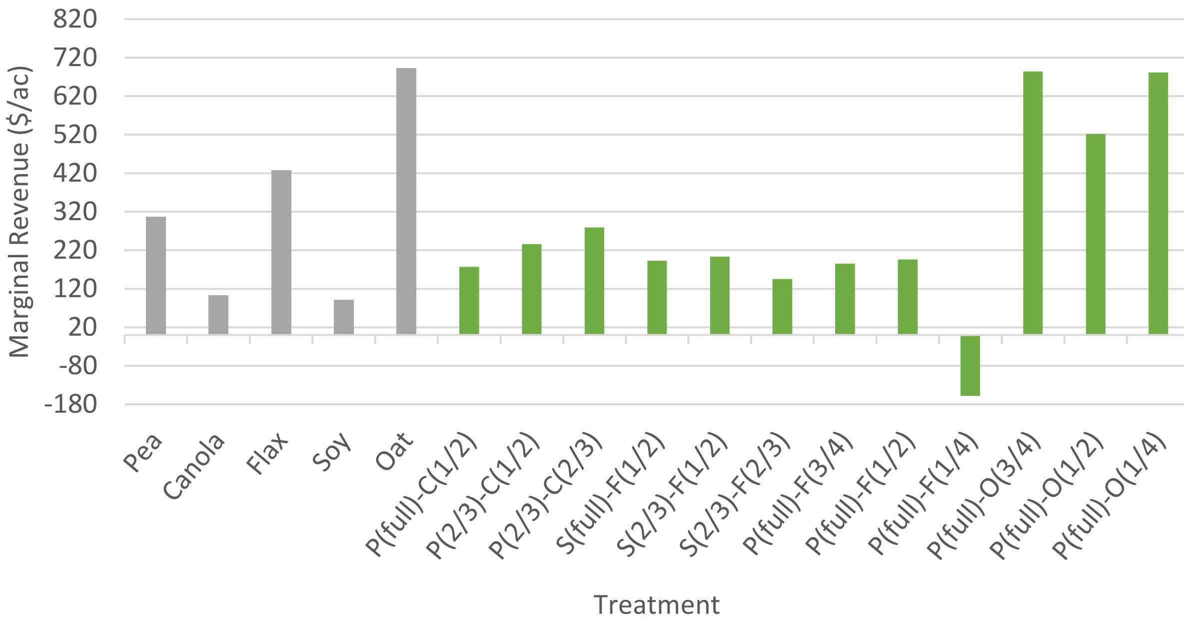

Figure 2. Average marginal revenue of monocrop and intercrop treatments at Arborg, MB in 2022.

Highlights of intercrop performance across 4 years of study at Arborg (2019-2022). A complete synopsis to follow.

- *Pea-canola* intercrop has consistently over-yielded, with LER from 1.07-1.65. Among the seeding rate treatments, seeding peas at 2/3 rate and canola at ½ to 2/3 rate has resulted in the greatest marginal revenue. Profitability ranking of pea-canola intercropping has been variable but often intermediate between pea and canola monocrops. Flea beetles have been a major constraint for both monocrop and intercrop canola.
- *Soybean-flax* produced an LER >1 in 1 out of 4 years (2022) and has ranged from 0.55-1.31. Profitability ranking of this intercrop was lower than flax monocrop in all years but higher than soybean in 3 out of 4 years. Seeding soybean at 2/3 rate and flax at ½ rate has performed better than the other seeding rates in 3 out of 4 years.
- *Pea-flax* intercropping has been inconsistent with LER ranging from 0.71-1.49. In 3 out of 4 years, LER has been close to or greater than 1.0 and profitability ranking has been similar to monocrop peas and flax. Maintaining a full pea seeding rate and reducing flax to a ¼ or ½ rate has resulted in greater marginal revenue among seeding rate treatments.
- *Pea-oat* intercrops have been the most profitable intercrop on average over the 4 years tested, even in years when LER was below 1.0. LER has ranged from 0.89 to 1.68. The performance of the seeding rate combinations has been variable year to year. All seeding rates tested maintain a full pea rate with oats ranging from ¼ to ¾ rate. Although grain varieties were used, forage nutrient analysis was collected to demonstrate the value of using the crop as an alternative feed source.

Table 2. Seeding rates, varieties, seed depth, plant stand, plant height, yield and marginal return of intercrop treatments in 2022 at Arborg, MB.

No.	Treatment	Crop	Seed rate strategy	Variety	Seeding rate (seeds/m^2)	Plant stand* (plants/m^2)	Height (cm)	Yield † (bu/ac)	Land Equivalent Ratio ¥	Gross ‡ revenue ($/ac)	Marginal return ‡ ($/ac)	Profit Rank
1	Pea	Pea	Full	AAC Chrome	100	61	84	34.5	1.00	$449	$307	6
2	Canola	Canola	Full	BY 5125 CL	108	11	10	15.4	1.00	$262	$103	15
3	Flax	Flax	Full	CDC Glas	700	361	69	24.2	1.00	$558	$428	5
4	Soybean	Soybean	Full	NSC Watson	49	13	43	13.7	1.00	$219	$92	16
5	Oats	Oats	Full	Souris	355	183	120	150.8	1.00	$754	$693	1
6	Pea-canola	Pea Canola	Full 1/2	AAC Chrome BY 5125 CL	100 54	33 9	67 101	14.4 10.7	1.11	$370	$177	13
7	Pea-canola	Pea Canola	2/3 1/2	AAC Chrome BY 5125 CL	66.7 54	22 12	57 86	10.7 15.3	1.30	$399	$236	8
8	Pea-canola	Pea Canola	2/3 2/3	AAC Chrome BY 5125 CL	66.7 72	30 24	72 99	14.8 15.6	1.44	$458	$279	7
9	Soy-Flax	Soybean Flax	Full 1/2	NSC Watson CDC Glas	49 350	16 208	51 67	10.9 12.5	1.31	$462	$193	11
10	Soy-Flax	Soybean Flax	2/3 1/2	NSC Watson CDC Glas	32.7 350	14 241	50 66	6.4 14.6	1.07	$439	$203	9
11	Soy-Flax	Soybean Flax	2/3 2/3	NSC Watson CDC Glas	33 467	17 406	49 69	5.5 13.2	0.95	$391	$145	14
12	Pea-Flax	Pea Flax	Full 3/4	AAC Chrome CDC Plava	100 525	33 165	73 69	7.9 12.3	0.74	$385	$185	12
13	Pea-Flax	Pea Flax	Full 1/2	AAC Chrome CDC Plava	100 350	40 97	59 65	5.9 13.2	0.71	$379	$196	10
14	Pea-Flax	Pea Flax	Full 1/4	AAC Chrome CDC Plava	100 175	5 49	56 58	No data, plots lost due to flooding				
15	Pea-Oat	Pea Oat	Full 3/4	AAC Chrome Souris	100 266	49 125	73 99	3.7 169.2	1.23	$894	$684	2
16	Pea-Oat	Pea Oat	Full 1/2	AAC Chrome Souris	100 177	33 96	54 117	3.7 131.7	0.98	$706	$522	4
17	Pea-Oat	Pea Oat	Full 1/4	AAC Chrome Souris	100 89	37 46	63 123	10.1 147.7	1.27	$869	$682	3

*Optimum plant stands for monocrops: peas (7-8 plants/ft^2 or 70-80 plants/m^2), canola (5-7 plants/ft^2 or 50-70 plants/m^2), flax (37-56 plants/ft^2 or 396-599 plants/m^2), soybean (4 plants/ft^2 or 40 plants/m^2) and oats (18-23 plants/ft^2 or 194-248 plants/m^2).

† Long-term average crop yields in the Bifrost-Riverton municipality: 38.9 bu/ac peas, 30.1 bu/ac canola, 18.5 bu/ac flax, 30.6 bu/ac soybean and 88.3 bu/ac oats (MASC, 1993-2022). 2022 average crop yields in the Bifrost-Riverton municipality: 38.2 bu/ac peas, 22.2 bu/ac canola, 0 bu/ac flax (due to below minimum acres, 8.2 bu/ac in 2021), 30.0 bu/ac soybean and 82.6 bu/ac oats (MASC, 2022).

‡ Profit margins were calculated as follows: *Gross revenue ($/ac)* = Yield x Market price
Marginal return ($/ac) = Gross revenue – Seed – Fertilizer – Pesticide – Separation ($0.25/bu)

(Market prices from Manitoba Agriculture 2023 Costs of Production: $13.00/bu peas, $17.00/bu canola, $23.00/bu flax, $16.00/bu soybean and $5.00/bu oats)

¥ Land equivalent ratio (LER) = $\frac{\text{yield of intercrop species 1}}{\text{yield of monocrop species 1}} + \frac{\text{yield of intercrop species 2}}{\text{yield of monocrop species}}$

Table 3. Seeding depth, weed control, fertility and general notes/observations of intercrop treatments in 2022 at Arborg, MB.

No.	Treatment	Crop	Seed rate	Depth	Herbicides/weed control	Fertilizer applied*	General notes and observations
1	Pea	Pea	Full	1.5”	Pre-emerge: Authority 480 In-crop: Odyssey Ultra NXT	15 lbs/ac P_2O_5	First pea aphid recorded July 26. Pea aphid counts reached economic threshold. Sprayed with Matador August 26 to control pea aphids. Harvested October 11.
2	Canola	Canola	Full	0.75”	Pre-emerge: Authority 480 In-crop: Odyssey Ultra NXT	60 lbs N/ac 15 lbs/ac P_2O_5 15 lbs S/ac	Sclerotinia disease risk very low. Harvested October 19. Very low plant population.
3	Flax	Flax	Full	0.75”	Pre-emerge: Authority 480 In-crop: Basagran Forte, Centurion	15 lbs/ac P_2O_5	Harvested October 11.
4	Soybean	Soybean	Full	1.25”	Pre-emerge: Authority 480 In-crop: Glyphosate 540	15 lbs/ac P_2O_5	Soybean IDC assessment values were low (some yellowing observed). Harvested October 19.
5	Oats	Oats	Full	1.5”	Pre-emerge: Authority 480 In-crop: Buctril M	60 lbs N/ac 15 lbs/ac P_2O_5	Harvested October 19.
6	Pea-canola	Pea Canola	Full 1/2	0.75”	Pre-emerge: Authority 480 In-crop: Odyssey Ultra NXT	15 lbs/ac P_2O_5	First pea aphid recorded July 26. Pea aphid counts reached economic threshold. Sprayed with Matador August 26 to control pea aphids. Harvested October 11 and 19. Very low canola plant population.
7	Pea-canola	Pea Canola	2/3 1/2	0.75”		15 lbs/ac P_2O_5	
8	Pea-canola	Pea Canola	2/3 2/3	0.75”		15 lbs/ac P_2O_5	
9	Soy-Flax	Soybean Flax	Full 1/2	1.25” 0.75”	Pre-emerge: Authority 480 In-crop: Basagran Forte, Centurion	15 lbs/ac P_2O_5	Soybean IDC assessment values were low (some yellowing observed). Harvested October 11 and 19.
10	Soy-Flax	Soybean Flax	2/3 1/2	1.25” 0.75”		15 lbs/ac P_2O_5	
11	Soy-Flax	Soybean Flax	2/3 2/3	1.25” 0.75”		15 lbs/ac P_2O_5	
12	Pea-Flax	Pea Flax	Full 3/4	0.75”	Pre-emerge: Authority 480 In-crop: Odyssey Ultra NXT	15 lbs/ac P_2O_5	First pea aphid recorded July 26. Pea aphid counts reached economic threshold. Sprayed with Matador August 26 to control pea aphids. Harvested October 19.
13	Pea-Flax	Pea Flax	Full 1/2	0.75”		15 lbs/ac P_2O_5	
14	Pea-Flax	Pea Flax	Full 1/4	0.75”		15 lbs/ac P_2O_5	
15	Pea-Oat	Pea Oat	Full 3/4	1.5”	Pre-emerge: Authority 480 In-crop: hand-weeded	15 lbs/ac P_2O_5	First pea aphid recorded July 26. Pea aphid counts reached economic threshold. Sprayed with Matador August 26 to control pea aphids. Harvested October 11 and 19.
16	Pea-Oat	Pea Oat	Full 1/2	1.5”		15 lbs/ac P_2O_5	
17	Pea-Oat	Pea Oat	Full 1/4	1.5”		15 lbs/ac P_2O_5	

*Inoculant (seed placed): Nod XL LQ, Nod Peat (1t) applied for all pea treatments; Optimize ST (1.5t) applied for all soybean treatments.

Table 4. Forage nutrient analysis of oat monocrop and pea-oat intercrop from Arborg 2022. Samples were collected on July 26, 2022 at pea flowering (R2) and oat heading (inflorescence).

	Feed Basis	Oat	Full pea, ¾ oat	Full pea, ½ oat	Full pea, ¼ oat
Acid Detergent Fibre (%)	**As Fed**	35.04	32.90	33.61	31.58
Calcium (%)	**As Fed**	0.23	0.54	0.40	0.73
Crude Protein (%)	**As Fed**	14.62	15.29	15.72	17.05
Digestible Energy (Mcal/kg)	**As Fed**	2.19	2.32	2.29	2.40
Dry Matter (%)	**As Fed**	88.39	88.98	89.15	89.51
Magnesium (%)	**As Fed**	0.23	0.31	0.27	0.38
Metabolizable Energy for Cattle (Mcal/kg)	**As Fed**	1.82	1.93	1.90	1.99
Moisture (%)	**As Fed**	11.61	11.02	10.85	10.49
Net Energy for Gain (Mcal/kg)	**As Fed**	0.57	0.65	0.63	0.70
Net Energy for Lactation (Mcal/kg)	**As Fed**	1.12	1.19	1.17	1.23
Net Energy for Maintenance (Mcal/kg)	**As Fed**	1.07	1.16	1.14	1.22
Neutral Detergent Fibre (%)	**As Fed**	52.17	47.65	49.11	41.77
Non-Fibre Carbohydrates (%)	**As Fed**	12.06	16.43	14.69	21.03
Phosphorus (%)	**As Fed**	0.25	0.29	0.29	0.28
Potassium (%)	**As Fed**	3.13	3.21	3.11	2.95
Sodium (%)	**As Fed**	0.55	0.30	0.44	0.35
Total Digestible Nutrients (%)	**As Fed**	49.75	52.62	52.03	54.55
Relative Feed Value	**Dry Matter**	91.67	104.67	100.67	123.33
Total Dry Matter (lbs/ac)	**Dry Matter**	3337	1431	1361	1125

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Figure 3. Pea-Canola treatment (plot 215) taken on August 11, 2022

Figure 4. Soybean-Flax treatment (plot 212) taken on August 11, 2022.

Figure 5. Pea-Flax treatment (plot 206) taken on August 11, 2022.

Figure 6. Pea-Oat treatment (plot 201) taken on August 11, 2022.

Intercropping with Soybeans and Peas in southern Manitoba

(Carman, MB • 2021 and 2022)

Intercropping is the practice of seeding, growing and harvesting 2 or more crops together. The concept is to utilize crop combinations that complement one another through mechanisms such as resource use efficiency, potentially resulting in over-yielding, yield stability, reduced risk, and/or greater profitability compared to monocropping. Careful consideration needs to be given to how the crops are seeded, managed, harvested, and separated. The most common intercrop grown commercially in Manitoba is pea-canola.

Beginning in 2019, we tested pea-canola, soybean-flax, pea-flax and pea-oat intercrop combinations at Arborg and Carman, MB. For each intercrop, 2-3 seeding rate ratios were tested and compared to sole crops.

To assess the productivity of intercrops compared to their component crops grown in monoculture, the land equivalent ratio (LER) is used. LER is a ratio of the individual crop yields from the intercrop divided by the respective monocrop yield. It is desirable to achieve a LER > 1 which indicates over-yielding (more land would be required to produce the same yield with individual monocrops compared to the intercrop). Gross and marginal revenues are also calculated because seasonal growing conditions and market prices are important variables that affect the productivity, yield and economic return of cropping in a given year.

Objectives

1. Gain experience in intercropping: observe and evaluate agronomic performance of intercropping compared to monocrops.
2. Evaluate yield, land equivalent ratio (LER) and profitability of intercropping compared to monocrops.
3. Overall, start a knowledge base on if and how intercrops can be utilized in cropping systems in Manitoba.

Materials and Methods

A detailed summary of agronomic practices (e.g. seeding rates, weed control, fertility etc.) for each intercrop treatment are provided in Tables 2-5.

Table 1. Site description for Carman 2021 and 2022.

	2021	**2022**
Seeding date	May 11	June 3
Seeder and row spacing	Disc opener on 7.5”	Disc opener on 7.5”
Soil type	Fine loamy	Fine loamy
Soil pH (0-6”,6-12”)	5.4, 7.3	5.8, 7.9
Soil test N (0-24”)	65 lbs/ac	15 lbs/ac
Soil test P	13 ppm	24 ppm

Seasonal Summary

Drought impacted crop yields in the 2021 trial (Fig. 1), resulting in crop failure of canola and flax. The 2021 growing season was warm and dry in Manitoba with drought experienced across most of the province, resulting in reduced crop yields. From May through August, the mean daily temperature was 17.1°C and 226 mm of precipitation fell. The preceding year of 2020 also received below normal precipitation contributing to the more severe drought in 2021.

Figure 1. Pea-flax, pea-canola, and pea-oat intercrop plots exhibit drought stress at Carman, MB on July 13, 2021.

Weed competition affected crop yields in the 2022 trial. The field location has a high population of green and yellow foxtail with suspected group 1 and 2 resistance, and wild buckwheat and redroot pigweed were also poorly controlled. The grassy weed population was particularly problematic for soybean-flax and pea-flax intercrops which are less competitive overall compared to pea-canola and pea-oat. After the in-crop herbicide pass, each plot was randomly split into a weedy and weed-free side and the weed-free side was hand-weeded (except the soybean, oat and pea-oat treatments). In the soy-flax intercrop, yield of soy and flax was reduced by 41 and 56%, respectively in the weedy plot. In the pea-flax intercrop, yield of pea and flax was reduced by 17 and 53%, respectively, in the weedy plot. The 2022 growing season also received below normal precipitation but spring soil moisture was good, and rainfall was well distributed, contributing to average to above average crop yields. From May through August, the mean daily temperature was 17.1°C and 265 mm of precipitation fell.

Overall, we have been testing intercrop systems at Carman and Arborg, MB since 2017. **A summary of each intercrop combination (pea-canola, pea-oat, soybean-flax and pea-flax) is also available within this report.** Future work should focus on refining agronomic management practices for the emerging intercrops, pea-flax and soybean-flax.

Figure 2. Intercrop experiment at Carman 2022 on July 29 (L) and August 16 (R).

Table 2. Seeding rates, varieties, seed depth, plant stand, plant height, yield and profit of intercrop treatments in **2021** at Carman, MB.

No.	Treatment	Crop	Seed rate strategy	Variety	Seeding rate (seeds/m^2)	Plant stand* (plants/m^2)	Height (cm)	Yield † (bu/ac)	Land Equivalent Ratio ¥	Gross ‡ revenue ($/ac)	Marginal revenue ‡ ($/ac)	Profit Rank
1	Pea	Pea	Full	CDC Amarillo	100	81	43	24.1	1.00	$312.86	$199.83	5
2	Canola	Canola	Full	BY 5125 CL	108	27	76	3.5	1.00	$63.28	-$133.22	17
3	Flax	Flax	Full	CDC Glas	700	220	46	3.6	1.00	$82.87	-$12.64	13
4	Soybean	Soybean	Full	S007-Y4	49	34	49	18.0	1.00	$269.64	$140.76	6
5	Oats	Oats	Full	Souris	355	167	54	67.8	1.00	$423.70	$336.39	1
6	Pea-canola	Pea Canola	Full 1/2	CDC Amarillo BY 5125 CL	100 54	80 6	45 71	19.0 2.0	1.35	$281.86	$129.86	9
7	Pea-canola	Pea Canola	2/3 1/2	CDC Amarillo BY 5125 CL	67 54	60 9	45 72	19.4 3.7	1.86	$319.19	$195.68	6
8	Pea-canola	Pea Canola	2/3 2/3	CDC Amarillo BY 5125 CL	67 72	59 14	45 72	15.5 4.0	1.77	$272.75	$138.91	8
9	Soy-Flax	Soybean Flax	Full 1/2	S007-Y4 CDC Glas	49 350	27 89	34 44	3.1 0.9	0.42	$66.73	-$98.81	15
10	Soy-Flax	Soybean Flax	2/3 1/2	S007-Y4 CDC Glas	33 350	19 104	30 44	1.7 0.8	0.31	$43.81	-$89.66	14
11	Soy-Flax	Soybean Flax	2/3 2/3	S007-Y4 CDC Glas	33 467	18 94	34 46	1.0 0.5	0.20	$26.67	-$117.40	16
12	Pea-Flax	Pea Flax	Full 3/4	CDC Amarillo CDC Plava	100 525	75 115	43 46	8.3 3.7	1.38	$193.36	$13.67	12
13	Pea-Flax	Pea Flax	Full 1/2	CDC Amarillo CDC Plava	100 350	73 103	42 44	10.0 3.7	1.45	$215.12	$51.25	11
14	Pea-Flax	Pea Flax	Full 1/4	CDC Amarillo CDC Plava	100 175	73 61	41 45	13.2 3.3	1.46	$246.84	$98.51	10
15	Pea-Oat	Pea Oat	Full 3/4	CDC Amarillo Souris	100 266	63 130	41 55	3.9 46.2	0.84	$339.31	$207.56	4
16	Pea-Oat	Pea Oat	Full 1/2	CDC Amarillo Souris	100 177	70 94	39 54	3.7 45.3	0.82	$330.81	$208.01	3
17	Pea-Oat	Pea Oat	Full 1/4	CDC Amarillo Souris	100 89	69 54	43 53	9.6 41.3	1.01	$383.29	$268.79	2

*Optimum plant stands for monocrops: peas (7-8 plants/ft^2 or 70-80 plants/m^2), canola (5-7 plants/ft^2 or 50-70 plants/m^2), flax (37-56 plants/ft^2 or 396-599 plants/m^2), soybean (4 plants/ft^2 or 40 plants/m^2) and oats (18-23 plants/ft^2 or 194-248 plants/m^2).

† Long-term average crop yields in the Dufferin municipality: 22.6 bu/ac peas, 36.0 bu/ac canola, 17.9 bu/ac flax, 34.3 bu/ac soybean and 97.2 bu/ac oats. 2021 average crop yields in the Dufferin municipality: 26.7 bu/ac peas, 24.4 bu/ac canola, 0 bu/ac flax (due to below minimum acres), 19.7 bu/ac soybean and 54.2 bu/ac oats. Source: MASC, 2022.

‡ Profit margins were calculated as follows: *Gross revenue ($/ac)* = Yield x Market price
Marginal revenue ($/ac) = Gross revenue – Seed – Fertilizer – Pesticide – Separation ($0.25/bu)

(Market prices from Manitoba Agriculture 2022 Costs of Production: $13.00/bu peas, $18.00/bu canola, $23.00/bu flax, $15.00/bu soybean and $6.25/bu oats)

¥ Land equivalent ratio (LER) = $\frac{\text{yield of intercrop species 1}}{\text{yield of monocrop species 1}} + \frac{\text{yield of intercrop species 2}}{\text{yield of monocrop species 2}}$

Table 3. Seeding depth, weed control, fertility and general notes/observations of intercrop treatments in **2021** at Carman, MB.

No.	Treatment	Crop	Seed rate	Depth	Herbicides/weed control	Fertilizer applied*	General notes and observations
1	Pea	Pea	Full	1.5”	Pre-emerge: Roundup WeatherMax In-crop: Odyssey Ultra NXT	15 lbs/ac P_2O_5	Drought. Sprayed silencer for pea aphids that met optimal plant staging and thresholds on July 7.
2	Canola	Canola	Full	0.75”	Pre-emerge: Roundup WeatherMax In-crop: Odyssey Ultra NXT	85 lbs N/ac 15 lbs/ac P_2O_5 15 lbs S/ac	Drought. Crop failure due to poor emergence (dry seeding conditions) and poor seed dispersion.
3	Flax	Flax	Full	0.75”	Pre-emerge: Roundup WeatherMax In-crop: Buctril M & Poast Ultra	15 lbs N/ac 15 lbs/ac P_2O_5	Drought. Crop failure due to high grassy weed pressure. Matured on average at 97 days after seeding.
4	Soybean	Soybean	Full	1.25”	Pre-emerge: Roundup WeatherMax In-crop: Roundup WeatherMax	15 lbs/ac P_2O_5	Drought. Plant vigour and yield affected by prolonged drought conditions. Late season precipitation delayed maturity.
5	Oats	Oats	Full	1.5”	Pre-emerge: Roundup WeatherMax In-crop: Buctril M	35 lbs N/ac 15 lbs/ac P_2O_5	Drought. Good plant establishment and rapid desiccation at maturity.
6	Pea-canola	Pea Canola	Full 1/2	0.75”	Pre-emerge: Roundup WeatherMax In-crop: Odyssey Ultra NXT	15 lbs/ac P_2O_5	Drought. Pea establishment as good or better than in the monocrop. Balanced intercrop in terms of crop competitiveness, physiology and maturity. Easy harvest and separation due to seed size differences.
7	Pea-canola	Pea Canola	2/3 1/2	0.75”		15 lbs/ac P_2O_5	
8	Pea-canola	Pea Canola	2/3 2/3	0.75”		15 lbs/ac P_2O_5	
9	Soy-Flax	Soybean Flax	Full 1/2	1.25” 0.75”	Pre-emerge: Roundup WeatherMax In-crop: Centurion & Basagran Forte	15 lbs/ac P_2O_5	Drought. Poor weed control due to limited herbicide options, herbicide resistances at site and lack of crop competitiveness of both soybeans and flax. Wide range of maturity dates between crops due to late season precipitation.
10	Soy-Flax	Soybean Flax	2/3 1/2	1.25” 0.75”		15 lbs/ac P_2O_5	
11	Soy-Flax	Soybean Flax	2/3 2/3	1.25” 0.75”		15 lbs/ac P_2O_5	
12	Pea-Flax	Pea Flax	Full 3/4	0.75”	Pre-emerge: Roundup WeatherMax In-crop: Centurion & Basagran Forte	15 lbs/ac P_2O_5	Drought. Decreased pea establishment and maintained flax establishment compared to monocrops. Pea and flax boll size very similar – a harvest consideration.
13	Pea-Flax	Pea Flax	Full 1/2	0.75”		15 lbs/ac P_2O_5	
14	Pea-Flax	Pea Flax	Full 1/4	0.75”		15 lbs/ac P_2O_5	
15	Pea-Oat	Pea Oat	Full 3/4	1.5”	Pre-emerge: Roundup WeatherMax In-crop: N/A	15 lbs/ac P_2O_5	Drought. Oats outcompeted peas, especially in oat ¾ treatment. Good weed control despite lack of in-crop herbicide options due to oat competitiveness. Very even maturity.
16	Pea-Oat	Pea Oat	Full 1/2	1.5”		15 lbs/ac P_2O_5	
17	Pea-Oat	Pea Oat	Full 1/4	1.5”		15 lbs/ac P_2O_5	

*Inoculant (seed placed): Nod XL LQ, Nod Peat (1t) applied for all pea treatments; Optimize ST (1.5t) applied for all soybean treatments.

Table 4. Seeding rates, varieties, seed depth, plant stand, plant height, yield and profit of weed-free intercrop treatments in **2022** at Carman, MB.

No.	Treatment	Crop	Seed rate strategy	Variety	Seeding rate (seeds/m²)	Plant stand* (plants/m²)	Height (cm)	Yield † (bu/ac)	Land Equivalent Ratio ¥	Gross ‡ revenue ($/ac)	Marginal revenue ‡ ($/ac)	Profit Rank
1	Pea	Pea	Full	AAC Chrome	100	68	64	37.8	1.00	$492	$333	2
2	Canola	Canola	Full	BY 5125 CL	108	36	115	16.5	1.00	$281	-$14	16
3	Flax	Flax	Full	CDC Glas	700	190	64	6.8	1.00	$156	-$21	17
4	Soybean	Soybean	Full	S007-Y4	49	46	46	33.1	1.00	$530	$385	1
5	Oats	Oats	Full	Souris	355	264	61	65.7	1.00	$329	$145	11
6	Pea-canola	Pea Canola	Full 1/2	AAC Chrome BY 5125 CL	100 54	53 23	41 64	24.1 3.6	0.85	$374	$162	7
7	Pea-canola	Pea Canola	2/3 1/2	AAC Chrome BY 5125 CL	67 54	50 20	46 64	21.6 3.8	0.80	$346	$165	6
8	Pea-canola	Pea Canola	2/3 2/3	AAC Chrome BY 5125 CL	67 72	53 24	63 17	13.2 15.3	1.27	$431	$235	3
9	Soy-Flax	Soybean Flax	Full 1/2	S007-Y4 CDC Glas	49 350	31 93	65 113	11.6 4.9	1.07	$298	$111	14
10	Soy-Flax	Soybean Flax	2/3 1/2	S007-Y4 CDC Glas	33 350	19 85	43 78	8.7 5.6	1.09	$268	$115	13
11	Soy-Flax	Soybean Flax	2/3 2/3	S007-Y4 CDC Glas	33 467	19 99	92 47	8.2 10.0	1.72	$362	$196	5
12	Pea-Flax	Pea Flax	Full 3/4	AAC Chrome CDC Plava	100 525	67 131	55 66	13.5 11.2	2.00	$431	$228	4
13	Pea-Flax	Pea Flax	Full 1/2	AAC Chrome CDC Plava	100 350	65 130	48 59	11.5 8.5	1.56	$346	$160	8
14	Pea-Flax	Pea Flax	Full 1/4	AAC Chrome CDC Plava	100 175	60 59	45 75	11.4 7.3	1.37	$316	$148	10
15	Pea-Oat	Pea Oat	Full 3/4	AAC Chrome Souris	100 266	34 200	57 49	3.8 33.9	0.62	$219	$39	15
16	Pea-Oat	Pea Oat	Full 1/2	AAC Chrome Souris	100 177	50 191	63 118	7.0 47.9	0.91	$330	$149	9
17	Pea-Oat	Pea Oat	Full 1/4	AAC Chrome Souris	100 89	52 109	52 84	10.9 31.7	0.77	$299	$132	12

*Optimum plant stands for monocrops: peas (7-8 plants/ft² or 70-80 plants/m²), canola (5-7 plants/ft² or 50-70 plants/m²), flax (37-56 plants/ft² or 396-599 plants/m²), soybean (4 plants/ft² or 40 plants/m²) and oats (18-23 plants/ft² or 194-248 plants/m²).

† Long-term average crop yields in the Dufferin municipality: 24.6 bu/ac peas, 36.7 bu/ac canola, 18.0 bu/ac flax, 34.9 bu/ac soybean and 98.7 bu/ac oats. 2022 average crop yields in the Dufferin municipality: 63.2 bu/ac peas, 49.9 bu/ac canola, 0 bu/ac flax (due to below minimum acres), 49.6 bu/ac soybean and 133.6 bu/ac oats. Source: MASC.

‡ Profit margins were calculated as follows: *Gross revenue ($/ac)* = Yield x Market price
Marginal revenue ($/ac) = Gross revenue – Seed – Fertilizer – Pesticide – Separation ($0.50/bu)

(Market prices from Manitoba Agriculture 2023 Costs of Production: $13.00/bu peas, $17.00/bu canola, $23.00/bu flax, $16.00/bu soybean and $5.00/bu oats)

¥ Land equivalent ratio (LER) = $\frac{\text{yield of intercrop species 1}}{\text{yield of monocrop species 1}} + \frac{\text{yield of intercrop species 2}}{\text{yield of monocrop species 2}}$

Table 5. Seeding rates, varieties, seed depth, plant stand, plant height, yield and profit of weedy intercrop treatments in **2022** at Carman, MB.

No.	Treatment	Crop	Seed rate strategy	Variety	Seeding rate (seeds/m^2)	Plant stand* (plants/m^2)	Height (cm)	Yield † (bu/ac)	Land Equivalent Ratio ¥	Gross ‡ revenue ($/ac)	Marginal revenue ‡ ($/ac)	Profit Rank
1	Pea	Pea	Full	AAC Chrome	100	68	64	31.9	0.84	$415	$256	2
2	Canola	Canola	Full	BY 5125 CL	108	36	115	12.8	0.77	$217	-$78	17
3	Flax	Flax	Full	CDC Glas	700	190	64	6.0	0.89	$138	-$38	16
4	Soybean	Soybean	Full	S007-Y4	49	46	46	33.1	1.00	$529	$416	1
5	Oats	Oats	Full	Souris	355	264	61	65.7	1.00	$328	$144	6
6	Pea-canola	Pea Canola	Full 1/2	AAC Chrome BY 5125 CL	100 54	53 23	41 64	22.2 2.0	0.71	$323	$113	8
7	Pea-canola	Pea Canola	2/3 1/2	AAC Chrome BY 5125 CL	67 54	50 20	46 64	21.5 3.2	0.76	$333	$153	4
8	Pea-canola	Pea Canola	2/3 2/3	AAC Chrome BY 5125 CL	67 72	53 24	63 17	19.6 6.4	0.91	$365	$170	3
9	Soy-Flax	Soybean Flax	Full 1/2	S007-Y4 CDC Glas	49 350	31 93	65 113	8.3 2.9	0.67	$198	$14	13
10	Soy-Flax	Soybean Flax	2/3 1/2	S007-Y4 CDC Glas	33 350	19 85	43 78	5.1 3.1	0.61	$153	$3	14
11	Soy-Flax	Soybean Flax	2/3 2/3	S007-Y4 CDC Glas	33 467	19 99	92 47	3.4 3.1	0.56	$125	-$35	15
12	Pea-Flax	Pea Flax	Full 3/4	AAC Chrome CDC Plava	100 525	67 131	55 66	12.1 6.2	1.23	$300	$99	9
13	Pea-Flax	Pea Flax	Full 1/2	AAC Chrome CDC Plava	100 350	65 130	48 59	9.0 4.2	0.86	$213	$32	11
14	Pea-Flax	Pea Flax	Full 1/4	AAC Chrome CDC Plava	100 175	60 59	45 75	9.3 2.6	0.63	$181	$16	12
15	Pea-Oat	Pea Oat	Full 3/4	AAC Chrome Souris	100 266	34 200	57 49	3.8 33.9	0.62	$219	$39	10
16	Pea-Oat	Pea Oat	Full 1/2	AAC Chrome Souris	100 177	50 191	63 118	7.0 47.9	0.91	$330	$149	5
17	Pea-Oat	Pea Oat	Full 1/4	AAC Chrome Souris	100 89	52 109	52 84	10.9 31.7	0.77	$299	$132	7

*Optimum plant stands for monocrops: peas (7-8 plants/ft^2 or 70-80 plants/m^2), canola (5-7 plants/ft^2 or 50-70 plants/m^2), flax (37-56 plants/ft^2 or 396-599 plants/m^2), soybean (4 plants/ft^2 or 40 plants/m^2) and oats (18-23 plants/ft^2 or 194-248 plants/m^2).

† Long-term average crop yields in the Dufferin municipality: 24.6 bu/ac peas, 36.7 bu/ac canola, 18.0 bu/ac flax, 34.9 bu/ac soybean and 98.7 bu/ac oats. 2022 average crop yields in the Dufferin municipality: 63.2 bu/ac peas, 49.9 bu/ac canola, 0 bu/ac flax (due to below minimum acres), 49.6 bu/ac soybean and 133.6 bu/ac oats. Source: MASC.

‡ Profit margins were calculated as follows: *Gross revenue ($/ac)* = Yield x Market price
Marginal revenue ($/ac) = Gross revenue – Seed – Fertilizer – Pesticide – Separation ($0.50/bu)
(Market prices from Manitoba Agriculture 2023 Costs of Production: $13.00/bu peas, $17.00/bu canola, $23.00/bu flax, $16.00/bu soybean and $5.00/bu oats)

¥ Land equivalent ratio (LER) = $\frac{\text{yield of intercrop species 1}}{\text{yield of monocrop species 2}} + \frac{\text{yield of intercrop species 2}}{\text{yield of monocrop species 2}}$

Table 6. Seeding depth, weed control, fertility and general notes/observations of intercrop treatments in **2022** at Carman, MB.

No.	Treatment	Crop	Seed rate	Depth	Herbicides/weed control	Fertilizer applied*	General notes and observations
1	Pea	Pea	Full	1.5”	Pre-emerge: Roundup WeatherMax In-crop: Odyssey Ultra NXT	15 lbs/ac P_2O_5	Matured 77-82 days after planting. Some lodging observed in all reps at R6.
2	Canola	Canola	Full	0.75”	Pre-emerge: Roundup WeatherMax In-crop: Odyssey Ultra NXT	135 lbs N/ac 15 lbs/ac P_2O_5 15 lbs S/ac	
3	Flax	Flax	Full	0.75”	Pre-emerge: Roundup WeatherMax In-crop: Buctril M & Poast Ultra	65 lbs N/ac 15 lbs/ac P_2O_5	Low plant establishment (27%). Matured 89 days after seeding. Some deer feeding damage noticed at maturity.
4	Soybean	Soybean	Full	1.25”	Pre-emerge: Roundup WeatherMax In-crop: Roundup WeatherMax	15 lbs/ac P_2O_5	Excellent weed control. Spayed for grasshoppers on August 17.
5	Oats	Oats	Full	1.5”	Pre-emerge: Roundup WeatherMax In-crop: Buctril M	85 lbs N/ac 15 lbs/ac P_2O_5	Weed competition from foxtail reduced yield. Sprayed for grasshoppers on August 17. Harvested on September 2.
6	Pea-canola	Pea Canola	Full 1/2	0.75”	Pre-emerge: Roundup WeatherMax In-crop: Odyssey Ultra NXT	15 lbs/ac P_2O_5	Good in-season weed control. Lower incidence of pea lodging near maturity. Canola matured 4-7 days after peas. Desiccated on August 29. Seed separation had limited loss by virtue of seed size disparity.
7	Pea-canola	Pea Canola	2/3 1/2	0.75”		15 lbs/ac P_2O_5	
8	Pea-canola	Pea Canola	2/3 2/3	0.75”		15 lbs/ac P_2O_5	
9	Soy-Flax	Soybean Flax	Full 1/2	1.25” 0.75”	Pre-emerge: Roundup WeatherMax In-crop: Poast Ultra & Basagran Forte	15 lbs/ac P_2O_5	Soybeans matured 5-9 days after flax. Some deer feeding damage observed to flax while at maturity. Similar sized soybean and flax bolls resulted in some flax harvest loss due to unthreshed bolls.
10	Soy-Flax	Soybean Flax	2/3 1/2	1.25” 0.75”		15 lbs/ac P_2O_5	
11	Soy-Flax	Soybean Flax	2/3 2/3	1.25” 0.75”		15 lbs/ac P_2O_5	
12	Pea-Flax	Pea Flax	Full 3/4	0.75”	Pre-emerge: Roundup WeatherMax In-crop: Poast Ultra	15 lbs/ac P_2O_5	Limited in-crop herbicide options and poor weed suppression against problematic weeds (e.g. green foxtail, redroot pigweed and wild buckwheat). Flax matured 5-12 days after peas. Desiccated on August 29.
13	Pea-Flax	Pea Flax	Full 1/2	0.75”		15 lbs/ac P_2O_5	
14	Pea-Flax	Pea Flax	Full 1/4	0.75”		15 lbs/ac P_2O_5	
15	Pea-Oat	Pea Oat	Full 3/4	1.5”	Pre-emerge: Roundup WeatherMax In-crop: N/A	15 lbs/ac P_2O_5	No in-crop herbicide options available, however oats were a strong competitor to suppress weeds (mostly green foxtail). Some nitrogen deficiency observed in oats.
16	Pea-Oat	Pea Oat	Full 1/2	1.5”		15 lbs/ac P_2O_5	
17	Pea-Oat	Pea Oat	Full 1/4	1.5”		15 lbs/ac P_2O_5	

*Inoculant (seed placed): Nod XL LQ, Nod Peat (1t) applied for all pea treatments; Optimize ST (1.5t) applied for all soybean treatments.

Intercrop Summaries

(Carman and Arborg, MB • 2018-2022)

The following pages include summary highlights of pea-canola, pea-oat, soybean-flax and pea-flax intercrops that have been studied at Carman and Arborg, MB from 2018-2022. Details on agronomic practices and individual treatments are available in the year-by-year reports.

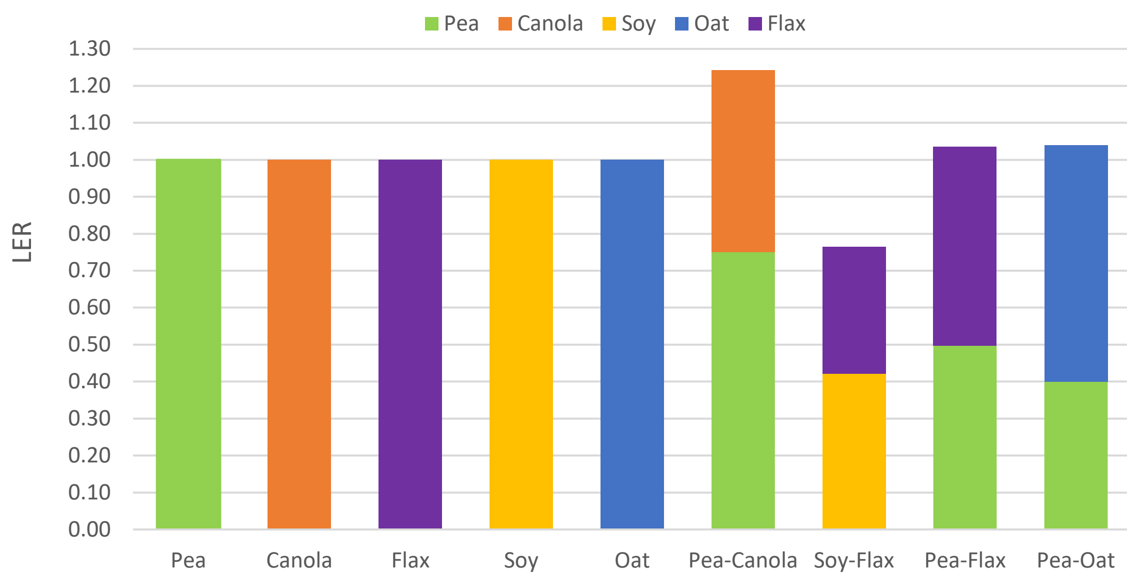

Figure 1. Average total and partial Land Equivalent Ratio (LER) for each intercrop treatment (n=5-6) among all site-years from 2018-2022 at Carman and Arborg, MB.

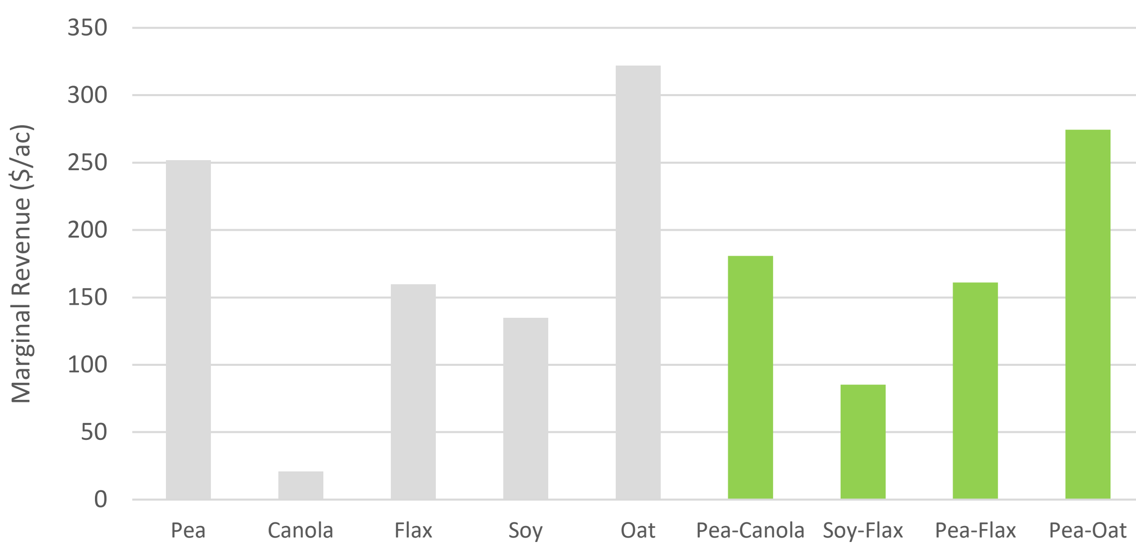

Figure 2. Average marginal revenue of for each monocrop and intercrop treatment (n=5-6) among all site-years from 2018-2022 at Carman and Arborg, MB.

Pea-Canola Intercrop Summary

(Carman and Arborg, MB • 2018-2022)

Overall, we have 8 site-years of data investigating pea-canola intercropping from 2018 to 2022 at Carman and Arborg, MB. Peas and canola were grown together in the same mixed row on narrow row spacing and we tested up to 3 variations of seeding rates relative to full seeding rates of pea (100 seeds/m^2) and canola (10 seeds/ m^2). See Table 1 for treatment details.

Pea-canola intercrop resulted in the highest Land Equivalent Ratio among all intercrops tested (Fig. 1), averaging 1.28 and over-yielding (LER >1.0) in 6 out of 7 site-years. Despite producing the highest LER, the average marginal revenue (MR) was $181/ac (range $-105 to $429/ac) ranking fourth overall following pea, oat, and pea-oat (Fig. 2). The MR for pea-canola was higher than canola in 5 out of 6 site-years but similar or less than peas in all site-years. Crop establishment was a challenge for canola grown as a sole crop or intercrop in most environments, mainly due to flea beetles. High-yielding canola environments would increase profitability of canola grown as a sole crop but would also likely further increase the productivity of the pea-canola intercrop.

Among the seeding rate treatments tested, seeding peas at 2/3 rate and canola at ½ to 2/3 rate has resulted in the greatest LER and MR. Pea-canola is the most widely studied intercrop in Manitoba, resulting in an average LER from 1.22 to 1.68 among Manitoba studies (Entz 2001-2003; Chalmers 2009-2011 and 2019-2021, MacMillan 2019-2022). Pea-canola is grown commercially on 5-10,000 acres annually in Manitoba.

- *Row orientation*: Mixed row
- *Row spacing:* 7.5" at Carman, 9" at Arborg
- *Seeding dates*: May 11 to June 8
- *Seed depth*: 0.75 to 1.25 inch.
- *Fertility:* no added N (soil N ranged from 15-122 lbs/ac) except for Carman 2018, 15 lbs P_2O_5/ac seed placed
- *Varieties:* CDC Amarillo peas and 5545 CL canola or AAC Chrome peas and BY 5125 CL canola
- *Weed management:* Odyssey NXT and Merge
- *Harvest:* Crops were desiccated, threshing and separating ease generally good.
- *Limitations:* Deep seeding (2018), flea beetles (Carman 2019, Arborg 2019, Arborg 2021), drought (Arborg 2019 and 2021, Carman 2021), excess moisture (Arborg 2022), grasshoppers (Arborg 2021)

Table 1. Summary of **Pea-Canola intercrop** and sole crop yield, land equivalent ratio (LER) and marginal return (MR) for 8 site-years tested (Arborg and Carman 2018-2022).

Site Year	Treatment	Yield (bu/ac) Pea	Canola	Inter. pea	Inter. canola	LER ¥	Marginal Return ‡ ($/ac) Pea	Canola	Intercrop	Rank /17
Arborg 2019	Pea (full), Canola (1/2)	31.4	17.7	29.6	3.9	1.20	$149	$38	$154	4
	Pea (2/3), Canola (1/2)			32.5	2.9	1.20			$174	2
Arborg 2020	Pea (full), Canola (1/2)	90.4	19.3	62.9	7.3	1.07	$612	$74	$406	10
	Pea (2/3), Canola (1/2)			62.8	7.2	1.07			$429	9
	Pea (2/3), Canola (2/3)			57.3	9.1	1.10			$388	12
Arborg 2021	Pea (full), Canola (1/2)	1.5	9.4	1.5	0.7	1.05	-$92	$55	-$105	16
	Pea (2/3), Canola (1/2)			2.0	1.5	1.47			-$55	12
	Pea (2/3), Canola (2/3)			2.1	2.3	1.65			-$51	10
Arborg 2022	Pea (full), Canola (1/2)	34.5	15.4	14.4	10.7	1.11	$306	$103	$176	13
	Pea (2/3), Canola (1/2)			10.7	15.3	1.30			$235	8
	Pea (2/3), Canola (2/3)			14.8	15.6	1.44			$279	17
	Average	**39.4**	**15.4**	**26.4**	**6.9**	**1.24**	**$244**	**$68**	**$184**	**10**

Site Year	Treatment	Yield (bu/ac) Pea	Canola	Inter. pea	Inter. canola	LER	Marginal Return ($/ac) Pea	Canola	Intercrop	Rank /17
Carman 2018	Pea (full), Canola (full)	34.5	-	43.4	0.2	-	-	-	-	-
Carman 2019	Pea (full), Canola (1/2)	5.0	6.7	4.7	3.9	1.51	-$13	-$81	-$40	-
Carman 2021	Pea (full), Canola (1/2)	24.1	3.5	19.0	2.0	1.35	$199	-$133	$130	9
	Pea (2/3), Canola (1/2)			19.4	3.7	1.86			$196	6
	Pea (2/3), Canola (2/3)			15.5	4.0	1.77			$139	8
Carman 2022	Pea (full), Canola (1/2)	37.8	16.5	24.1	3.6	0.85	$332	-$14	$162	7
	Pea (2/3), Canola (1/2)			21.6	3.8	0.80			$165	6
	Pea (2/3), Canola (2/3)			13.2	15.3	1.27			$235	3
	Average	**25.4**	**8.9**	**20.1**	**4.6**	**1.34**	**$266**	**-$73**	**$171**	**7**

¥ Land equivalent ratio (LER) = $\frac{\text{yield of intercrop species 1}}{\text{yield of monocrop species 1}} + \frac{\text{yield of intercrop species 2}}{\text{yield of monocrop species}}$

‡ Marginal return ($/ac) = Gross revenue (yield x market price) – Seed – Fertilizer – Pesticide – Separation ($0.25/bu)

Pea-Oat Intercrop Summary

(Carman and Arborg, MB • 2018-2022)

Overall, we have 7 site-years of data investigating pea-oat intercropping from 2018-2022 at Carman and Arborg, MB. Peas and oats were grown together in the same mixed row arrangement on narrow spacing without N fertilizer and we tested up to 3 variations of seeding rates relative to full seeding rates of pea (100 seeds/m^2) and oat (355 seeds seeds/m^2). See Table 3 for treatment details.

Pea-oat intercropping ranked among the highest in profitability in most years among the sole crops and intercrops tested (Table 3 and Fig. 2). The marginal revenue (MR) of pea-oat intercropping met or exceeded MR of peas in 4 out of 6 years and oats in 2 out of 6 years. The overall average Land Equivalent Ratio for the pea-oat intercrop was 1.03 and ranged from 0.62 to 1.68.

The performance of the seeding rate combinations was variable year to year. Seeding rates tested included a 2/3 to full rate of peas and a 1/4 to 3/4 rate of oats. Although grain varieties were used, forage nutrient analysis was collected to demonstrate the value of using pea-oat intercrop as an alternative feed source. Compared to oats alone, a pea-oat intercrop can increase relative feed value and crude protein by about 15% but reduces total dry matter by 10-50%. The pea-oat values are the average among seeding rate treatments in each year.

- *Row orientation*: Mixed row
- *Row spacing:* 7.5” at Carman, 9” at Arborg
- *Seeding dates*: May 11 to June 8
- *Seed depth*: 1.25 to 1.5 inch
- *Fertility:* no added N (soil N ranged from 15-122 lbs/ac), except Carman 2018 and 15 lbs P_2O_5/ac seed placed
- *Varieties:* CDC Amarillo (2018-2021) or AAC Chrome (2022) peas and Souris oats
- *Weed management:* Pre-seed tillage or glyphosate (9). No in-crop herbicide options. The pea-oat intercrop provided good weed suppression, but plots were hand-weeded in some years where problematic weeds (e.g. wild oats) were a challenge.
- *Harvest:* Crops matured evenly, pea seed coat damage was lower than pea-flax and pea-canola and crops separated easily.
- *Limitations:* Drought (Arborg 2019 and 2021, Carman 2021), excess moisture (Arborg 2022), grasshoppers (2021), weed control (Carman 2022).

Table 2. Average forage nutrient analysis of oat and pea-oat intercrop over 3 years at Arborg (2020-22).

	Feed basis	Oat	Pea-oat
Relative Feed Value	Dry Matter	96.3	110.4
Total Digestible Nutrients (%)	As Fed	56.5	55.9
Crude protein (%)	As Fed	12.6	14.7
Total dry matter (lbs/ac)	As Fed	5130	3745

Table 3. Summary of **Pea-Oat intercrop** and sole crop yield, land equivalent ratio (LER) and marginal revenue (MR) for 6 site-years tested (Arborg and Carman 2018-2022).

Site Year	Treatment	Yield (bu/ac) Pea	Oat	Inter. pea	Inter. oat	LER ¥	Marginal Return ‡ ($/ac) Pea	Oat	Intercrop	Rank /17
Arborg 2019	Pea (full), Oat (1/2)	31.4	-	12.4	48.5	-	$149	-	$205	1
	Pea (2/3), Oat (2/3)			5.4	48.1	-			$166	3
Arborg 2020	Pea (full), Oat (3/4)	90.4	105.2	55.0	43.6	1.02	$612	$375	$513	3
	Pea (2/3), Oat (1/2)			45.6	46.4	0.95			$455	7
	Pea (2/3), Oat (1/4)			64.8	18.0	0.89			$509	4
Arborg 2021	Pea (full), Oat (3/4)	1.5	17.8	0.7	11.3	1.13	-$92	$61	-$52	11
	Pea (2/3), Oat (1/2)			0.9	13.9	1.39			-$25	6
	Pea (2/3), Oat (1/4)			1.8	8.6	1.68			-$37	9
Arborg 2022	Pea (full), Oat (3/4)	34.5	150.8	3.7	169.2	1.23	$306	$693	$683	2
	Pea (2/3), Oat (1/2)			3.7	131.7	0.98			$521	4
	Pea (2/3), Oat (1/4)			10.1	147.7	1.27			$681	3
	Average	**39.4**	**91.2**	**18.5**	**62.4**	**1.17**	**$244**	**$376**	**$329**	**5**

Site Year	Treatment	Yield (bu/ac) Pea	Oat	Inter. pea	Inter. oat	LER	Marginal Return ($/ac) Pea	Oat	Intercrop	Rank /17
Carman 2018		34.5	-	15.8	11.0	-	-	-	-	-
Carman 2021	Pea (full), Oat (3/4)	24.1	67.8	3.9	46.2	0.84	$199	$336	$207	4
	Pea (2/3), Oat (1/2)			3.7	45.3	0.82			$208	3
	Pea (2/3), Oat (1/4)			9.6	41.3	1.01			$268	2
Carman 2022	Pea (full), Oat (3/4)	37.8	65.7	3.8	33.9	0.62	$332	$144	$38	15
	Pea (2/3), Oat (1/2)			7.0	47.9	0.91			$148	9
	Pea (2/3), Oat (1/4)			10.9	31.7	0.77			$131	12
	Average	**31.0**	**66.8**	**6.5**	**41.1**	**0.83**	**$266**	**$240**	**$167**	**8**

¥ Land equivalent ratio (LER) = $\frac{\text{yield of intercrop species 1}}{\text{yield of monocrop species 1}} + \frac{\text{yield of intercrop species 2}}{\text{yield of monocrop species 2}}$

‡ Marginal return ($/ac) = Gross revenue (yield x market price) – Seed – Fertilizer – Pesticide – Separation ($0.25/bu)

Soybean-Flax Intercrop Summary

(Carman and Arborg, MB • 2018-2022)

Overall, we have 8 site-years of data investigating soybean-flax intercropping from 2018 to 2022 at Carman and Arborg, MB. Each crop type was grown in separate and alternating rows (except Arborg18) and we tested up to 3 variations of seeding rates relative to full seeding rates of soybean (200,000 seeds/ac) and flax (55-65 seeds/ft^2). See Table 4 for treatment details.

The success of soybean-flax intercropping was variable, depending on the site and yield of the sole crops. Row separation and a well-planned weed control program are important for this intercrop. Fields with group 1 and 2 resistant grass weeds are problematic because in-crop grass herbicide options are limited to group 1 and 2 products. Redroot pigweed and wild buckwheat are also problematic weeds. Pre-plant Edge or Treflan could be used. Our observations suggest that soybean-flax was less competitive against the same weed community than pea-flax due to lower competitive ability of soybean compared to pea, and the alternating row arrangement. Soybean seeded at 2/3 rate (132,000 seeds/ac) and flax at ½ rate (27 seeds/ft^2) was the most profitable in all years tested.

The Land Equivalent Ratio (LER) for soybean-flax was 0.76 on average, ranging from 0.2 to 1.31 across site-years. Since LER is inflated when sole crop yields are low, we also calculated marginal return. The MR for soybean-flax was $85/ac on average, ranging from -$117/ac to $304/ac, compared to average MR of $135/ac for soybean and $160/ac for flax. Intercropping soybean-flax tended to be more profitable than soybeans and less profitable than flax at Arborg, where flax productivity was higher than soybean. At Carman, intercropping was more profitable than flax and less profitable than soybean, because soybeans yielded well while flax failed due to disease and poor weed control.

- *Row orientation*: Separate, alternating rows (except Arborg18 which were mixed rows, but this was not successful as flax outcompeted soybean).
- *Row spacing:* 7.5” at Carman, 4.5” at Arborg (soybean seeded down the mid-row)
- *Seeding dates*: May 11 to June 8
- *Seed depth*: 0.75-1.5” for both crop types or 1.25” for soybean and ¾ to 1” for flax.
- *Fertility:* no added N (soil N ranged from 15 to 122 lbs/ac), 15 lbs P_2O_5/ac seed placed
- *Varieties:* CDC Glas flax (later maturing to better align with soybean maturity), S007-Y4 soybean (Carman) or NSC Watson (Arborg).
- *Weed management:* pre-emerge Authority 480 (14) or glyphosate (9), in-crop Centurion (1), Clethodim (1), Assure II (2) or Poast Ultra (1) for grassy weed control, and Basagran Forte (6) for broadleaves, hand weeding in some site-years.
- *Harvest:* Appropriate variety selection to narrow the maturity window between crops. Crops were desiccated in some years which can aid in plant dry down and lower the threshing aggressiveness needed for flax bolls (since flax bolls and soybean seed are similar in size, damage to the soybean seed can occur when aggressive threshing is required for the flax bolls).
- *Limitations:* Drought (Arborg 2019, 2021, Carman 2018, 2019, 2021), excess moisture (Arborg 2022), disease (Carman 2019), weed control (Carman 2018 and 2022), grasshoppers (2021).

Table 4. Summary of **soybean-flax intercrop** and sole crop yield, land equivalent ratio (LER) and marginal revenue (MR) for 8 site-years tested (Arborg and Carman 2018-2022).

Site Year	Treatment	Yield (bu/ac)				LER ¥	Marginal Return ‡ ($/ac)			Rank /17
		Soybean	Flax	Inter. soy	Inter. flax		Soybean	Flax	Intercrop	
Arborg 2019	Soybean (full), flax (1/2)	12.4	19.9	0.1	10.9	0.56	$10.23	$147.36	-$22.76	12
	Soybean (2/3), flax (2/3)			0.0	11.0	0.55			$4.79	11
Arborg 2020	Soybean (full), flax (1/2)	25.5	35.7	11.3	19.2	0.98	$173.77	$433.66	$261.99	15
	Soybean (2/3), flax (1/2)			12.4	19.2	1.02			$304.00	13
	Soybean (2/3), flax (2/3)			9.8	21.6	0.99			$303.97	14
Arborg 2021	Soybean (full), flax (1/2)	8.6	3.1	8.2	0.3	1.04	$7.98	-$17.86	-$26.09	7
	Soybean (2/3), flax (1/2)			6.6	0.3	0.87			-$17.24	4
	Soybean (2/3), flax (2/3)			6.4	0.3	0.86			-$29.82	8
Arborg 2022	Soybean (full), flax (1/2)	13.7	24.2	10.9	12.5	1.31	$91.98	$428.26	$192.67	11
	Soybean (2/3), flax (1/2)			6.4	14.6	1.07			$203.30	9
	Soybean (2/3), flax (2/3)			5.5	13.2	0.95			$145.56	14
	Average	**15.1**	**20.8**	**7.1**	**11.2**	**0.93**	**$70.99**	**$247.86**	**$120.03**	**11**

Site Year	Treatment	Yield (bu/ac)				LER ¥	Marginal Revenue ($/ac)			Rank /17
		Soybean	Flax	Inter. soy	Inter. flax		Soybean	Flax	Intercrop	
Carman 2018	Soybean (full), flax (full)	23.6	-	6.9	6.3	-	-	-	-	-
Carman 2019	Soybean (1/2), flax (1/2)	8.9	0.0	7.1	0.0	-	-	-	-	-
	Soybean (2/3), flax (2/3)			0.0	0.0	-	-	-	-	-
Carman 2021	Soybean (full), flax (1/2)	18.0	3.6	3.1	0.9	0.42	$140.76	-$12.64	-$98.81	15
	Soybean (2/3), flax (1/2)			1.7	0.8	0.31			-$89.66	14
	Soybean (2/3), flax (2/3)			1.0	0.5	0.20			-$117.40	16
Carman 2022	Soybean (full), flax (1/2)	33.1	6.8	11.6	4.9	1.07	$384.69	-$20.63	$111.31	14
	Soybean (2/3), flax (1/2)			8.7	5.6	1.09			$114.77	13
	Soybean (2/3), flax (2/3)			8.2	10.0	1.72			$195.52	5
	Average	**34.6**	**5.2**	**5.7**	**3.8**	**0.80**	**$262.73**	**-$33.27**	**$19.29**	**13**

¥ Land equivalent ratio (LER) = $\frac{\text{yield of intercrop species 1}}{\text{yield of monocrop species 1}} + \frac{\text{yield of intercrop species 2}}{\text{yield of monocrop species 2}}$

‡ Marginal return ($/ac) = Gross revenue (yield x market price) – Seed – Fertilizer – Pesticide – Separation ($0.25/bu)

Pea-Flax Intercrop Summary

(Carman and Arborg, MB • 2019-2022)

Overall, we have 6 site-years of data investigating pea-flax intercropping from 2019 to 2022 at Carman and Arborg, MB. Peas and flax were grown together in the same mixed row arrangement on narrow spacing and we tested up to 3 variations of seeding rates relative to full seeding rates of pea (100 seeds/m^2) and flax (55-65 seeds/ft^2) and flax. See Table 5 for treatment details. We also monitored pea aphids to see if populations differed between the pea sole crop and pea intercrops.

The Land Equivalent Ratio (LER) for pea-flax was 1.30 on average, ranging from 0.71 to 2.0, across site-years. An LER ≥ 1.0 occurred in 5 out of 6 site-years, however, since LER is inflated when sole crop yields are low (e.g. Arborg 2021, Carman 2021 and 2022), we also calculated marginal revenue (MR). The MR for pea-flax was $161/ac on average, ranging from $-112/ac to $520/ac, compared to average MR of $252/ac for pea and $160/ac for flax. Although over-yielding occurred more frequently than not, intercropping pea-flax was less profitable than peas in 5 out of 6 site-years and canola in 3 out of 6 site-years.

Maintaining a full pea seeding rate and reducing flax to a ¼ or ½ rate tended to have a lower LER but greater profitability among seeding rate treatments. A well-planned weed control program is important for this intercrop. In-crop grass weed control is limited to group 1 and 2 herbicides so fields with group 1 and/or 2 resistant grass weeds are problematic. Redroot pigweed and wild buckwheat are also problematic weeds. Pre-plant Edge or Treflan could be used. Redroot pigweed and wild buckwheat are also difficult to control. We have observed that pea-flax is more competitive compared to soybean-flax. Harvest can also be an issue where aggressive threshing of flax bolls results in pea seed coat damage and potential downgrading since flax bolls and pea seeds are similar in size. Desiccation can help by aiding plant dry down.

- *Row orientation*: Mixed row
- *Row spacing:* 7.5” at Carman, 9” at Arborg
- *Seeding dates*: May 11 to June 8
- *Seed depth*: 0.75 to 1 inch.
- *Fertility:* no added N (soil N ranged from 15-122 lbs/ac), 15 lbs P_2O_5/ac seed placed
- *Varieties:* CDC Amarillo (2019-2021) or AAC Chrome (2022) peas and CDC Plava flax (earlier maturing to align maturity windows, crops matured within 10 days of one another)
- *Weed management:* pre-emerge Authority 480 (14) or glyphosate (9), in-crop Centurion (1), Clethodim (1), Assure II (2) or Poast Ultra (1) for grassy weed control, and Basagran Forte (6) for broadleaves, hand weeding in some site-years.
- *Harvest:* Appropriate variety selection to narrow the maturity window between crops. Crops were desiccated in some years which may reduce pea seed coat damage and flax yield loss due to less aggressive threshing of flax bolls that is required.
- *Limitations:* Drought (Arborg 2019 and 2021, Carman 2021), excess moisture (Arborg 2022), grasshoppers (2021), weed control (Carman 2021 and 2022).

Table 5. Summary of **pea-flax intercrop** and sole crop yield, land equivalent ratio (LER) and marginal return (MR) for 6 site-years tested (Arborg and Carman 2019-2022).

Site Year	Yield (bu/ac)					LER ¥	Marginal Return ‡ ($/ac)			Rank
	Treatment	Pea	Flax	Inter. pea	Inter. flax		Pea	Flax	Intercrop	
Arborg 2019	Pea (full), flax (1/2)	31.4	19.9	16.1	10.2	1.02	$150	$147	$136	7
	Pea (2/3), flax (2/3)			13.6	10.8	0.98			$135	8
Arborg 2020	Pea (full), flax (3/4)	90.4	35.7	45.8	17.5	1.00	$612	$434	$486	6
	Pea (full), flax (1/2)			53.6	14.1	0.99			$504	5
	Pea (full), flax (1/4)			61.7	10.2	0.97			$520	2
Arborg 2021	Pea (full), flax (3/4)	1.5	3.1	1.4	1.4	1.35	-$92	-$18	-$112	17
	Pea (full), flax (1/2)			1.7	1.1	1.49			-$98	15
	Pea (full), flax (1/4)			1.7	0.7	1.34			-$91	13
Arborg 2022	Pea (full), flax (3/4)	34.5	24.2	7.9	12.3	0.74	$307	$428	$185	12
	Pea (full), flax (1/2)			5.9	13.2	0.71			$196	10
	Pea (full), flax (1/4)			-	-	-			-	-
	Average	**39.5**	**20.7**	**20.9**	**13.0**	**1.06**	**$244**	**$248**	**$186**	**10**

Site Year	Yield (bu/ac)					LER				Rank /17
	Treatment	Pea	Flax	Inter. pea	Inter. flax		Pea	Flax	Intercrop	
Carman 2021	Pea (full), flax (3/4)	24.1	3.6	8.3	3.7	1.38	$200	-$13	$14	12
	Pea (full), flax (1/2)			10.0	3.7	1.45			$51	11
	Pea (full), flax (1/4)			13.2	3.3	1.46			$98	10
Carman 2022	Pea (full), flax (3/4)	37.8	6.8	13.5	11.2	2.00	$333	-$21	$228	9
	Pea (full), flax (1/2)			11.5	8.5	1.56			$160	11
	Pea (full), flax (1/4)			11.4	7.3	1.37			$148	12
	Average	**31.0**	**5.2**	**11.3**	**6.3**	**1.54**	**$266**	**-$17**	**$117**	**11**

¥ Land equivalent ratio (LER) = $\frac{\text{yield of intercrop species 1}}{\text{yield of monocrop species 1}} + \frac{\text{yield of intercrop species 2}}{\text{yield of monocrop species 2}}$

‡ Marginal return ($/ac) = Gross revenue (yield x market price) – Seed – Fertilizer – Pesticide – Separation ($0.25/bu)

FEATURE

Relay Crop Soybeans And Winter Wheat – Boom Or Bust?

Kristen P. MacMillan, MPSG Agronomist-in-Residence, University of Manitoba

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HARVESTING A SOYBEAN crop in the same year following harvest of a winter wheat or fall rye crop is one of the latest cropping systems to be evaluated in Manitoba. Termed "relay cropping", the idea is to maximize growing season resources by seeding one crop, then seeding another crop and having their growing seasons overlap for a period. The first crop is harvested, and the second crop continues to grow until it is harvested. The winter wheat-soybean system has been popularized in Indiana and other parts of the mid-western US.. The concept of constant canopy cover and the potential for increased revenue have gained interest from farmers in the northern prairies. What would a relay crop system look like in Manitoba?

The soybean and pulse agronomy team has been experimenting with relay crop systems at Carman, MB since 2017. We've tested several crop combinations that include winter wheat, fall rye and winter camelina as the fall-seeded crops with soybeans, dry beans and peas as the spring relay crop sown directly into the established fall crop. The focus of this article will be the winter wheat-soybean relay crop system.

When evaluating alternative cropping systems, objective-based metrics should be identified. To most farmers, the primary objective is to maximize profitability, but secondary objectives, specifically when considering relay crop systems, may include over-yielding, increased soil cover and biodiversity, improvement in soil quality and risk mitigation. The metrics chosen to evaluate cropping systems in this study are Land Equivalent Ratio (LER) and Gross Margin (GM). LER is commonly used in multi-crop systems to compare how much land is required to produce the same amount of crop in monocrop vs. multi-crop systems. However, LER is inflated when monocrop yields are low, so considering multiple metrics is important.

AGRONOMY

Winter wheat was planted between September 18 and 21 using a drill or planter at 26-35 seeds/ft^2. In the relay crop systems, the inter-row spacing was the same, which reduced the overall seeding rate by about half, depending on the spatial arrangement. In the relay crop system, we tested alternating rows of winter wheat and soybeans as well as twin rows where two rows of winter wheat (7.5" spacing) were planted and then three or five rows were skipped for a row of soybean (15" and 22.5" spacing). Fertilizer application included 60-100 lbs N/ac and 30 lbs P_2O_5/ac for both winter wheat and relay crop systems. Soybeans were planted between May 16 and 26 at 200,000 seeds/ac. Some variations of row spacing and seeding rates were also tested. In our trials, we hand-harvested the winter wheat, but specialized row guards are used on commercial combines to push down the soybeans. Combine tires must also align with the winter wheat rows to avoid damaging soybeans.

In-crop herbicide options are limited in the relay crop system – specifically, to a broadleaf herbicide (groups 4 + 6) application prior to soybean emergence. In some years, we applied a directed spray of glyphosate on the soybean rows, but this can damage the wheat. Using an RR2 Extend soybean variety would provide group 4 dicamba as an in-crop herbicide option but the application window is limited by the growth stage of the winter wheat. Alternatively, using a conventional soybean variety would reduce the seed input cost of the relay crop system.

RESULTS

Over five growing seasons, relay cropping winter wheat and soybeans have reduced productivity and profitability compared to growing either winter wheat or soybeans alone (Table 1). Neither crop was able to produce at least 50% of its monocrop yield in the relay crop system, thus the LER has been <1 and additional expenses have not been recovered. For the first four growing seasons (2018-2021), my hypothesis has been that moisture deficit is the limiting factor. So, in 2022, with near normal precipitation at Carman (but

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Table 1. Yield, Land Equivalent Ratio (LER) and Gross Margin (GM) of winter wheat and soybean monocrops compared to relay crops at Carman, MB from 2018-2022.

Year	System	Wheat	Soybean	Relay wheat	Relay soybean	LER	Wheat GM	Soybean GM	Relay GM
		Yield[x] (bu/ac)					Gross Margin[y] ($/ac)		
2018	Single row, full rates	n/a	23.6	15.5	3.7	n/a	n/a	n/a	n/a
2019	Single row, full rates	44.7	8.9	30.3	0	0.68	185	-21	7
	Single row, ½ cereal rate			25.8	0	0.58			-6
2020	Single row	67.0	30.5	64.4	0.4	0.97	322	178	207
	Twin row			39.2	4.5	0.73			149
2021	2021 Twin row 100% soy rate	20.1	25.9	7.7	11.7	0.84	-23	250	61
	Twin row 80% soy rate			7.1	10.2	0.74			51
	Twin row 60% soy rate			8.2	8.8	0.75			61
	Twin row XL			6.9	10.7	0.76			61
2022	Twin row 100% soy rate	59.2	66.2	24.3	24.7	0.79	411	843	404
	Twin row 80% soy rate			28.3	20.4	0.79			396
	Twin row 60% soy rate			21.9	24.4	0.74			416
	Twin row XL			22.8	25.2	0.77			431
Range		20 to 67	9 to 66	7 to 64	0 to 25	0.58 to 0.97	-23 to 411	-21 to 843	-6 to 431
Average		48	31	24	11.1		224	313	187

[x] Gross Margin ($/ac) = Gross revenue – Seed – Fertilizer – Pesticide – Separation ($0.25/bu)

[y] Land equivalent ratio (LER) = $\frac{\text{yield of relay crop species 1}}{\text{yield of monocrop species 1}} + \frac{\text{yield of relay crop species 2}}{\text{yield of monocrop species 2}}$

still below average), I expected to see the relay crop system shine. The relay crop system improved, but not nearly to the extent that the precipitation favoured soybeans, which surpassed all production systems. Thus, the ideal precipitation amount and pattern for successful relay cropping in Manitoba is unknown, and likely rare. Soybeans produced an impressive 66 bu/ac in 2022, beating out the winter wheat yield of 59 bu/ac and the relay crop system which produced 24 bu/ac of winter wheat and 24 bu/ac of soybeans. Thus, even under near-average moisture, the relay crop system did not improve productivity or profitability at Carman. Also of note is that seeding rate and row spacing rarely had an overall impact on relay crop yield or gross margin.

MOISTURE

Although this applied study did not attempt to explain the ecological principles of relay cropping, a lack of available soil moisture is likely the primary factor. Over the course of this study, growing season precipitation (May through August) has been between 175 and 265 mm (55-83% of normal). Growing season precipitation in Manitoba ranges from about 260 to 320 mm which is generally sufficient to produce most annual crops that use between 260 to 430 mm. Even with additional precipitation from the shoulder season (i.e., September and April), we still do not receive adequate rainfall to sustain two full-season cash crops in Manitoba, or elsewhere on the prairies. Areas where relay crop systems have been popularized have longer, warmer, and wetter growing seasons. Indiana, for example, receives about 550 mm of rain throughout the growing season.

VERDICT

Relay cropping winter wheat and soybeans has been a bust at Carman under dryland conditions over the past five years (2017-2022). Over-yielding has not occurred (LER <1) and profitability has been reduced (Table 1). In some years, gross margins have been comparable to the underperforming monocrop, but our gross margin calculation includes input cost only, and not the additional labour and fuel cost of a second seeding and harvest operation.

We have been studying this system during a five-year period of below-average precipitation. which has been 5 years in a row. At this point, winter wheat and fall rye are best utilized as cash crops alone. Winter cereals also serve well as fall seeded cover crops with the objective to reduce soil erosion and provide some weed suppression ahead of low-residue crops like soybeans and dry beans, with termination occurring at or before planting the cash crop. Attempting to harvest both for cash crops is a risky endeavour in our dryland region. Future work could test relay crop systems under irrigation, and one crop combination that warrants additional investigation is the winter cereal-yellow pea relay intercrop. Full details on our relay and intercropping studies will be available in the 2022 Annual Report this winter. ■

Twin row winter wheat (7.5″ spacing) relay cropped with soybeans (22.5″ spacing) at Carman 2022.

Growing Season Weather Summary

Site	Mean daily temperature (°C)						Precipitation, mm					
	May	June	July	Aug	M-A		May	June	July	Aug	M-A	
Arborg17	10.1	16.2	18.9	16.9	15.5		23	54	76	56	209	↓
Arborg18	13.3	18.4	19.8	17.9	17.4	↑	34	37	58	61	190	↓
Arborg19	8.7	16.3	19.6	17.2	15.5		24	32	67	26	148	↓
Arborg20	9.3	17.2	20.0	18.5	16.2		12	84	61	34	190	↓
Arborg21	9.5	18.7	21.2	17.8	16..8		19	40	12	116	187	↓
Arborg22	10.4	16.1	21.2	20.2	17.0	↑	112	116	187	39	454	↑
LTA-Arborg	10.0	15.8	18.6	17.5	15.5		55	81	70	69	276	
Carman17	12.1	17.1	19.4	17.7	16.6		25	64	23	23	135	↓
Carman18	14.7	18.8	19.9	19.1	18.1		48	97	43	31	219	↓
Carman19	9.6	17.3	19.6	18.1	16.2		37	38	57	62	194	↓
Carman20	10.7	18.3	20.2	18.7	17.1		27	71	54	24	175	↓
Carman21	10.7	18.3	20.2	18.7	17.1		27	103	17	78	226	↓
Carman22	10.9	17.6	19.2	19.3	16.8		99	35	83	49	265	↓
LTA-Carman	11.6	17.2	19.4	18.5	16.7		70	96	79	75	319	
Dauphin18	13.6	18.8	19.1	17.3	17.2	↑	38	104	91	3	236	↓
Dauphin19	8.6	16.2	19.1	16.8	15.2		11	60	66	46	183	↓
LTA-Dauphin	10.5	15.7	18.7	17.7	15.7		55	82	73	61	271	
Melita17	12.2	16.8	21.6	18.7	17.4		6	64	45	39	154	↓
Melita18	15.3	19.1	19.4	18.8	18.1	↑	11	98	54	23	187	↓
Melita19	9.7	16.9	19.5	17.6	15.9		16	85	74	101	275	
Melita20	11.2	18.2	20.2	19.0	17.1		20	63	63	35	181	↓
Melita21	10.5	19.2	21.9	18.8	17.6		28	87	36	125	276	
Melita22	11.5	17.1	19.9	19.9	17.1		84	55	49	13	201	↓
LTA-Melita	11.2	16.5	19.2	18.5	16.3		65	87	62	47	260	
Minto15	12.0	18.0	21.0	20.0	17.8	↑	39	26	41	21	127	↓
Minto17	12.0	16.0	20.0	19.0	16.8	↑	18	61	28	20	128	↓
LTA-Minto	12.0	16.6	12.2	11.1	13.0		61	86	82	67	296	
Portage15	11.3	18.1	20.8	18.8	17.4	↑	76	53	178	64	177	↓
Portage17	11.7	17.2	20.3	18.4	17.0		24	63	15	15	115	↓
Portage18	14.9	19.5	20.6	19.5	18.6	↑	22	93	37	20	172	↓
Portage19	9.8	17.4	20.4	18.1	16.4		33	35	68	37	172	↓
Portage20	11.0	18.4	21.1	19.4	17.4	↑	21	50	60	46	177	↓
Portage21	10.8	20.1	22.3	18.9	18.0	↑	49	70	13	78	210	↓
Portage22	11.2	17.4	20.6	19.9	17.3		134	52	92	74	351	↑
LTA-Portage	10.6	16.1	18.9	17.9	15.9		62	86	70	63	280	
Roblin20	10	15.7	18.5	17.5	15.4	↓	18	111	70	44	242	↓
Roblin21	9.3	17.7	20.1	16.6	15.9	↓	50	62	37	83	233	↓
Roblin22	9.9	15.2	18.2	17.9	15.3	↓	132	77	111	25	345	↑
LTA-Roblin	9.3	21.4	24.1	23.5	19.6		53	83	72	66	273	

LTA = long term average (1991-2020 for Melita, 1981-2010 for all other sites)
↑ ↓ = +/- 10% of normal
Data sources: Manitoba Agriculture and Environment Canada