ECONOMICS OF THE SCOTT LONG-TERM CROP ROTATION SYSTEMS

R.P. Zentner, S.A. Brandt, and C.A. Campbell

1 Agriculture and Agri-Food Canada, Research Centre, P.O. Box 1030, Swift Current, Saskatchewan. S9H 3X2.

2 Agriculture and Agri-Food Canada, Research Farm, Scott, Saskatchewan. SOK 4A0.

Introduction

The low commodity prices of recent years, coupled with changing government policies and increasing concerns about environmental degradation, have caused significant change in land use practices throughout western Canada. Traditionally, producers in the Dark Brown soil zone of Saskatchewan have grown spring wheat, and to a lesser extent barley, in fallow-crop or fallow-crop-crop rotations (Campbell *et al.* 1986). Recently, however, area producers have begun to extend and diversify their crop rotations, becoming less reliant on summerfallow and monoculture cereal cropping. Since 1992, the area planted to crops such as canola, flax, mustard, field pea, lentils, and sunflower has grown to 16% of the total cropland area, while summer-fallow now occupies less than 29% of the area compared to 40% a decade ago (Saskatchewan Agriculture and Food 1994b). These changes in cropping patterns have increased the demand for information about the agronomic, environmental, and economic performance of alternative production systems.

The objective of this study was to compare production costs, net returns, and riskiness of various monoculture cereal and mixed oilseed-cereal rotations based on data from a long-term crop rotation experiment conducted at Scott, Saskatchewan.

Materials and Methods

Experimental Data

The long-term crop rotation experiment located at the Scott Research Farm was initiated in 1964 on an Elstow loam to clay loam, an Orthic Dark Brown Chemozemic soil. Ten crop rotations were originally established; however, modifications were made to the crop types in 1972 and 1980. Consequently, only 9 systems in place during the 1980 to 1991 period were used in this study (Table 1). The rotations were arranged in a randomized complete block design with 4 replicates. All phases of each rotation were present every year.

Farm-sized equipment was used to perform most cultural and tillage operations in accordance with general recommended practices for the region. In the early years, weeds were controlled on fallow areas with an average of 5 (range 3 to 6) tillage operations; the frequency of tillage was reduced to an average of 4 operations in later years. The main tillage implement was a heavy-duty cultivator. During 1980 to 1986, seedbeds were prepared with two preseed tillage operations. Since 1987, seedbeds were prepared using one medium-duty cultivator operation. A double disc press drill was used for planting during 1980 to 1986, since then a high clearance hoe press drill was used.

Table 1. Crop rotation treatments (1980-91)

Rot. No.	Rotation sequence	Abbreviation
1	Fallow-wheat	F-W
2	Fallow-canola	F-C
3	Fallow-wheat-wheat	F-W-W
4	Fallow-wheat-barley	F-W-B
5	Fallow-canola-wheat	F-C-W
6	Fallow-canola-barley	F-C-B
7	Fallow-canola-barley-hay[y]	F-C-B-H
8	Fallow-canola-wheat-barley-hay[y]-hay[y]	F-C-W-B-H-H
9	Continuous wheat	Cont. W

Y Hay = alfalfa.

Crops grown on fallow received an average of 6 kg ha^{-1} of N plus 12.4 kg ha^{-1} of P applied with the seed. Crops grown on stubble received an average of 39 kg ha^{-1} of N, broadcast and soil incorporated by preseeding tillage from 1980 to 1984, and banded from 1985 to 1991; plots cropped continuously to wheat received 45 kg ha^{-1} of N from 1985 to 1991. In addition, 5 kg ha^{-1} of N and 10 kg ha^{-1} of P were placed with the seed. Alfalfa hay plots received no fertilizer.

Herbicides were applied as required for in-crop weed control using recommended methods and rates of application. For broadleaf weed control in wheat and barley crops, 2,4-D, MCPA, and bromoxynil were typically used alone and in combination; barley plots undersown to alfalfa received 2,4-DB or MCPB. Diclofop-methyl was used each year for control of wild oats and other grassy weeds in cereal crops. On plots planted to canola, trifluralin was routinely applied and soil incorporated with tillage during the previous summerfallow year. Herbicides were not applied to the alfalfa forage plots.

Analytical Procedure

Annual production costs and net returns were determined for each rotation system using methods described by Zentner et al. (1990). Net return was defined as the income remaining after.paying for all cash costs (seed, fertilizer, herbicides, fuel, oil, machine repair, crop insurance, land tax, miscellaneous, and interest), labor, and overhead costs associated with machinery and grain storage; as such it represents the residual return to management and equity in land.

Each rotation was evaluated for various plausible economic conditions using a representative farm of 485 ha and a typical complement of machinery for each rotation treatment. Prices for products and costs for inputs and field operations (Table 2) were initially held constant at approximate 1993-94 values (Saskatchewan Agriculture and Food 1994a); wheat prices were adjusted by rotation treatment and year in accordance with the 1994 schedule for protein content established by the Canadian Wheat Board. In addition, product prices were varied from 50% lower to 50% higher than the base values to test the sensitivity of the results to changes in these economic parameters. Participation in the Canada/Saskatchewan all-risk crop insurance program was assumed to be at the 70% yield coverage and variable price options for cereals and oilseeds. Forage crops were assumed to be uninsured.

All economic performance data were expressed on a total rotation basis, which includes the costs and returns for both the cropped and fallowed portions of each rotation system (unless stated otherwise). Performance data were analyzed using analysis of variance for split-plot designs with rotations as main plots and years as subplots; differences among treatment means were determined using LSD ($P<0.05$) (Statistical Analysis System Institute, Inc. 1985). Riskiness of the rotations was assessed using stochastic dominance analysis (Goh et al. 1989) to compare the cumulative probability distributions of net returns among treatments for producers possessing low, medium, and high risk aversion as defined by Zentner et al. (1992).

Results and Discussion

Effect of Crop Rotation and Crop Type on Production Costs

Production costs for the complete rotation systems increased with cropping intensity (Table 3). Relative to the 2-yr F-W system (avg cost of \$126 ha^{-1}), total costs averaged 20% to 30% higher for 3-yr fallow-type rotations, 20% higher for 4-yr and 6-yr alfalfa hay rotations, and 80% higher for continuously cropped wheat. This pattern of total expenditures was also reported for other long-term crop rotation studies in Saskatchewan, and it reflects the greater requirements for seed, fertilizers (particularly N), machine operations, and other inputs as frequency of cropping is increased (Zentner and Campbell 1988; Zentner *et al*. 1990).

Table 2. Summary of product prices and selected input costs

Item	Price/Cost		Units
Products			
Wheat (< 13.5% protein)'	147		$\$t^{-1}$
Barley	104		$\$t^{-1}$
Canola	302		$\$t^{-1}$
Hay	67		$\$t^{-1}$
Selected Inputs			
Fuel[y]			
Diesel	0.46		$\$L^{-1}$
Gasoline	0.49		$\$L^{-1}$
Fertilizer			
N	0.63		$\$kg^{-1}$
P_2O_5	0.57		$\$kg^{-1}$
Herbicides[x]			
2,4-D ester	9.56		$\$kg^{-1}$
2,4-DB	13.54		$\$kg^{-1}$
MCPA ester	13.10		$\$kg^{-1}$
Bromoxynil & MCPA (1:1)	22.54		$\$kg^{-1}$
Fenoxyaprop & bromoxynil & MCPA (1:9:9)	45.63		$\$kg^{-1}$
Diclofop methyl	45.25		$\$kg^{-1}$
Diclofop methyl & bromoxynil (23:8)	40.48		$\$kg^{-1}$
Trifluralin	23.76		$\$kg^{-1}$

z Wheat prices were adjusted by treatment and year in accordance with the 1994 schedule of protein premiums.

Y Costs exclude eligible tax rebates.

x Costs for all herbicides are per unit of active ingredient.

In this study, and as reported at Melfort (Zentner et al. 1990), production costs for rotations that included canola tended to be lower (avg \$10 ha^{-1} less) than for comparable monoculture cereal systems, reflecting the accumulated small savings in most input categories. Expenditures for seed plus fertilizer represented about 18% of total costs for all systems except Cont W, where they averaged 25% (data not shown). Herbicide expenditures comprised 10% of total costs for the 2-yr fallow-crop and hay rotations, 14% for the 3-yr systems, and 18% for Cont W because of the greater weed control requirements with this latter system. Expenditures for machine operations plus overhead represented between 40% and 50% of total rotation costs.

Table 3. Costs of production for complete rotation systems (1980-91)

Rotation	Cash Costs[z] Mean	Cash Costs[z] SD[y]	Machine & Building Overhead	Total Cost Mean	Total Cost SD[y]	Proportion of F-W
	($ ha^{-1})					(%)
F-W	86.51	8.52	39.76	126.27	9.99	100
F-C	79.37	8.16	36.91	116.28	9.37	92
F-W-W	117.30	9.27	47.28	164.58	12.12	130
F-W-B	114.94	10.69	48.28	163.22	13.56	129
F-C-W	110.17	6.61	46.09	156.26	8.46	124
F-C-B	104.70	7.83	46.65	151.35	10.16	120
F-C-B-H	102.51	8.05	47.51	150.02	12.09	119
F-C-W-B-H-H	104.96	9.15	48.69	153.65	13.61	122
Cont W	166.23	12.68	61.09	227.32	16.22	180
LSD (rotation)	10.85	--	3.08	12.67	--	

z Includes seed, fertilizer, herbicides, machine operation, labor, crop insurance premiums, land taxes, interest on operating capital, and an allowance for electricity and other utility costs.

Y SD = standard deviation calculated over years.

Production costs per unit of grain or forage produced (\$ t^{-1}), differed substantially among crops grown within rotations (Table 4). These values represent the average breakeven prices which must be obtained for products in order to generate suffkient revenue to recover production costs (excluding land and management costs). The unit total cost of producing wheat was lowest when grown on fallow (avg \$91 t^{-1}); it averaged 16% higher when grown on stubble after canola, 27% higher when grown on wheat stubble in fallow-type rotations, and 46% higher when grown on continuous wheat stubble. These results reflect the lower yields of wheat when grown on stubble compared to fallow (Brandt and Zentner 1995), and the somewhat higher input costs per unit area for stubble seeded crops. Unit production costs for wheat when based on cash costs alone (i.e., excluding machine and building overhead) ranged from \$28 to \$36 t-l lower than when based on total costs.

Table 4. Cost per unit of grain or forage produced (1980-91)

	Per unit grain or forage produced			
	Cash Cost[z]		Total Cost	
Crop/Summerfallow	Mean	SD	Mean	SD
	($ t^{-1})			
Wheat on fallow	63.50[y]	15.91	91.09[y]	21.94
Canola on fallow	119.75[y]	23.72	172.44[y]	33.07
Wheat on wheat stubble[x]	84.02	29.32	115.65	39.78
Wheat on canola stubble	76.03	33.48	105.98	44.49
Continuous wheat	97.33	32.39	132.94	43.42
Barley on wheat stubble[w]	59.08	21.23	83.44	28.92
Barley on canola stubble[w]	50.81	13.91	74.05	19.02
Barley on stubble (underseeded)[v]	71.64	29.76	95.83	37.92
Alfalfa hay	36.61	24.40	74.19	56.18

z Includes all costs except machine and building overhead.

Y Includes costs of summerfallowing.

X Shown for fallow-type rotations.

W Shown for rotations without alfalfa hay.

V Includes costs of underseeding alfalfa.

The unit cost of producing canola on fallow averaged 89% higher than the comparable cost of producing wheat (Table 4). In contrast, the unit cost of producing barley on stubble was lower than that of wheat because of the higher barley yields. Unit barley costs were lowest when grown on canola stubble (avg $74 t^{-1}), intermediate when grown on wheat stubble (avg 13% higher), and highest when grown on stubble underseeded to alfalfa (avg 29% higher).

Effect of Crop Rotation on Net Return for Base Price Assumptions

Net returns differed significantly ($P<0.05$) among rotations and years (Table 5), reflecting the highly variable precipitation patterns and grain yields that were obtained over the study period (Brandt and Zentner 1995). In general, mean annual net returns were highest (and similar) for F-C-W, F-C, and F-C-B (avg $107 ha^{-1}), and were lowest for F-C-B-H, F-C-W-B-H-H, and Cont W (avg 33% less). The traditional monoculture cereal systems (F-W, F-W-W, and F-W-B) ranked intermediate with a mean annual net return of $95 ha^{-1} or 11% less than the best systems. The economic advantage of the mixed oilseed-cereal rotations (e.g., F-C-W and F-C-B) over the comparable monoculture cereal systems (e.g., F-W-W and F-W-B) reflects the differences in product prices and yields among fallow-seeded crops, but also the higher yields of stubble-seeded cereals when grown on canola compared to wheat stubble (Brandt and Zentner 1995). This latter yield benefit from using mixed rotations was attributed to higher residual soil water reserves after canola compared to a cereal, and to reduced leaf diseases and weed infestations in the subsequent cereal crops (Brandt and Zentner 1995). The effects of these factors were most evident in the relatively low economic returns earned with the Cont W system.

The poor economic performance of the alfalfa hay rotations (Table 5) reflects the generally low and variable forage yields obtained due to poor stand establishment when under-seeding alfalfa on stubble areas, and the poor distribution of growing season precipitation (for forage crops) that occurred in several study years (Brandt and Zentner 1995).

Annual variability in net returns (as measured by coefficient of variation) was highest for Cont W, intermediate for monoculture cereal systems that included fallow, and lowest for rotations that included canola and alfalfa hay (Table 5). These trends reflect the lower year to year variability in crop yields for mixed rotations compared to monoculture systems (Brandt and Zentner 1995). Despite low grain yields in years when precipitation was low or poorly distributed, economic losses were not incurred with any rotation due, in part, to the revenue protection provided through the Canada/Saskatchewan Crop Insurance Program. Crop insurance payouts were received in 1 of 12 yr with F-C, F-W, and F-W-B systems, in 2 of 12 yr with F-C-W, F-W-W, and F-C-B-H, in 3 yr with F-C-B and F-C-W-B-H-H, and in 4 of 12 yr with Cont. W (data not shown). The benefit of all-risk crop insurance in helping to reduce income variability and the risk of financial loss, particularly in extended rotations, was reported in previous studies (Zentner and Campbell 1988; Zentner et al. 1990).

Effect of Changes in Product Prices on Net Returns

Changes in product prices had a significant impact on the relative profitability rankings of the rotations (Table 6). At the lowest product price levels examined (i.e., 50% less than the base values), all cropping systems lost money, with the extent and frequency of losses being lowest for F-W and F-C and greatest for Cont W. Revenue from crop insurance (which varies with product price) was not sufficient to prevent financial losses from occurring at these low price levels. In contrast, at the highest product price levels (i.e., 50% above the base values) F-C-W and F-C-B were the most profitable systems. There was generally little difference in mean net returns among other rotations at these high product price levels, except for alfalfa hay systems which were generally lower.

Table 5 Annual net return by rotation for base product price levels

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Table 6 Mean annual net return by rotation at low and high grain price levels (1980-g 1)

	Low Prices[z]		High Prices[y]	
Rotation	Mean	SD	Mean	SD
	($ ha^{-1})			
F-W	- 7.20	27.03	201.28	85.47
F-C	- 1.75	21.92	211.83	66.60
F-W-W	-24.60	21.82	216.83	78.11
F-W-B	-27.52	22.66	210.79	81.24
F-C-W	-14.82	21.39	238.98	66.40
F-C-B	-18.26	21.23	224.27	74.23
F-C-B-H	-31.19	14.46	190.47	56.37
F-C-W-B-H-H	-39.81	10.69	167.81	46.96
Cont W	-64.37	25.69	205.31	96.30
LSD (rotation)	6.51	--	22.32	--

Z Refers to 50% lower product prices than base values.

Y Refers to 50% higher product prices than base values.

Changes in the price of one product relative to another also impacted profitability and the rankings of rotations. It was generally more profitable to grow canola than wheat on fallow in a 2-yr fallow-crop rotation when the ratio of canola price to wheat price (equivalent weight basis) was greater than 2.0 (data not shown). Similarly, it was profitable to substitute canola for wheat grown on fallow in F-W-W and F-W-B rotations when the canola/wheat price ratios were greater than 1.8 and 1.9, respectively. These threshold price ratios are very similar to those reported for canola production at Melfort (Zentner et al. 1990). The threshold barley/wheat price ratio above which it was more profitable to substitute barley for wheat grown on stubble in the 3-yr rotations averaged about 0.75. Similarly, the threshold hay/wheat price ratio above with it was profitable to include alfalfa hay in the rotation averaged 0.8 for F-C-B-H and 0.9 for F-C-W-B-H-H. The recent historical (1977 to 1990) hay/wheat price ratios have ranged from 0.4 to 0.6, thus indicating that area producers will not likely find alfalfa hay rotations economically attractive in the foreseeable future, except possibly by those with a specialized need for high quality alfalfa hay (e.g., dairy).

Riskiness of Rotations

When choosing among alternative crop rotations producers are often faced with a trade-off between increases in annual net return and increases in income variability (Zentner et al. 1988). The final selection depends on the risk attitudes (willingness to gamble) of producers, expectations about product prices, and the nature of the probability distributions of possible net return for the rotations. Under the conditions of the experiment at Scott, producers would choose among F-C, F-C-W, F-C-B, and F-W-W, depending upon product prices and degree of risk aversion (Table 7). At lower wheat price levels (i.e., less than \$147 t^{-1}), producers would choose F-C or F-C-B, while at wheat prices higher than \$184 t^{-1} producers would choose F-C-W or F-W-W. The F-W rotation would be considered for use by medium to high risk averse producers, but usually only when grain prices were expected to be low. The F-W-B rotation would be considered usually only under the combination of high wheat and barley prices relative to canola. The alfalfa hay and Cont W systems would not be selected, except under extreme price combinations.

Conclusions

The results of this study showed that producers in the Dark Brown soil zone of west-central Saskatchewan will do best, from a profitability and risk perspective, when using a F-C, F-C-W, F-C-B, or F-W-W rotation. However, these rotations may not be best for maintaining soil organic carbon and total nitrogen. The overall best economic rotation depended upon producers' price expectations and risk preferences. Producers must remain flexible in their choice of a crop rotation so as to respond appropriately to changing market conditions. We showed that it was generally more profitable to produce canola than wheat on fallow when the canola/wheat price ratio was greater than 1.8. Further, it was more profitable to produce barley than wheat on stubble when the barley/wheat price ratio exceeded 0.75. The F-W and F-W-B rotations generally ranked intermediate in economic returns; they became attractive alternatives usually only under conditions of low relative canola prices. Continuously cropped wheat and rotations that included alfalfa hay were not economically competitive under most situations studied because of the high production costs per unit of grain or forage produced under these systems.

Income variability and the risk of financial loss were generally lower for mixed rotations compared monoculture cereal systems, reflecting the benefits of including canola in cereal-based rotations in terms of increasing available soil water reserves and reducing pressures from weeds and diseases for subsequent cereal crops (Brandt and Zentner 1995). Using intermediate length rotations (5 or 6 yr), or rotations with more diversified crop types, may offer area producers even greater opportunity to increase economic returns while maintaining or lowering income variability; however, the economics of these systems must wait until sufficient data from new experiments are available.

Table 7. Risk efficient crop rotations for three levels of risk aversion and selected combinations of product price

Wheat Price ($ t^{-1})	High Risk Aversion	Medium Risk Aversion	Low Risk Aversion
Canola = \$302 t^{-1}; Barley = \$104 t^{-1}; Hay = \$67 t^{-1}			
110	F-C; F-C-B	F-C	F-C
147	F-C; F-C-W	F-C-W	F-C-W
184	F-C-W; F-W-W	F-W-W	F-W-W
221	F-W-W	F-W-W	F-W-W
Canola = \$378 t^{-1}; Barley = \$104 t^{-1}; Hay = \$67 t^{-1}			
110	F-C	F-C	F-C
147	F-C	F-C	F-C
184	F-C-W	F-C-W	F-C-W
221	F-C-W	F-C-W; F-W-W	F-W-W
Canola = \$378 t^{-1}; Barley = \$130 t^{-1}; Hay = 84 t^{-1}			
110	F-C;F-C-B	F-C-B	F-C-B
147	F-C; F-C-B	F-C-B	F-C-B
184	F-C-W	F-C-W	F-C-W
221	F-C-W	F-C-W; F-W-W	F-W-W
Canola = \$227 t^{-1}; Barley = \$104 t^{-1}; Hay = \$67 t^{-1}			
110	F-C-B	F-C-B	F-C-B
147	F-W; F-W-B; F-W-W	F-W-W	F-W-W
184	F-W-W	F-W-W	F-W-W
221	F-W-W	F-W-W	F-W-W
Canola = \$227 t^{-1}; Barley = \$130 t^{-1}; Hay = \$67 t^{-1}			
110	F-C-B	F-C-B	F-C-B
147	F-W-B; F-C-B	F-W-B	F-W-B
184	F-W-B; F-W-W	F-W-W	F-W-W
221	F-W-W	F-W-W	F-W-W

The economic results of this study support the growing trend of producers in the Dark Brown soil zone to diversify their rotations away from the more traditional 2-yr and 3-yr monoculture cereal rotations to those that include alternative crop types such as canola. Including alfalfa hay along with cereals and oilseeds was generally not an economical means of diversifying rotations under the conditions of this experiment.

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Table 5. Annual net return by rotation for base product price levels

Rotation	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989'	1990	1991	Mean	CV
			($ ha^{-1})											(%)
F-W	84	98	139	69	22	128	210	74	23	79	125	113	97	58
F-C	156	76	164	95	59	92	170	83	131	73	60	102	105	42
F-W-W	115	118	139	89	12	130	181	82	37	73	85	93	96	52
F-W-B	64	125	136	52	11	126	206	74	51	68	90	95	92	56
F-C-W	100	104	151	121	51	142	200	128	102	49	86	111	112	39
F-C-B	85	118	154	93	66	95	213	107	100	46	96	61	103	46
F-C-B-H	56	87	112	60	42	58	149	81	99	85	58	70	80	43
F-C-W-B-H-H	33	86	113	46	28	62	106	57	51	67	63	56	64	44
Cont W	53	129	163	82	8	132	126	53	11	36	39	15	70	86
Mean	83	105	141	79	33	107	174	82	67	64	78	79	91	

LSD (rotation) = 14; LSD (year) = 11; LSD (rotation x year) = 33