EXPECTED NET FARM INCOMES, RESOURCE REQUIREMENTS, AND BREAK-EVEN YIELDS FOR CROP ROTATIONS IN SOUTHWESTERN SASKATCHEWAN

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INTRODUCTION

In 1966 an on going crop rotation experiment was established on the "South Farm" of the Agriculture Canada Research Station at Swift Current. The major objectives of this experiment were to evaluate the influence of rotation length, summerfallow substitute crops, and N and P fertilizers on crop yields, grain protein, N and P uptake by the plants, changes in soil chemical, physical, and biological properties, and the potential economic returns from these rotations.

The information collected during the first 12 years of study is now being summarized. A paper dealing with yield and grain protein was recently completed (Campbell et al. 1983). In the present paper, findings pertaining to three of the major economic considerations affecting crop rotation selections are discussed. The discussion of expected net farm incomes, resource requirements, and break-even stubble/fallow yield ratios for the rotations takes the short-run perspective of an individual producer. These and other economic considerations affecting crop rotation selections such as level of farm indebtedness, grain delivery quotas, crop insurance, and level of income variability or risk are discussed in a forthcoming paper (Zentner et al. 1983).

MATERIALS AND METHODS

The Experimental Data

Twelve crop rotations considered potentially suitable for southwestern Saskatchewan (Table 1) were established in 1966 on 81 plots (each 0.04 ha in size) in a three-replicate experiment. Prior to the experiment, the area had been in a fallow-wheat rotation since 1922. The soil was a Wood Mountain loam (Orthic Brown chernozem).

Commercial farm equipment was used for all cultural and tillage operations associated with the rotations. An average of 3.3 tillage operations with a heavy-duty cultivator and/or rodweeder, plus a late fall application of 2,4-D ester herbicide, were required to control weeds on summerfallow areas. Seedbed preparation generally consisted of one operation with a heavy-duty cultivator with rodweeder attachment. The plots were seeded with a hoe-press drill at the recommended rates of 67, 31, 63, and 76 $kg.ha^{-1}$ for spring wheat, flax, fall rye, and oats, respectively. Seeding took place generally in early May, except for rye which was usually sown in the first week of September. Fertilizer N (i.e., 33-0-0) was broadcast prior to seeding and fertilizer P (i.e., 11-48-0) was placed with the seed according to treatment specifications (Table 1) and in accordance with general recommendations of the Saskatchewan Soil Testing Laboratory (Table 2, Campbell et al. 1983). Herbicides were applied to the cropped areas using recommended methods and rates. The continuous-type rotations generally received more N fertilizer and more herbicides than the less intensive rotations.

Table 1. Crop rotations and treatments

Rotation number	Rotation	Comments
1	Fallow-wheat-wheat	P applied as required but no N applied
2	Fallow-wheat-wheat	N and P applied as required
3	Fallow-flax-wheat	N and P applied as required
4	Fallow-fall rye-wheat	N and P applied as required
5	Fallow-wheat-wheat	N applied as required but no P applied
6	Oat hay-wheat-wheat	N and P applied as required
7	Flax-wheat-wheat	N and P applied as required
8	Continuous wheat	N and P applied as required
9+	Continuous wheat	[fallow if less than 60 cm of moist soil at planting time, otherwise crop] N and P as required
10+	Continuous wheat	[fallow if grassy weeds become a problem otherwise crop] N and P applied as required
11	Fallow-wheat	N and P applied as required
12	Continuous wheat	P applied as required but no N applied

+ Rotations 9 and 10 were cropped continuously because the criteria necessary for fallowing (see comments) did not occur during the 12-year study period.

Plots were harvested at the full ripe stage, except for oat hay which was cut at the soft dough stage, dried naturally, baled, and weighed. On all other cropped plots, yield determinations were made by cutting a swath 5 m wide by 40 m long through the middle of the plot and harvesting the grain at maturity with a combine. After harvest, all plots received an application of 2,4-D ester herbicide at recommended rates to control winter annual weeds.

Economic Analysis

A computer model of dryland cereal and oilseed production for farms in the Brown soil zone of western Canada (Zentner et al., 1978) was revised and used in the economic evaluation of the twelve crop rotations included in the experiment. The revised model was used as a computerized farm budget wherein the farm level impacts of using the different rotations were evaluated in terms of expected net farm income, cash flows, level and seasonality of resource use, and variability in income. Break-even stubble/fallow yield ratios and other performance measures were also calculated.

Each criterion was examined for nine economic scenarios, representing different levels of product price, input price, andmanagement ability (Table 2). The base situation assumptions reflect the prices that Saskatchewan producers might reasonably expect to pay for inputs and to receive for products produced in the 1982-83 crop-year. Furthermore, it represents the assumptions against which the other economic scenarios were compared. The low and high grain prices represent one standard deviation (calculated over the period 1966 to 1980) below and above the medium grain price assumptions. The low fertilizer prices represent a 25% reduction from the 1982 price levels and reflect a situation where producers might normally purchase their fertilizer supplies in the fall prior to planting. The high fertilizer prices represent a 25% increase over the 1982 price levels and reflect a situation (or location) where fertilizers may have been in limited supply or where producers may have incurred additional transportation or storage costs. The labor price assumptions reflect different opportunity costs for farm labor. The low labor price is reflective of producers who have no marketable skills, no apparent opportunities for off-farm employment, or those who do not wish to value their own labor. The high labor price is reflective of producers who are highly skilled or trained (e.g., welder or mechanic). The medium energy prices reflect 1982 conditions for the major inputs that are produced from crude oil or that require the use of substantial crude oil or natural gas products in their manufacture. The high energy prices reflect the prices for crude oil and natural gas products that can be expected in 1985 under the National Energy Program. The high management ability situation reflects producers with above average management skills, or management skills equivalent to those utilized in the experiment. Since experimental results often overstate farm-level results, a medium management ability situation was included to closer reflect the performance of an "average" producer. It was comprised of a 10% lower level of labor and machine use efficiency together with a 9.3% lower level of yield for crops grown on fallow and a 20.6% lower level of yield for crops grown on stubble than were obtained in the experiment. These average yield reductions were calculated based on a comparison of fallow and stubble yields reported by producers in southwestern Saskatchewan over the period 1967 to 1978 and the experimental yields.

Table 2. Summary of economic scenarios examined

	Scenario Description					Price Assumptions								
						Grains				Fertilizer		Labor	Liquid fuels	
	Grain Price[a]	Fert. price[b]	Labor price[c]	Energy price[d]	Management skills[e]	Wht	Flax	Rye	Oat Hay	N	P		Dies.	Gas
						- - -$/tonne- - -				-$/kg- -		$/hr	- -¢/ℓ - -	
1.(base)	Med.	Med.	Med.	Med.	High	184	354	148	72	0.73	0.68	6	32	34
2.	Low	Med.	Med.	Med.	High	125	246	105	55	0.73	0.68	6	32	34
3.	High	Med.	Med.	Med.	High	243	462	191	89	0.73	0.68	6	32	34
4.	Med.	Low	Med.	Med.	High	184	354	148	72	0.55	0.51	6	32	34
5.	Med.	High	Med.	Med.	High	184	354	148	72	0.91	0.85	6	32	34
6.	Med.	Med.	Low	Med.	High	184	354	148	72	0.73	0.68	0	32	34
7.	Med.	Med.	High	Med.	High	184	354	148	72	0.73	0.68	12	32	34
8.	Med.	Med.	Med.	High	High	184	354	148	72	1.01	0.82	6	50	52
9.	Med.	Med.	Med.	Med.	Med.	184	354	148	72	0.73	0.68	6	32	34

[a] Medium grain prices reflect a reasonable price estimate for the 1982-83 crop year. Low and high grain prices reflect one standard deviation below and above the medium prices, respectively, based on the period 1966 to 1980.

[b] Medium prices for N and P fertilizers reflect 1982 conditions. Low and high prices represent a 25% reduction and increase from the medium prices, respectively.

[c] Medium price for labor represents an average opportunity cost for farm labor (i.e., an individual with some skills). The low price represents an individual with no skills or one who does not wish to consider his labor input. The high price represents an individual who is highly skilled (e.g., mechanic, welder).

[d] Medium prices for energy reflects 1982 conditions for the major inputs that are produced from crude oil or natural gas products in their manufacture. The high prices reflect the prices that can be expected in 1985 under the guidelines of the National Energy Program.

[e] High management ability reflects the level of management expertise that was utilized in the experiment. Medium management ability reflects a 10% lower level of labor and machine use efficiency, together with a 9.3 and 20.6% lower level of yield for crops grown on fallow and stubble, respectively.

Comparisons of the rotations were based on model runs for a 486-ha farm in the Brown soil zone. Inventories of land, machines, and buildings typical of the region were assumed. Prices for capital items were representative of 1982 values. The mean results for rotations 8, 9, and 10 are reported in the paper because the criteria necessary for summerfallowing under rotations 9 and 10 (see comments Table 1) did not occur during the 12 years of study.

RESULTS AND DISCUSSION

Expected Net Farm Income

The 12-yr mean net farm incomes for the different rotations and economic scenarios were calculated on a per-unit-of-cultivated land basis (Table 3). These values represent the average annual expected return to owner equity and management per hectare-of-rotation. They constitute the funds (above all cash costs, depreciation, and labor) that are available for income tax, principal payments on farm debt, and interest allowance on owned equity.

a) Base Situation Assumptions

Average net farm income was greatest for the 3-yr fallow-wheat-wheat rotation receiving recommended rates of N and P fertilizers (rot. 2), and lowest for the flax-wheat-wheat rotation receiving recommended rates of N and P fertilizers (rot. 7) (Table 3). The 2-yr fallow-wheat rotation (rot. 11) ranked fourth highest with an average net farm income that was 23% lower than for the best rotation. On an annual basis, net farm income for the 2-yr rotation was greater than for the 3-yr wheat rotation (rot. 2) in only 3 of 12 years (data not shown). These tended to be years of low growing season rainfall. The continuous wheat rotation with N and P fertilizers applied (rot. 8,9,10) ranked sixth highest with an average net farm income that was 25% lower than for the comparable 3-yr wheat rotation (rot. 2). However, on an annual basis, net farm income for the continuous wheat rotation was greater than for the 3-yr wheat rotation in 6 of the first 9 years of the study (data not shown). In the latter years of the study period, net farm income for the continuous wheat rotation was substantially below that obtained for the 3-yr wheat rotation. This was attributed to the encroachment of grassy weeds in the continous wheat rotation which reduced grain yields and increased herbicide requirements.

Average net farm income for the rotations that included flax, fall rye, or oat hay did not rank above the fifth position and ranged from 23 to 62% lower than for the best rotation. The effect of substituting flax for wheat in the 3-yr rotation (rot. 3 vs. rot. 2) and in the continuous rotation (rot. 7 vs. rot. 8,9,10) was to reduce net farm income in 11 of the 12 study years (data not shown). Substituting fall rye for wheat in the 3-yr rotation (rot. 4 vs. rot. 2) reduced net farm income in 6 of the 12 years (data not shown).

The application of recommended rates of N and P fertilizers were profitable in all treatment situations. Fertilizer N increased

Table 3. Average expected net farm income ($\$.ha^{-1}$ of rotation) by rotation and economic scenario, 1967-1978

Rotation	Fertilizer		Base	Grain Price[1]		Fertilizer Price[1]		Labor Price[1]		High energy	Medium management
	N	P	Situation	Low	High	Low	High	Low	High	price	skills
1. F-W-W	0	√	80.98	18.96	142.20	84.04	77.91	94.25	67.63	69.40	47.30
2. F-W-W	√	√	86.73*	20.36*	151.63*	90.81*	82.55*	100.26*	72.98*	73.19*	50.93*
3. F-Flx-W	√	√	50.70	-8.20	106.79	54.96	46.40	64.27	36.80	33.72	15.62
4. F-Ry-W	√	√	67.01	12.52	120.25	71.04	62.90	79.32	54.45	55.40	33.84
5. F-W-W	√	0	68.86	9.79	126.66	69.85	67.85	82.48	54.96	56.06	36.07
6. O(hay)-W-W	√	√	56.83	-23.67	133.47	59.55	39.24	75.31	38.06	24.48	-16.90
7. Flx-W-W	√	√	32.89	-47.63	106.75	42.59	22.82	50.54	14.38	-0.24	-31.69
8,9,10. Contin. W	√	√	64.67	-25.80	150.38	75.10	54.08	82.39	46.65	31.44	-4.90
11. F-W	√	√	67.08	13.50	120.63	69.50	64.65	79.35	54.80	56.55	47.94
12. Contin. W	0	√	57.91	-21.30	133.06	62.97	52.64	74.46	40.90	33.47	-4.08
Grand Mean			63.36	-5.15	129.18	68.04	57.10	78.26	48.16	43.30	17.41

[1] The low and high grain prices, fertilizer prices, and labor prices may not be symmetrical about the base situation because of differences in interest costs associated with borrowing operating capital.

* Indicates the rotation with the highest average expected net farm income for that economic scenario.

average net farm income for the 3-yr (rot. 1 vs. rot. 2) and continuous (rot. 12 vs. rot. 8, 9,10) wheat rotations by 6.6 and 10.5%, respectively. The effect of P fertilizer was even more pronounced, increasing average net farm income for the 3-yr wheat rotation (rot. 5 vs. rot. 2) by 20.6%.

b) Effect of Changes in the Base Situation Assumptions

The effects of changes in input and product price assumptions on average expected net farm income were greatest for the continuous crop rotations and smallest for the 2-yr crop rotation (Table 4). Under the low grain price assumptions, expected net farm income for the rotations were reduced (from the base situation) by an average of 68.51 $\$.ha^{-1}$. The relative rankings (highest to lowest) of the average net farm incomes for the 2-yr, 3-yr, and continuous wheat rotations receiving N and P fertilizers were 3, 1, and 9 (out of a possible 10), respectively. Alternatively, under the high grain price assumptions, expected net farm incomes increased (from the base situation) by an average of 65.82 $\$.ha^{-1}$. The relative rankings of the same three wheat rotations were 7, 1, and 2, respectively. These results indicate that the less intensive crop rotations are more favorable under low grain prices, while the more intensive crop rotations are more favorable under high grain prices. This occurs because as grain prices increase, the value of the grain output produced rises which, in turn, raises the opportunity cost of leaving land idle for a cropping season.

Reducing prices for fertilizers and labor (but holding the quantities utilized constant) raises expected net farm income for the rotations by an average of 4.68 and 14.90 $\$.ha^{-1}$, respectively. Raising the prices for fertilizers and labor lowers average expected net farm incomes from the rotations by about similar amounts, respectively. The effects of fertilizer and labor price changes are also greater for the continuous rotations because of the greater requirements for these inputs.

Higher energy prices reduce the expected net farm incomes for the rotations by an average of 20.06 $\$.ha^{-1}$. The effect was smallest for the 2-yr rotation (10.53 $\$.ha^{-1}$) and greatest for the continuous wheat rotation receiving recommended rates of N and P fertilizers (33.23 $\$.ha^{-1}$). Furthermore, the high energy costs associated with the manufacture of N fertilizer make it unprofitable on average to apply the recommended rates of N to wheat in the continuous rotation (rot. 8,9,10 vs. rot. 12).

When the level of management skills was changed to more closely relfect an "average" producer, expected net farm incomes for the rotations were lowered by an average of 45.95 $\$.ha^{-1}$. The 3-yr wheat rotation receiving recommended rates of N and P fertilizers (rot. 2) still provided the highest average net farm income, however, the 2-yr wheat rotation ranked a close second. The continuous wheat rotation with N and P fertilizer applied (rot. 8,9,10) ranked eighth. All continuous type rotations had expected net farm incomes that were negative.

Resource Requirements

The average cost of resource services (e.g., seed, fertilizer, herbicides, fuel and oil, machine repair, labor, etc.) were lowest for the 2-yr rotation and highest for the continuous rotations. The 12-yr average cash costs (under the base situation assumptions) were 69.78, 84.66 and 148.75$.ha^{-1} for the 2-yr (rot. 11), 3-yr (rot. 2), and continuous (rot. 8,9,10) wheat rotations, respectively. The resource categories most affected by rotation length were fertilizers, herbicides, machine operating (machine repairs plus fuel and oil), and labor (Fig. 1). Fertilizer costs for the 3-yr and continuous wheat rotations averaged 68 and 266% higher than for the 2-yr wheat rotation, respectively. Similarly, herbicide costs for the same rotations averaged 23 and 402% higher than for the comparable 2-yr rotation. These results are a direct consequence of the greater fertilizer and herbicide requirements associated with the more intensive crop rotations. Machine services and labor requirements each averaged about 9 and 32% higher for the 3-yr and continuous wheat rotations, respec-

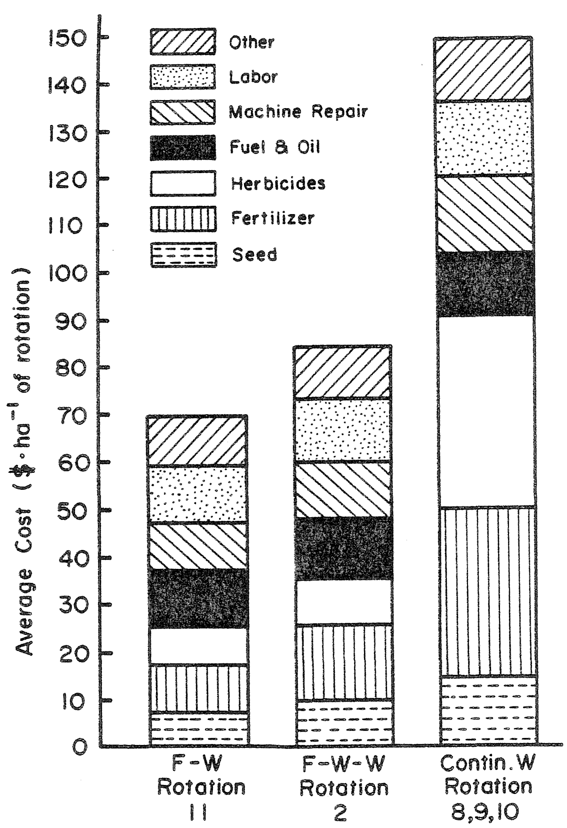

Fig. 1 Comparison Of Average Input Costs For Three Wheat Rotations.

tively, than for the 2-yr wheat rotation. Seed and other cash costs such as building repairs increased in proportion to the area cropped.

The seasonality of labor requirements also differed greatly with length of rotation (Fig. 2). Total labor requirements for the 3-yr and continuous wheat rotations averaged 11 and 32% greater, respectively, than for the 2-yr wheat rotation. Furthermore, labor requirements for the 2-yr wheat rotation were relatively uniform during the growing season. However, for the 3-yr and continuous wheat rotations, labor requirements were concentrated in the spring and fall periods. The crop rotation that included fall rye used less spring labor but more summer labor than those that included only spring-sown crops (data not shown).

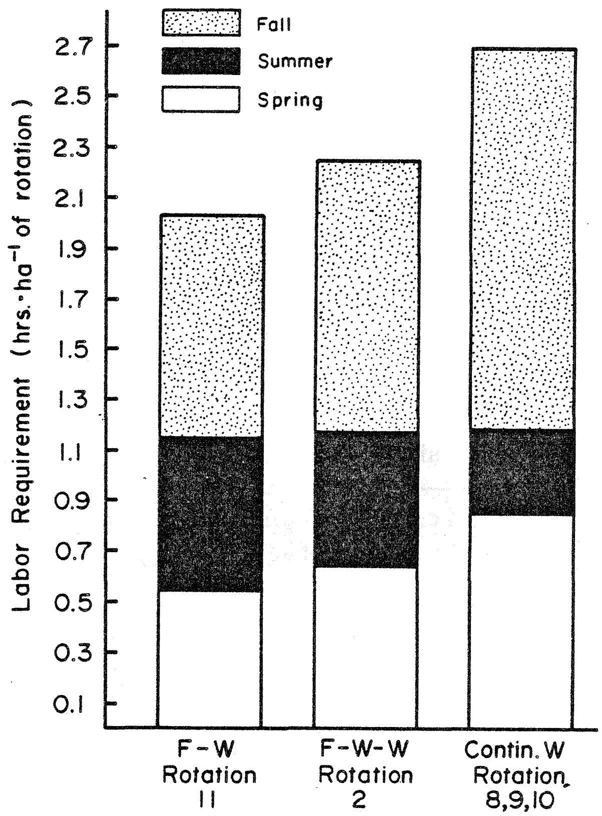

Fig.2 Comparison Of Average Seasonal Labor Requirements For Three Wheat Rotations.

Break-Even Stubble/Fallow Yield Ratios

The yields of crops grown on fallow were seldom twice as great as comparable yields of crops grown on stubble (data not shown). A 100% yield increase for crops grown on fallow is necessary every other year if the same level of total physical production is to be obtained. However, because of the non-yield benefits from summerfallowing, fallow yields need not be 100% greater than comparable stubble yields to be economical (Ali and Johnson, 1981) (Table 4). These break-even yield ratios represent the average relationship that must exist between the yields of wheat grown on stubble and on fallow for equivalent levels of net farm income to be obtained. Actual stubble/fallow yield ratios greater than the break-even values imply that stubble cropping is more profitable than fallow cropping, and vice versa.

Table 4. Average break-even stubble/fallow yield ratios+ for the 3-yr and continuous wheat rotations (N and P fertilizer applied at recommended rates)

Economic Scenario	Fallow-Wheat-Wheat (rot. 2)	Continuous wheat (rot. 8,9,10)
1. Base situation	.63	.75
2. Low grain price	.69	.84
3. High grain price	.60	.68
4. Low fertilizer price	.62	.72
5. High fertilizer price	.65	.77
6. Low labor price	.62	.72
7. High labor price	.64	.76
8. High energy price	.66	.79
9. Medium management skills	.66	.82

+ The yield ratio required for equivalent levels of net farm income to be obtained from stubble and fallow cropping.

The average break-even yield ratios were lower for the 3-yr wheat rotation than for the continuous wheat rotation. This occurred because of greater costs associated with cropping the stubble land under the continuous rotation than for the 3-yr rotation. Under the conditions of the experiment, the average stubble/fallow yield ratio obtained for the 3-yr wheat rotation (i.e., 0.78) exceeded the break-even values under all economic scenarios. Alternatively, the average stubble/fallow yield ratio for the continuous wheat rotation (i.e., 0.75) exceeded the break-even values only for the high grain price and low input price assumptions.

CONCLUSIONS

On the basis of the first 12 years of results from this long-term rotation study, producers in southwestern Saskatchewan should consider selecting more intensive crop rotations. The 3-yr fallow-wheat-wheat rotation receiving recommended rates of N and P fertilizers was the most profitable under most reasonable input and product price assumptions. Producers must, however, be prepared to supply or finance the purchase of the additional resources required in production (compared to the traditional 2-yr fallow-wheat rotation). Fertilizers and herbicides are the resource categories most affected; however, for some producers, additional capital purchases (e.g., machinery and grain storage buildings) may also be required.

Unfortunately, a 4-yr or 5-yr wheat rotation was not included in the experiment, so it is unknown whether extending the rotation length slightly beyond 3 years would be more or less profitable. Continuous wheat can only be recommended in periods of high expected grain prices and grain delivery quotas, and for producers who have the financial capability to purchase the more than double the resources required (compared to the 2-yr rotation) in production. Furthermore, because of the high income variability, or risk, associated with continuous rotations, (Zentner et al., 1983) it should only be considered by producers who are willing or able to withstand major fluctuations in income. Producers who expect grain prices to be low, or who have high outstanding debts, low operating capital, or are highly averse to risk will likely do best by continuing with the 2-yr fallow-wheat rotation.

Producers in southwestern Saskatchewan should consider introducing flax, fall rye, or oat hay into the wheat rotations only when the price of these grains is high relative to that for wheat. Finally, the results of this study strongly support the practice of soil testing and applying the recommended rates of N and P fertilizers.

These recommendations are not without a word of caution. First, the results of this study are not necessarily applicable to all farms and to all producers in southwestern Saskatchewan. Farms and producers differ markedly in terms of the physical properties of the soil, physical and financial resources, management ability, and attitudes towards risk. Secondly, the perspective of the discussion has been short-run, which ignores the long-term implications (e.g., salinity, erosion, soil degradation) of these cropping practices. Consequently, the results of this study underestimate the full costs associated with the crop rotations.

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