SPRING WHEAT ROTATIONS IN NORTH-CENTRAL SASKATCHEWAN

R.P. Zentner, K.E. Bowren, C.A. Campbell, A. Moulin,
and L. Townley-Smith

ABSTRACT

Effects of rotation length, crop sequence, and fertilization on yields and economic performance of 10 spring wheat-based rotations are examined over a 27-year period (1960-86) on an Orthic Black Chernozem at Melfort, Saskatchewan. The silty clay loam soil had an initial organic N content of about 0.55% (0-15 cm depth). During 1960-71, fertilized plots received N and P based on general recommendations for the region; thereafter, fertilizer was applied based on soil tests. Yields of wheat grown on fertilized fallow were similar for F-W, F-W-W and a 6-yr fallow-wheat-legume hay (F-W-W-H-H-W) rotation (avg 2519 kg ha^{-1} in 1960-71 and 3036 kg ha^{-1} in the wetter 1972-86 period). Fertilized stubble wheat yields in a F-W-W rotation averaged 88% of comparable fallow wheat yields, while continuous wheat averaged only 66% due to greater weed and disease problems. Inclusion of grass-legume hay or legume green manure crops in the rotations provided no yield benefit for subsequent wheat crops in this fertile soil. Results of the economic analysis showed that at wheat prices greater than 147 \$ t-1, fertilized F-W-W, F-C-W and F-W-W-H-H-W generally provided the best overall economic return. At lower wheat prices unfertilized F-W-W and F-W-W-H-H-W, and fertilized F-W often provided the highest net income. It was profitable to substitute canola for wheat grown on conventional fallow or on partial fallow after grass-legume hay when the ratio of canola to wheat price was greater than about 2.0. Similarly, it was profitable to include grass-legume hay in wheat rotations when the hay price was greater than about one-half that of wheat. Continuous wheat and legume green manure rotation were not economically competitive with the best rotations at any of the price options examined. Fertilizer application was profitable in the F-W-W and continuous wheat rotations when the ratio of fertilizer N cost to wheat price was less than about 5.0; it was profitable in F-W-W-H-H-W when this ratio was less than 3.5. The cost of producing wheat, income variability, and the frequency of economic losses increased with cropping intensity.

INTRODUCTION

Cropping systems in the Black soil zone of western Canada have been traditionally more diverse and intensive in nature than those in the drier Brown and Dark Brown soil zones (Campbell et al. 1986). Alternating cereal with oilseeds, reducing the frequency of summerfallow, applying appropriate rates of inorganic fertilizers, and including legume forage and legume green manure crops in rotations with annual grain crops are recommended practices in this region. However, on soils with inherently high organic matter and natural fertility, several of these practices have not provided significant nor consistent agronomic or soil quality benefits (Campbell et al. 1989; Zentner et al. 1990), and thus they may offer little economic incentive for adoption by producers.

This paper summarizes the effect of rotation length, crop sequence, fertilization, and inclusion of legumes on yields and economic returns for 10 spring wheat-based rotations over a 27 year period on a highly fertile Black soil at Melfort, Saskatchewan.

MATERIALS AND METHODS

The experiment was established in 1957 on a Melfort silty clay loam soil, an Orthic Black Chernozem with an organic nitrogen content of 0.55% in the 0-15 cm depth. Eight of the original eleven crop rotations (Rot 1 to 8) were maintained throughout the years (Table 1); rotations 9 and 10 were established in 1972 as modifications to other previously existing rotations. All stages of each rotation were present every year and each rotation was cycled on its assigned plots. Treatments were arranged in a randomized complete block design with four replicates.

Table 1. Rotations and fertilizer treatments

Rot.	Rotation Sequence+	N & P§
1	Fallow-Wheat	Yes
2	Fallow-Wheat-Wheat	Yes
3	Fallow-Wheat-Wheat	No
4	Green Manure-Wheat-Wheat	Yes
5	Fallow-Wheat-Wheat-Hay-Hay-Wheat	Yes
6	Fallow-Wheat-Wheat-Hay-Hay-Wheat	No
7	Continuous Wheat	Yes
8	Continuous Wheat	No
9*	Fallow-Canola-Wheat	Yes
10*	Fallow-Canola-Wheat-Hay-Hay-Canola	Yes

\+ Green manure refers to sweetclover and hay refers to bromegrass-alfalfa.
* Established in 1972.
§ General recommendations used during 1960-71; rates based on soil tests since 1972.

All crops and rotations were managed using field-sized equipment and the recommended cultural, tillage, and pest control practices for the region. During 1960-71, fertilized rotations received N and P based on general recommendations for the region as provided by the Saskatchewan Advisory Council on Soils. Wheat grown on conventional fallow and on partial fallow after plowdown of sweetclover received an average of 7 kg ha^{-1} N plus 32 kg ha^{-1} P_2O_5, while wheat grown on wheat stubble or after bromegrass-alfalfa hay received an average 27 kg ha^{-1} N plus 23 kg ha^{-1} P_2O_5. Hay plots received only N, at an average rate of 75 kg ha^{-1}. After 1972, N and P fertilizers were applied to fertilized rotations based on soil tests and guidelines for field crop fertilization as prepared by the Saskatchewan Advisory Council on Soils. During this period, wheat grown on fallow and partial fallow after ploughdown of sweetclover received an average of 18 kg ha^{-1} N plus 41 kg ha^{-1} P_2O_5; canola grown on fallow received 12 plus 38, wheat grown on wheat stubble 73 plus 42, wheat and canola grown after hay 37 plus 40, and hay plots received an average of 82 plus 28 kg ha^{-1} of N and P_2O_5, respectively.

The economic analysis, which uses annual data on the types and frequency of field operations; amounts, application methods, and types of herbicides, insecticides, and fertilizers used; and the grain and forage yields obtained over the 1960-86 period, was designed to elicit the performance of the rotations under current and some possible future economic scenarios (Table 2). Each rotation was evaluated annually in regard to level of net income, resource needs, riskiness, and total and average unit costs of grain production. Net income was defined as the returns above cash costs, labor, and depreciation on machinery and buildings. No allowance was made for interest on owned equity. All economic data were expressed on a total rotation basis and thus include the costs and returns of both the cropped and fallowed areas.

All data were statistically analyzed using analysis of variance for randomized complete block designs with years, rotations, and replicates as factors (SAS Institute Inc. 1985). In the event of significant rotation by year interactions, further analyses were conducted by individual year. The data were analyzed for 1960-71 and 1972-86 separately, to coincide with the change in fertilization practice. Throughout the paper the following abbreviations are used: F = fallow, W = spring wheat, Gm = sweetclover green manure, H = bromegrass-alfalfa hay, and C = canola.

Table 2. Summary of product prices and selected input costs

Item Description	Base	Range	Units
Products			
Wheat	147	73-221	$ t^{-1}
Canola	262	130-394	$ t^{-1}
Hay	67	33-101	$ t^{-1}
Selected Inputs			
Fuel			
Diesel	0.36	0.18-0.54	$ L^{-1}
Gasoline	0.39	0.22-0.56	$ L^{-1}
Fertilizer			
N	0.58	0.29-0.87	$ kg^{-1}
P_2O_5	0.60	0.30-0.90	$ kg^{-1}
Herbicides+			
2,4-D ester	7.91	7.23-8.59	$ kg^{-1}
MCPA amine	8.70	8.27-9.13	$ kg^{-1}
Bromoxynil & MCPA (1.1)	19.20	18.21-20.19	$ kg^{-1}
Dicamba	49.12	46.42-51.82	$ kg^{-1}
Triallate	19.38	18.60-20.16	$ kg^{-1}
Diclofop methyl	45.95	44.85-47.05	$ kg^{-1}
Trifluralin	18.13	16.86-19.40	$ kg^{-1}
Insecticides+			
Carbofuran	4.90	4.61-5.19	$ kg^{-1}
Malathion	21.60	20.31-22.89	$ kg^{-1}
Legume inoculant	2.80	2.66-2.94	$ pack^{-1}
Labor	10	0-20	$ hr^{-1}
Interest rate	12	-	%

+ Costs are per unit of active ingredient

RESULTS AND DISCUSSION

Weather Conditions

Average growing season (May 1 to August 31) and total annual precipitation received during 1960-71 (192 and 379 mm, respectively) were lower than the long-term (49 yr) averages of 227 mm and 411 mm, respectively. In contrast, average growing season precipitation received during 1972-86 was 8% higher than the long-term average and about 28% higher than that received during 1960-71. The driest years were 1961, 1962, 1967, and 1969 when less than 124 mm of growing season precipitation was received; the wettest years were 1973 and 1974 when precipitation exceeded 345 mm.

Effects of Rotation Length and Crop Sequence on Yields of Wheat in Fertilized Treatments

Wheat yields from fertilized fallow were similar ($P<0.05$) for F-W, F-W-W, and F-W-W-H-H-W (rot-yr 5-2) in all but 3 years (data not shown). In comparison, yields of wheat grown on partial fallow in Gm-W-W and F-W-W-H-H-W (rot-yr 5-6) were significantly lower ($P<0.05$) than yields of wheat grown on regular fallow in 9 and 13 of 27 years, respectively. Most of the yield differences occurred in years when growing season precipitation was below average or unfavorably distributed during the critical heading and filling stages of plant development. Overall, yields of wheat grown on partial fallow in the legume green manure rotation averaged 212 kg ha-1 lower (8% less) than in F-W or F-W-W during 1960-71, and 165 kg ha-1 lower (5% less) during the more moist 1972-86 period (Table 3). Similarly, yields of wheat grown on partial fallow in the legume hay rotation averaged 446 kg ha-1 lower (18% less) than on regular fallow during 1960-71, and 331 kg ha-1 lower (11% less) during 1972-86. This is attributable mainly to lower soil moisture reserves because of the shortened fallow period in the legume-containing rotations (avg 412 mm of water in top 122 cm of soil at time of planting in Gm-W-W and 393 mm in F-W-W-H-H-W, compared to 432 mm in regular fallow plots). The lack of yield benefit from legumes in the rotations is also perhaps due to fertilization and the high inherent fertility and organic matter content of the soil. Campbell et al. (1989) who studied the soils at Melfort and Indian Head found no difference in soil organic matter due to legumes or fertilizers at Melfort, but on the less fertile Indian Head soil, organic matter and N supplying power were significantly improved by including legumes in the rotation.

Wheat yields from fertilized stubble were generally highest for F-W-W, intermediate for Gm-W-W, F-W-W-H-H-W and F-C-W-H-H-C (1972-86 only), and lowest for continuous monoculture wheat (Table 3). Stubble wheat yields in the legume-containing rotations were significantly lower ($P<0.05$) in 8 of 27 years compared to F-W-W due mainly to moisture competition by the grass-legume crop and by weeds because of restrictions on control practices (data not shown). Continuous wheat yields were significantly lower ($P<0.05$) in 20 of 27 years, and averaged 25% less than in the F-W-W rotation because of greater observed weed infestations and incidence of disease (primarily common root rot and take-all). Yields of wheat grown on stubble in the 3-year and legume-containing rotations averaged 77 to 84% of fallow wheat yields during 1960-71 when low rates of fertilizer were used, but during 1972-86 when higher rates of fertilizer were applied to stubble crops based on soil tests and growing season precipitation was greater, stubble wheat yields averaged 82 to 91% of fallow wheat yields.

The coefficient of variability in wheat yields calculated over years were higher for stubble than for fallow grown wheat and higher during 1960-71 than during 1972-86 (Table 3). The lower year-to-year variability in fallow wheat yields reflects the higher soil moisture reserves generally available to the fallow crop (Table 5) and the higher growing season precipitation in the later period.

Table 3. Mean yields of Wheat by rotation-year

Rot-yr	Rotation Sequence[f]	Fertilized	(1960 - 71) Mean yield	(1960 - 71) % of check	(1960 - 71) CV[#]	(1972 - 86) Mean yield	(1972 - 86) % of check	(1972 - 86) CV	(1960 - 86) Mean yield	(1960 - 86) % of check	(1960 - 86) CV
			(kg ha^{-1})		(%)	(kg ha^{-1})		(%)	(kg ha^{-1})		(%)
Wheat on Fallow											
1 - 2	F-W̲ (check)	Yes	2553	100	48	2986	100	21	2794	100	34
2 - 2	F-W̲-W	Yes	2479	97	44	3015	101	22	2776	99	33
3 - 2	F-W̲-W	No	2161	85	47	2604	87	24	2407	86	35
4 - 2	Gm-W̲-W	Yes	2307	90	48	2871	96	26	2620	94	37
5 - 2	F-W̲-W-H-H-W	Yes	2524	99	44	3108	104	24	2849	102	34
5 - 6	F-W-W-H-H-W̲	Yes	2073	81	56	2705	91	25	2424	87	40
6 - 2	F-W̲-W-H-H-W	No	2210	87	42	2682	90	24	2473	89	33
6 - 6	F-W-W-H-H-W̲	No	1801	71	58	2288	77	32	2071	74	44
Wheat on Stubble											
2 - 3	F-W-W̲	Yes	2113	83	57	2755	92	21	2470	88	39
3 - 3	F-W-W̲	No	1818	71	58	2105	70	22	1977	71	40
4 - 3	Gm-W-W̲	Yes	1940	76	59	2489	83	21	2245	80	40
5 - 3	F-W-W̲-H-H-W	Yes	2015	79	48	2521	84	22	2296	82	35
6 - 3	F-W-W̲-H-H-W	No	1820	71	52	2061	69	25	1954	70	38
7 - 1	Cont. W̲	Yes	1573	62	64	2055	69	35	1841	66	49
8 - 1	Cont. W̲	No	1252	49	62	1383	46	36	1325	47	48
9 - 3	F-C-W̲	Yes	--	--	--	2667	89	21	--	--	--
10 - 2	F-C-W̲-H-H-C	Yes	--	--	--	2628	88	23	--	--	--
	Sx[§]		43			46			36		

[f] Yields pertain to the rot-yr underlined.
[#] Coefficient of variation calculated over years.
[§] Standard error of the means.

Effect of Fertilization on Wheat Yields

Recommended rates of fertilizer significantly increased ($P<0.05$) yields of wheat grown on fallow and stubble in the monoculture and legume-containing rotations in 15 to 20 of 27 years (data not shown). Fallow wheat yields in F-W-W and F-W-W-H-H-W were increased by an average 14 to 18% by N and P fertilization (Table 3). Stubble wheat yields in these same rotations were increased 11 to 16% by fertilization during 1960-71, and continuous wheat yields were increased by 26%. Between 1972 and 1986 when higher fertilizer rates were applied, stubble wheat yields were increased by 22 to 31% for fallow-containing rotations and by 49% for continuous wheat.

Effect of Rotation Length and Fertilization on Total Wheat Production

Total wheat production for the fertilized monoculture wheat rotations increased ($P<0.05$) as the proportion of fallow in the rotation declined (Table 4). Fertilized continuous wheat had the highest total annual wheat production, while F-W and unfertilized continuous wheat had the lowest. During the period when fertilizer was applied according to soil tests, fertilized F-W-W and continuous wheat produced 29% and 38% more wheat than F-W, respectively.

Yields of Canola (1972-86)

Yields of canola were, on average, 11% higher ($P<0.1$) when grown in F-C-W (1524 kg ha^{-1}) than in F-C-W-H-H-C (1377 kg ha^{-1}). In the latter rotation, yields were similar ($P>0.1$) in 11 of 15 years when canola was grown on conventional fallow or after the grass-legume hay. The lack of yield benefit from inclusion of grass-legume hay in the rotation with canola was similar to that observed with wheat.

Dry Matter Yields of Bromegrass-Alfalfa Hay

Dry matter yields of bromegrass-alfalfa hay in fertilized and unfertilized rotations were significantly higher ($P<0.05$) in second-year than in first-year stands during 1960-71, but were similar ($P>0.05$) during 1972-86 (Table 5). This reflects the more favorable precipitation and improved weed control during establishment year because of increased availability of suitable herbicides in the later period. The application of 75 kg N ha^{-1} to the forage plots during 1960-71 increased ($P<0.05$) first-year dry matter yields by an average 42% and second-year yields by 27%. During 1972-86, fertilizer increased first- and second-year hay yields by 34% and 22%, respectively.

Table 4. Total Annual Wheat Production by rotation

Rot.	Rotation Sequence	Fertilizer	(1960 - 71) Mean	(1960 - 71) % of check	(1972 - 86) Mean	(1972 - 86) % of check	(1960 - 86) Mean	(1960 - 86) % of check
			(kg ha^{-1} yr^{-1})		(kg ha^{-1} yr^{-1})		(kg ha^{-1} yr^{-1})	
1	F - W (check)	Yes	1277	100	1493	100	1397	100
2	F - W - W	Yes	1530	120	1923	129	1749	125
3	F - W - W	No	1326	104	1570	105	1461	105
4	Gm - W - W	Yes	1416	111	1789	120	1622	116
7	Cont. W	Yes	1573	123	2055	138	1841	132
8	Cont. W	No	1252	98	1383	93	1325	95
	Sx		35		31		23	

Table 5. Dry Matter Yield of bromegrass-alfalfa hay by rotation - year

Rot-yr	Rotation Sequence	Fertilizer	(1960 - 71) Hay Yield	(1960 - 71) CV[f]	(1972 - 86) Hay Yield	(1972 - 86) CV[f]
			($kg\ ha^{-1}$)	(%)	($kg\ ha^{-1}$)	(%)
5 - 4	F-W-W-H-H-W	Yes	1704	75	4664	40
5 - 5	F-W-W-H-H-W	Yes	3707	36	4463	43
6 - 4	F-W-W-H-H-W	No	1196	76	3471	44
6 - 5	F-W-W-H-H-W	No	2915	48	3661	48
10 - 4	F-C-W-H-H-C	Yes	--	--	4976	29
10 - 5	F-C-W-H-H-C	Yes	--	--	4579	44
	Sx		66		111	

[f] Coefficient of variation calculated over years.

Effect of Crop Rotation and Fertilization on Net Income

For the 1960-71 period, fertilized F-W-W was the most profitable rotation ($P<0.1$) when wheat prices were greater than 147 \$ t^{-1} (Figure 1a). At lower wheat prices, F-W and F-W-W had the highest economic return or lowest loss. The legume-containing rotations and continuous wheat were not economically competitive with the best rotations at any of the price levels examined. Most rotations lost money when product prices were below the base values.

During 1972-86 (Figure 1b), average net income was highest for fertilized F-W-W, F-C-W, and F-W-W-H-H-W when wheat prices were above 184 \$ t^{-1}. At wheat prices between 147 and 184 \$ t^{-1}, fertilized F-W-W and F-C-W were the most profitable rotations, while at lower product prices the best rotations included F-W, F-W-W, F-C-W (Figure 1b), and unfertilized F-W-W-H-H-W (data not shown). When the price of canola was greater than 1.9 times that of wheat, it was profitable to substitute canola for wheat grown on fallow in fertilized F-W-W, and when the ratio was greater than 2.2 it was profitable to substitute canola for wheat grown on conventional and partial fallow in F-W-W-H-H-W (data not shown). Similarly, it was profitable to include bromegrass-alfalfa hay in rotation with wheat (compared to monoculture wheat) when the hay:wheat price ratio (\$ kg^{-1}/\$ kg^{-1}) was greater than 0.5. As found in the first period, Gm-W-W and continuous wheat were not economically competitive with the other rotations.

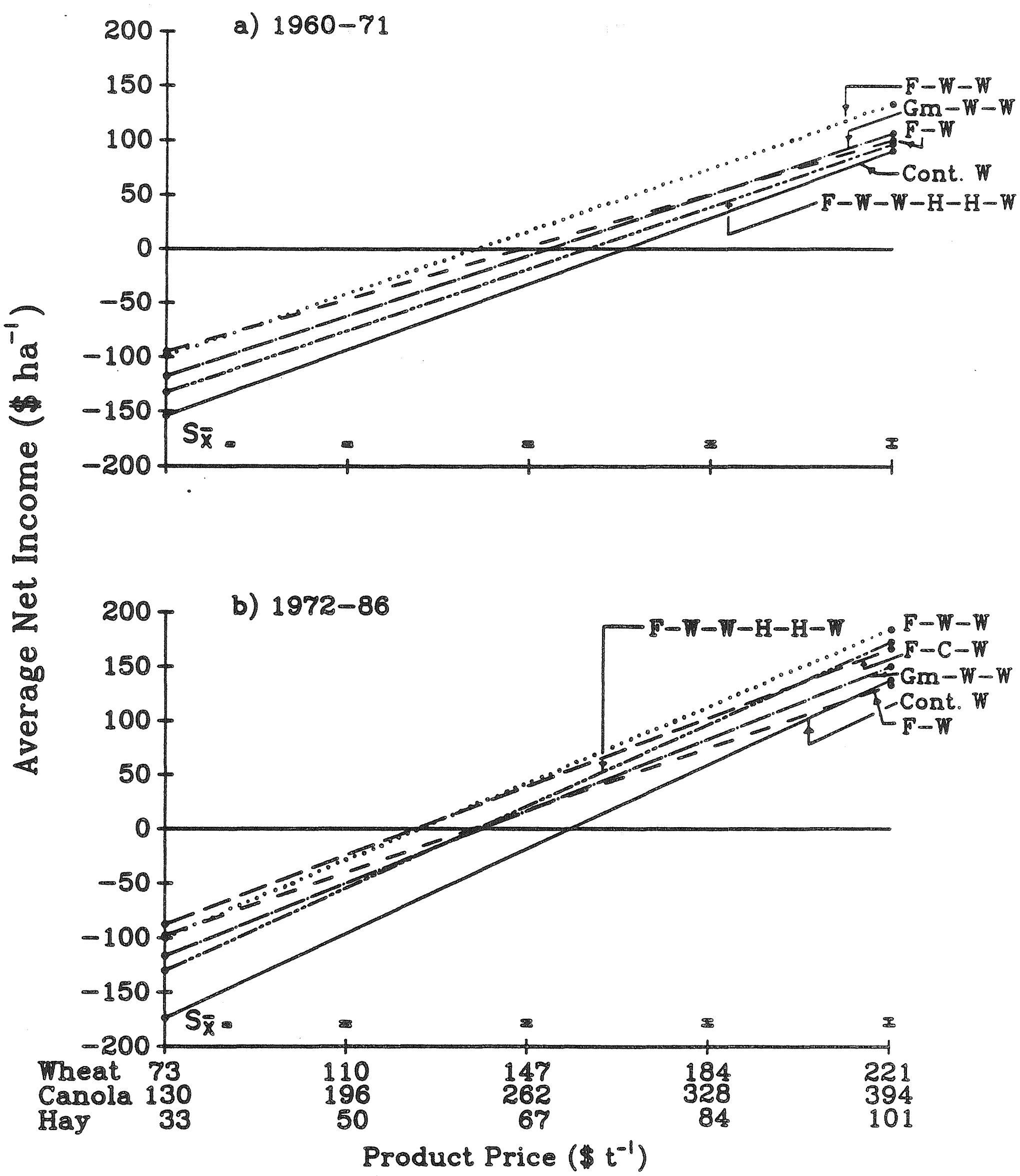

Figure 1. Effect of product price changes on average net income of fertilized rotatins.

The profitability of fertilizer application was inversely related to the ratio of fertilizer cost to product price (Figure 3). During the period 1960-71, application of the generally recommended rates of N and P fertilizer for the Black soil zone to wheat grown in F-W-W and continuous crop rotations was profitable when the ratio of fertilizer N cost to wheat price was less than 4.9 and 4.4, respectively (Figure 3a). Similarly, it was profitable to fertilize F-W-W-H-H-W when the N cost:wheat price ratio was less than 3.3 (assuming the price for wheat was 2.2 times price for hay). During 1972-86, it was profitable to fertilize F-W-W, continuous wheat, and F-W-W-H-H-W at soil test rates when the N cost:wheat price ratios were less than 5.2, 5.1, and 3.6, respectively (Figure 3b). The low N cost:wheat price ratio above which fertilizer application became uneconomic in F-W-W-H-H-W reflects: i) the lower yield increases obtained from fertilizer when wheat was grown on wheat stubble in F-W-W-H-H-W compared to wheat in monoculture systems, and ii) the low hay yield increases obtained from application of high N rates to the grass-legume forage phases.

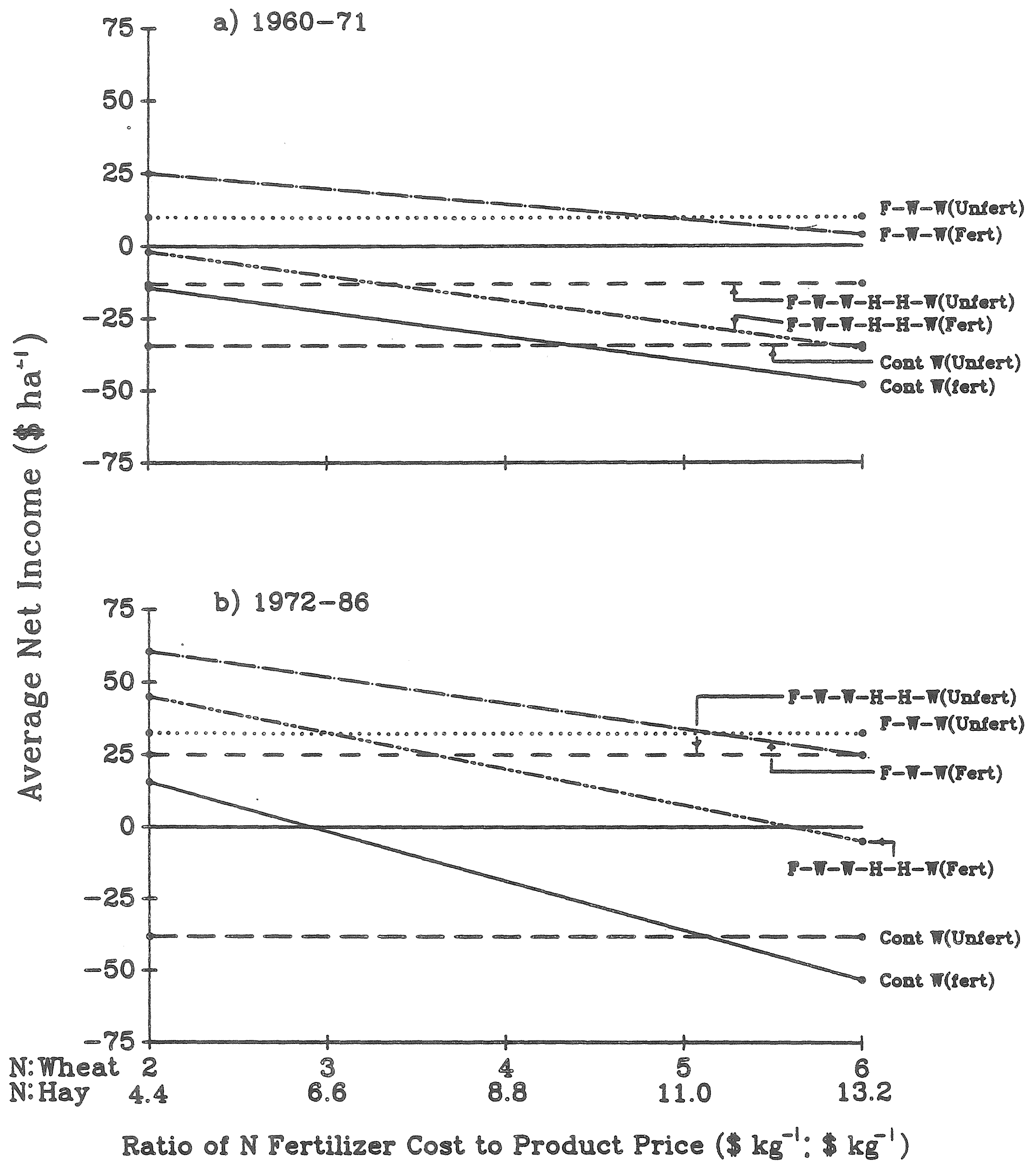

Figure 2. Effect of changes in relative cost of fertilizer on average net income of selected rotations.

Cost of Production

Total cash costs per hectare were higher in 1972-86 than 1960-71 due to greater use of fertilizers and herbicides (Table 6). The costs were lowest for shorter, fallow-containing, and unfertilized systems. Cost differences among rotations reflected not only differences in proportion of cropped land, but also the greater expenditures per unit of cropped area for some inputs as rotation lengths increase (Figure 3). Fertilizer and herbicide expenditures increased most when cropping intensity increased, while machine operation costs increased least because the extra machine requirements for planting and harvesting the additional crop area were partly offset by lower tillage costs of the reduced fallow area. Including sweetclover green manure in a 3-year wheat rotation had little effect on total cash costs because the extra cost for legume seed generally offset the savings in costs of fallow tillage. In contrast, substituting canola for wheat grown on conventional or partial fallow reduced total cash expenditures by 10-16 \$ ha^{-1} because of lower costs for seed, fertilizer, and chemicals.

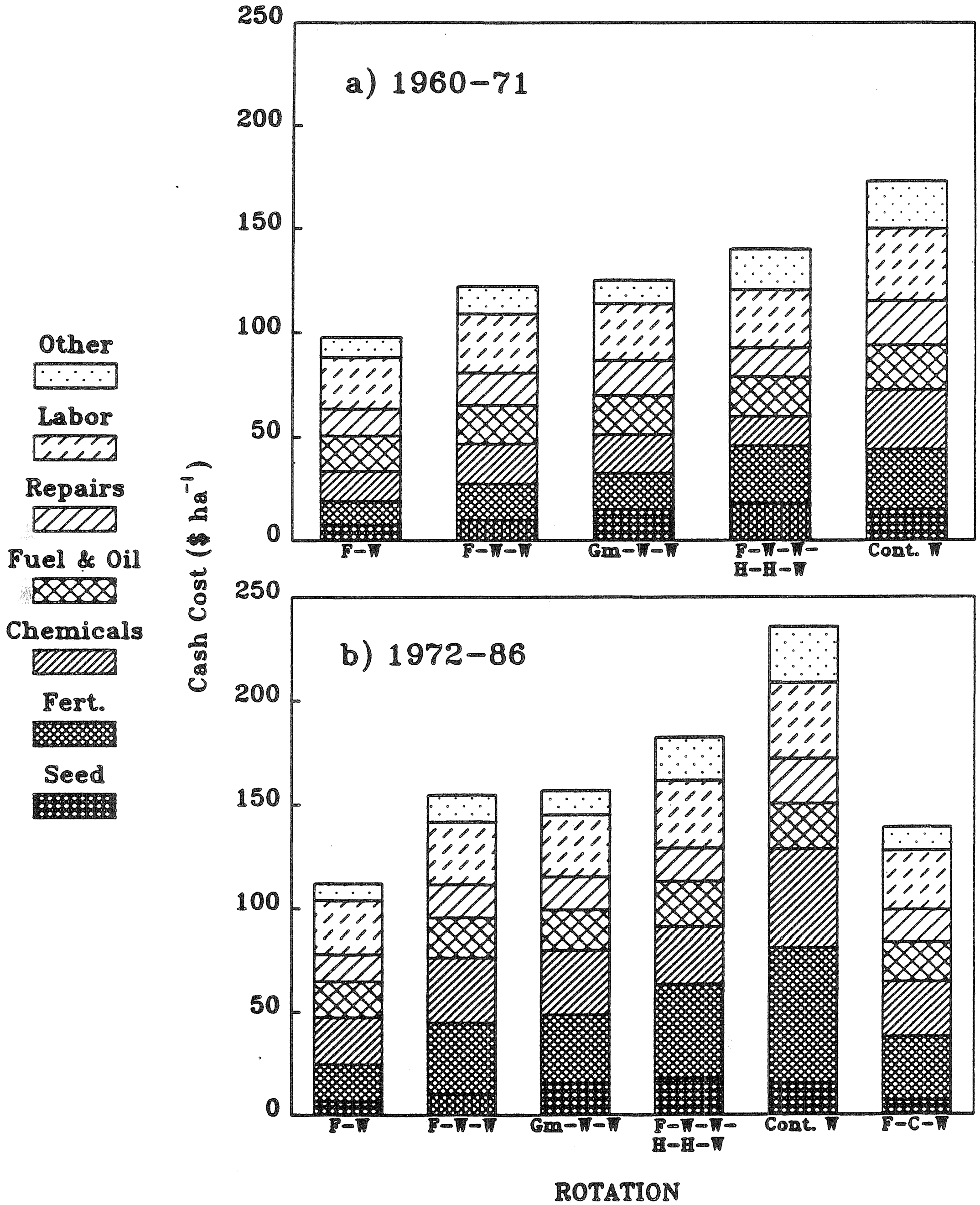

Figure 3. Total cash costs by resource category for fertilized rotations.

Table 6. Total cash costs by rotations

			(1960-71)				(1972-86)			
			Cost per unit land		Cost per unit wheat prod.		Cost per unit land		Cost per unit wheat prod.	
Rot.	Rotation Sequence	N & P Fert.	Mean	Range	Mean	Range	Mean	Range	Mean	Range
			($ ha^{-1})	($ ha^{-1})	($ t^{-1})	($ t^{-1})	($ ha^{-1})	($ ha^{-1})	($ t^{-1})	($ t^{-1})
1	F-W	Yes	98	93-113	97	50-188	112	101-125	77	59-101
2	F-W-W	Yes	122	114-142	103	53-186	155	140-169	83	62-115
3	F-W-W	No	97	93-107	94	44-173	110	104-132	72	53-96
4	Gm-W-W	Yes	125	117-141	115	51-240	157	134-184	90	69-124
5	F-W-W-H-H-W	Yes	140	132-146	-	-	183	154-206	-	-
6	F-W-W-H-H-W	No	103	97-108	-	-	126	107-153	-	-
7	Cont. W	Yes	173	160-191	193	57-543	236	191-268	128	75-258
8	Cont. W	No	129	122-136	164	57-453	152	137-182	119	68-196
9	F-C-W	Yes	-	-	-	-	139	123-156	-	-
10	F-C-W-H-H-W	Yes	-	-	-	-	173	150-196	-	-

The effect of rotation length on cash costs per unit of wheat produced (Table 6) generally mimicked the costs per unit of land area, except that values were lower in 1972-86 than 1960-71 due to greater production from more favorable growing season precipitation.

Income Variability and Riskiness

Crop rotations characterized by high average net income and low income variability are desired by most producers for planning purposes. However, producers are usually faced with a tradeoff between increases in average net income and increases in income variability or risk (Figure 4). At Melfort, F-W-W, F-W, and F-W-W-H-H-W generally displayed the lowest income variability, while continuous wheat displayed the highest. Participation in the Canada/Saskatchewan Crop Insurance Program was effective in reducing the level of financial risk associated with the rotations, with the relative effect being greater as cropping intensity increased (Figure 4).

A producer's final choice of a crop rotation depends on his or her willingness to take risks, and the probability distributions of possible outcomes. Results of risk analysis using stochastic dominance (Anderson et al. 1977) for the 1960-71 period indicated that more conservative producers would probably only choose fertilized or unfertilized F-W-W when prices were below the base values. At higher product prices, producers would likely choose among the fertilized and unfertilized F-W-W and F-W-W-H-H-W rotations. When the analysis was repeated for 1972-86, the risk efficient set of rotations included F-C-W and F-W-W at wheat prices below 110 $ t^{-1} and canola prices below 196 $ t^{-1}, while at higher prices F-W-W-H-H-W was also a possibility. These results imply that under conditions of this experiment, risk averse producers would likely not consider using F-W, Gm-W-W, F-C-W-H-H-C, or continuous wheat even with all-risk crop insurance. It is possible that annual crop rotations of intermediate length that include fallow every 5 or 7 years may have proven more economical or less risky than the systems tested here. Unfortunately, no such intermediate length annual cropping systems were included in the study.

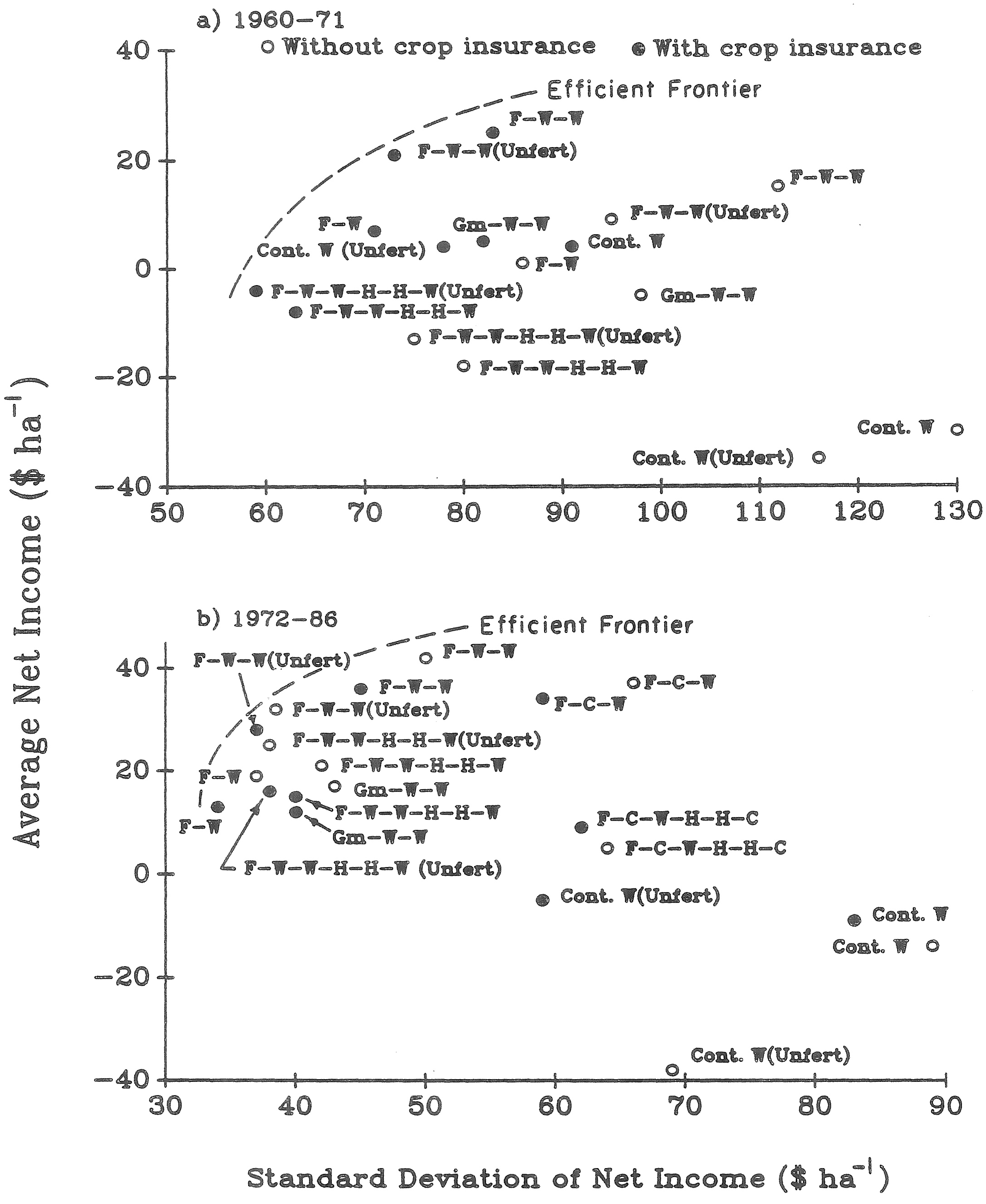

Figure 4. Tradeoff between average net income and income variability [rotations not designated (unfert) were fertilized with N and P].

CONCLUSIONS

Twenty-seven years of data for 10 spring wheat-based rotations grown on a highly fertile Orthic Black Chernozemic silty clay loam soil in north-central Saskatchewan have shown that, from a yield and economic perspective, producers will generally do best by using F-W-W, F-C-W, or F-W-W-H-H-W rotations. It was profitable to replace wheat grown on conventional or partial fallow in F-W-W and F-W-W-H-H-W rotations with canola when the price for canola was double or more than that of wheat. Similarly, it was profitable to incorporate bromegrass-alfalfa hay into fertilized wheat rotations when the hay:wheat price ratio was greater than 0.5.

In general, the application of N and P fertilizer was profitable when the ratio of N cost to wheat price was less than about 5.0 in F-W-W and continuous wheat rotations, and less than 3.5 in F-W-W-H-H-W. Including a legume green manure crop such as sweetclover in the rotation for the purpose of improving plant available nutrients was not profitable on this inherently very fertile soil. Net income from fertilized Gm-W-W was less than that earned by using fertilizer alone. Continuous wheat also performed poorly in this study because of reduced grain yields resulting from increased weed and disease problems. However, we believe that the yield and economic performance of this rotation was not indicative of the potential performance of continuous-type rotations in this area. Periodic substitution of other annual crop types for wheat would help to control weeds and break disease cycles when continuous cropping, and would likely have improved the relative profitability of these rotations; unfortunately, only one continuous-type rotation was included in this study.

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