Productivity and Economic Performance of Spring Wheat Production Using Conventional Tillage Practices in Southwestern Saskatchewan – Revisited

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INTRODUCTION

- Producers in semiarid regions have historically used fallow (F)-based cropping systems with mechanical tillage methods to produce spring wheat (W) (e.g., F-W and F-W-W). These monoculture cropping systems have proven to be profitable and risk efficient given typically low growing season precipitation and the economic conditions of the day (Zentner and Campbell 1988).

- In the past few decades, however, government polices and programs have changed, as have the choices of crop types, management methods, input costs, marketing opportunities, and weather patterns.

- A 36-year crop rotation experiment established at the Semiarid Prairie Agricultural Research Centre in 1967 and which uses conventional tillage practices provides an ideal opportunity to re-examine the profitability of these traditional cropping systems under today's economic and environmental conditions.

OBJECTIVE

- To re-examine the economic merits of spring wheat production systems that use conventional tillage management practices for the Brown soil zone of southwestern Saskatchewan in regard to the optimal cropping frequency, value of applying N and P fertilizer at soil test rates, and the benefit of including a pulse or oilseed crop in the rotation. The analysis is focused on comparing the performance of the cropping systems in the latter 18-years to that of the first 18-yr period.

MATERIALS AND METHODS

- Twelve crop rotations were originally established on 81 plots in a randomized complete block design with three replicates (Campbell et al. 1983; Campbell et al. 2004, 2005). In this paper we discuss 9 of the rotations (Table 1). All phases of each rotation were present every year. The soil is a Swinton loam and was under F-W cropping for 70 years prior to initiation of the experiment.

Table 1. Crop rotations and fertilizer treatments

Rotation sequence	Fertilizer application	Abbreviation
Fallow-Wheat	N and P	F-W (N + P)
Fallow-Wheat-Wheat	N and P	F-W-W (N + P)
Fallow-Wheat-Wheat	N only	F-W-W (N only)
Fallow-Wheat-Wheat	P only	F-W-W (P only)
Fallow-Flax-Wheat	N and P	F-Flx-W (N + P)
Fallow-Wheat-Wheat-Wheat-Wheat-Wheat[z]	N and P	F-W-W-W-W-W (N + P)
Continuous wheat	N and P	Cont W (N + P)
Continuous wheat	P only	Cont W (P only)
Wheat-Lentil[y]	N and P	W-Lent (N + P)

[z] Established in 1985 from N and P fertilized Oat(hay)-W-W and Flx-W-W systems.
[y] Established in 1979 from two N and P fertilized Cont W systems.

- The rotations were managed using stubble mulch tillage techniques to conserve as much surface crop residue as possible. Seedbeds were typically prepared with one operation of a sweep cultivator with mounted harrows. Full-sized equipment was used to perform all cultural and tillage operations.

- Fertilizer N and P were applied in accordance with rotation specifications (Table 1) and the soil test levels of these nutrients. From 1967 to 1990, we used the fertilizer guidelines established by the Saskatchewan Soil Testing Laboratory. In 1990, the fertilizer guidelines were increased for all crops, except pulses (Saskatchewan Soil Testing Laboratory 1990). Wheat grown on fallow (for treatments designated to receive N fertilizer) received about 8 kg ha^{-1} yr^{-1} prior to 1991 and since then about 41 kg ha^{-1} yr^{-1} (the N was broadcast and incorporated with seedbed tillage). Wheat grown on wheat stubble received about 30 kg N ha^{-1} yr^{-1} prior to 1991 and 50 kg ha^{-1} yr^{-1} since then. Wheat grown on lentil stubble received 23 kg N ha^{-1} yr^{-1} from 1979-1990 and 39 kg ha^{-1} yr^{-1} thereafter. Flax received 6 and 11 kg N ha^{-1} yr^{-1} in the respective periods, while lentil received 14 kg N ha^{-1} yr^{-1}. Fertilizer P (seed placed) was applied to the designated treatments at an average annual rate of 9-10 kg P ha^{-1}.

- Weeds were controlled in-crop (as required) using the most common herbicides of the day and the full recommended application rates for the crop and area. In fall, after harvest, 2,4-D ester was applied to all cropped plots to control winter annual weeds (no fall tillage was performed).

- Summerfallow areas received an average of 4 (range 2 to 5) tillage operations (using a cultivator or rodweeder) to control weeds during the spring and summer periods, plus a fall application of 2,4-D herbicide.

- For the economic analysis, all purchased inputs and machine operations were valued and held constant at their 2003 cost levels (Saskatchewan Agriculture, Food and Rural Revitalization 2003; University of Saskatchewan 2003). The net farm-gate prices for grains were taken at their respective 10-yr average values (1993/93 - 2001/02), namely \$169 t^{-1} for wheat (13.5% protein), \$266 t^{-1} for flax, and \$334 t^{-1} for lentil. The price for wheat was adjusted by treatment, replicate, and year for the grain protein content in accordance with the 2003 protein price schedule established by the Canadian Wheat Board (Canadian Wheat Board 2003). Prices for all grains were varied to test the sensitivity of the findings to changes in these price conditions.

- Participation in the Canada/Saskatchewan Crop Insurance Program was assumed to be at the 70% yield coverage for all crops. The 2003 premium rates and payout criteria for Risk Area # 10 of Saskatchewan were assumed (Saskatchewan Crop Insurance Corporation 2003).

- All economic results are expressed on a per hectare basis for the complete rotation systems, which includes the costs and returns for all cropped and fallow portions of each rotation, and all data were subjected to analysis of variance for split-plot designs with rotation as main plot and year as sub-plot (Gomez and Gomez 1984). Riskiness was assessed using stochastic dominance analysis to compare the probability density functions of net returns from the rotation treatments for producers with low, medium, and high risk aversion (Zentner et al. 1992).

RESULTS AND DISCUSSION

Weather Conditions

- Growing season (1 May - 31 August) precipitation (GSP) over the 36-year study period averaged 203 mm, which is near the long-term mean of 210 mm for this region.

- During the first 18 years (1967-1984) of the experiment, GSP averaged 176 mm or 16% lower than the long-term mean, and it was less than 80% of normal in 9 of the 18 years.

- In contrast, during the latter 18-yr period (1985-2002), GSP averaged 230 mm and was average to well above average in 10 of 18 years.

- Thus, 1967-1984 represents a relatively dry period, while 1985-2002 represents a period of generally favorable growing conditions for annual crops.

Grain Yields and Wheat Protein Concentrations

- Grain yields of N and P fertilized crops averaged 30 to 45% higher during 1985-2002 than in 1967-1984 (Table 2), reflecting the higher available water and increased rates of fertilizer that were applied to crops since 1991.

- Rotation length or cropping frequency had no effect on the yields of well-fertilized wheat grown on fallow or stubble in either period (Table 2). Further, our data showed no significant yield advantage to growing wheat in mixed rotations with flax or lentil compared to monoculture wheat.

- Applying recommended rates of N and P fertilizer, compared to applying N fertilizer alone (i.e., the response to the addition of P fertilizer), increased wheat yields during the 1985-2002 period by an average of 22% when the crop was grown on fallow and by 15% when it was grown on stubble; this compares to yield increases from P fertilization for fallow and stubble wheat of about 11% during the drier 1967-1984 period.

- Similarly, applying N and P fertilizer versus applying P fertilizer alone (i.e., the response to N fertilizer) increased yields of wheat grown on fallow by 9% and increased stubble wheat yields by 48% during 1985-2002; in the earlier 18-yr period the responses from N fertilization averaged 2% (non-significant) for wheat on fallow, and 7% and 11% for wheat grown on stubble in the F-W-W and Cont W rotations, respectively.

- Flax yields averaged 1160 kg ha^{-1} during 1985-2002; this was 45% higher than the yields obtained during 1967-1984. Lentil yields averaged 1122 kg ha^{-1}.

- Grain protein concentrations were typically lower during 1985-2002 than in 1967-1984, especially for stubble wheat, reflecting dilution by the higher yields (Table 2). Further, wheat protein was typically highest when grown after flax or lentil, and lowest when the crop was fertilized with P alone.

Table 2. Grain yields and protein concentrations by rotation phase and period

Rotation phase[z]	Fert.	1967-1984		1985-2002		1967-2002	
		Yield	Protein[y]	Yield	Protein[y]	Yield	Protein[y]
		kg ha^{-1}	%	kg ha^{-1}	%	kg ha^{-1}	%
Grown on fallow							
F-(W)	N + P	1898	14.9	2560	14.2	2231	14.6
F-(W)-W	N + P	1912	14.6	2640	14.3	2278	14.4
F-(W)-W	N only	1715	14.7	2160	14.6	1938	14.6
F-(W)-W	P only	1872	14.7	2430	13.0	2154	13.9
F-(Flx)-W	N + P	798	22.8	1160	20.8	982	21.8
F-(W)-W-W-W-W	N + P	n/a	n/a	2668[x]	14.8	n/a	n/a
Grown on stubble							
F-W-(W)	N + P	1403	14.6	1830	14.0	1617	14.3
F-W-(W)	N only	1263	14.6	1590	14.2	1430	14.4
F-W-(W)	P only	1307	14.0	1240	12.4	1273	13.2
F-Flx-(W)	N + P	1376	15.1	1940	14.3	1660	14.7
F-W-(W)-W-W-W	N + P	n/a	n/a	1803	13.3	n/a	n/a
F-W-W-(W)-W-W	N + P	n/a	n/a	1774	13.3	n/a	n/a
F-W-W-W-(W)-W	N + P	n/a	n/a	1863	13.3	n/a	n/a
F-W-W-W-W-(W)	N + P	n/a	n/a	1883	13.2	n/a	n/a
Cont (W)	N + P	1354	14.4	1820	13.9	1589	14.2
Cont (W)	P only	1162	13.0	1230	12.0	1196	12.5
(W)-Lent	N + P	n/a	n/a	1824	15.4	n/a	n/a
W-(Lent)	N + P	n./a	n/a	1122	23.5	n/a	n/a

[z] The rotation phase of interest is shown in parentheses.
[y] Corrected to 13.5% moisture.
[x] Excludes 1985 when wheat grown on fallow was not yet in proper sequence.

Production Costs and Breakeven Conditions

- Production costs for the complete rotation systems averaged \$10-30 ha^{-1} yr^{-1} higher during 1985-2002 compared to 1967-1984, reflecting the higher rates of N fertilizer applied since 1991 and the greater requirement for weed control in the latter period due to the more favorable growing conditions (Table 3).

Table 3. Effect of crop rotation on production costs by period

Crop rotation	1967-1984	1985-2002	1967-2002
	---------------- (\$ ha^{-1} yr^{-1}) ---------------		
F-W (N + P)	151	176	164
F-W-W (N + P)	179	210	195
F-W-W (N only)	164	192	178
F-W-W (P only)	171	186	178
F-Flx-W (N + P)	173	191	182
F-W-W-W-W-W (N + P)	n/a	240	n/a
Cont W (N + P)	248	278	263
Cont W (P only)	222	232	227
W-Lent (N + P)	278[z]	296	292[y]
LSD (P<0.10)	6	10	8

[z] 1979-1984.
[y] 1979-2002.

- During 1985-2002, total costs for the N and P fertilized systems were lowest for F-W at \$176 ha^{-1} yr^{-1} and highest for W-Lent at \$296 ha^{-1} yr^{-1}. Total costs for F-W-W averaged 19% more than for F-W, while costs for F-W-W-W-W-W averaged 36% more and costs for Cont W averaged 58% more.

- Withholding the application of N or P fertilizer generated costs savings that averaged between \$8 and \$46 ha^{-1} yr^{-1}, but as shown later these savings were substantially less than the value of the additional yield (and protein) gained by proper fertilization.

- The unit cost of producing wheat, or alternatively the 'breakeven prices' needed to recover production costs, were lower during 1985-2002 than 1967-1984 (Table 4). This reflects that the higher yields obtained in the later period more than offset the higher production costs.

- The breakeven prices for N and P fertilized wheat averaged \$154 t^{-1}, and were typically lowest for F-W and highest for Cont W. Further, the breakeven prices were lower for the well-fertilized than for the N-only or P-only systems.

Table 4. Effect of crop rotation on breakeven prices for wheat by period

Crop rotation	1967-1984	1985-2002	1967-2002
	------------------ ($ t^{-1}) ------------------		
F-W (N + P)	159	138	147
F-W-W (N + P)	161	141	150
F-W-W (N only)	165	154	159
F-W-W (P only)	161	152	156
F-Flx-W (N + P)[z]	173	140	154
F-W-W-W-W-W (N + P)	n/a	147	n/a
Cont W (N + P)	183	153	166
Cont W (P only)	191	189	190
W-Lent (N + P)[y]	195[x]	145	155[w]

[z] The breakeven price for flax averaged $347 t^{-1} for 1967-1984, $260 t^{-1} for 1985-2002, and $296 t^{-1} for 1967-2002.
[y] The breakeven price for lentil averaged $443 t^{-1} for 1979-1984, $293 t^{-1} for 1985-2002, and $331 t^{-1} for 1979-2002.
[x] 1979-1984.
[w] 1979-2002.

Net Returns

- At the base grain price levels, the 1985-2002 mean net returns for the N and P fertilized rotations (i.e., income, including crop insurance payouts, above the costs of production) were highest for W-Lent ($93 ha^{-1} yr^{-1}) and lowest for F-Flx-W ($38 ha^{-1} yr^{-1}) (Table 5). Net returns for well-fertilized F-W, F-W-W, F-W-W-W-W-W, and Cont W during this same period were similar, averaging about $52 ha^{-1} yr^{-1} or 44% less than for W-Lent.

- During the drier 1967-1984 period, N and P fertilized F-W and F-W-W produced the highest net returns, while Cont W and F-Flx-W produced significantly lower (and often negative) net returns (Table 5).

- The economic benefit of applying recommended rates of N and P fertilizer in accordance with soil tests was clearly evident, particularly during 1985-2002 when it increased net returns for the F-W-W systems by $18 ha^{-1} yr^{-1} compared to application of N alone and by $32 ha^{-1} yr^{-1} compared to application of P alone. For the Cont W systems, applying N and P fertilizer increased net returns by $71 ha^{-1} yr^{-1} compared to withholding the N fertilizer.

- Changes in the market price for grains significantly influenced the mean net returns and relative rankings of the rotations. Higher grain prices favored the more intensive cropping systems because of the greater total quantity of grain that is normally produced with extended rotations, and vice versa for lower grain prices (data not shown).

Table 5. Effect of crop rotation on net returns by period for base grain prices

Crop rotation	1967-1984	1985-2002	1967-2002
	----------------	($ ha^{-1} yr^{-1})	---------------
F-W (N + P)	23	50	37
F-W-W (N + P)	23	52	38
F-W-W (N only)	18	34	26
F-W-W (P only)	19	20	20
F-Flx-W (N + P)	-3	38	18
F-W-W-W-W-W (N + P)	n/a	56	n/a
Cont W (N + P)	4	49	26
Cont W (P only)	-17	-22	-20
W-Lent (N + P)	n/a	93	72[z]
LSD (P<0.10)	12	13	13

[z] 1979-2002.

Riskiness

- Producers are faced with a tradeoff between the potential to earn higher net returns on one hand and the need to accept higher risk or income variability on the other hand (Fig. 1).

- Based on a risk analysis of the probability distributions of net returns for the cropping systems (and with all-risk crop insurance), producers with high risk aversion (i.e., those least willing to gamble or accept risk) would typically choose cropping systems that included some summerfallow [i.e., F-W (N +P), F-W-W (N + P), or F-W-W-W-W-W (N + P)], while less conservative producers would choose W-Lent (N + P) (Fig . 1).

- Without all-risk crop insurance, all producers would typically consider only F-W (N + P) or F-W-W (N + P).

CONCLUSIONS

- Grain yields for these conventionally tilled cropping systems were typical for this semiarid region during 1967-1984, but were much above normal during 1985-2002 reflecting the more favorable growing conditions, together with the higher recommended rates of fertilizer in the latter period.

- Wheat yields were not influenced by cropping frequency, with yields of N and P fertilized wheat grown on stubble averaging 70-72% of fallow wheat yields.

- Grain protein content of wheat was highest when grown on lentil or flax stubble compared to being grown on wheat stubble, providing evidence of significant rotational benefits from using mixed cropping systems.

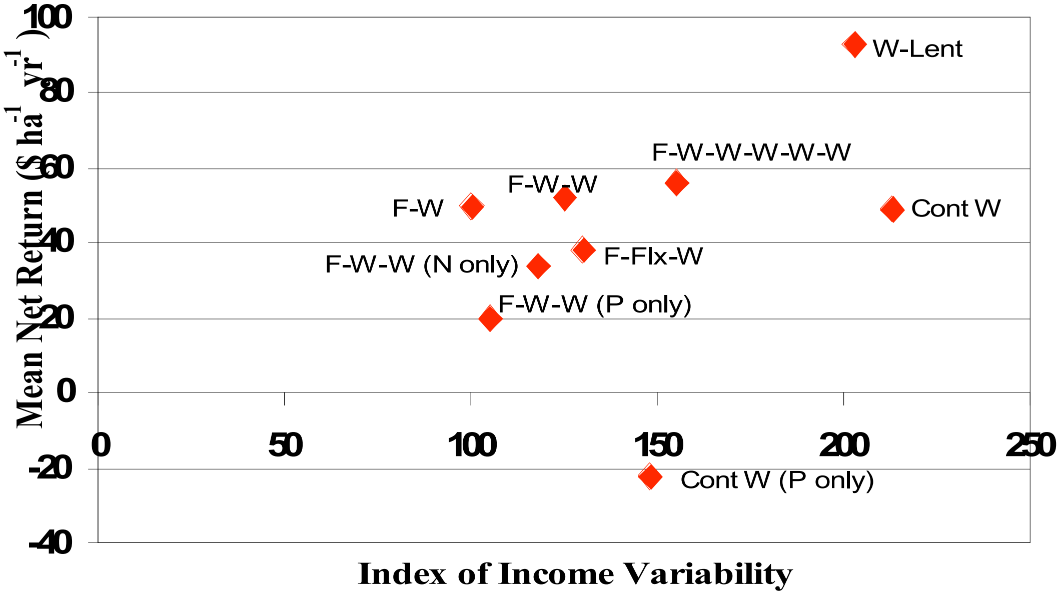

Fig 1. Tradeoff between net return and income variability, assuming participation in the Canada/Saskatchewan all-risk crop insurance program

- Total production costs increased with cropping frequency, as did the cost (or breakeven price) per unit of wheat produced.

- Net returns were generally highest for W-Lent during 1985-2002, and were highest for F-W (N + P) and F-W-W (N + P) during the drier 1967-1984 period.

- Applying recommended rates of N and P fertilizer was highly profitable compared to applying N or P fertilizer alone, emphasizing the importance of soil tests and applying balanced rates of fertilizer nutrients.

- Substituting flax for wheat grown on fallow was not economically advantageous under any of the price conditions evaluated.

- From a risk management perspective, moderate to high risk averse producers would continue to opt for cropping systems that include some summerfallow, although there was a tendency to reduce summerfallow frequency in the rotation. Producers who are less risk averse would choose W-Lent, essentially eliminating fallow from their crop rotation.

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