Final Extension Report

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Elwin Smith, Danny Le Roy, Scott Jeffrey and Derek Brewin

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Western Grains Research Foundation and partners Alberta Pulse Growers Commission (APG), Alberta Wheat Commission (AWC), Brewing and Malting Barley Research Institute (BMBRI), Manitoba Pulse & Soybean Growers (MPSG), Prairie Oat Growers Association (POGA), and Saskatchewan Wheat Development Commission (SWDC)

Executive Summary: Economic Value of Diversified Cropping Systems

The purpose of the project was to improve understanding of the value of diversified cropping for three regions of the Canadian Prairies with different climatic conditions. These included the Parkland region where canola dominates cropping systems, southern Manitoba where warmer season crops such as corn and soybean can be grown, and the semi-arid prairies where pulse crops such as lentil are widely grown. The research motivating problem was how intensive cropping of a crop can eventually lead to reduced yields and productivity due to increased disease or allelopathic effects of previous crop residues. Funding was provided over four years by the Western Grains Research Foundation and six additional funding partners. The three regional components of the project were undertaken at the Universities of Alberta (Parkland), Manitoba (southern Manitoba) and Lethbridge (semi-arid prairies).

Description of Research and Results:

Parkland

Crop rotations and risk

There is an ongoing concern with the continual concentration of canola (*Brassica napus*) in crop production systems. The limited number of break-years between canola crops provides an ideal environment for diseases such as clubroot (*Plasmodiophora brassicae*) and black leg (*Leptospaeria maculans*) to overcome genetic resistance in current canola cultivars. Frequent canola in current cropping systems can be attributable to the short-term profitability of canola relative to competing crops, such as wheat and barley. Another factor often overlooked in cropping decisions is the influence of business risk management (BRM) programs, especially crop insurance and AgriStability. There have been studies that found significant agronomic benefits from less canola-intensive and more diversified cropping systems, but with newer hybrids and changing crop prices the economic benefit could still favour intensive canola cropping. Understanding the role of production factors and prices in determining risk efficient crop rotations is important for producers and those upstream and downstream from them in the industry.

The study examined canola cropping systems representative of the cooler Parkland region of Alberta (Black – Camrose and Dark Gray – Smoky River soils), and Saskatchewan (Black soil - northwest). The simulation analysis determined the expected net returns from crop production for representative cropping operations for three representative farms in the areas of study. In addition to average expected returns, production and market price risks were incorporated through modeling of stochastic processes. Farm-level benefits, costs, net present value were analyzed in a risk framework to identify risk efficient rotations. The cropping system of spring wheat and canola was the base rotation for all representative farms. Alternative cropping systems were varied in terms of crops included and length of rotation. In addition to spring wheat and canola, crops in rotations included barley, oats, field peas, and flax. Varying the length and the number of crops made the impacts of different levels of output diversification clear and comprehensible.

All rotations for the three representative farms had positive expected returns at the yields and prices used in the modelling. More specialized crop production, such as rotations with intensive canola rotations, had higher returns in the short-term. Long-term actual and potential costs were less than the higher economic benefits of intensive canola rotations. For producers to adopt less intensive canola-based crop rotations, the returns from these rotations need to be higher. The annualized additional per acre returns, for a risk neutral producer, were approximately $34, $2, and $11 in the counties of Camrose and Smoky River, and in Saskatchewan, respectively. The risk analysis also indicated that participation in BRM programs, such as crop insurance, reinforced the benefits from intensive canola-based rotations over more diverse rotations. The results highlighted economic aspects of negative productivity factors (e.g., disease event incidence and severity) from intensive canola cropping, information that producers could exploit to improve their cropping decisions.

Clubroot

A second analysis of canola-based rotations was with the presence of previous clubroot damage. The analysis examined the expected effect of canola resistance breakdown on long-term profits. There is considerable field evidence that over time pathotypes not affected by the resistance become the dominant clubroot pathotypes and resistance will eventually be broken. There are fields where resistance broke the third time a cultivar with resistance was planted, in these cases a period of five years. Having at least two years between canola crops will slow the rate of clubroot pathogen buildup and increase the time frame current resistance will be effective. Clubroot also tends to be more problematic in soils with lower soil pH, so the break between canola planting is more important when cropping on these soils

The analysis determined the expected annualized net returns from cropping systems with a different number of years between planting canola. Hard red spring wheat was grown between canola crops. The analysis assumed a hybrid with new clubroot resistance was grown. Cropping systems included canola every second, third, or fourth year. Additional systems allowed more years without canola once the severity of clubroot increased. For example, there could be a switch from canola every second year to once every third or fourth year. This switch could happen very early in anticipation of resistance breakdown, as soon as resistance breakdown is identified, or later if resistance breakdown is not identified until subsequent canola crops. Two soil types in the Edmonton area were used, one with a low soil pH and one with a neutral soil pH. Production costs were current costs and prices were an average of the past 11 years. The ratio of the canola to wheat price over this time period was similar to the ratio in the fall of 2022.

The disease-free returns from canola were higher than from wheat, so there was an incentive to plant canola as frequently as possible. A canola yield loss of about 20% would reduce the annual returns from canola to that of wheat. This would be the expected yield loss that would occur when resistance initially breaks, and if no action is taken the yield loss will increase over time. When adopting a cultivar with new clubroot resistance, there was an economic incentive to plant canola every second year for the first two plantings. The best cropping system, if canola had been planted every second year, was to switch to canola every third or fourth year before clubroot resistance is likely to break. The annualized net return when switching to two years of wheat between canola crops before evidence of clubroot resistance breakdown was about $60/acre/year higher than staying with one year of wheat, and $11/acre/year higher than if waiting for resistance to break before going to more years between canola crops.

Crop sequencing

There is evidence that crop yields will depend on the previous crop. Using reported crop yield data from the Agricultural Financial Services Corporation of Alberta, reported by risk area (RA), year and current and previous crop, relative yields by sequence were determined. The yield of a crop following hard red spring (HRS) wheat was assigned a relative yield index of 1.0. Relative yields less than 1.0 indicated the yield was lower than if the crop had followed HRS wheat, and if greater than 1.0 the yield was higher.

Yield indices for six crops in Alberta were reported in the following table: barley, canola, oats, Canada Prairie Spring (CPS) wheat, field peas and HRS wheat. Excluded crops tended to be common either by region or year. For example, lentils, flax, and durum wheat were primarily grown in south-southeast RAs, and faba bean in central RAs. Soft white spring wheat was a more recent crop in many areas, as was faba bean. Mustard and flax were primarily grown in central to south RAs. For the crops that were regionally grown, provincial averages were not computed because climatic factors (precipitation, heat units, etc.) would have dominated the sequence effects. As an illustration, for HRS wheat after lentil, while higher yielding in the lentil growing areas than if following HRS wheat, the yield would appear to be lower following lentil if averaged over the province because the non-lentil growing areas tend to have much higher HRS wheat yields.

Crop yield on the same stubble type (e.g. barley after barley) was generally lower than if grown on any other stubble. Canola after canola yielded 7% lower than if canola were grown after HRS wheat. Field peas after field peas had a 15% yield reduction relative to being grown after HRS wheat. Crop yield, other than for canola and field peas, were higher following canola than HRS wheat. Yield for oats and the wheats where higher after canola and field peas than when following other crops. Of note was that all crops yielded less after oats then after HRS wheat and most other crops.

Relative crop yields of six selected crops in Alberta, by current and previous crop

	Previous Crop					
Current Crop	Barley	Canola	Oats	Wheat-CPS	Field Peas	HRS Wheat
Barley	0.94	1.09	0.86	1.06	1.04	1.00
Canola	0.98	0.93	0.93	1.02	0.96	1.00
Oats	1.07	1.30	0.98	1.09	1.14	1.00
CPS Wheat	0.99	1.16	0.92	0.97	1.17	1.00
Field Peas	0.99	0.97	0.89	0.97	0.85	1.00
HRS Wheat	1.04	1.16	0.97	1.03	1.15	1.00

Southern Manitoba

To determine how diverse crop rotations will influence yield in southern Manitoba, this study determined relative yields by crop sequence for six of the major crops in Manitoba: barley, canola, grain corn, oats, soybean and spring wheat. The analysis used 12 years of data from Manitoba Crop Insurance. Data were available at the field level and included over 51,000 records with current and previous crop yield, inputs applied, soil quality, and the year. The large 12-year dataset facilitated the separation of the crop sequence effect on yield from other yield factors. An econometric yield model was used to estimate the crop sequence effect. The factors included were the added major crop nutrients (N, P, K and S), seeding date, the previous crop planted in the field, the soil quality class, the crop insurance risk area, and a yield trend over the 12 years.

The results from the regression model for all of the risk areas in Manitoba are summarized in the following table. A value of 100% indicated the yield of the crop sequence was the same as the average yield, hence sequence had no effect on crop yield. While there were some values close to 100%, there were other sequences that differed from 100%. All situations where a crop was planted on the stubble of the same crop (barley after barley, for example) had a crop yield less than the average expected yield. The decreased yield ranged from 11.4% less for oats following oats to 4% less for soybean following soybean. Positive yield benefits ranged up to 5.2% for canola following corn grain. Most crops benefited from following corn grain and soybean. The higher yield could possibly be a nitrogen benefit from residual nitrogen not accounted for by current nitrogen application. Yields of most crops following barley and oats had depressed yields.

When developing crop rotations, there are some sequences that should be considered, and others that should be avoided. Crop sequences that should be considered include: canola following barley, soybean following oats, barley following soybean, canola following corn grain. There are also some others that have a small yield benefit. Crop sequences to avoid include: any crop following the same crop, most crops following oats, and most crops following barley. These yield indices can be used to specify rotations that benefit crop yield, such as barley-canola-oats-soybean-spring wheat-grain corn.

Yield responses (% change) of current to previous crop in the rotation in Manitoba (2006-2018).

	Previous Crop					
Current Crop	Barley	Canola	G. Corn	Oats	Soybean	S. Wheat
Barley	90.7	103.3	101.8	93.3	104.5	99.7
Canola	100.4	92.6	105.2	97.2	100.3	100.8
G. Corn	96.6	97.7	93.3	94.6	99.4	100.0
Oats	95.1	100.8	100.0	88.6	103.2	99.2
Soybean	98.8	100.5	102.7	100.1	96.0	101.1
S. Wheat	94.1	100.0	102.4	93.0	103.8	90.3

Semi-Arid Prairies

A farm-level simulation modelling approach was used to evaluate pulse-based rotations in the semi-arid Prairies. The analysis was in three main stages. The first was to determine the net cash flow from feasible crop rotations with different break-years between pulse crops if there was no plant disease nor yield damage from *Aphanomyces euteiches*. This provided a base for comparisons in the presence of disease. With no disease, the shorter rotations with frequent pulse crop production were more profitable than longer rotations with more crop diversity. The second stage was to determine the level of disease damage at which the net cash flow from the shorter rotations equalled that of the longer seven-year rotations. This stage was done with both constant prices and yields, and with stochastic prices and yields. The third stage was an analysis with stochastic price, yield, and yield damage. This required developing a disease model to predict disease severity and yield damage. Disease was modelled probabilistically and was higher if previous disease was high, there were fewer break-years between pulse crops, and moisture conditions were favourable for disease expression. The net cash flow was simulated for different rotations, both lentil and field-pea-based. Crop insurance was modelled to evaluate the effect on returns and the variability of returns. The simulated results were compared using risk efficiency methods.

The initial net cash flow analysis showed that in the absence of disease, shorter pulse-based rotations had higher net cash flows than longer (seven-year) rotations, with the advantage varying by region. For the seven-year rotations to be more profitable, yield damage for a lentil-durum rotation in the Brown Soil Zone of Saskatchewan needed to be 14.5%, 4% for a lentil-canola-durum rotation in the Dark Brown Soil Zone of Saskatchewan, and 20% for a lentil-durum-canola-durum rotation in the Brown Soil Zone of Alberta. With stochastic prices and yields, the yearly damage levels for lentil rotations were similar to the values above. Disease damage to field peas would have to be at least 3%, 0%, and 12%, respectively, to prompt growers to switch to longer rotations. In all cases, the damage occurred at disease severity ratings not much higher than prodromal levels when damage is first observable on plants. It took a very low level of disease and its associated damage to switch from short to longer pulse-based rotations.

The stochastic simulation used a model in which the precise levels for prices, yields, and disease damage were not given, but followed defined probability distributions amenable to statistical analysis. The results, with or without crop insurance, found the longer seven-year rotations were more profitable. When accounting for disease damage, the average net cash flow was higher for a seven-year rotation, regardless of crop insurance, for both Saskatchewan regions. For the Alberta Brown Soil Zone, the four-year rotation with durum and canola had higher average net cash flow. While some simulated outcomes had higher net cash flow for the shorter rotations, most short rotations had lower return or a large loss due to disease damage. Crop insurance did not favour any rotation over another, but it did reduce net cash flow variability due to indemnifying payouts triggered by low crop yields or prices.

The risk analysis showed that for risk neutral growers in each Saskatchewan region, the seven-year rotation was the dominant preference. In the Brown Soil zone of Alberta, the dominant preference of risk neutral growers was the four-year lentil-durum-canola-durum rotation. Using crop insurance was a suboptimal strategy for risk neutral growers in all three regions. However, as the level of a grower's aversion to risk increased having crop insurance was preferred to any rotation without it. In the Alberta region there was a shift to a seven-year insured rotation as risk aversion increased for both lentil and field pea-based cropping systems. With price risk and production uncertainties and across each of the three regions, the results suggest pea and lentil growers should consider adopting agronomically recommended rotations with at least six break-years in pulse production when *A. euteiches* is present in their fields. Maintaining a pulse intensive crop rotation until disease and yield becomes high was less profitable than less pulse intensive systems.

Relevance to Farmers and Need for Future Research:

The study of crop sequencing in Manitoba determined the sequencing of crops had a significant effect on crop yield, the main one being that planting the same crop for more for two years, or more, will depress yield. There were yield benefits to rotating crops and using a more diverse crop rotation. The studies of canola-based systems in the Parkland and pulse-based systems in the semiarid Prairies showed a long-term benefit to more diverse cropping systems. In most crop production situations, a diversity in cropping was profitable. Short-term benefits might be gained from fewer break-years between crops where there are known root diseases, but this will impose higher future costs and lower returns because of increased disease pressures.

Growers need to consider their cropping choices in a long-term framework to maintain productivity and profitability over time. A first step would be to follow industry recommendations on frequency of growing a specific crop. A minimum of two years between canola crops to lessen clubroot yield depression and slow its spread, and for pulse crops six years between pulse crops when *Aphanomyces euteiches* is severe enough for observable plant damage. The choice between growing canola or a pulse crop will reflect the grower's perceptions of their productive capacity and of information communicated through relative prices. In the Parkland region, hard red spring wheat and barley are two options, but there are other minor crops that could also fit in well in some areas, such as oats, flax, grain corn and soybean in Manitoba. Field peas would be an option in a canola-based system. In the semiarid Prairie region, durum wheat and hard red spring wheat are most common, but there are opportunities for barley, oats, flax, chickpeas, and canola in a pulse-based rotation.