ECONOMICS OF CROP ROTATIONS AT INDIAN HEAD

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INTRODUCTION

Producers in the more humid regions of the Prairie Provinces have begun to adopt crop rotations with less summerfallow (Table 1). Although there may be several explanations for this trend, economic survival likely ranks near the top.

Table 1. Historical land use patterns in the Prairie Provinces

Year	Soil zone	% of area occupied by crop or fallow					
		Wheat	Oats	Barley	Flax	Canola	Fallow
57-60	Brown	44	3	7	5	-	42
61-64	Brown	47	3	3	2	-	46
65-68	Brown	49	2	3	1	-	44
69-72	Brown	38	3	7	3	1	49
73-76	Brown	45	2	4	1	1	46
77-80	Brown	48	2	4	1	1	46
81-84	Brown	50	1	3	-	-	45
57-60	Dk. Brown	40	6	8	4	-	42
61-64	Dk. Brown	46	5	4	2	-	44
65-68	Dk. Brown	48	4	5	1	1	41
69-72	Dk. Brown	30	5	11	3	4	47
73-76	Dk. Brown	39	5	9	1	3	43
77-80	Dk. Brown	41	3	8	2	5	41
81-84	Dk. Brown	48	2	8	1	4	37
57-60	Black	32	13	17	3	-	36
61-64	Black	37	12	11	3	-	38
65-68	Black	37	9	12	3	5	34
69-72	Black	22	9	18	2	8	40
73-76	Black	28	9	20	2	6	35
77-80	Black	29	5	18	3	13	32
81-84	Black	38	5	20	2	11	24

Source: Statistics Canada

This paper examines the effects of rotation length, crop sequence, and fertilization practice on crop yields and on economic returns for farms in the Black soil zone of Saskatchewan. Data from an ongoing crop rotation study at the Indian Head Experimental Farm are used. The discussion take a short-run perspective in that it does not consider the effects of the crop rotations on such aspects as soil quality or environmental pollution.

MATERIALS AND METHODS

a) Experimental Data

The crop rotation experiment at the Indian Head Experimental Farm was established in 1958. The soil was an Indian Head heavy clay, a Rego Black Chernozem (Canada Soil Survey Committee, Subcommittee on Soil Classification 1978), with an organic nitrogen content of about 0.2% (0-15 cm depth) and a surface pH of 6.7-7.0.

Eleven crop rotations were originally included in the study (Table 2). Ten of these rotations had 6 replicates; the remaining rotation had 5 replicates. In 1968, three flax-wheat-barley rotations were added to the study using 4 replicates. With the exception of rotations 6 and 7, all stages of each rotation were present each year. Thus, for example, 2 plots per replicate were assigned to each of the 2-yr rotations, 3 plots per replicate to each of the 3-yr rotations, and 1 plot per crop type per replicate to each of the continuous-type rotations. Each rotation was cycled on its assigned plots. Rotations 6 and 7 represent split-rotations in that plots seeded to forage were left in hay production for 4 years before being broken, while the remaining plots comprising the rotation were cycled in the normal manner. For example, under rotation 6, stubble wheat would be undersown to bromegrass-alfalfa only in those years when the hay plots were to be broken (i.e., after 4 years of utilization); otherwise the stubble wheat plots would be summer-

Table 2. Crop rotations and fertilizer treatments at Indian Head

Rot.	Rotation Sequence	Fert. Applic.	Year Init.	Reps	Plots
1.	Fallow-Wheat	N & P	1958	6	12
2.	Fallow-Wheat	None	1958	6	12
3.	Fallow-Wheat-Wheat	N & P	1958	6	18
4.	Fallow-Wheat-Wheat (straw removed)	N & P	1958	6	18
5.	Fallow-Wheat-Wheat	None	1958	6	18
6.	Fallow-Wheat-Wheat-Hay (4 yr)*	None	1958	6	24
7.	Fal.-Wht-Clover-Oats-Hay (4 yr)*	None	1958	6	30
8.	Fallow-Wheat-Wheat-Hay-Hay-Hay	None	1958	6	36
9.	Continuous Wheat	N & P	1958	6	6
10.	Continuous Wheat	None	1958	6	6
11.	Green Manure-Wheat-Wheat*	None	1958	5	15
12.	Flax-Wheat-Barley	N & P	1968	4	12
13.	Flax-Wheat-Barley (high N fert.)	N & P	1968	4	12
14.	Flax-Wheat-Barley	None	1968	4	12
				Total	231

*Green manure = sweet clover; hay = bromegrass-alfalfa hay.

fallowed in the subsequent year as part of a fallow-wheat-wheat system. Consequently, sixteen years were required to complete one cycle of this rotation. For ease of reference, the rotation-year treatments will be designated by rotation number followed by year number (e.g., rotation 1, year 1= Rot. 1-1).

Commerical farm equipment was used to perform all tillage, seeding, spraying, and harvest operations associated with the management of the rotations. The seedbed was usually prepared with one operation by a heavy-duty cultivator and harrow. Stubble to be seeded was harrowed twice. Seeding was done, usually in early May, with a double disc press drill. The plots were seeded at the recommended rates: 129, 36, 81, 99, 11, and 13/7 kg/ha for spring wheat, flax, barley, oats, sweet clover, and bromegrass-alfalfa, respectively. Forage crops were established by seeding them with the preceeding cereal crop the year previous to their first year of utilization (i.e., underseeding). On plots being undersown to bromegrass-alfalfa, the rates of seeding used were 101 kg/ha for spring wheat and 76 kg/ha for oats; when underseeding sweet clover, the rate of seeding used for spring wheat was 112 kg/ha. Recommended varieties of seed were used each year. All plots were harrowed once after seeding.

During the period 1958-77, rates of N and P fertilizers were applied to wheat grown on fallow (i.e., an average of 6 kg/ha N plus 27 kg/ha P_2O_5) and stubble (i.e., an average of 24 kg/ha N plus 21 kg/ha P_2O_5) in accordance with the rotation specifications and the generally recommended rates as provided for the area by the Saskatchewan Soil Testing Laboratory. Since 1978, fertilizer N and P were applied according to soil tests (i.e., an average of 6 kg/ha N plus 25 kg/ha P_2O_5 for wheat grown on fallow; 83 kg/ha N plus 22 kg/ha P_2O_5 for wheat grown on stubble). Under the high N fertility flax-wheat-barley rotation, an average of 72 kg/ha N plus 25 kg/ha P_2O_5 was applied to each crop, whereas, each crop in the normal fertilized flax-wheat-barley rotation received an average of 49 kg/ha N plus 23 kg/ha P_2O_5. The fertilizer was applied with the seed in the early years, but beginning in the late 1960s, N fertilizer was also broadcast and incorporated at time of seeding or in the previous fall.

Herbicides were applied as required for in-crop weed control using recommended methods and rates. In the earlier years of the study, 2,4-D formulations were used for broadleaf weed control and Carbyne was used for wild oat control. Avadex was first used in 1966, usually applied in the fall and incorporated with a tandem disc and harrow. In recent years Buctril M was the main broadleaf herbicide used and Hoegrass replaced Avadex as the herbicide for control of wild oats. Very little herbicide was used on the forage plots over the years. Malathion was used since 1970 for control of weavil in sweet clover.

Plots were swathed at the full-ripe stage (usually early September), except for the forage plots which were cut at full-bloom (usually mid June), dried, baled, and the hay weighed. On all other cropped plots, yield determinations were made by threshing the grain from the entire plot with a conventional combine. The straw was distributed on the plots by a paddle-type spreader attachment on the combine, except for rotation 4 where the straw was baled and removed. Green manure crops were soil incorporated by roto-tilling in mid June. All cropped plots were usually cultivated once in late fall.

On summerfallow areas weed control was achieved by use of mechanical tillage. An average of 5 operations (range 4 to 6) with a heavy-duty cultivator were required. In some years the rodweeder replaced one or more cultivation operations and in the early years of the study a disc was also used.

b) Analytical Procedure

A computer model of dryland crop production for western Canada (Zentner et al. 1978) was used in the 'farm-level' evaluation of the crop rotations under study at Indian Head. For this analysis, information on the particular type, sequence, and timing of field and cultural operations performed, the amounts, application methods, and types of herbicides, pesticides, and fertilizers used, and the crop yields obtained in the experiment for each rotation treatment, year, and replicate were used as input data. The revised model was used to compute the future performance of the different rotations in terms of expected levels of net farm income, cash flows, level and seasonality of resource use, and variability in income (or riskiness) for various plausible economic scenarios. Breakeven stubble/fallow yield ratios, total, average, and marginal costs of grain production, and other performance measures were also calculated.

Fifteen economic scenarios, representing different levels (and ratios) of

Table 3. Summary of economic scenarios examined

	Scenario Description								Price and Cost Assumptions									
	Wht. Price	Bar. Price	Flax Price	For. Price	Fert. Cost	Labor Cost	Ener. Cost	Crop Insur.	Grains and Forage				Fert.		Labor	Fuels		Herb. Cost Ind.
									Wht.	Bar.	Flax	Hay**	N	P_2O_5		Dies.	Gas	
									- -	($/tonne)	- -		(¢/kg)		($/hr)	-(¢/L)-		(base= 100)
1*	Med.	Med.	Med.	Med.	Med.	Med.	Med.	No	184	130	360	84	62	64	10	39	41	100
2	Low	Low	Low	Low	Med.	Med.	Med.	No	147	104	288	67	62	64	10	39	41	100
3	High	High	High	High	Med.	Med.	Med.	No	221	156	432	101	62	64	10	39	41	100
4	Med.	Low	Med.	Med.	Med.	Med.	Med.	No	184	104	360	84	62	64	10	39	41	100
5	Med.	High	Med.	Med.	Med.	Med.	Med.	No	184	156	360	84	62	64	10	39	41	100
6	Med.	Med.	Low	Med.	Med.	Med.	Med.	No	184	130	288	84	62	64	10	39	41	100
7	Med.	Med.	High	Med.	Med.	Med.	Med.	No	184	130	432	84	62	64	10	39	41	100
8	Med.	Med.	Med.	Low	Med.	Med.	Med.	No	184	130	360	67	62	64	10	39	41	100
9	Med.	Med.	Med.	High	Med.	Med.	Med.	No	184	130	360	101	62	64	10	39	41	100
10	Med.	Med.	Med.	Med.	Low	Med.	Med.	No	184	130	360	84	46	48	10	39	41	100
11	Med.	Med.	Med.	Med.	High	Med.	Med.	No	184	130	360	84	77	80	10	39	41	100
12	Med.	Med.	Med.	Med.	Med.	Low	Med.	No	184	130	360	84	62	64	0	39	41	100
13	Med.	Med.	Med.	Med.	Med.	High	Med.	No	184	130	360	84	62	64	20	39	41	100
14	Med.	Med.	Med.	Med.	Med.	Med.	High	No	184	130	360	84	82	71	10	48	49	105
15	Med.	Med.	Med.	Med.	Med.	Med.	Med.	Yes	184	130	360	84	62	64	10	39	41	100

* base scenario

** dry matter basis. Straw was valued at one-half the value of hay.

product prices, input costs, and participation in government programs were examined (Table 3). The base scenario, against which all other scenarios were compared, reflects the prices and costs that producers might reasonably expect to receive for products produced and to pay for inputs purchased in the 1984-85 crop year. They were obtained from published sources (Saskatchewan Agriculture 1984; Alberta Agriculture 1984) and through interviews with farm input suppliers. Straw that was baled and removed from the field was valued at 50% of the value for hay. The effect of changes in product prices (with input costs unchanged) on the profitability of the rotations and fertilizer use practices were examined for a 20% absolute decrease in product prices from the base assumptions and for a 20% absolute increase in product prices. In addition, the effect of changes in the relative prices for products (i.e., the price of one product relative to another product) on the degree of economic substitution of one product for another was also examined. This was done by comparing the economic performance of the rotations for all nonwheat price combinations relative to the base price for wheat.

The low fertilizer costs represent a 25% reduction from the base price levels and reflect a situation where producers might normally purchase their fertilizer supplies in the fall when costs of fertilizer are often lower, or those producers who obtain a quantity discount. The high fertilizer costs represent a 25% increase over the base price levels and reflects those producers who have incurred additional transportation or storage costs, or those located in areas where fertilizer supplies were limited. The labor cost assumptions reflect different opportunity costs for farm labor. The low labor cost is reflective of producers (or family members) who have no marketable skills, or opportunities for off-farm employment, or those who do not wish to value their own labor. The high labor cost is reflective of producers who are highly skilled or trained or have considerable opportunity for off-farm employment (e.g., welder or mechanic). The medium energy costs reflect present costs for the major inputs that are produced directly from crude oil, as well as those requiring substantial input of crude oil or natural gas products in their manufacture. The high energy costs reflect a 25% rise in the cost of diesel fuel. The costs for all other energy inputs (e.g., other forms of liquid fuel, fertilizers, herbicides, insecticides, machinery and machinery repairs) were ajusted upward according to their embodied energy contents measured in diesel fuel equivalents (Jensen 1977, Jensen and Stephanson 1975, Leach 1976). The crop insurance situation reflects whether there was or was not participation in the Canada/Saskatchewan Crop Insurance Program. Participation was assumed to be at the 70% yield coverage and the high grain price options for all crops except forage. Forage was assumed to be uninsured. The 1984-85 Saskatchewan Crop Insurance Board's base premium rates, premium discounts, and payout criteria for Risk Area 7 (Indian Head) were assumed.

All results, unless otherwise indicated, are reported on a per-unit-of-cultivated land basis (i.e., gives consideration to the proportion of crop and fallow in the rotation). The discussion of results was divided into two time intervals to correspond with the addition of new crop rotations.

RESULTS AND DISCUSSION

a) Weather Conditons

The weather during the 25 years of study was characterized by near normal amounts of growing season rainfall (May-July) but with a highly variable distribution, slightly above average winter precipitation (August 1 - April 30), and favorable summer temperatures (Table 4). Total precipitation received during the crop-year (August - July) was lowest in 1960-61 and in 1983-84 when it averaged less than 55% of the long-term mean. Growing season

Table 4. Precipitation and growing season weather at Indian Head

Crop-Year	Precipitation (mm)						Degree Days			
	Winter*	May	June	July	GS**	Total***	May	June	July	GS**
1959-60	334	42	62	8	111	445	161	273	525	959
1960-61	136	24	12	21	57	193	160	398	533	1091
1961-62	203	74	55	34	163	366	142	305	440	888
1962-63	212	54	98	90	242	454	128	277	516	921
1963-64	226	69	62	51	182	408	200	241	530	971
1964-65	194	23	97	38	259	453	129	292	476	897
1965-66	236	17	93	53	163	399	144	258	522	925
1966-67	260	10	17	13	40	300	144	258	494	896
1967-68	226	34	21	26	82	307	139	280	463	882
1968-69	307	26	54	59	139	446	165	200	410	775
1969-70	306	86	61	78	225	531	109	351	528	987
1970-71	278	12	122	75	208	486	180	298	384	862
1971-72	167	53	41	79	173	339	197	335	396	929
1972-73	191	91	149	34	274	465	146	297	469	912
1973-74	292	108	27	42	177	468	74	290	534	897
1974-75	351	6	51	32	89	440	153	257	584	994
1975-76	380	62	182	27	275	656	205	329	469	1004
1976-77	79	95	69	48	211	290	285	313	470	1068
1977-78	264	103	64	68	236	499	217	275	485	977
1978-79	246	44	11	90	144	390	124	278	543	945
1979-80	231	5	29	96	130	360	297	301	478	1076
1980-81	284	16	129	143	288	572	180	265	522	968
1981-82	243	52	27	150	229	472	178	257	471	907
1982-83	238	65	70	176	311	549	133	277	514	924
1983-84	147	37	62	18	117	264	129	307	552	987
Avg.	241	52	67	62	181	422	160	276	492	928
L.T. Avg.	191	44	78	52	173	418				

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[*] August 1 to April 30.
[**] Growing season (May - July).
[***] August 1 to July 31.

rainfall was less than 130 mm in 7 of 25 years, between 130 and 230 mm in 11 of 25 years, and greater than 230 mm in 7 of 25 years. In 1960-61 and 1966-67, growing season rainfall was less than 33% of the long-term average. In contrast, growing season rainfall was highest in 1972-73, 1975-76, 1980-81, and 1982-83 when it averaged more than 58% above normal. Precipitation received over the winter period was considerably below average in 1960-61, 1971-72, 1976-77, and 1983-84; considerably above average in 1959-60, 1968-

69, 1969-70, 1974-75, and 1975-76.

Rainfall during the early part of the growing season (i.e., May) was less than 20% of average in 1966-67, 1974-75, and 1979-80, and nearly twice the normal in the periods 1972-74 and 1976-78. Rainfall during the critical grain filling stage of plant growth (i.e., July) was well above normal in the 1978-83 cropping period and in 1962-63.

Growing season temperatures (as measured by degree-days above a base temperature of 5°C) often displayed the converse trend to rainfall. In years of low rainfall, temperatures during the growing season were usually high resulting in considerable stress on growing plants and high moisture losses through evapotranspiration. Air temperatures were highest in 1960-61, 1976-77, and 1979-80; lowest in 1968-69.

b) Grain and Forage Yields

i) Wheat yields. On a seeded area basis (Table 5), the mean yield of wheat grown on adequately fertilized fallow in the F-W rotation was similar to the mean yield of wheat grown on fertilized fallow in the conventional F-W-W rotation where the straw was returned to the land; but, it was 6% lower than the mean yield of wheat grown on fertilized fallow in the F-W-W rotation where the straw was removed. The higher fallow wheat yields obtained in this latter rotation may be related to better seed placement or to lower soil N losses by denitrification because of lower carbon substrate for denitrifiers. A study at Swift Current also found that yields of wheat grown on fertilized conventional fallow were similar under 2-year and 3-year wheat rotations (Campbell et al. 1983).

Within the monoculture wheat rotations, wheat grown on fertilized stubble gave similar yields regardless of the rotation employed (Table 5). Wheat grown on fertilized stubble yielded 71-75% of that obtained from the compar-

Table 5. Mean yields of wheat by rotation-year at Indian Head

		Fert.		(1960-1984)			(1968-1984)		
Rot-Yr	Rot. Sequence	N	P	Yield^{+} (kg/ha)	% of Check	CV* (%)	Yield^{+} (kg/ha)	% of Check	CV* (%)
1-2	F-W (check)	+	+	2459	100	25	2504	100	24
2-2	F-W	0	0	2239	91	24	2256	90	23
3-2	F-W-W	+	+	2551	104	24	2580	103	24
4-2	F-W-W(str.rem.)	+	+	2615	106	23	2659	106	22
5-2	F-W-W	0	0	2268	92	25	2310	92	24
6-2	F-W-W-H(4 yr)	0	0	2583	105	24	2704	108	22
7-2	F-W-Cl-O-H(4 yr)	0	0	2619	107	27	2714	108	27
8-2	F-W-W-H-H-H	0	0	2801	114	26	2928	117	23
11-2	GM-W-W	0	0	2565	104	25	2654	106	23
	$S\bar{x}$			23			29		
3-3	F-W-W	+	+	1840	75	37	1920	77	32
4-3	F-W-W(str.rem.)	+	+	1870	76	36	1958	78	30
5-3	F-W-W	0	0	1103	45	49	1002	40	42
6-3	F-W-W-H(4 yr)	0	0	1433	58	43	1522	61	38
8-3	F-W-W-H-H-H	0	0	1843	75	42	1879	75	41
9-1	Cont. W	+	+	1810	74	38	1976	79	33
10-1	Cont. W	0	0	1047	43	38	1038	41	33
11-3	GM-W-W	0	0	1491	61	46	1433	57	45
12-2	Flx-W-B	+	+				2334	93	41
13-2	Flx-W-B(high N)	+	+				2568	103	39
14-2	Flx-W-B	0	0				1338	53	61
	$S\bar{x}$			20			25		
	$S\bar{x}^{**}$			24			28		

[*] Coefficient of variation.
[**] Overall standard error of the mean.
[+] Yields are for the underlined wheat crop in the rotation

able crop of wheat grown on fallow when calculated over the period 1960-84, and 75-79% when calculated over the period 1968-84. Furthermore, the relative variability in yields (as measured by the coefficient of variation) was greater for wheat grown on stubble than for wheat grown on fallow. This difference in yield and yield variability can be attributed to reduced weed competition and to additional stored soil moisture that was available to the fallow crop. Similar relationships between fertilized stubble and fallow wheat yields were also observed at Swift Current, where stubble yields averaged 76% of fallow yields (Campbell et al. 1983).

The yields of fertilized wheat grown on stubble were similar or higher than fertilized yields of wheat grown on fallow in 5 of 25 years (Fig. 1). These tended to be years with above average growing season rainfall and occurred mainly in the most recent years. Fallow wheat yields displayed no significant time trend; however, fertilized stubble wheat yields generally increased with time reflecting the combined effects of improved technologies (e.g., new varieties, more effective herbicides) and increased rates of N and P fertilizer use. Yields were significantly correlated with growing season rainfall (r = 0.30 for fallow wheat and r = 0.38 for stubble wheat). Rainfall distribution also had an important influence on grain yields with June rainfall having the highest correlation with fallow yields (i.e., r = 0.28), and July rainfall having the highest correlation with stubble yields (i.e., r = 0.33).

The yield of wheat grown after flax in Flx-W-B rotations averaged 20-32% higher (i.e., 300 to 620 kg/ha more) than the yield of wheat following wheat in monoculture rotations (Table 5). In fact, under the high N fertility Flx-W-B rotation (i.e., Rot. 13), the 17-year mean yield of wheat grown on flax stubble was statistically similar to the mean yield of wheat grown on fertilized fallow in monoculture rotations (Rot. 3-2). Under the Flx-W-B rotation that received normal rates of N and P fertilizers (i.e., Rot. 12), stubble wheat yields averaged 93% of fertilized fallow wheat yields. The high yield of wheat grown on flax stubble in this study is similar to that reported in the Black soil zone at Portage la Prairie, Manitoba (Austenson 1978); but, opposite to that reported in the Black soil zone at Brandon, Manitoba (Spratt et al. 1975) and in the Brown soil zone at Swift Current,

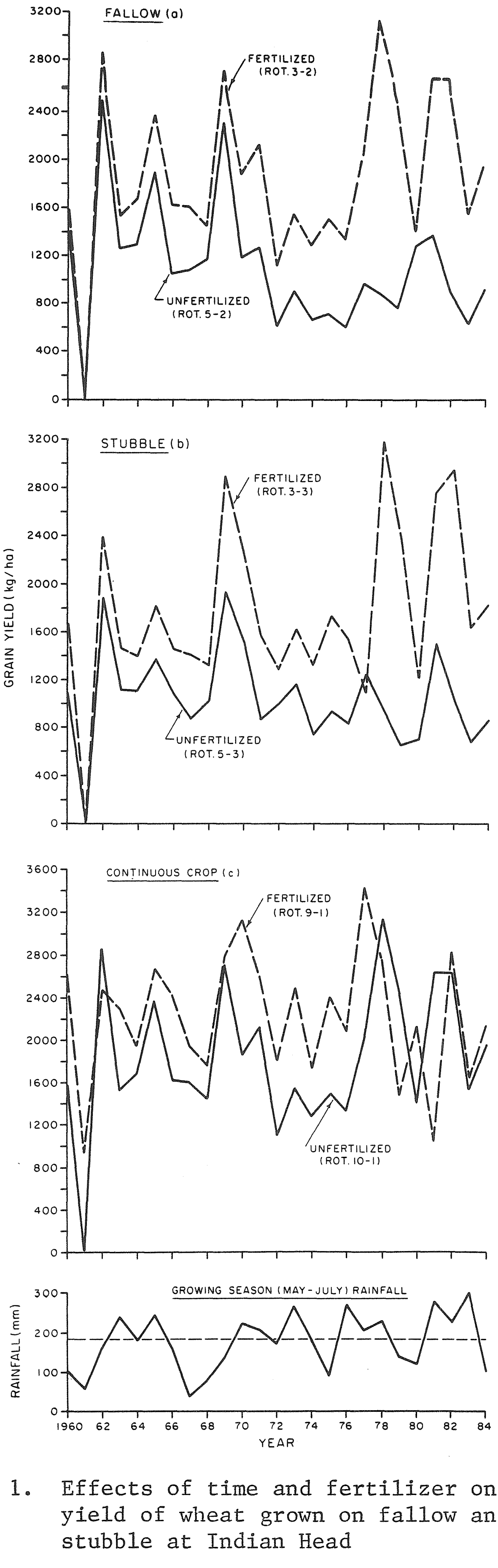

Fig. 1. Effects of time and fertilizer on the yield of wheat grown on fallow and stubble at Indian Head

Saskatchewan (Campbell et al. 1983) and may be related to lower soil moisture and soil nitrogen use by the flax crop.

Application of N and P fertilizers increased the yields of wheat grown on both fallow and stubble (Table 5 and Fig. 1). Under the F-W and F-W-W rotations, fertilizer N and P increased yields of wheat grown on fallow by an average 8-10% (compared to no fertilizer). The yield advantage from fertilization of wheat grown on fallow was significant about 70% of the time (i.e., in 17 of 25 years). Fertilization increased stubble wheat yields by an average of 67% in the F-W-W rotation and 73% in the continuous wheat rotation. In all years except the driest year (1960-61), fertilization of wheat grown on stubble in the monoculture wheat rotations produced significantly higher grain yields (compared to no fertilizer). In the Flx-W-B rotations, normal fertilization (i.e., an average of 49 kg/ha N plus 23 kg/ha P_2O_5) increased wheat yields by an average 74%, while high N fertilization (i.e., an average of 72 kg/ha N plus 25 kg/ha P_2O_5) increased wheat yields by an average of 92%.

The yield of wheat grown on fallow in rotations that periodically included a forage crop (i.e., bromegrass-alfalfa or sweetclover) but no fertilizer (i.e., Rots. 6,7, and 8), were 14-24% higher than the yield of wheat grown in unfertilized rotations that did not include a forage crop (Table 5). They also averaged 5-14% higher than yields of wheat grown on fertilized fallow in the monoculture rotations. The highest average yield of wheat grown on fallow was obtained under the unfertilized F-W-W-H-H-H rotation.

Similarly, yields of unfertilized wheat grown on stubble in rotations that included forage crops were 30-67% higher than yields from unfertilized wheat grown on stubble in rotations that did not include forage crops (Table 5). Stubble wheat yields obtained in the F-W-W-H-H-H rotation were similar or higher than the yields obtained from the fertilized monoculture wheat rotations 60% of the time (data not shown). This complementary relationship between a forage and subsequent crop of wheat is likely a result of a build-up of soil nitrogen by the alfalfa crop. In contrast, a study of rotations that included forage crops in the Dark Brown soil zone at Saskatoon (Austenson et al. 1970) found that wheat grown on fallow after alfalfa yielded significantly less than after bromegrass, and both yielded significantly less than wheat grown on fallow in which no forage was included. In a study in the Brown soil zone at Lethbridge, Alberta, Pittman (1977) found that inclusion of grass or grass-alfalfa in unfertilized rotations with wheat had little benefical effect on the average yield of wheat grown on fallow, but yields of wheat grown on stubble were enhanced. At Swift Current, Kilcher and Anderson (1963) also found that spring wheat grown the year following breaking of stands of crested wheatgrass or bromegrass yielded significantly less than wheat grown on fallow in a fallow-wheat rotation.

The use of biennial sweet clover as a green manure crop (incorporated into the soil in mid-June and then partially fallowed during the rest of the crop year) increased the yield of unfertilized wheat subsequently grown on the partial fallow by 13% and on stubble by 35% (Table 5). Yields of the fallow wheat (Rot. 11-2) were similar in many years, and sometimes higher, than those obtained on fertilized fallow in the monoculture wheat rotations (Rot. 3-2). In contrast, stubble wheat yields obtained in the green manure rotation were 19-26% lower than the yields obtained from fertilized monoculture wheat rotations.

Expressing the quantity of wheat produced on a per farm basis (i.e., kg/ha/yr) showed that total production was inversely related to the frequency of fallow in the rotation (Table 6). Considering only the well-fertilized

Table 6. Total production for wheat rotations at Indian Head, 1960-1984

Rot.	Rotation Sequence	Fertilizer N	Fertilizer P	25-yr total production (t/ha)	Avg. annual yield (kg/ha)	% of check
1.	F-W (check)	+	+	30.75	1230	100
2.	F-W	0	0	28.00	1120	91
3.	F-W-W	+	+	36.60	1464	119
4.	F-W-W (straw removed)	+	+	37.38	1495	122
5.	F-W-W	0	0	28.10	1124	91
9.	Cont. W	+	+	45.25	1810	147
10.	Cont. W	0	0	26.18	1047	85
11.	GM-W-W	0	0	33.80	1352	110

rotations, the F-W rotation produced the least amount of wheat, while the continuous wheat rotation produced the greatest amount (i.e., 47% more). The F-W-W rotation was intermediate with a total production that averaged 19% above that for the F-W rotation. Fertilizer N and P increased total wheat production by 9% for the F-W rotation, 30% for the F-W-W rotation, and 73% for the continuous wheat rotation. The use of a green manure crop in the rotation increased total wheat production by 20% over that for the unfertilized F-W-W rotation.

ii) Other grains and forage yields. Flax yields were increased 54% from application of 48 kg/ha N plus 21 kg/ha P_2O_5, and by 72% from application of 71 kg/ha N plus 23 kg/ha P_2O_5 (Table 7). The relative variability in yield of flax was considerably higher than that for wheat. In 3 of 17 years, poor establishment of the flax crop resulted in the plots not being harvested.

Barley yields were also increased by fertilization (Table 7). On plots that received normal N and P fertilizer, yields averaged 84% higher compared to the unfertilized plots, and 109% higher on plots that received high rates of N and P fertilizer. Yield variability was also greater for barley grown

Table 7. Mean yields of flax, barley, and forage at Indian Head

		Fert.		1960-84		1968-84	
Rot-Yr	Rot. Sequence	N	P	yield (kg DM/ha)	CV (%)	yield (kg/ha)	CV (%)
12-1	Flx-W-B	+	+			909	62
13-1	Flx-W-B (high N)	+	+			1015	60
14-1	Flx-W-B	0	0			591	67
	$S\bar{x}$					16	
12-3	Flx-W-B	+	+			2412	50
13-3	Flx-W-B (high N)	+	+			2743	52
14-3	Flx-W-B	0	0			1310	74
	$S\bar{x}$					31	
6-4	F-W-W-H (4 yr)	0	0	2840	51		
7-5	F-W-Cl-O-H (4 yr)	0	0	2180	67		
8-4	F-W-W-H-H-H	0	0	1224	80		
8-5	F-W-W-H-H-H	0	0	2798	48		
8-6	F-W-W-H-H-H	0	0	2938	48		
	$S\bar{x}$			51			

+ yields are for the crop underlined in the rotation.

on stubble than for wheat grown on stubble and was higher on the unfertilized plots than on the fertiized plots.

The 25-year mean yield of oats obtained in the experiment was 2891 kg/ha (CV = 34%).

Bromegrass-alfalfa yields were 129-140% higher on second and third year utilization stands than on first year utilization stands (Table 7). This result likely reflects the effects of moisture and nutrient competition and shading by the companion crop (Lawrence 1967). The average yield from established stands was 2689 kg DM/ha. Problems with poor stand establishment were reported particularly in the early years of the experiment. The 25-year mean yield of sweet clover was 3766 kg DM/ha (CV = 74%).

c) Economic Performance

i) Expected net farm income (base assumptions). Expressed on a per-unit-of-cultivated-land basis, the net farm income values represent the average annual expected return to owner equity and management per hectare of rotation (Table 8). 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.

Focusing first on the 25-year (1960-84) means, average net farm income was highest for the GM-W-W and lowest for continuous wheat rotation with no fertilizer applied. Only this latter rotation produced economic losses on average. The 6-year F-W-W-H-H-H rotation ranked second highest, with an average net farm income that was 9% lower than for the GM-W-W rotation. The economic performance of the other rotations that included forage (i.e. bromegrass-alfalfa), but no applied fertilizer (i.e., Rots. 6 and 7), were better than the unfertilized, and similar to most fertilized monoculture wheat rotations. The fertilized F-W-W, continuous wheat, and F-W rotations ranked third, fifth, and sixth highest (out of 11), respectively, with mean net farm incomes that were 16%, 23%, and 32% below that for the best rotation (i.e., the unfertilized GM-W-W). The fertilized F-W-W rotation produced economic returns that averaged 24% or $12.50/ha higher than the comparable F-W rotation, and $4.84/ha or 8% higher than the fertilized continuous wheat rotation. Baling and removing the straw, although producing slightly higher grain yields than returning the straw to the soil (i.e., Rot. 3) (Table 8), resulted in $13.59/ha or 21% lower economic returns. This occurred because the cost of baling and removing the straw plus the additional capital costs of the haying equipment was greater than the returns earned from the sale of the straw. Under the F-W, F-W-W, and continuous wheat rotations, economic returns

Table 8. Average net farm income ($/ha of rotation) by rotation and economic scenario at Indian Head

						Relative Grain & Forage Price										High	
	Fert.		Base	Grain & For. Pr.		Low	High	Low	High	Low	High	Fert. Cost		Labor Cost		Energy	Crop
Rotation Sequence	N	P	Sit'n	Low	High	feed	feed	oils.	oils.	for.	for.	Low	High	Low	High	Cost	Insur.
(1960-1984)																	
1 F-W (check)	+	+	53.11	7.44	98.44	53.11	53.11			53.11	53.11	55.57	50.63	79.57	28.50	45.79	51.44
2 F-W	0	0	42.91	1.51	84.10	42.91	42.91			42.91	42.91	42.91	42.91	69.20	16.03	37.08	41.46
3 F-W-W	+	+	65.61	10.74	119.82	65.61	65.61			65.61	65.61	70.73	60.44	96.27	33.35	54.28	62.64
4 F-W-W (str. rem.)	+	+	52.02	-4.32	107.52	52.02	52.02			52.02	52.02	57.19	46.79	85.75	16.10	39.76	49.51
5 F-W-W	0	0	25.58	-16.25	67.02	25.58	25.58			25.58	25.58	25.58	25.58	55.62	-5.54	18.80	28.39
6 F-W-W-H (4 yr)	0	0	61.67	12.82	110.52	61.67	61.67			49.78	73.57	61.67	61.67	91.07	32.09	54.97	58.72
7 F-W-Cl-O-H (4 yr)	0	0	53.13	8.59	97.29	39.38	66.43			40.19	66.07	53.13	53.13	80.56	25.58	47.05	53.24
8 F-W-W-H-H-H	0	0	71.81	23.90	119.70	71.81	71.81			52.37	91.24	71.81	71.81	97.36	46.15	65.97	70.91
9 Cont. W	+	+	60.77	-9.09	128.87	60.77	60.77			60.77	60.77	71.91	49.49	99.71	17.65	40.47	57.29
10 Cont. W	0	0	-32.54	-74.10	7.88	-32.54	-32.54			-32.54	-32.54	-32.54	-32.54	4.23	-74.65	-41.47	-26.99
11 GM-W-W	0	0	78.50	28.71	128.24	78.50	78.50			78.50	78.50	78.50	78.50	107.04	49.65	72.37	76.89
$S\bar{x}$			2.16	1.73	2.59	2.13	2.20			2.12	2.20	2.16	2.16	2.16	2.16	2.16	1.95
(1968-1984)																	
1 F-W (check)	+	+	54.63	8.25	100.73	54.63	54.63	54.63	54.63	54.63	54.63	57.01	52.23	82.33	26.93	47.78	52.08
2 F-W	0	0	41.59	-0.07	83.08	41.59	41.59	41.59	41.59	41.59	41.59	41.59	41.59	68.88	14.30	36.16	38.82
3 F-W-W	+	+	66.48	10.08	122.05	66.48	66.48	66.48	66.48	66.48	66.48	72.03	60.83	99.42	33.54	55.06	60.06
4 F-W-W (str. rem.)	+	+	53.55	-4.67	110.75	53.55	53.55	53.55	53.55	53.55	53.55	59.19	47.85	90.27	16.83	41.21	47.48
5 F-W-W	0	0	18.14	-23.05	58.84	18.14	18.14	18.14	18.14	18.14	18.14	18.14	18.14	49.79	-13.51	11.84	19.66
6 F-W-W-H (4 yr)	0	0	72.57	20.71	124.40	72.57	72.57	72.57	72.57	59.55	85.64	72.57	72.57	102.60	42.27	65.59	67.69
7 F-W-Cl-O-H (4 yr)	0	0	58.09	12.70	103.13	43.63	72.05	58.09	58.09	45.07	71.30	58.09	58.09	85.27	30.92	52.11	58.57
8 F-W-W-H-H-H	0	0	86.10	35.12	137.07	86.10	86.10	86.10	86.10	64.56	107.64	86.10	86.10	112.14	60.07	80.10	83.83
9 Cont. W	+	+	74.96	-1.43	149.34	74.96	74.96	74.96	74.96	74.96	74.96	87.70	62.05	119.60	30.32	53.43	64.91
10 Cont. W	0	0	-42.30	-84.06	-1.75	-42.30	-42.30	-42.30	-42.30	-42.30	-42.30	-42.30	-42.30	1.40	-86.00	-50.89	-38.99
11 GM-W-W	0	0	80.83	30.71	130.87	80.83	80.83	80.83	80.83	80.83	80.83	80.83	80.83	109.37	52.29	75.27	78.73
12 Flx-W-B	+	+	75.68	1.53	148.73	53.95	97.26	53.17	97.92	75.68	75.68	88.34	62.83	113.90	33.51	53.65	84.20
13 Flx-W-B(hi.N fer.)	+	+	99.33	16.47	181.22	74.60	123.80	74.28	124.14	99.33	99.33	116.06	82.83	138.37	56.26	71.87	106.78
14 Flx-W-B	0	0	32.33	-18.56	82.65	20.53	44.09	17.70	46.91	32.33	32.33	32.33	32.33	67.17	-6.33	23.90	40.41
$S\bar{x}$			2.79	2.24	3.32	2.72	2.83	2.74	2.82	2.74	2.84	2.79	2.79	2.79	2.79	2.81	2.60

were increased an average of $10, $40, and $93/ha by application of recommended rates of N and P fertilizer, respectively.

The rotation that produced the highest average net farm income based on the most recent 17-year period (1968-84) was the high N fertility Flx-W-B system (Table 8, bottom). The least profitable rotation was still unfertilized continuous wheat. The average economic returns for the GM-W-W and F-W-W-H-H-H rotations had their rankings reversed (compared to the 25-year period); the latter rotation produced 11% greater net farm income than the former rotation. The fertilized continuous, 3-year, and 2-year wheat rotations ranked sixth, seventh, and ninth highest (out of 14), respectively. As with the 25-year means, application of recommended rates of N and P fertilizers were highly profitable. Economic returns were increased an average of $13/ha by proper fertilization under the F-W rotation, $47/ha under F-W-W, $113/ha under continuous wheat, $43/ha under normal fertilized Flx-W-B, and $67/ha under the high N fertility Flx-W-B rotation.

On an annual basis and within the fertilized monoculture wheat rotations, continuous wheat displayed the highest income variability and F-W the lowest; the F-W-W rotation being intermediate (Fig. 2). The fertilized F-W and F-W-W rotations produced ecomonic returns that did not cover all cash costs plus depreciation (i.e., resulted in negative net farm income) in 3 of 25 years (or 12% of the time). The comparable continuous wheat rotation resulted in economic losses in 6 of 25 years (or 24% of the time). In relation to the F-W rotation, the F-W-W rotation produced economic returns that were similar in 6 of 25 years and were higher in 13 of 25 years. By comparison, the continuous wheat rotation produced economic returns that were similar to the F-W rotation in 4 of 25 years and produced higher economic returns in 6 of 25 years.

The economic benefit from fertilization was significant in most years,

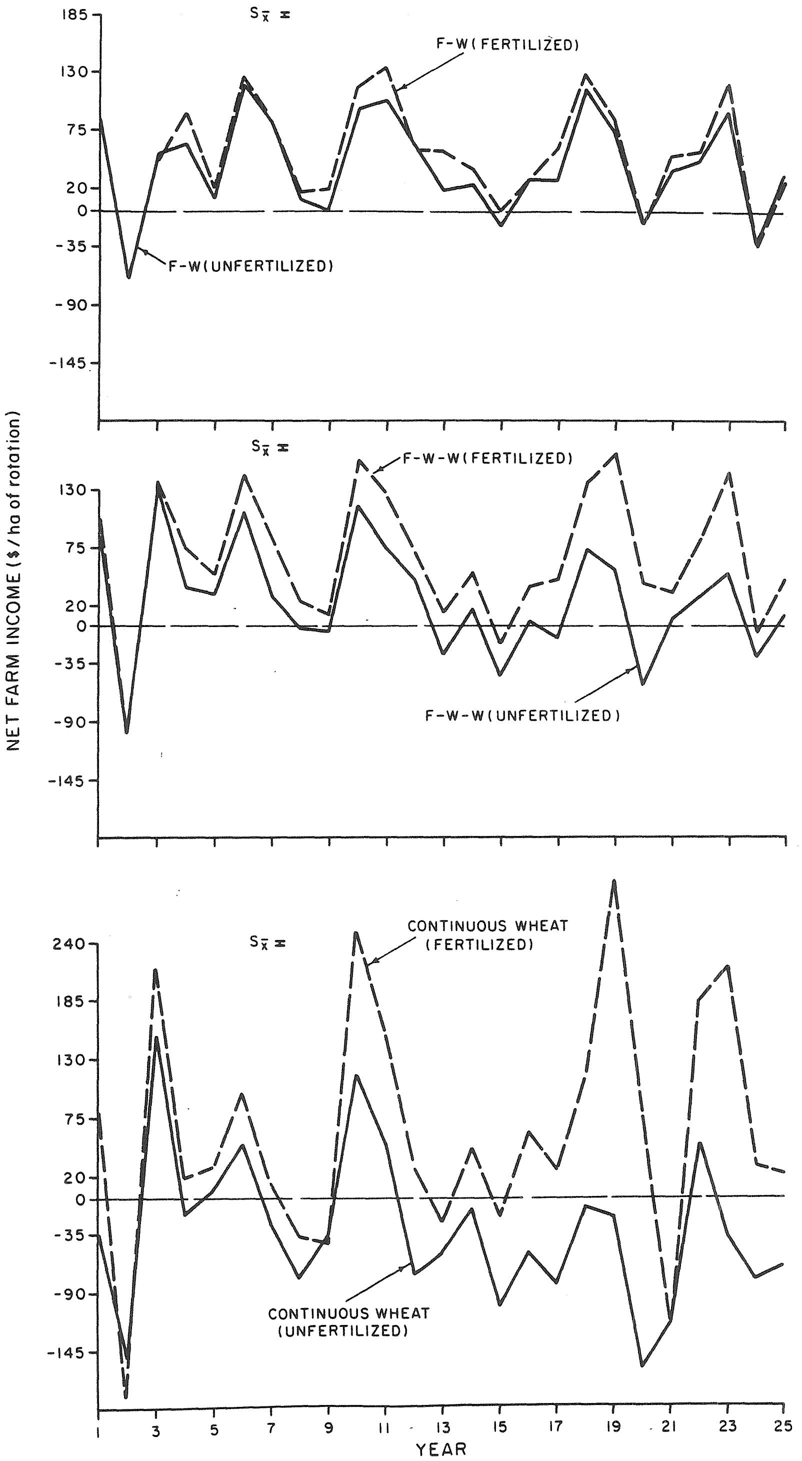

Fig. 2. Effect of rotation length and fertilizer on net farm income for three wheat rotations at Indian Head

particularly for the more intensive crop rotations and in years of favorable moisture (Fig. 2). Proper fertilization had the favorable effect of amplifying the levels of net farm income in years of favorable growing conditions and diminishing the economic losses in years of unfavorable growing conditions. This results because fertilizer generally increases moisture use efficiency of the crop (Stepphun et al. 1984). The divergent spread over time in the levels of economic return for the fertilized and unfertilized rotation treatments likely implies that fertilizer rates used in the early periods of the study were lower than the economic optimums. This could also be related to organic matter declines and reduced nitrogen supplying power of the soil for those rotation treatments receiving no fertilizer (Biederbeck et al. 1984).

ii) Effect of changes in the base assumptions. The effects of changes in product price and input cost assumptions on the mean levels of net farm income were greatest for the more intensive crop rotations and smallest for the rotations that included high proportions of summerfallow (Table 8). Under the low grain and forage price assumptions, net farm income for the rotations were reduced an average of $40-70/ha based on the past 25 years and $41-83/ha based on the past 17 years. At these lower product price levels, 4-6 rotations produced economic losses on average, although all rotations displayed economic losses in some years (data not shown). The relative rankings of the rotations (highest to lowest) were changed to favor the lesser intensive cropping systems, particularly those receiving no fertilizer. For example, the ranking of the 25-year means for the unfertilized F-W rotation improved from ninth to seventh, whereas, that for fertilized continuous wheat decreased from fifth to ninth. At these low product price levels, the fertilized F-W and continuous wheat rotations produced economic returns that were similar or higher than for the comparable F-W-W rotation 76% and 32% of the time, respectively (data not shown). Increases in the absolute prices for grain and forage (from the base assumptions) had opposite effects. A 20% increase in product prices increased the rankings of the more intensive crop rotations, with the fertilized continuous wheat rotation producing the highest average net farm income based on the past 25 years, and the high fertility continuous Flx-W-B rotation producing the highest average net farm income based on the past 17 years. At these high product price levels, the fertilized F-W and continuous wheat rotations produced similar or higher economic returns than the F-W-W rotation 44% and 52% of the time, respectively. These results occur because as grain and forage prices increase, the value of the products produced rise, which in turn, raises the opportunity cost of leaving land idle for a cropping season or of not applying recommended levels of fertilizer (and other inputs).

Changes in product price ratios influence the type or mix of products that should be produced. Increases (decreases) in the price of one product relative to another increases (decreases) the profitability of producing the former product. For example, at low relative prices for feed grains (i.e., for barley and oats) relative to prices for other grains, the 17-year mean economic returns for the F-W-Cl-O-H (4 yr) and Flx-W-B rotations were reduced by an average of $13-22/ha (Table 8). This resulted in the most profitable rotation becoming F-W-W-H-H-H (compared to the high N fertility Flx-W-B rotation that was most profitable for the base price assumptions). Thus, a reduction in the relative price for feed grains would result in a substitution away from the production of barley (and oats) towards the production of the higher valued crops (e.g., wheat, forage, and summerfallow in the above example). Reductions in the relative price for oilseeds (i.e., flax) had similar effects. In contrast, low relative prices for forages reduced the mean economic returns associated with rotations that included forage by an average of $12-25/ha, but left the most profitable rotation unchanged (i.e., GM-W-W for the 25-year period and high N fertility Flx-W-B for the 17-year period). Increases in the relative prices for feed grains and for oilseeds resulted in the Flx-W-B (high N fertility) rotation remaining the most profitable. At the high relative forage prices, economic returns were greatest for the F-W-W-H-H-H rotation.

Reducing the cost of fertilizer (but holding the quantities utilized constant) increased the mean economic returns of the rotations receiving fertilizer by 5-18% or $2-17/ha (compared to the base). The economic benefit from reduced fertilizer costs was greatest for the continuous-type rotations and lowest for the rotations that included high proportions of summerfallow. This occurs because summerfallow acts as a partial (short-term) substitute for fertilizer due to nitrogen mineralization during the fallow period. Low fertilizer costs also reduced the economic value of the complementary effect of including forage and legume green manure crops in the rotation. Conversely, high fertilizer costs reduced the economic returns for the fertilized rotations and increased the economic value of including summerfallow and forage or legume green manure crops in the rotations.

Changes in the opportunity cost of farm labor influenced the profitability of all rotations, but as with changes in the cost of fertilizer, the effects were greatest for the continuous-type rotations because of higher labor requirements. Placing a zero opportunity cost on farm labor increased the mean net farm income of the rotations by $26-41/ha (compared to the base). Conversely, placing a $20/hr opportunity cost on farm labor reduced the rankings of the continuous-type and the forage-containing rotations relatively more than for the less intensive crop rotations.

A 25% increase in the cost of energy reduced the average net farm incomes for the rotations by $6-27/ha (compared to the base) (Table 8). Under the fertilized F-W, F-W-W, and continuous wheat rotations, the higher energy costs reduced economic returns by $8/ha (14%), $12/ha (18%), and $22/ha (33%), respectively, compared to the base situation. In contrast, economic returns for the respective unfertilized rotations were reduced by only $6, $7, and $9/ha. Nevertheless, application of recommended rates of N and P fertilizer were still profitable. Rising energy costs also increased the economic benefits of including forage and legume green manure crops in the rotation.

The Saskatchewan Crop Insurance Program provides producers with a means of passing along some of the risk associated with weather, insects, disease, and other uncontrollable events. Under the 1984-85 criteria for the Program (and assuming that forage was uninsured), all rotations received payouts in at least 2 of 25 years. The unfertilized F-W and F-W-W-H-H-H rotations, and the fertilized F-W, F-W-W, and continuous wheat rotations received payouts in only 2 of 25 years or 8% of the time. In contrast, the unfertilized F-W-W, Flx-W-B, and continuous wheat rotations received payouts 40% (10 of 25 years), 59% (10 of 17 years), and 44% (11 of 25 years) of the time, respectively. The annual payouts for these latter rotations (expressed on a per hectare of rotation basis) ranged from $3.30-$87.20/ha, $3.07-$137.85/ ha, $3.69-$147.34/ha, respectively. The mean levels of net farm income for the rotations that received payouts under the Program only infrequently were similar or were slightly lower than for the base situation (i.e., with no crop insurance) (Table 8). This occurred because the payouts received under the Program were largely offset by the value of the annual premiums paid into the Program. In contrast, the mean net farm incomes for rotations that received frequent (and sizeable) payouts under the Program generally increased. The greatest effect from participation in the Program was in terms of its income-stabilizing role (discussed in a later section).

iii) Resource requirements and costs of production. Total cash costs for resource services and for operation of the farm business (e.g., seed, fertilizer, herbicides, insecticides, fuel and oil, machine repair, labor, interest paid on operating loans, real estate taxes, etc.) were lowest for rotations that included high proportions of summerfallow and for rotations that included forage and legume green manure crops (Table 9). Furthermore, total cash costs for all rotations were higher in the more recent time period because of the greater use of fertilizers and herbicides. The fertilized F-W-W and continuous-type rotations required 32-48% and 102-125% greater cash expenditures, respectively, than for the fertilized F-W rotation.

Table 9. Total cash costs for crop rotations at Indian Head

Rotation Sequence	Fert. N	Fert. P	1960-1984 Cost ($/ha)	1960-1984 % of Check	1968-1984 Cost ($/ha)	1968-1984 % of Check
1. F-W (check)	+	+	95.80	100	98.32	100
2. F-W	0	0	85.89	90	88.75	90
3. F-W-W	+	+	126.00	132	131.74	134
4. F-W-W (str. removed)	+	+	139.39	146	145.87	148
5. F-W-W	0	0	103.82	108	107.59	109
6. F-W-W-H (4 yr)	0	0	99.71	105	103.69	105
7. F-W-Cl-O-H (4 yr)	0	0	86.55	90	86.21	88
8. F-W-W-H-H-H	0	0	84.99	89	86.10	88
9. Cont. W	+	+	193.81	202	209.73	213
10. Cont. W	0	0	147.92	154	156.05	159
11. GM-W-W	0	0	92.78	97	92.33	94
12. Flx-W-B	+	+			202.07	206
13. Flx-W-B (high N)	+	+			220.96	225
14. Flx-W-B	0	0			135.47	138

The resource categories most affected by increases in rotation length were fertilizers, chemicals (herbicides and insecticides), machine operation, and labor (Fig. 3). Within the monoculture wheat rotations, fertilizer expenditures represented 10-22% of total cash costs, while chemical expenditures represented 11-15% of total cash costs. Fertilizer costs for the F-W-W and continuous wheat rotations averaged $10/ha or 98% greater and $30/ha or 302% greater than that for the comparable F-W rotation, respectively. Fertilizer expenditures for the Flx-W-B rotations averaged $36/ha or 369% higher (Rot. 11) and $50/ha or 519% higher (Rot. 12) than for the fertilized F-W rotation (data not shown). These results are a direct consequence of the higher rates of N and P fertilizers that were applied to stubble seeded crops compared to crops grown on fallow. Herbicide and insecticide costs also increased greatly with the more intensive crop rotations (compared to the F-W rotations), but

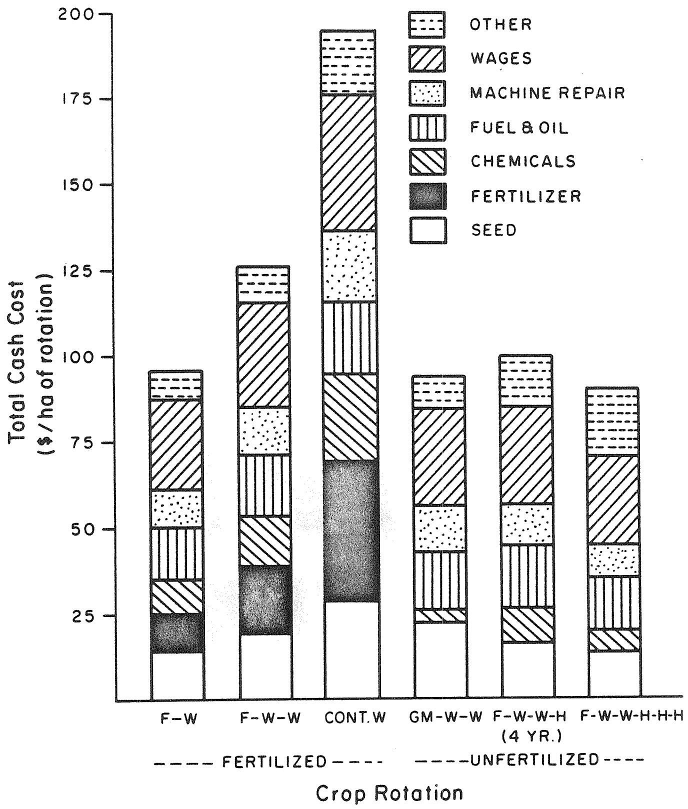

Fig. 3. Total cash costs for selected rotations at Indian Head

were similar or lower for rotations that included forage or legume green manure crops because little herbicide was applied to these crops and to the cereal areas being undersown to forage or sweet clover. Under the fertilized monoculture wheat rotations, herbicide expenditures for the F-W-W rotation averaged $5/ha or 51% higher than for the F-W rotation; the continuous wheat rotation averaged $16/ha or 160% higher.

Fuel (including oil) increased by $2/ha or 12% and machine repair expenditures increased by $3/ha or 26% as the rotation was increased from a 2-year to a 3-year wheat system. Lengthening the rotation from a 2-year to a continuous wheat system resulted in these costs increasing by $6/ha or 36% and $10/ha or 89%, respectively. Labor costs averaged 16% ($4/ha) and 47% ($13/ha) higher for the fertilized F-W-W and continuous wheat rotation relative to the comparable F-W rotation, respectively. The seasonality of labor requirements also differed greatly among rotations (Fig. 4). Under the F-W rotations, the requirements for labor were distributed uniformly over the growing season. In comparison, those for the F-W-W and continuous wheat rotations tended to be concentrated more in the spring and fall periods. Rotations that included forage crops required less labor in the spring period but more labor in the summer period than those that included only cash grains.

Seed costs and other cash costs, such as building repair and interest on operating capital increased in direct proportion to the area being cropped.

The relative requirements for total resource services among crop rotations at Indian Head were quite similar to those reported for comparable rotations at Swift Current; however, there were differences among the individual resource categories. Zentner et al. (1984) reported that total cash costs for the well-fertilized F-W, F-W-W, and continuous wheat rotations at Swift Current averaged $70, $85 (or 121% relative to F-W), and $149/ha (or

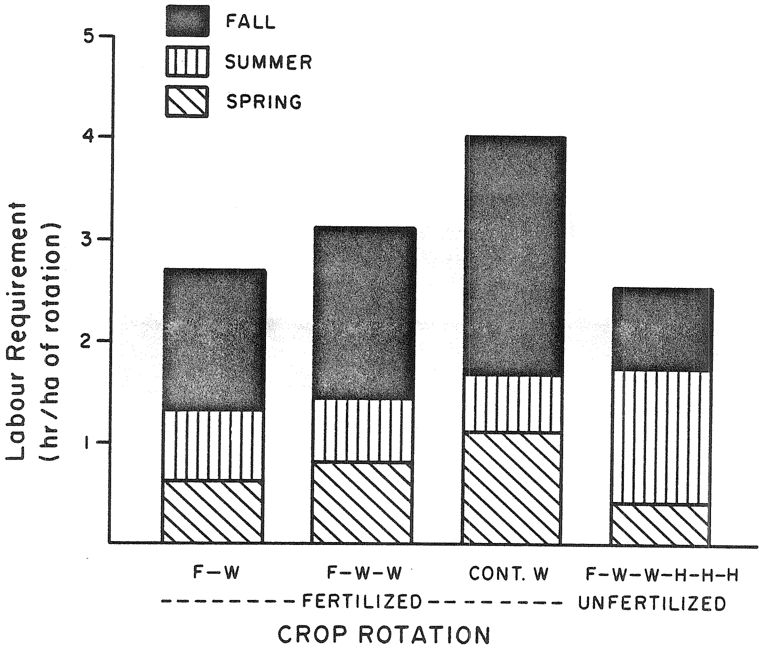

Fig. 4. Average seasonal labor requirements of selected wheat and forage rotations at Indian Head

212% relative to F-W) (measured at 1982 cost levels). The relative expenditures for fertilizers among the rotations were lower at Swift Current than at Indian Head because of the lower recommended rates of applied N and P fertilizers. In contrast, herbicide costs were considerably higher for the continuous wheat rotation at Swift Current than for the similar rotation at Indian Head. The high (relative) cost for herbicides in the continuous wheat rotation at Swift Current was due to a heavy infestation of grassy weeds that evolved in this rotation compared to rotations that included summerfallow. The relative expenditures for other resource services (e.g., fuel, machine repair, and labor) among rotations at Swift Current were also somewhat lower than for comparable rotations at Indian Head.

The average cash cost per tonne of grain produced at Indian Head was lowest for the GM-W-W rotation and highest for the unfertilized continuous wheat rotation (Table 10). The fertilized F-W-W and continuous wheat rotations had average costs that were 11% and 38% higher than for the comparable F-W rotation. Application of recommended rates of N and P fertilizer generally reduced the average cost per unit of grain produced.

Table 10. Average cash cost per tonne of wheat produced at Indian Head

Rotation Sequence	Fertilizer N	Fertilizer P	Average Cost ($/t)	% of check
1. F-W (check)	+	+	77.87	100
2. F-W	0	0	76.69	99
3. F-W-W	+	+	86.07	111
5. F-W-W	0	0	92.37	119
9. Cont. W	+	+	107.08	138
10. Cont. W	0	0	141.28	181
11. GM-W-W	0	0	68.62	88

Marginal cost is defined as the additonal cost associated with increasing the quantity of output by one unit, and as such, it represents the supply function for an individual producer. It indicates the quantity of grain that a producer would be willing to provide at any level of product price (Fig 5). When prices are high producers are willing to increase the quantity of product being produced; conversely, when prices are low producers are willing to

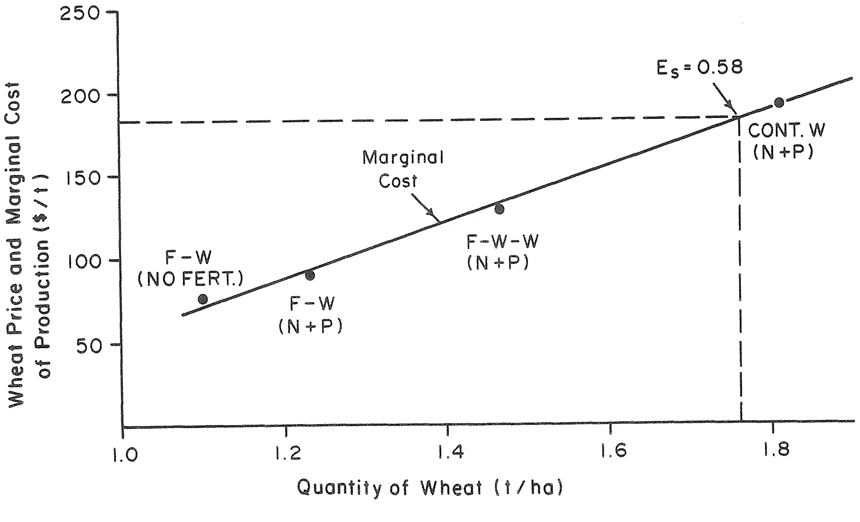

Fig. 5. Marginal cost of wheat production at Indian Head

supply less of the product. In this study and only for the monoculture wheat rotations, the marginal cost curve shows how producers would change their rotation length (in order to increase the quantity produced, given fixed levels of input useage) in response to changes in product price. For example, if the price for wheat was less than $125/t, producers would supply wheat using the least intenive crop rotation (i.e., F-W). Alternatively, if the price for wheat was $190/t or higher, producers would produce wheat using the most intensive cropping system (i.e., continuous wheat). The degree of responsiveness in the quantity produced to changes in product price is referred to as the price elasticity of supply (E_s). For example, when the price for wheat is $184/t, the elasticity of supply is 0.58. In other words, a 1% increase in the price for wheat would bring about only a 0.58% increase in the quantity supplied. The price elasticity of supply varies with the location on the curve. Furthermore, a change in the cost of inputs will shift the marginal cost curve and change the profit maximizing rotation. For example, if the cost of fertilizer is increased, the marginal cost curve will shift upwards. The slope of the curve will also increase because of the greater differential requirements of the more intensive crop rotations. Accordingly, the elasticity of supply (at any given product price and quantity) would decrease, thus discouraging stubble cropping (or increases in the quantity of product supplied). A reduction in the cost of an input would have the opposite effect.

iv) Breakeven stubble/fallow yield ratios. The yields of wheat grown on fallow were seldom twice as great as the yields of wheat grown on stubble (Table 5 and Fig. 1). Fallow yields must average 100% above stubble yields in order that the same total quantity of grain is produced; however, because summerfallowing offers cost savings compared to stubble cropping (e.g., reduced expenditures for fertilizers, fuel, chemicals), fallow yields need not be double those for stubble to be economical (Table 11). These breakeven stubble/fallow yield ratios represent the average relationship that must exist between the yields of wheat grown on stubble and on fallow in order that equivalent levels of net farm income are obtained. Actual stubble/ fallow yield ratios greater than the breakeven values imply that stubble cropping is more profitable than fallow cropping, and vice versa. The average breakeven stubble/fallow yield ratios calculated for the two time periods were higher for the fertilized continuous wheat rotation than for the fertilized F-W-W rotation because of the greater resource requirements per unit of stubble land cropped. The relative yield of wheat grown on stubble needed to produce economic returns equivalent to wheat grown on fallow increased with decreases in the price for wheat and with increases in the cost of inputs. Conversely, the breakeven stubble/fallow yield ratios decreased with increases in the price for wheat and with decreases in the cost of inputs. The average stubble/fallow yield ratios obtained in the experiment for both the fertilized F-W-W and continuous wheat rotations ranged from 0.71 to 0.75 for the 1960-84 period and from 0.75 to 0.79 for the 1968-84 period (Table 5). Thus, stubble cropping was profitable under most economic situations.

Table 11. Average breakeven stubble/fallow yield ratios for two wheat rotations at Indian Head

	F-W-W (N & P)		Cont. Wheat (N & P)	
Economic Scenario	1960-84	1968-84	1960-84	1968-84
1. Base Situation	.70	.71	.71	.74
2. Low Grain Prices	.75	.78	.77	.81
3. High Grain Prices	.66	.68	.67	.70
10. Low Fertilizer Costs	.68	.69	.69	.72
11. High Fertilizer Costs	.72	.74	.73	.76
12. Low Labor Costs	.67	.67	.67	.71
13. High Labor Costs	.73	.75	.75	.77
14. High Energy Costs	.72	.74	.74	.76
15. With Crop Insurance	.71	.73	.72	.75

v) <u>Income variability.</u> Income variability arises from yield risk, price risk, or both. Yield risk originates from variations in the amounts and distribution on rainfall, temperatures, and other weather factors, insects, diseases, weeds, timeliness of field operations, management ability of the operator, and other uncontrollable factors of production. Price risk arises from unexpected changes in input costs, product prices, and marketing opportunities.

Decision-making in a risky environment usually entails making a trade-off between increases in expected net farm income and increases in income variability; a higher level of expected net farm income generally requires giving up a lower level of income variability (Fig. 6). Low standard deviations indicate low income variability (or risk). The amount of income variability

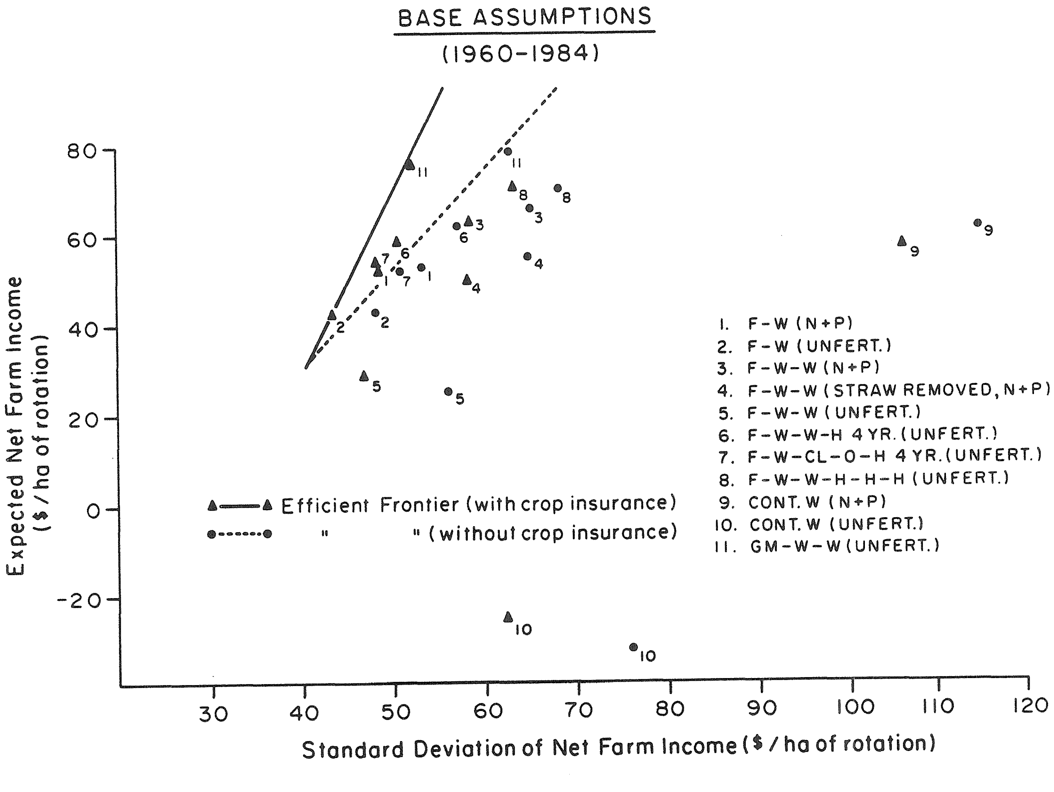

Fig. 6. Trade-off between increases in expected net farm income and increases in income variability, and the influence of the Saskatchewan Crop Insurance Program at Indian Head

that a producer is willing to accept depends on personal preferences, attitudes towards risk, and financial position or ability to accept risk. Producers who are averse to risk (i.e., do not like to gamble) are less willing to adopt crop rotations with high income variability than are producers who are less risk averse.

Rotations that included high proportions of summerfallow, forage, or legume green manure crops generally had the lowest income variability, while the continuous-type rotations generally had the highest income variability. Crop insurance was an effective means of reducing (but not eliminating) the risk or income variability associated with most rotations; its effect being greatest for the more intensive crop rotations, particularly for those that included oilseeds or did not receive recommended rates of fertilizers.

Under the base price assumptions, producers who are highly averse to taking risks would be most willing to choose among unfertilized GM-W-W, or F-W-W-H-H-H, and the fertilized F-W-W rotations, whereas, producers who are less risk averse would be most willing to choose among fertilized continuous wheat, high N fertility Flx-W-B, and unfertilized F-W-W-H-H-H. When product prices are high, highly risk averse producers would choose among unfertilized GM-W-W, F-W-W-H (4 yr), F-W-W-H-H-H, and fertilized F-W-W; less risk averse producers would choose among unfertilized GM-W-W, F-W-W-H-H-H, and the fertilized F-W-W, Flx-W-B, or continuous wheat rotations (data not shown). At low product prices all producers would choose somewhat less intensive crop rotations (compared to the base price assumptions).

CONCLUSIONS

Among the 14 crop rotations examined at Indian Head, three rotations, viz., well N fertilized flax-wheat-barley (Flx-W-B), unfertilized fallow-wheat-wheat-bromegrass/alfalfa hay-hay-hay (F-W-W-H-H-H) and sweet clover green manure-wheat-wheat (GM-W-W) produced the highest net farm income under most reasonable input cost and product price assumptions. We suspect that the profitability of the two latter rotations might be improved even further with application of appropriate rates of P fertilizer to the forage and cereal crops (and possibly with some N fertilizer applied to wheat grown on stubble). Fertilized monoculture continuous wheat and fallow-wheat-wheat (F-W-W) were also members of the five most profitable crop rotations; their rankings were often second or third highest, especially when wheat prices were expected to be high (and grain delivery quotas non-restrictive) or input costs low. The fertilized fallow-wheat (F-W) rotation generally ranked no higher than intermediate, and would not be recommended for adoption by producers except when grain prices and marketing opportunities are very low, interest costs are high, or by producers who are highly averse to risk.

Among the group of most profitable rotations, several factors might limit adoption of the mixed rotations. For example, although no serious problem was reported in the experiment, the potential exists for volunteer barley to become a problem in the flax crop under Flx-W-B. Similary, while F-W-W-H-H-H may be attractive to producers with beef or dairy enterprises, the use of rotations that include forage crops might be unattractive to cash-grain producers because of the additional capital requirements for forage harvesting equipment, greater management requirements, reduced amount of leisure time during the summer period, or the hassle that might arise in marketing the hay, particularly in years when forage is in ample supply. However, the mixed rotations do offer producers the advantages of highest grain yields and greater marketing opportunities in periods when grain delivery quotas are expected to be restrictive. It also offers better soil conserving potential and reduces the risk of disease and insect build-up often common in monoculture systems.

Resource requirements increased as cropping became more intensive. Total, average, and marginal costs of production were lowest for F-W, GM-W-W and rotations that included high proportions of forage crops, while continuous-type rotations had the highest production costs. The difference between the low and high cost values was often as great as 100 to 125%. Fertilizers and herbicides were the resource categories most affected by increases in the rotation length. Expenditures on fuel and oil also increased as cropping became more intensive, but to a lesser extent, because the additional fuel required for planting and harvesting the extra crop was partially offset by the savings from reduced summerfallow tillage. Machine repair expenditures increased with intensity of cropping, particularly for planting and harvest equipment. Increased crop intensification may also require additional capital expenditures in the form of planting and harvest machinery and grain storage. The high cash requirements of the more intensive crop rotations may cause additional cash-flow problems especially in periods of lower product prices and marketing opportunities and when interest rates are high. Requirements for farm labor were greater and were skewed more towards the spring and fall periods with the more intensive crop rotations.

Income variability and the frequency with which economic losses were generated were lowest for rotations that included high proportions of summerfallow or forage crops, intermediate for 3-year fallow-crop-crop rotations, and greatest for the continuous-type rotations. These results occurred because of lower cash expenditures and lower yield variability of crops grown on fallow compared to crops grown on land that had just been cropped. Furthermore, income variability tended to be lower for rotations that included wheat than for rotations that included other cereal or oilseeds crops. A tradeoff existed between increases in expected net farm income and increases in income variability. The rotation of choice depends upon the risk preferences of an individual producer. All-risk crop insurance was effective in reducing or minimizing the income variability (or risk), particularly for the more intensive crop rotations.

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