1977

SOIL PLANT NUTRIENT RESEARCH REPORT

compiled by

J.L. Henry and T.J. Hogg

Department of Soil Science
University of Saskatchewan
Saskatoon, Saskatchewan

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ACKNOWLEDGMENTS

This report summarizes the field research investigations on soil fertility and productivity carried out during the 1977 season by the staff of the Department of Soil Science, University of Saskatchewan, Saskatoon. These studies were supported by research funds provided from the following sources: the Saskatchewan Department of Agriculture, the Canada Department of Agriculture and the Western Co-operative Fertilizers Limited.

In soil fertility research, it is vital to conduct experiments under a wide variety of soil and climatic conditions. Almost all of the investigations were carried out on individual farms throughout the province. Without the generous cooperation of the many farmers involved, it would be impossible to conduct research of this type. A sincere thank you is extended to all farmers who put up with considerable inconveniences to accommodate these experiments.

All field operations associated with plot establishment and maintenance were carried out by summer assistants including Dale Tomasiewicz, David Shortt, Mark Beaulieu, Marie Boehm, Sandra Burton and Larry Spearing. Staff of the Crop Development Centre seeded the phosphate placement plots at Outlook and carried out some of the weed control and harvest operations on those plots.

Nitrogen and phosphorus analyses of plant material were performed by Dorothy Czarnota and Jackie Moir of the Soil Science Department and staff of the Crop Development Centre. The Saskatchewan Soil Testing Laboratory performed all routine soil analysis.

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INTRODUCTION

Previous research by the Department of Soil Science, University of Saskatchewan, in the South Saskatchewan River Irrigation Project has shown that the major factors influencing the yield and quality of irrigated crops are nutrient levels and the timing of irrigation applications. Nitrogen was found to be the major nutrient limiting the yields of cereals and oilseed crops. Depending on initial soil NO_3-N levels increases in crop yield were generally obtained with nitrogen fertilizer rates up to 168 to 224 kg N/ha. As well, protein levels increased with an increase in nitrogen fertilization particularly at high application rates where yields had reached a maximum. However, the presence of nitrogen in excess of crop requirements can result in severe lodging of cereals, undesirably high protein content of soft wheat or malting barley and a significant decline in the oil content of oilseed crops.

The timing of irrigation applications was found to be important in preventing moisture stresses at critical stages of crop growth. A moisture stress early in the growing season and midway through the crop growth was found to cause a greater yield reduction than a stress somewhat later in the growing season. As well, the greater the moisture stress the higher the protein content of the crop.

Most of this research has been carried out utilizing barley, soft wheat and rapeseed. Little information is available for hard wheat and utility wheat. Therefore, with the growing interest in protein content of wheat and the introduction of protein grading into the marketing system it was considered important to obtain information on the effects of nitrogen fertilization and irrigation scheduling on different wheat varieties.

PURPOSE

To assess the effects of nitrogen fertilization and irrigation scheduling on the yield and quality of hard wheat, utility wheat and soft wheat.

EXPERIMENTAL METHODS

One site was selected for this experiment on an Elstow loam soil (Tomasiewicz farm). This site had been seeded to hard wheat in 1976.

Soil analyses from samples taken at seeding time indicate a medium level of nitrogen (Table 1.1.1). It should also be noted that substantial quantities of nitrogen were present in the 30 to 120 cm depth. As well, some salinity was present at depth.

The cultivars used were Sinton hard wheat, Glenlea utility wheat and Fielder soft wheat. The plots were rototilled prior to seeding with a double disc press drill with seven rows per treatment and an 18 cm row spacing. Plot length was 4.5 metres.

Phosphate applications with the seed were made to all plots at a rate of 45 kg P_2O_5/ha. Monoammonium phosphate (11-55-0) was used as the phosphate source throughout.

The fertility treatments included a range of nitrogen rates from 0 to 224 kg N/ha (Table 1.1.2). All nitrogen was applied as a surface broadcast application of ammonium nitrate (34-0-0) applied at the time of seeding.

Table 1.1.1. Spring soil analyses for the nitrogen x water scheduling x wheat varieties experiment

Treatment	Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4-S
				------	kg/ha*	------	
Water A and B	0-15	7.2	0.3	16	4	460	17
	15-30	7.6	0.3	8	2	240	7
	30-60	8.1	0.4	12	2	540	18
	60-90	8.3	1.3	14	2	720	48+
	90-120	8.0	4.5	16	10	880	48+
Water C and X	0-15	7.2	0.3	20	8	650	24+
	15-30	7.5	0.2	6	4	270	17
	30-60	8.0	0.4	14	2	560	14
	60-90	8.5	0.8	26	2	680	48+
	90-120	8.4	1.3	36	4	870	48+

* kg/ha = ppm x 2 for 15 cm depth and ppm x 4 for 30 cm depth

Table 1.1.2. Fertility and water treatments used in the nitrogen x water scheduling x wheat varieties experiment

Treatment Number	Nitrogen Applied (kg/ha)
1	0
2	56
3	84
4	112
5	168
6	224

Water Schedule	Treatment
A	Missed first irrigation
B	Missed second irrigation
C	Received all irrigations
X	Dryland

Post-emergent herbicides included Hoegrass for the control of wild oats and green foxtail and Buctril M for the control of broad-leaf weeds. Weed control was generally good although there were wild oat patches in the Fielder soft wheat and Russian thistle patches throughout the entire plot area.

For the irrigation scheduling portion of the experiment, four water schedules were utilized (Table 1.1.2.). In water schedule A the first irrigation was deleted, in water schedule B the second irrigation was deleted whereas water schedule C received all irrigations. Water schedule X was the dryland treatment and did not receive any irrigation applications.

The actual scheduling of irrigation was determined by tensiometers. Shallow tensiometers were installed at the 10 to 15 cm level initially and then moved down to the 15 to 23 cm level in late June. Deeper tensiometers were installed initially at the 25 to 30 cm level and moved down to the 40 to 45 cm level in late June. The shallow tensiometers were installed in fertility treatment 3 of all water treatments and in all four replicates. The deeper tensiometers were installed only in replicate three of fertility treatment 3 in all water treatments.

The tensiometers were utilized to determine both the timing of irrigation and the amount to apply. Irrigation water was applied when the shallow tensiometers indicated a soil moisture tension of 0.5 atm. The amount of water to apply was determined by the readings obtained on the deep tensiometers as indicated in Table 1.1.3.

Neutron access tubes were installed to a depth of 120 cm in fertility treatment 3 of all replicates and all water treatments.

Table 1.1.3. Depth of water required to replenish soil moisture.

Deep Tensiometer Reading	Depth of Water (mm)
0.3	64
0.3 - 0.7	89
greater than 0.7	114

Moisture monitoring was then conducted with the neutron probe except for the 0-15 cm depth which was done gravimetrically. Moisture measurements were made at the time of installation, at seeding time, at two week intervals until harvest and again at harvest.

Irrigation water was applied through the use of a custom designed sprinkler system which allowed separate timing and amounts of water to the various irrigation treatments under study. The timing and amounts of irrigation water applied are presented in Table 1.1.4.

At harvest, yield samples were taken from all treatments by clipping at the soil surface the three centre rows of the seven-row plot over a length of 3 metres. The samples were then dried, weighed and threshed. The grain samples were then cleaned and weighed. Subsamples of straw and the Glenlea wheat grain were taken, replicates of individual treatments bulked, mixed and ground. Subsamples of the Sinton and Fielder wheat grain were taken, replicates kept separate, mixed and ground. Analyses were performed for protein content of the grain using a Technicon Infra Analyzer while straw nitrogen content was determined by wet digestion and colorimetric analysis using a Technicon Auto Analyser II System.

Table 1.1.4. Amounts and timing of irrigation applications for the nitrogen x water scheduling x wheat varieties experiment

Variety and Water Schedule	Dates and Amounts of Irrigation Applications Growing Season Rainfall = 189 mm	Total Water (Irrigation + Rain) (mm)
Sinton		
A	June 26, 86 mm; July 4, 97 mm; July 15, 65 mm; July 25, 68 mm	505
B	June 17, 83 mm; July 4, 77 mm; July 15, 78 mm; July 25, 67 mm	494
C	June 26, 84 mm; June 27, 88 mm; July 5, 90 mm; July 18, 84 mm; August 1, 48 mm	583
Glenlea		
A	June 26, 103 mm; July 4, 87 mm; July 15, 73 mm; July 25, 67 mm	519
B	June 17, 84 mm; July 4, 96 mm; July 15, 93 mm; July 25, 83 mm	545
C	June 16, 76 mm; June 27, 72 mm; July 5, 88 mm; July 18, 81 mm; August 1, 41 mm	547
Fielder		
A	June 26, 104 mm; July 4, 94 mm; July 15, 77 mm; July 25, 64 mm	528
B	June 17, 68 mm; July 4, 101 mm; July 15, 83 mm; July 25, 66 mm	507
C	June 16, 85 mm; June 27, 102 mm; July 5, 98 mm; July 18, 68 mm; August 1, 41 mm	583

RESULTS AND DISCUSSION

The results of the effect of nitrogen fertilization and irrigation scheduling on the yield, protein content and nitrogen uptake of hard wheat, utility wheat and soft wheat are presented in Tables 1.1.5 to 1.1.7 and Figures 1.1.1. to 1.1.3. The dryland results represent the mean value of three replicates since the fourth replicate received some irrigation water as a result of sprinkler carry over when Water C was being irrigated. The results for Water A, B and C are the mean value of four replicates.

Grain yields for the three wheat varieties, grown on the Elstow soil which had a low to medium nitrogen level, showed a strong response to nitrogen fertilization where little or no moisture stress was involved (Water C). Where a moisture stress was involved (Water A and Water B) the response to nitrogen fertilization was reduced. A moisture stress early in the growing season (Water A) reduced the response to the fertilizer nitrogen more than a moisture stress later in the growing season (Water B). There was no response to nitrogen fertilization under dryland conditions. The differences in grain yield for the three irrigation schedules (Water A, B and C) were more pronounced for Sinton hard wheat and Glenlea utility wheat than for Fielder soft wheat.

Highest grain yields, of approximately 5000 kg/ha, were found for the Glenlea utility wheat where little or no moisture stress was involved and high rates of nitrogen fertilizer applied. The Sinton hard wheat and Fielder soft wheat produced yields of 4100 to 4200 kg/ha under the same conditions. Previous research in the South Saskatchewan River Irrigation Project has indicated hard wheat yields similar to

Table 1.1.5. The effect of nitrogen fertilization and irrigation scheduling on the yield, nitrogen content and nitrogen uptake of Sinton hard wheat grown on Elstow soil

N Applied kg/ha	Yield (kg/ha)		Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake (kg/ha)		
	Grain	Straw				Grain	Straw	Total
				WATER A				
0	1399	1891	0.74	11.9	0.35	33.8	6.6	40.4
56	1917	4026	0.48	13.9	0.63	54.0	25.4	79.4
84	1996	4221	0.48	14.3	0.63	57.9	26.6	84.5
112	1937	4411	0.45	14.8	0.63	58.1	27.8	85.9
168	1854	4973	0.38	15.2	0.74	57.2	36.8	94.0
224	1915	5301	0.36	15.2	0.81	59.0	42.9	101.9
				WATER B				
0	1310	1687	0.78	9.6	0.25	25.5	4.2	29.7
56	2587	3838	0.68	11.5	0.31	60.3	11.9	72.2
84	2968	4175	0.71	12.7	0.35	76.4	14.6	91.0
112	2905	4747	0.64	13.1	0.35	77.2	16.6	93.8
168	3092	4895	0.64	14.4	0.47	90.3	23.0	113.3
224	3155	5080	0.62	15.0	0.56	96.0	28.4	124.4
				WATER C				
0	1179	1632	0.72	11.5	0.27	27.5	4.4	31.9
56	3049	4386	0.70	11.0	0.19	68.0	8.3	76.3
84	3142	5168	0.61	12.0	0.29	76.5	15.0	91.5
112	3958	5779	0.69	13.0	0.31	104.4	17.9	122.3
168	4186	6192	0.68	13.9	0.41	118.0	25.4	143.4
224	4173	6600	0.64	14.5	0.46	122.7	30.4	153.1
				DRYLAND				
0	1042	1263	0.82	13.4	0.40	28.3	5.1	33.4
56	1009	1544	0.65	16.3	0.52	33.4	8.0	41.4
84	1123	1764	0.63	15.9	0.65	36.2	11.5	47.7
112	966	1581	0.61	16.6	0.78	32.5	12.3	44.8
168	934	1540	0.61	17.4	0.84	33.0	12.9	45.9
224	1104	1651	0.67	17.1	0.74	38.3	12.2	50.5
L.S.D. (0.05)	393	730	0.08					

[1]Grain protein content based on % N at 13.5% moisture x 5.7; straw % N on oven-dry basis.

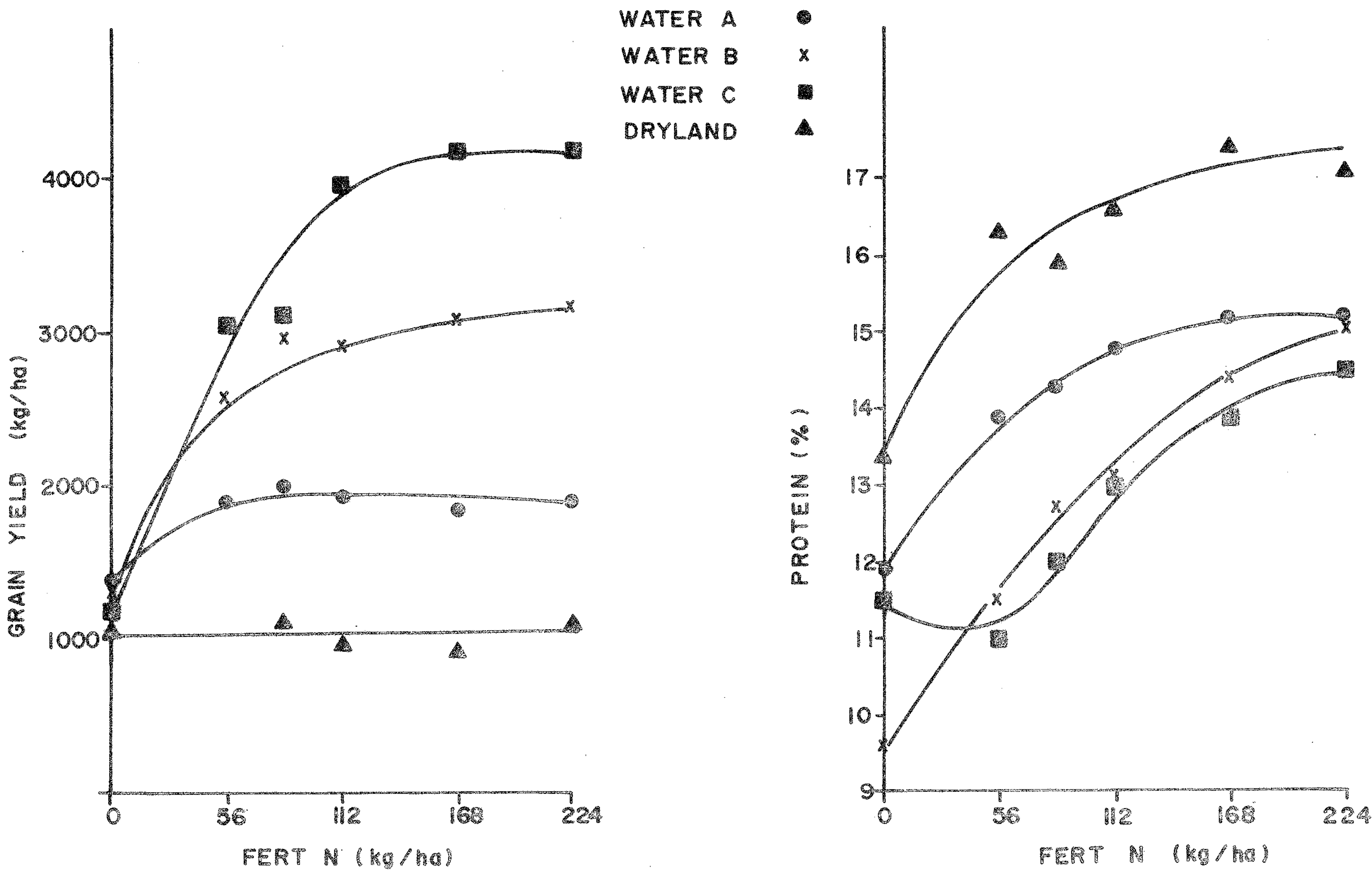

Figure 1.1.1. The effect of nitrogen fertilization on the yield and protein content of Sinton hard wheat.

Table 1.1.6. The effect of nitrogen fertilization and irrigation scheduling on the yield, nitrogen content and nitrogen uptake of Glenlea utility wheat grown on Elstow soil

N Applied kg/ha	Yield (kg/ha)		Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake (kg/ha)		
	Grain	Straw				Grain	Straw	Total
				WATER A				
0	1805	2614	0.70	11.4	0.40	41.7	10.5	52.2
56	2055	5133	0.40	13.1	0.82	54.6	42.1	96.7
84	2127	6362	0.34	13.6	0.66	58.7	42.0	100.7
112	2199	6792	0.33	13.9	0.65	62.0	44.1	106.1
168	2258	7151	0.31	14.3	0.65	65.5	46.5	112.0
224	2302	7495	0.31	14.6	0.80	68.2	60.0	128.2
				WATER B				
0	1631	1903	0.86	9.0	0.27	29.8	5.1	34.9
56	2911	3796	0.77	10.3	0.25	60.8	9.5	70.3
84	2975	4792	0.63	11.7	0.37	70.6	17.7	88.3
112	3233	4716	0.69	12.2	0.43	80.0	20.3	100.3
168	3812	6001	0.63	13.6	0.53	105.1	31.8	136.9
224	3552	6003	0.59	13.6	0.57	98.0	34.2	132.2
				WATER C				
0	1900	2181	0.88	9.9	0.27	38.2	5.9	44.1
56	3539	5039	0.70	9.7	0.22	69.6	11.1	90.7
84	4522	6716	0.48	10.3	0.24	94.5	16.1	110.6
112	4964	7495	0.67	11.0	0.27	110.7	20.2	130.9
168	4800	7918	0.61	12.5	0.43	121.7	30.0	151.7
224	4980	7517	0.66	13.5	0.38	136.4	28.6	165.0
				DRYLAND				
0	1001	1449	0.69	12.5	0.38	25.4	5.5	30.9
56	939	1745	0.54	16.6	0.62	31.6	10.8	42.4
84	975	1812	0.54	17.1	0.78	33.8	14.1	47.9
112	1096	2125	0.53	17.2	0.71	38.2	15.1	53.3
168	914	1854	0.50	17.5	0.91	32.4	16.9	49.3
224	951	2095	0.47	17.8	0.94	34.3	19.7	54.0
L.S.D. (0.05)	585	1026	0.09					

[1] Grain protein content based on % N at 13.5% moisture x 5.7; straw % N on oven-dry basis.

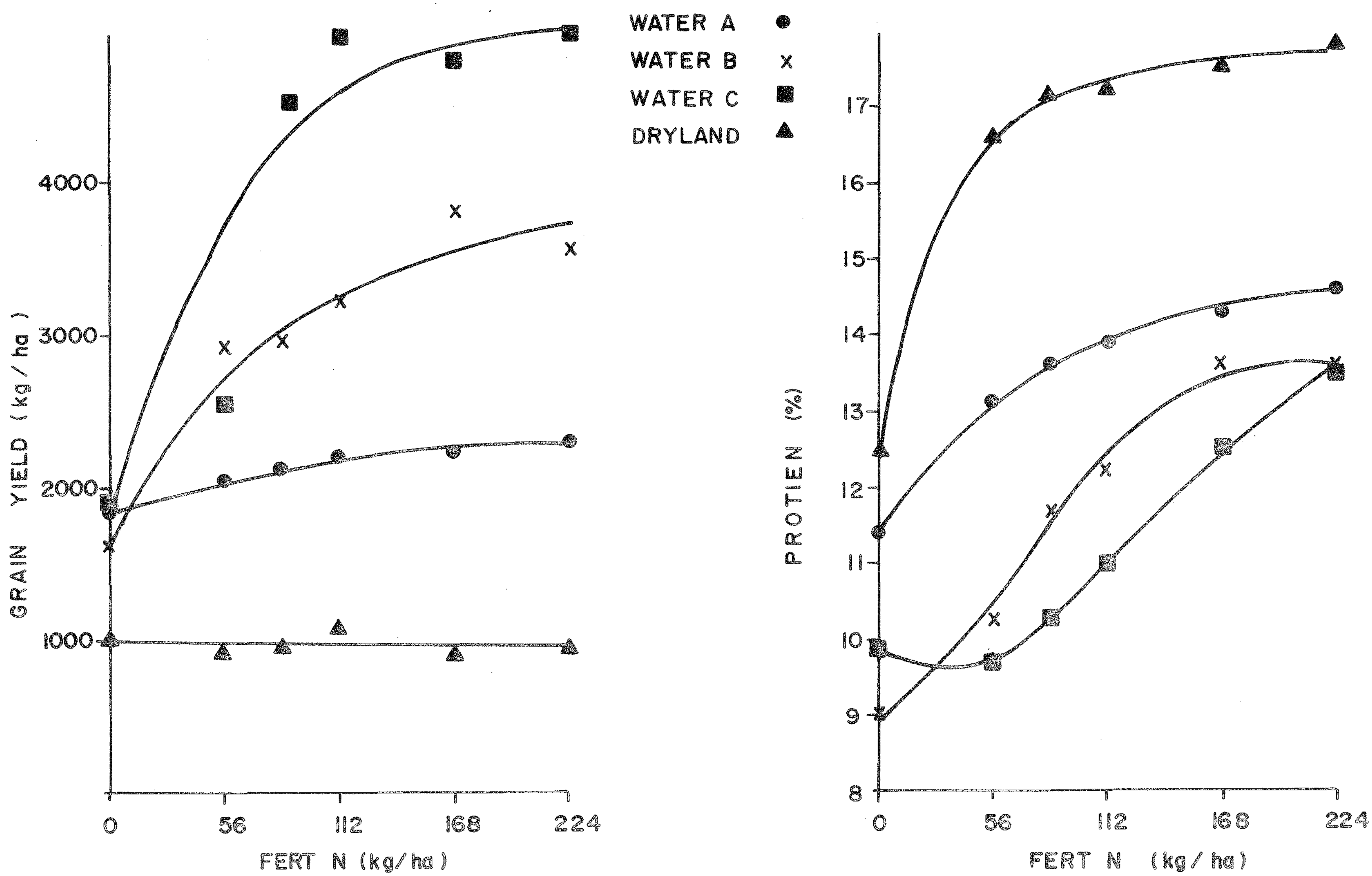

Figure 1.1.2. The effect of nitrogen fertilization on the yield and protein content of Glenlea utility wheat.

Table 1.1.7. The effect of nitrogen fertilization and irrigation scheduling on the yield, nitrogen content and nitrogen uptake of Fielder soft wheat grown on Elstow soil

N Applied kg/ha	Yield (kg/ha) Grain	Straw	Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake (kg/ha) Grain	Straw	Total
				WATER A				
0	1910	1878	1.05	10.0	0.37	38.7	6.9	45.6
56	2552	3748	0.69	10.7	0.59	55.4	22.1	77.5
84	3012	3993	0.85	10.6	0.51	64.8	20.4	85.2
112	2703	5274	0.51	11.6	0.56	63.6	29.5	93.1
168	3034	6233	0.49	12.0	1.01	73.8	63.0	136.8
224	2547	5750	0.45	11.9	0.89	61.5	51.2	112.7
				WATER B				
0	1502	1428	1.05	9.2	0.29	28.0	4.1	32.1
56	2870	3467	0.84	10.0	0.32	58.2	11.1	69.3
84	3119	3801	0.81	10.9	0.37	69.0	14.1	83.1
112	3294	4533	0.74	11.0	0.43	73.5	19.5	93.0
168	3006	4526	0.67	11.6	0.57	70.7	25.8	96.5
224	3393	5812	0.59	11.8	0.75	81.2	43.6	124.8
				WATER C				
0	1863	2093	0.89	10.2	0.34	38.5	7.1	45.6
56	2960	4060	0.73	9.8	0.32	58.8	13.0	71.8
84	3027	6112	0.52	10.2	0.63	62.6	38.5	101.1
112	3437	6661	0.52	10.5	0.44	73.2	29.3	102.5
168	4114	7456	0.55	11.4	0.54	95.1	40.3	135.4
224	4139	8248	0.53	11.5	0.92	96.5	75.9	172.4
				DRYLAND				
0	1324	1553	0.86	11.5	0.45	30.9	7.0	37.9
56	1377	1947	0.71	12.8	0.65	35.7	12.7	48.4
84	1139	1607	0.70	14.0	0.65	32.3	10.4	42.7
112	1190	2179	0.58	14.1	0.69	34.0	15.0	49.0
168	1332	2060	0.65	14.3	0.84	38.6	17.3	55.9
224	1215	1857	0.65	14.6	0.85	36.0	15.8	51.8
L.S.D. (0.05)	1060	1027	0.23					

[1] Grain protein content based on % N at 13.5% moisture x 5.7; straw % N on oven-dry basis.

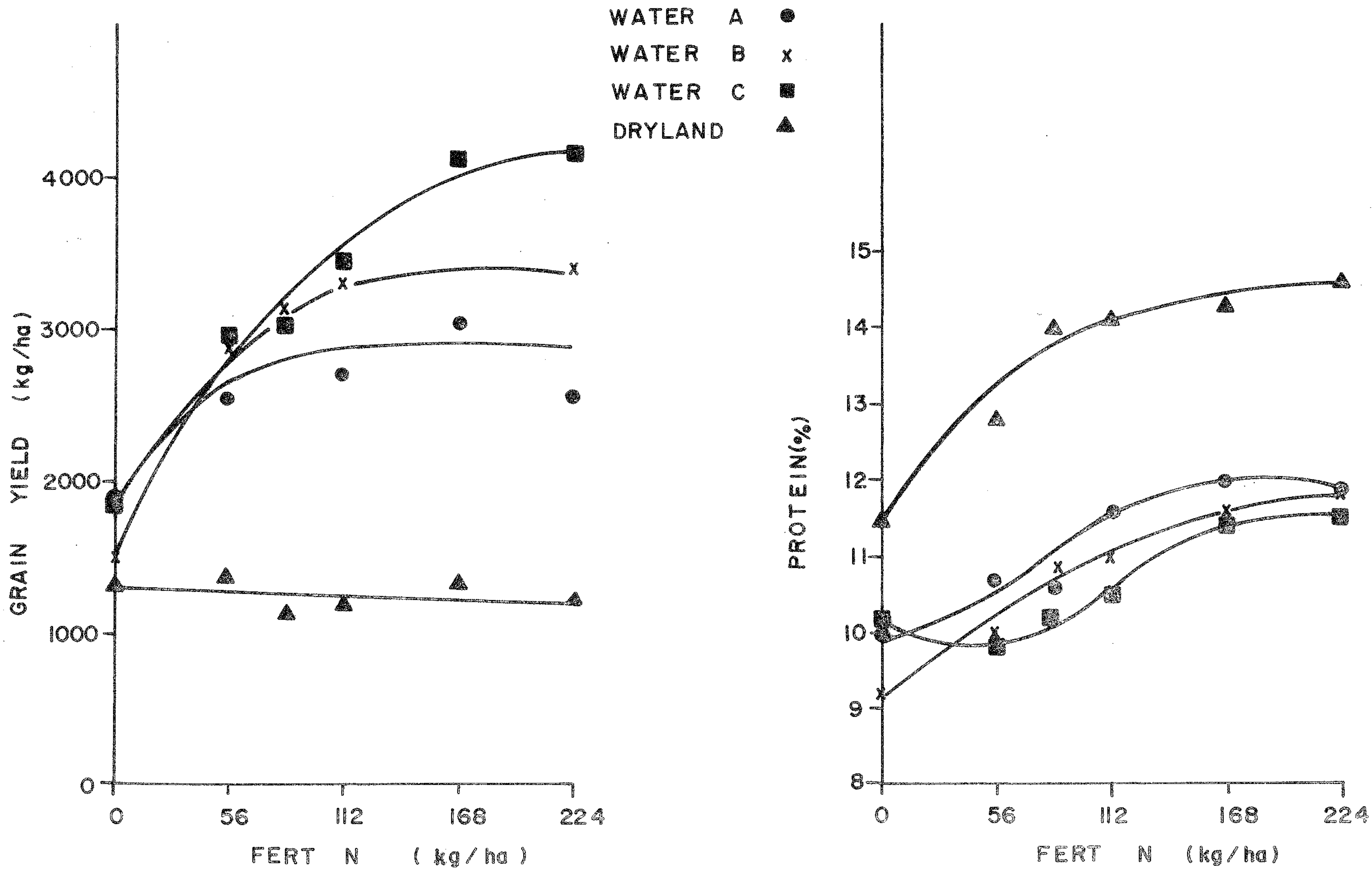

Figure 1.1.3. The effect of nitrogen fertilization on the yield and protein content of Fielder soft wheat.

those found in this study. However, higher soft wheat yields, on the order of 5300 kg/ha, have been obtained than were found for the Fielder soft wheat in this study. Utility wheat has not been studied under irrigation in this area before.

Straw yields showed the same response as grain yields to added fertilizer nitrogen in that they increased with an increase in the rate of nitrogen added. However, the increase in straw yield was greater than the increase in grain yield since grain/straw ratios decreased as the rate of nitrogen fertilizer applied was increased. This trend has been observed in previous research and would indicate that grain production does not increase as rapidly as total plant material with an increase in nitrogen fertilization.

The effect of the water treatments on the grain/straw ratios did not show the same trends for the three wheat varieties. The order of the grain/straw ratios for the three wheat varieties was as follows:

Sinton, Water A < Water B, Water C and Dryland

Glenlea, Water A < Dryland < Water B and Water C

Fielder, Water A and Water C < Water B and Dryland

Previous research with soft wheat has indicated higher grain/straw ratios on optimum irrigated plots than on dryland plots suggesting that grain production is more efficient when more moisture is available for crop growth. Obviously, the present research does not show this.

Grain protein content and straw nitrogen content increased with increases in nitrogen fertilization where the wheat was subjected to a moisture stress. Where little or no moisture stress was involved (Water C) increases in protein and straw nitrogen content did not occur until 112 kg N/ha were applied. The greater the moisture stress the higher were both grain protein and straw nitrogen values which were of the order Dryland >> Water A > Water B > Water C.

A direct result of increased yields and increased protein and nitrogen content of the plant material with increased rates of nitrogen is an overall increase in total nitrogen uptake by the wheat varieties. As well, the greatest nitrogen uptake occurred where little or no moisture stress was involved and it decreased the greater was the moisture stress.

Table 1.1.8. Seasonal water use of hard wheat, utility wheat and soft wheat

Crop	Water Schedule	Rainfall	Irrigation	ΔS*	Total Water Use**
		mm			
Sinton	A	189	316	-71	434
	B	189	305	-68	426
	C	189	394	-84	499
	X	183	0	70	253
Glenlea	A	189	330	-38	481
	B	189	356	-62	483
	C	189	358	-43	504
	X	183	0	60	243
Fielder	A	189	339	-32	496
	B	189	318	-30	477
	C	189	394	-40	543
	X	183	0	62	245

* Δ S = change in soil moisture content (spring - fall)

** Total water use = rainfall + irrigation + Δ S

Table 1.1.9. Residual nitrate nitrogen levels from selected rates of nitrogen application and irrigation treatments

Depth (cm)	Water A N Rate (kg/ha)		Water C N Rate (kg/ha)		Dryland N Rate (kg/ha)	
	0	224	0	224	0	224
	kg NO_3-N/ha*					
			Sinton			
0-15	8	11	13	15	9	90
15-30	7	7	6	9	3	68
30-60	12	35	10	70	22	23
60-90	12	84	11	51	24	29
90-120	15	25	20	26	17	27
			Glenlea			
0-15	9	8	9	10	22	88
15-30	6	8	5	8	8	44
30-60	11	74	9	31	12	33
60-90	15	96	11	21	27	30
90-120	21	29	14	26	26	30
			Fielder			
0-15	10	12	12	13	10	85
15-30	6	6	7	11	5	38
30-60	11	39	12	66	13	26
60-90	12	54	13	51	16	21
90-120	15	20	16	23	18	20

*kg/ha = ppm x 2 for 15 cm depth and ppm x 4 for 30 cm depth

Table 1.1.10. Residual nitrate-nitrogen levels in the 0-15 cm depth for the dryland treatment

Crop	NO_3-N (kg/ha*; 0-15 cm)					
	(N Applied (kg/ha))					
	0	56	84	112	168	224
Sinton	9	26	32	37	66	90
Glenlea	22	25	35	43	65	88
Fielder	10	18	27	45	55	85
Average	14	23	31	42	62	88

* kg/ha = ppm x 2 for 15 cm depth

1.2 The response of irrigated annual crops to nitrogen fertilization on alfalfa breaking

INTRODUCTION

Alfalfa stands established when irrigation was introduced in the South Saskatchewan River Irrigation Project are now becoming less productive. For this reason, many of these alfalfa stands will be taken out of production by breaking them and seeding the breaking to some annual crop. The nitrogen status of alfalfa breaking under irrigation has not been adequately studied and current nitrogen requirement guidelines are based on those for stubble seeded crops. Therefore, it was considered necessary to carry out a research project to establish the response of annual irrigated crops grown on alfalfa breaking to nitrogen fertilization. A research project of this nature would have to include a range of soil types and annual crops. The results from several years research would then provide adequate information for making nitrogen fertilizer recommendations to irrigation farmers.

PURPOSE

To assess the response of irrigated annual crops to nitrogen fertilization on alfalfa breaking.

EXPERIMENTAL METHODS

One site was selected in the spring of 1977 on an Asquith sandy loam soil (Roger Pederson farm). This site had been seeded down to alfalfa since it was developed for gravity irrigation in 1969. The alfalfa was broken up in the spring of 1977.

Soil analyses from samples taken at seeding time indicate medium nitrogen levels present (Table 1.2.1). The major part of the nitrogen was present in the 0-60 cm depth with smaller amounts present in the 60-120 cm depth. The analyses for each replicate indicated the variations that occur within a small area with values varying from 30 to 122 kg NO_3-N/ha (0-60 cm). Phosphorus levels were low and the maximum application rate for irrigated crops would be required. Potassium and sulfur levels were adequate.

The site was seeded to Glenlea utility wheat with all pre-seeding tillage and seeding operations as conducted by the co-operating farmer. Phosphate was applied with the seed during the seeding operation.

The experimental plot established was of a randomized complete block design containing 10 treatments replicated six times. The fertility treatments (Table 1.2.2) included a range of nitrogen applications as ammonium nitrate (34-0-0) from 28 to 224 kg N/ha. The six replicates were extended down the outside border strip of the field. The fertilizer was broadcast after the field had been seeded. Each individual treatment covered an area 6 metres x 1.5 metres.

All herbicide applications for weed control and irrigation applications were as conducted by the co-operating farmer.

One of the control treatments which received no addition of nitrogen (Treatment 8) was used for time-step sampling throughout the growing season. The growth stages at which plant samples were taken included tillering, flag leaf, heading, early milk and maturity. The area sampled was four drill rows over a length of 1 metre. Total above ground dry matter production was recorded and

Table 1.2.1. Spring soil analyses for the wheat on alfalfa breaking experiment under irrigation (R. Pederson)

Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4-S
			----------	----------	kg/ha*	----------
0-15	7.8	0.9	20	8	236	19
15-30	7.8	1.3	25	9	240	24+
30-60	8.1	1.3	14	8	495	48+
60-90	8.4	1.3	5	5	428	48+
90-120	8.4	1.3	5	3	515	48+

* kg/ha = ppm x 2 for 15 cm depth and ppm x 4 for 30 cm depth

Table 1.2.2. Fertility treatments for wheat on alfalfa breaking experiment under irrigation

Treatment Number	N Applied (kg/ha)
1	0
2	28
3	56
4	84
5	112
6	168
7	224
8	Spare
9	Spare
10	Spare

then the samples were ground in preparation for total nitrogen and phosphorus analyses.

At harvest, yield samples were taken from all treatments, except Treatment 8, by clipping at the soil surface three rows over a length of 3 metres. The samples were dried, weighed and then threshed. The grain samples were cleaned and weighed. Subsamples of straw, replicates of individual treatments composited, and all individual grain samples were mixed and ground. Analyses were performed for nitrogen content of the straw by wet digestion and colorimetric analysis on an Auto Analyzer II System and for protein content of the grain with a Technicon Infra Analyzer.

RESULTS AND DISCUSSION

The results for the time-step sampling throughout the growing season are presented in Table 1.2.3. Total above ground yield increased significantly with each growth stage sampled. The nitrogen content and phosphorus content of the plant material decreased significantly with time. However, nitrogen and phosphorus uptake increased with time due to the large yield increases.

The results for the effect of nitrogen fertilization on the yield, protein content and nitrogen uptake of the irrigated Glenlea wheat grown on the alfalfa breaking are presented in Table 1.2.4. The applied nitrogen had no effect on either the grain or straw yield and grain/straw ratios. Protein content of the grain and nitrogen content of the straw showed no consistant trends due to the nitrogen applications. However, nitrogen uptake showed a slight increase at the 112 and 168 kg N/ha treatments over all other treatments.

Table 1.2.3. The yield, nitrogen content, nitrogen uptake, phosphorus content and phosphorus uptake of irrigated Glenlea wheat at five growth stages grown on alfalfa breaking (R. Pederson)

Growth Stage	# Days After Seeding	Yield (kg/ha)	% N	Nitrogen Uptake (kg/ha)	% P	Phosphorous Uptake (kg/ha)
Tillering	22	300	4.45	13.35	0.463	1.39
Flag leaf	43	2699	2.25	60.73	0.322	8.69
Heading	54	4846	1.65	79.96	0.243	11.78
Early Milk	71	7777	1.33	103.43	0.228	17.73
Maturity	105	10785	1.06	114.32	0.213	22.97
L.S.D. (0.05)		1864	0.26		0.001	

Table 1.2.4. The effect of nitrogen fertilization on the yield, nitrogen content and nitrogen uptake of irrigated Glenlea wheat grown on alfalfa breaking (R. Pederson site)

N Applied (kg/ha)	Yield (kg/ha) Grain	Straw	Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake (kg/ha) Grain	Straw	Total
0	4924	6858	0.72	12.1	0.40	120.8	27.4	148.2
28	5051	7054	0.71	12.1	0.36	124.0	25.4	149.4
56	4965	7099	0.69	12.2	0.42	122.9	29.8	152.7
84	4519	7185	0.65	12.3	0.35	112.7	25.1	137.8
112	5457	8410	0.66	12.3	0.58	136.1	48.8	184.9
168	5275	7661	0.69	12.6	0.52	134.8	39.8	174.6
224	4926	7118	0.69	12.2	0.47	121.9	33.5	154.4
0	4251	5413	0.79	12.1	0.36	104.3	19.5	123.8
0	4531	6336	0.72	12.1	0.40	111.2	25.3	136.5
L.S.D. (0.05)	840	1184	0.08					

[1] Grain protein content based on % N at 13.5% moisture x 5.7; straw % N on oven-dry basis

This work indicates that sufficient nitrogen was supplied to grow a crop of irrigated wheat on alfalfa breaking. Additional nitrogen applications did not increase grain yield or protein levels. However, this work was only conducted on one soil type and one crop. A wide range of soil types and crops will have to be investigated before changes in the present nutrient requirement guidelines are recommended.

1.3 Comparison of the two nitrogen sources aqua ammonia and ammonium nitrate under irrigation

INTRODUCTION

The response of annual crops to nitrogen fertilization under irrigation has been well documented by research conducted by the Department of Soil Science, University of Saskatchewan, in the South Saskatchewan River Irrigation Project. The source of nitrogen utilized throughout this research was granular ammonium nitrate (34-0-0). The efficiency of other nitrogen sources in comparison to ammonium nitrate under irrigation has not been thoroughly investigated. Therefore, with the introduction of aqua ammonia (20-0-0) to the Outlook irrigation district in the spring of 1977 it was considered of practical importance to compare it to ammonium nitrate as a soure of nitrogen.

PURPOSE

To compare aqua ammonia and ammonium nitrate as nitrogen sources for irrigated annual crops.

EXPERIMENTAL METHODS

One site was selected in the spring of 1977 in the Outlook irrigation district to compare the two nitrogen sources, aqua ammonia and ammonium nitrate. The test crop was barley, a crop that generally shows a response to nitrogen fertilization under irrigation.

The experimental design consisted of standard strip tests, the length of the field with six sites (replicates) selected for soil sampling and yield determinations. Composite soil samples were taken to a depth of 60 cm prior to plot establishment across the width of the plot at each of the six replicates. Analyses of the soil samples indicated medium levels of NO_3-N present (Table 1.3.1).

The two nitrogen fertilizers were both applied using commercial applicators. Aqua ammonia was applied to a depth of 5 to 10 cm with a shank-type applicator which was 15 metres wide with 40 cm shank spacings. Two rates of aqua ammonia were applied in one pass down the field by using different orifice sizes in the nozzles on one side of the applicator than the other. Thus, each aqua ammonia test strip was 7.5 metres wide. The actual rate of aqua ammonia applied was taken as the amount determined from a calibration conducted prior to each pass down the field. Ammonium nitrate was surface broadcast using a Barber granular applicator which consisted of two separate 4 metre wide sections. Each section was set for a different rate so that with one pass down the field two rates of ammonium nitrate were applied in 4 metre wide strips. The actual rate of ammonium nitrate applied was calculated from the difference in the quantity of fertilizer present in the applicator before and after one pass down the field. A 3.6 metre wide check strip was left down the centre of the plot.

Some problems were encountered while establishing this plot. First, due to a heavy demand on the aqua ammonium applicator the fertilizer was not applied until late in May after the barley crop had been seeded and had already germinated. The pass over the field with the applicator tended to dislodge some of the young seedlings. Thus, to ensure that the dislodging effect did not override the effect of the fertilizer treatments the ammonium nitrate and check strips were passed over with the aqua ammonia applicator. The entire plot area was then packed down by driving a dual-wheel tractor up

Table 1.3.1. Spring soil analyses for the aqua ammonia vs ammonium nitrate experiment (M. Larson)

Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4-S
			-------	-------	kg/ha*	-------
0-15	7.2	0.3	26	16	430	23
15-30	7.5	0.3	13	4	171	17
30-60	7.8	0.3	13	2	263	30

* kg/ha = ppm x 2 for 15 cm depth and ppm x 4 for 30 cm depth

and down the plot. A second problem encountered was that of the desired fertilizer application rates. Some of the desired rates were not achieved and thus the full range in rates were not present for both nitrogen sources for comparison purposes. The actual rates applied are presented in Table 1.3.2.

All pre-seeding tillage, seeding and irrigation operations were as conducted by the co-operating farmer. The amounts and timing of irrigation applications are presented in Table 1.3.3. Phosphate was seed-placed by the farmer at seeding time.

At harvest yield samples were taken from each fertilizer treatment at each replicate by clipping at the soil surface an area equal to two square metres. The samples were then dried, weighed and threshed. Grain samples were cleaned and weighed. Subsamples of straw, replicates of individual treatments were composited, and each individual grain sample were mixed and ground. Analyses were performed for nitrogen content of the straw and protein content of the grain by wet digestion and colorimetric analysis using a Technicon Auto Analyser II System.

RESULTS AND DISCUSSION

The results for the effect of aqua ammonia and ammonium nitrate on the yield, nitrogen uptake and nitrogen content of irrigated barley are presented in Table 1.3.4. Grain yields for the barley showed a response to the applied nitrogen but did not show a consistant increase with each increase in fertilizer nitrogen. Straw yields on the other hand responded to the applied nitrogen and increased as the rate of nitrogen was increased. These observations were further reflected in the grain/straw ratios which decreased as

Table 1.3.2. Nitrogen treatments for the aqua ammonia vs ammonium nitrate experiment

N Source	Desired N Application Rate (kg/ha)	Actual N Application Rate (kg/ha)
	0	0
Aqua Ammonia	56	56
	84	84
	112	81
	168	168
Ammonium Nitrate	56	64
	84	82
	112	114
	168	111

Table 1.3.3. Amounts and timing of irrigation applications

Dates and amounts of irrigation applications Growing Season Rainfall = 32 mm*	Total Water (Irrigation + Rain) (mm)
June 5, 19 mm; June 11, 25 mm; June 27, 28 mm; July 5, 25 mm; July 11, 41 mm; July 12, 37 mm; July 18, 55 mm; July 27, 9 mm; Aug. 4, 60 mm	334

* Records only start at June 5. Rain received in the month of May was not recorded at this site

Table 1.3.4. The effect of different nitrogen fertilizers on the yield, nitrogen content and nitrogen uptake of irrigated Betzes barley (Larson site)

N Source	N Application Rate (kg/ha)	Yield (kg/ha)		Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake (kg/ha)			Grain % P
		Grain	Straw				Grain	Straw	Total	
	0	3532	4434	0.81	9.22	0.24	60.2	10.6	70.8	.36
Aqua NH_3 (20-0-0)	56	4053	6582	0.63	8.73	0.27	65.4	17.8	83.2	.38
	84	4141	6620	0.64	8.45	0.30	64.7	19.9	84.6	.36
	81	4354	7238	0.60	9.01	0.30	72.6	21.7	94.3	.37
	168	3753	9486	0.40	11.65	0.72	81.2	68.3	149.5	.36
Ammonium Nitrate (34-0-0)	64	3661	5144	0.72	8.32	0.26	56.3	13.4	69.7	.37
	82	3446	6607	0.54	9.79	0.40	62.4	26.4	88.8	.37
	114	4310	8692	0.50	9.91	0.46	79.0	40.0	119.0	.36
	111	4232	8656	0.51	10.71	0.49	83.8	42.4	126.2	.37
L.S.D. (P=0.05)		754	1516	0.12	0.86					

[1] Grain protein based on % N at oven-dry moisture x 6.25; straw % N on oven-dry basis.

the rate of nitrogen applied was increased.

The grain yields at the two lowest application rates were greater for the aqua ammonia than the ammonium nitrate. This would suggest that the aqua ammonia was possibly more efficient than the ammonium nitrate at the lower application rates. Comparisons between the two nitrogen sources at the higher rates of application was not possible since the full range in rates was not achieved.

For aqua ammonia at the highest rate of application the grain yield was reduced compared to that of the lower application rates. However, the straw yield showed a large increase over that of the lower application rates. This reduced grain yield accompanied by a large increase in straw yield was possibly due to lodging of the barley which was evident in the field. Unfortunately, the ammonium nitrate did not get applied at as high a rate as the aqua ammonia and it is not known whether lodging of the barley would have occurred. However, previous research using ammonium nitrate has indicated that an over-supply of nitrogen can result in the lodging of cereal crops.

Straw nitrogen content increased as the rate of application of nitrogen fertilizer was increased. A large increase in straw nitrogen content occurred for the highest rate of aqua ammonia, further evidence to indicate lodging of the barley.

The protein content of the barley showed an initial decrease at the low nitrogen application rates before increasing at the higher rates. No differences were observed between the two nitrogen sources. The protein levels obtained were well within the acceptable level for malting barley even at the highest rates of application.

Previous research has indicated that at high rates of nitrogen application protein levels generally exceed the acceptable level for malting barley. However, the full range of application rates was not achieved in the present work and possibly explains the low protein levels.

1.4 The effect of phosphate placement and irrigation scheduling on the growth of selected crops

INTRODUCTION

Recent research has shown that phosphate placed in a band below and to the side of the seed can lead to substantial yield increases for crops like flax, rapeseed and peas. There is a need to test these results under a wider range of soil and climatic conditions and for a wider range of crops.

PURPOSE

To determine the effect of phosphate placement on the growth of fababeans, peas, field beans, lentils, flax and rapeseed under irrigated and dryland conditions.

This was the second year of a joint project between the Crop Development Centre and the Department of Soil Science, University of Saskatchewan.

EXPERIMENTAL METHODS

The site selected for the experiment was on an Elstow loam soil in the South Saskatchewan River Irrigation Project. This site had been seeded to wheat in 1976. The plot was duplicated to provide a dryland and an irrigated treatment.

Soil analyses from samples taken at seeding time indicated low levels of phosphorus (0-15 cm) according to current Soil Test benchmarks (Table 1.4.1). Nitrogen levels (0-60 cm) were in the medium range.

The cultivars used were: fababeans - Erfordia, peas - Trapper, beans - Great Northern U.S. 1140, lentils - P. I. 179307, flax-

Table 1.4.1. Spring soil analyses for the phosphorus placement experiment

Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4-S
			kg/ha*			
Irrigated flax, rapeseed and fababeans						
0-15	7.3	0.3	18	4	425	17
15-30	7.6	0.3	6	2	250	7
30-60	8.2	0.7	32	2	500	48+
60-90	8.4	1.5	26	6	720	48+
90-120	8.0	4.3	32	12	850	48+
Irrigated peas, beans and lentils						
0-15	7.5	0.2	12	4	340	10
15-30	7.9	0.3	6	2	205	6
30-60	8.3	0.6	18	4	490	32
60-90	8.6	1.3	32	8	740	48+
90-120	8.0	4.2	30	20	960	48+
Dryland peas, beans and lentils						
0-15	7.6	0.4	15	6	390	18
15-30	8.0	0.3	8	2	210	7
30-60	7.8	0.9	40	6	540	48+
60-90	8.0	3.2	48	16	780	48+
90-120	7.8	4.6	40	24	1030	48+
Dryland flax, rapeseed and fababeans						
0-15	7.2	0.3	20	8	540	24+
15-30	7.6	0.3	10	3	215	10
30-60	8.1	1.2	44	6	540	48+
60-90	8.2	2.5	28	8	650	48+
90-120	7.9	4.7	28	14	820	48+

* kg/ha = ppm x 2 for 15 cm depth and ppm x 4 for 30 cm depth

Redwood 65 and rapeseed - Tower.

The plots were rototilled prior to seeding with a hoe-press drill with eight rows per plot and an 18 cm row spacing. This hoe-press drill was especially designed by the Crop Development Centre, University of Saskatchewan, to allow for fertilizer placement with the seed or as a sideband application. For the sideband application, the fertilizer was applied 2.54 cm to the side and 2.54 cm below the seed. Plot length was 4.6 metres.

The fertilizer treatments are presented in Table 1.4.2. The phosphorus source utilized was monoammonium phosphate (11-55-0) for all treatments. No additional nitrogen was utilized for legume crops, but for flax and rapeseed an additional application of 112 kg N/ha was utilized for all treatments except Treatment 7. This nitrogen was applied as surface broadcast ammonium nitrate (34-0-0) at seeding time. In addition, the irrigated rapeseed received an additional application of 112 kg N/ha as broadcast ammonium nitrate (34-0-0) in June.

Trifluralin (Treflan) at 1.12 kg/ha in 110 l/ha of water was spring applied and incorporated preplant by rototilling for all crops except field beans and lentils. Post-emergent herbicides included Tropotox plus (MCPB) for fababeans and lentils at a rate of 1.38 l/ha, Buctril - M for flax at a rate of 0.54 l active/ha, hoegrass for lentils and flax at a rate of 0.69 l active/ha and TOK/RM for rapeseed at a rate of 1.34 kg active/ha. All post-emergent herbicides were applied in 110 l/ha of water. Some additional hand weeding was done on all plots.

A severe infestation of Russian Thistle and herbicidal damage

Table 1.4.2. The treatment used in the phosphate placement experiment

Treatment* Number	P_2O_5 Applied (kg/ha)	Placement
1	0	--------
2	17	With seed
3	34	With seed
4	50	With seed
5	67	With seed
6	101	With seed
7	0	--------
8	17	Sideband
9	34	Sideband
10	50	Sideband
11	67	Sideband
12	101	Sideband

* For rapeseed and flax all treatments except Number 7 received an additional application of 112 kg N/ha as broadcast ammonium nitrate (34-0-0) at seeding

to the lentils resulted in the loss of this crop.

At approximately three to four weeks after seeding stand counts were taken by counting the number of plants in the centre four rows of each individual plot over a distance of 1.5 metres.

Irrigation of the plot designated for this purpose was conducted using a specially designed sprinkler system for small plot work. The actual scheduling of irrigation was determined by tensiometers. Shallow tensiometers were installed at the 10 to 15 cm depth initially and then moved down to the 15 to 23 cm depth in late June. Deeper tensiometers were installed initially at the 25 to 30 cm depth and moved down to the 40 to 45 cm depth in late June. The shallow tensiometers were installed in fertility treatments 3 and 10 in all four replicates of each crop. The deeper tensiometers were installed in fertility treatment 10 in all four replicates of each crop.

The tensiometers were utilized to determine both the timing of irrigation and the amount to apply. Irrigation water was applied when the shallow tensiometers indicated a soil moisture tension of 0.5 atm for rapeseed, flax and fababeans, and 0.8 atm for peas and beans. The amount of water to apply was determined by the readings obtained by the deep tensiometers as indicated in Table 1.4.3. The timing and amounts of irrigation water applied are presented in Table 1.4.4.

Neutron access tubes were installed to a depth of 120 cm in fertility treatment 10 of all replicates in all crops of the irrigated plot. Moisture monitoring was then conducted with the neutron probe at 15 cm intervals except for the 0-15 cm depth which was done gravimetrically. Moisture measurements were made at the

Table 1.4.3. Depth of water required to replenish soil moisture in the irrigated plot of the phosphorus placement experiment

Deep Tensiometer Reading (atm)	Amount of Water to Apply (mm)
0.3	64
0.3 - 0.7	89
greater than 0.7	114

Table 1.4.4. Amounts and timing of irrigation applications for the phosphorus placement experiment

Crop	Growing Season Rainfall (mm)	Dates and Amounts of Irrigation Applications	Total Water (Irrigation + Rain) (mm)
Fababeans	197	June 15, 52 mm; June 24, 70 mm; July 5, 102 mm; July 15, 66 mm; July 24, 70 mm; Aug. 10, 75 mm; Aug. 22, 45 mm	677
Peas	189	June 26, 104 mm; July 7, 81 mm; July 21, 9 mm; July 22, 77 mm	461
Beans	153	June 26, 107 mm; July 7, 67 mm; July 21, 15 mm; Aug. 10, 26 mm	433
Rapeseed	146	June 15, 64 mm; June 24, 77 mm; July 2, 98 mm; July 11, 20 mm; July 12, 76 mm; July 18, 68 mm; July 24, 73 mm; Aug. 5, 12 mm; Aug. 6, 46 mm	681
Flax	153	June 15, 55 mm; June 24, 66mm; July 4, 98 mm; July 15, 78 mm; July 22, 75 mm; Aug. 10, 36 mm	562

time of installation at seeding time, at two intervals until harvest and again at harvest time. At harvest time the moisture was also monitored with the neutron probe in fertility treatment 10 of all replicates in all crops of the dryland plot.

At harvest, yield samples were taken, for all crops except irrigated peas, dry peas and dry beans, from all treatments by hand cutting at the soil surface the four centre rows of the eight row plot over a length of 2.3 metres. For the dry peas and dry beans the entire 8 row plot was taken by hand cutting at the soil surface. The samples were then dried, weighed and threshed. The irrigated peas were harvested using a small plot Hege combine and the straw material was collected, dried and weighed. All grain samples were cleaned and weighed. Subsamples of both grain (replicates kept separate) and straw (replicates bulked) were ground in preparation for nitrogen and phosphorus analyses. Nitrogen was determined on the grain by the dye-binding method. Straw nitrogen and phosphorus contents were determined by wet digestion and colorimetric analysis using a Technicon Auto Analyser II System.

After harvest soil samples were taken from treatment 4 of each crop to a depth of 60 cm by bulking three cores from each of replicates 1 and 2 and three cores from each of replicates 3 and 4. The soil cores were taken midway between the crop rows to avoid the phosphorus that was placed with the seed at seeding time.

RESULTS AND DISCUSSION

Seeding of the entire plot was interrupted by a rain storm. This resulted in the beans, rapeseed and flax being seeded 5 days later than the fababeans, peas and lentils. Thus, direct comparisons between crops will be entirely valid.

The information obtained on the stand counts is presented in Figure 1.4.1. The irrigated and dryland plots were averaged as the two moisture treatments had been handled identically up to the time that stand counts were taken.

For fababeans there was no effect of phosphorus by either placement methods.

For peas, beans and lentils the sideband phosphate treatment resulted in little change in the crop stand. However, in all cases seed-placed phosphate reduced the stand, particularly at the higher rates.

For flax and rapessed sidebanded phosphorus increased the stand at the higher rates, whereas seed-placed phosphorus reduced the stand drastically.

Similar results for stand counts for all the crops were found in 1976.

The results for the effect of phosphate fertilizer rate and placement on the yield, protein content, nitrogen uptake and phosphorus content of the crops are presented in Tables 1.4.5 to 1.4.14. Grain and straw yields are also presented graphically in Figures 1.4.2 and 1.4.3 respectively.

Under dryland conditions grain yields (Figure 1.4.2) showed no response to the phosphorus fertilizer rates or placement for all of the crops. Similar results were found in 1976 where only peas and rapeseed showed a small response to the sideband treatment.

Under irrigation conditions grain yields showed a small

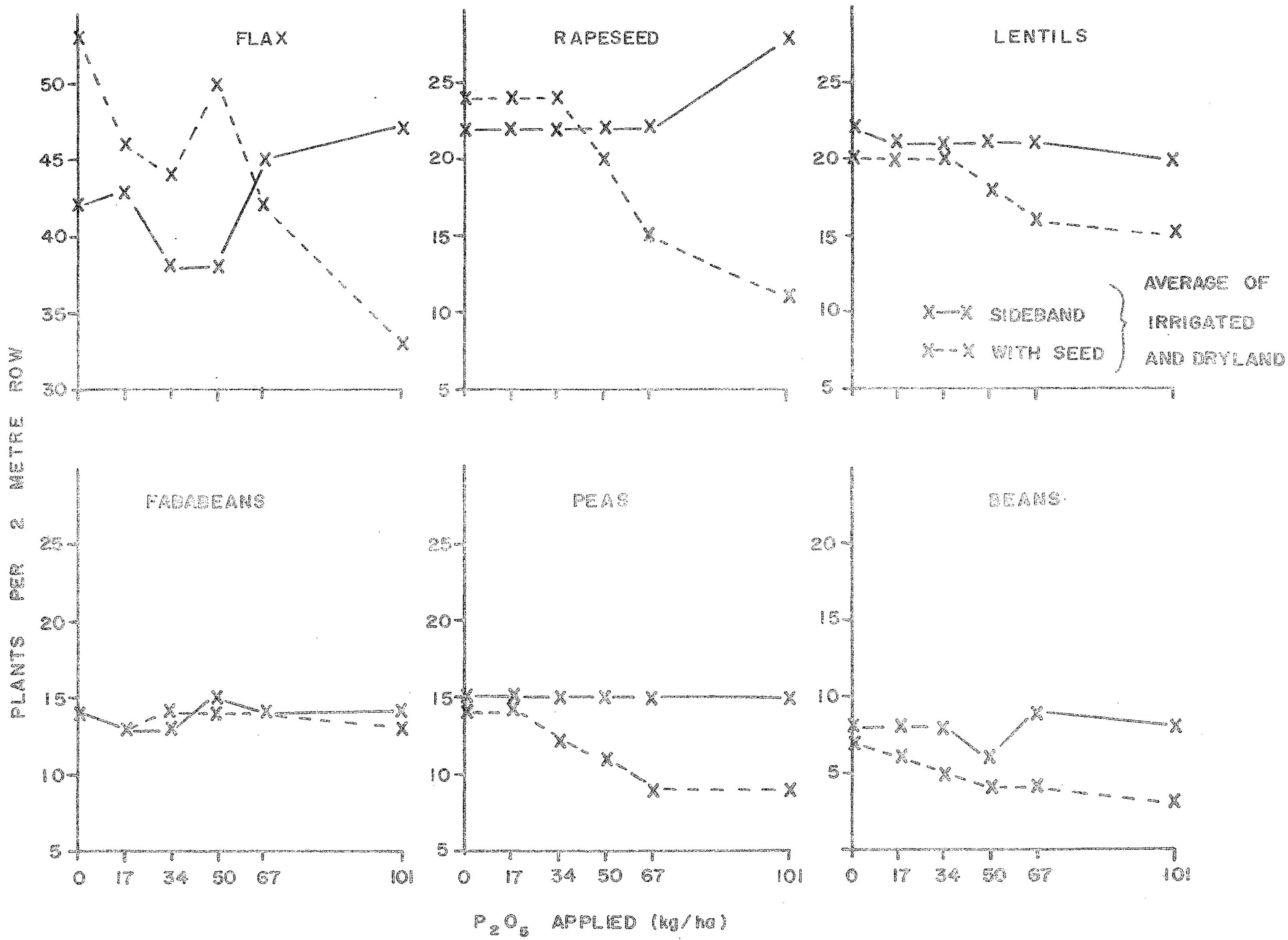

Figure 1.4.1. The effect of phosphate rate and placement on the stand of crops

Table 1.4.5. The effect of P fertilizer rate and placement on yield and nutrient uptake for irrigated fababeans

P_2O_5 Applied (kg/ha)	Fertilizer Placement	Yield Grain (kg/ha)	Yield Straw (kg/ha)	Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake Grain (kg/ha)	Nitrogen Uptake Straw (kg/ha)	Nitrogen Uptake Total (kg/ha)	Grain[2] % P
0	Seed-placed	3192	3918	0.81	28.9	0.95	147.6	37.2	184.8	0.49
17		3453	4312	0.79	28.5	1.05	157.5	45.3	202.8	0.51
34		2928	3769	0.78	27.7	0.80	129.8	30.2	160.0	0.47
50		3366	4041	0.82	28.6	1.08	154.0	43.6	197.6	0.50
67		3160	3922	0.79	28.7	0.82	145.1	32.2	177.3	0.53
101		3985	4779	0.83	28.2	0.94	179.8	44.9	224.7	0.54
0	Side-banded	2552	3375	0.77	27.0	0.87	110.2	29.4	139.6	0.57
17		2419	2931	0.82	26.9	0.70	104.1	20.5	124.6	0.55
34		3179	3684	0.87	29.4	0.64	149.5	23.6	173.1	0.52
50		2784	3654	0.77	28.4	1.34	126.5	49.0	175.5	0.54
67		2923	3737	0.78	28.1	0.88	131.4	32.9	164.3	0.54
101		3187	4005	0.79	28.5	1.43	145.3	57.3	202.6	0.51
L.S.D. (P = 0.05)		1081	1143	0.12	1.7					

[1] Grain % Protein based on % N at air-dry moisture x 6.25; straw % N on oven-dry basis.

[2] Grain % P on "as is" basis.

Table 1.4.6. The effect of P fertilizer rate and placement on yield and nutrient uptake for dryland fababeans

P_2O_5 Applied (kg/ha)	Fertilizer Placement	Yield Grain (kg/ha)	Yield Straw (kg/ha)	Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake Grain (kg/ha)	Nitrogen Uptake Straw (kg/ha)	Nitrogen Uptake Total (kg/ha)	Grain[2] % P
0	Seed-placed	622	743	0.83	21.8	0.57	21.7	4.2	25.9	0.50
17		603	684	0.88	21.2	0.56	20.5	3.8	24.3	0.59
34		825	884	0.92	21.6	0.52	28.5	4.6	33.1	0.52
50		558	733	0.77	20.5	0.53	18.3	3.9	22.2	0.65
67		410	578	0.71	20.8	0.56	13.6	3.2	16.8	0.66
101		564	817	0.69	21.3	0.53	19.2	4.3	23.5	0.66
0	Side-banded	548	662	0.82	20.2	0.52	17.7	3.4	21.1	0.55
17		633	768	0.82	21.8	0.59	22.1	4.5	26.6	0.60
34		678	823	0.82	21.2	0.56	23.0	4.6	27.6	0.59
50		551	702	0.79	21.1	0.50	18.6	3.5	22.1	0.59
67		469	637	0.72	21.7	0.59	16.3	3.8	20.1	0.69
101		628	824	0.76	20.9	0.49	21.0	4.0	25.0	0.65
L.S.D. (P = 0.05)		184	159	0.12	2.2					

[1] Grain % Protein based on % N at air-dry moisture x 6.25; straw % N on oven-dry basis.

[2] Grain % P on "as is" basis.

Table 1.4.7. The effect of P fertilizer rate and placement on yield and nutrient uptake for irrigated peas

P_2O_5 Applied (kg/ha)	Fertilizer Placement	Yield Grain (kg/ha)	Yield Straw (kg/ha)	Grain/Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake Grain (kg/ha)	Nitrogen Uptake Straw (kg/ha)	Nitrogen Uptake Total (kg/ha)	Grain[2] % P
0	Seed-placed	1771	1378	1.29	20.0	1.00	56.7	13.8	70.5	0.45
17		1877	1510	1.25	19.5	0.88	58.6	13.3	71.9	0.44
34		1638	1347	1.22	20.3	1.04	53.2	14.0	67.2	0.47
50		1818	1465	1.24	19.9	0.87	57.9	12.7	70.6	0.47
67		1818	1674	1.09	20.2	0.89	58.8	14.9	73.7	0.46
101		2051	1735	1.17	19.1	1.00	62.7	17.4	80.1	0.47
0	Side-banded	1768	1568	1.12	19.6	0.81	55.4	12.7	68.1	0.44
17		2119	1628	1.29	19.5	0.76	66.1	12.4	78.5	0.45
34		1473	1448	1.01	19.4	1.01	45.7	14.6	60.3	0.47
50		2189	2043	1.07	18.8	0.97	65.8	19.8	85.6	0.47
67		2011	1770	1.16	19.3	0.81	62.1	14.3	76.4	0.48
101		2444	1941	1.28	18.8	0.83	73.5	16.1	89.6	0.48
L.S.D. (P = 0.05)		631	435	0.22	1.3					

[1] Grain % Protein based on % N at air-dry moisture x 6.25; straw % N on oven-dry basis.

[2] Grain % P on "as is" basis.

Table 1.4.8. The effect of P fertilizer rate and placement on yield and nutrient uptake for dryland peas

P_2O_5 Applied (kg/ha)	Fertilizer Placement	Yield Grain (kg/ha)	Yield Straw (kg/ha)	Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake Grain (kg/ha)	Nitrogen Uptake Straw (kg/ha)	Nitrogen Uptake Total (kg/ha)	Grain[2] % P
0	Seed-placed	825	1066	0.79	20.1	0.88	26.5	9.4	35.9	0.35
17		980	1232	0.80	19.8	0.84	31.0	10.3	41.3	0.38
34		940	1128	0.85	19.8	0.74	29.8	8.3	38.1	0.39
50		838	1398	0.63	20.2	0.60	27.1	8.4	35.5	0.38
67		1054	1212	1.15	19.3	0.67	32.5	8.1	40.6	0.39
101		868	1580	0.57	20.0	0.76	27.8	12.0	39.8	0.42
0	Side-banded	807	969	0.84	19.2	0.66	24.8	6.4	31.2	0.36
17		1003	1274	0.80	19.7	0.94	31.6	12.0	43.6	0.36
34		789	1035	0.76	19.5	0.73	24.6	7.6	32.2	0.39
50		1024	1385	0.76	19.5	0.76	31.9	10.5	42.4	0.36
67		947	1350	0.72	18.6	0.78	28.2	10.5	38.7	0.39
101		1020	1398	0.73	21.0	0.84	34.3	11.7	46.0	0.41
L.S.D. (P = 0.05)		209	323	0.41	0.8					

[1] Grain % Protein based on % N at air-dry moisture x 6.25; straw % N on oven-dry basis.

[2] Grain % P on "as is" basis.

Table 1.4.9. The effect of P fertilizer rate and placement on yield and nutrient uptake for irrigated beans

P_2O_5 Applied (kg/ha)	Fertilizer Placement	Yield Grain (kg/ha)	Yield Straw (kg/ha)	Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake Grain (kg/ha)	Nitrogen Uptake Straw (kg/ha)	Nitrogen Uptake Total (kg/ha)	Grain[2] % P
0	Seed-placed	1127	646	1.72	17.7	0.80	31.9	5.2	37.1	0.46
17		1320	728	1.81	19.6	0.82	41.4	6.0	47.4	0.49
34		1456	923	1.58	18.8	0.93	43.8	8.6	52.4	0.51
50		1235	685	1.79	18.9	0.85	37.3	5.8	43.1	0.52
67		1363	810	1.74	18.9	0.80	41.2	6.5	47.7	0.54
101		1066	683	1.60	19.2	0.83	32.7	5.7	38.4	0.53
0	Side-banded	1293	643	2.06	17.4	0.88	36.0	5.7	41.7	0.55
17		1389	768	1.83	17.0	0.82	37.8	6.3	44.1	0.54
34		1426	833	1.71	17.1	0.86	39.0	7.2	46.2	0.53
50		1027	587	1.80	16.7	0.86	27.4	5.0	32.4	0.56
67		1821	1152	1.59	18.1	0.98	52.7	11.3	64.0	0.54
101		1795	1073	1.68	17.6	0.95	50.5	10.2	60.7	0.54
L.S.D. (P = 0.05)		588	343	0.33	1.6					

[1] Grain % Protein based on % N at air-dry moisture x 6.25; straw % N on oven-dry basis.

[2] Grain % P on "as is" basis.

Table 1.4.10. The effect of P fertilizer rate and placement on yield and nutrient uptake for dryland beans

P_2O_5 Applied (kg/ha)	Fertilizer Placement	Yield Grain (kg/ha)	Yield Straw (kg/ha)	Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake Grain (kg/ha)	Nitrogen Uptake Straw (kg/ha)	Nitrogen Uptake Total (kg/ha)	Grain[2] % P
0	Seed-placed	480	460	1.14	23.3	0.69	17.9	3.2	21.1	0.46
17		512	474	1.13	22.8	0.80	18.7	3.8	22.5	0.48
34		449	434	1.11	23.9	0.60	17.2	2.6	19.8	0.45
50		456	450	1.07	23.1	0.62	16.9	2.8	19.7	0.48
67		498	404	1.24	23.5	0.79	18.7	3.2	21.9	0.51
101		397	429	1.21	22.3	0.78	14.2	3.3	17.5	0.51
0	Side-banded	478	311	1.78	23.4	0.69	17.9	2.1	20.0	0.50
17		542	452	1.22	23.5	0.66	20.4	3.0	23.4	0.47
34		486	396	1.24	23.5	0.71	18.3	2.8	21.1	0.50
50		524	377	1.41	23.7	0.73	19.9	2.8	22.7	0.51
67		549	451	1.22	23.7	0.68	20.8	3.1	23.9	0.51
101		504	408	1.24	24.7	0.70	19.9	2.9	22.8	0.54
L.S.D. (P = 0.05)		127	159	0.53	1.6					

[1] Grain % Protein based on % N at air-dry moisture x 6.25; straw % N on oven-dry basis.

[2] Grain % P on "as is" basis.

Table 1.4.11. The effect of P fertilizer rate and placement on yield and nutrient uptake for irrigated rapeseed

P_2O_5 Applied (kg/ha)	Fertilizer Placement	Yield Grain (kg/ha)	Yield Straw (kg/ha)	Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake Grain (kg/ha)	Nitrogen Uptake Straw (kg/ha)	Nitrogen Uptake Total (kg/ha)	Grain[2] % P
0	Seed-placed	2572	6525	0.39	21.2	0.63	87.2	41.1	128.3	0.58
17		3261	7331	0.44	20.9	0.79	109.0	57.9	166.9	0.56
34		3229	7197	0.45	20.8	0.63	107.5	45.3	152.8	0.62
50		2571	6677	0.39	20.6	0.57	84.7	38.1	122.8	0.61
67		2679	6245	0.43	19.1	0.51	81.9	31.8	113.7	0.62
101		2784	7742	0.36	19.9	0.94	88.6	72.8	161.4	0.67
0	Side-banded	2151	5098	0.43	21.2	0.46	73.0	23.5	96.5	0.56
17		2770	7040	0.40	20.2	0.53	89.5	37.3	126.8	0.56
34		2942	6683	0.44	19.0	0.66	89.4	44.1	133.5	0.61
50		2823	6901	0.41	21.3	0.86	96.2	59.3	155.5	0.62
67		2746	6795	0.42	19.6	0.85	86.1	57.8	143.9	0.64
101		3065	7664	0.42	18.8	0.92	92.2	70.5	162.7	0.67
L.S.D. (P = 0.05)		888	1879	0.09	1.8					

1 Grain % Protein based on % N at air-dry moisture x 6.25; straw % N on oven-dry basis.

2 Grain % P on "as is" basis.

Table 1.4.12. The effect of P fertilizer rate and placement on yield and nutrient uptake for dryland rapeseed

P_2O_5 Applied (kg/ha)	Fertilizer Placement	Yield (kg/ha)		Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake (kg/ha)			Grain[2] % P
		Grain	Straw				Grain	Straw	Total	
0	Seed-placed	216	1625	0.12	29.8	1.40	10.3	22.8	33.1	0.77
17		166	1565	0.11	30.1	1.40	8.0	21.9	29.9	0.79
34		159	1496	0.10	28.9	1.62	7.4	24.2	31.6	0.86
50		243	1753	0.13	28.8	1.68	11.2	29.5	40.7	0.84
67		122	1450	0.08	28.5	1.19	5.6	17.3	22.9	0.79
101		232	1698	0.13	27.3	1.24	10.1	21.1	31.2	0.85
0	Side-banded	184	1529	0.11	29.7	1.21	8.7	18.5	27.2	0.79
17		108	1227	0.09	30.3	1.44	5.2	17.7	22.9	0.83
34		85	1449	0.06	26.4	1.39	3.6	20.1	23.7	0.82
50		129	1432	0.08	29.1	1.39	6.0	19.9	25.9	0.79
67		149	1462	0.11	28.0	1.65	6.7	24.1	30.8	0.83
101		299	1863	0.14	28.4	1.11	13.6	20.7	34.3	0.81
L.S.D. (P = 0.05)		186	410	0.08	1.7					

[1] Grain % Protein based on % N at air-dry moisture x 6.25; straw % N on oven-dry basis.

[2] Grain % P on "as is" basis.

Table 1.4.13. The effect of P fertilizer rate and placement on yield and nutrient uptake for irrigated flax

P_2O_5 Applied (kg/ha)	Fertilizer Placement	Yield (kg/ha)		Grain/Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake (kg/ha)			Grain[2] % P
		Grain	Straw				Grain	Straw	Total	
0	Seed-placed	1745	2604	0.67	18.5	0.28	51.7	7.3	59.0	0.43
17		1884	2749	0.69	18.2	0.24	54.9	11.0	65.9	0.48
34		1968	3010	0.66	18.7	0.24	58.9	7.2	66.1	0.49
50		1463	2837	0.55	17.3	0.27	40.5	7.7	48.2	0.57
67		2079	3398	0.64	18.5	0.25	61.5	8.5	70.0	0.50
101		1754	2778	0.64	17.1	0.22	48.0	6.1	54.1	0.62
0	Side-banded	1298	2686	0.50	19.5	0.29	40.5	7.8	48.3	0.46
17		1579	2408	0.67	17.9	0.25	45.2	6.0	51.2	0.52
34		1751	2697	0.65	17.6	0.22	49.3	5.9	55.2	0.51
50		1483	2346	0.65	16.7	0.23	39.6	5.4	44.0	0.60
67		1696	2557	0.66	17.3	0.25	46.9	6.4	53.3	0.55
101		1640	2455	0.67	16.8	0.25	44.1	6.1	50.2	0.61
L.S.D. (P = 0.05)		283	713	0.13	1.6					

[1] Grain % Protein based on % N at air-dry moisture x 6.25; straw % N on oven-dry basis.

[2] Grain % P on "as is" basis.

Table 1.4.14. The effect of P fertilizer rate and placement on yield and nutrient uptake for dryland flax

P_2O_5 Applied (kg/ha)	Fertilizer Placement	Yield Grain (kg/ha)	Yield Straw (kg/ha)	Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake Grain (kg/ha)	Nitrogen Uptake Straw (kg/ha)	Nitrogen Uptake Total (kg/ha)	Grain[2] % P
0	Seed-placed	548	1286	0.43	24.7	0.41	21.7	5.3	27.0	0.44
17		642	1212	0.53	24.5	0.39	25.2	4.7	29.9	0.40
34		640	1287	0.50	24.1	0.40	24.7	5.1	29.8	0.44
50		720	1523	0.47	24.3	0.38	28.0	5.8	33.8	0.46
67		591	1250	0.48	24.5	0.44	23.2	5.5	28.7	0.48
101		649	1329	0.49	24.7	0.42	25.6	5.6	31.2	0.50
0	Side-banded	566	1220	0.47	24.9	0.45	22.5	5.5	28.0	0.44
17		674	1288	0.52	23.7	0.38	25.6	4.9	30.5	0.42
34		630	1159	0.56	24.2	0.38	24.4	4.4	28.8	0.45
50		701	1249	0.56	24.4	0.37	27.4	4.6	32.0	0.43
67		660	1318	0.51	24.8	0.38	26.2	5.0	31.2	0.48
101		656	1375	0.48	24.3	0.41	25.5	5.6	31.1	0.53
L.S.D. (P = 0.05)		157	305	0.07	1.0					

[1] Grain % Protein based on % N at air-dry moisture x 6.25; straw % N on oven-dry basis.

[2] Grain % P on "as is" basis.

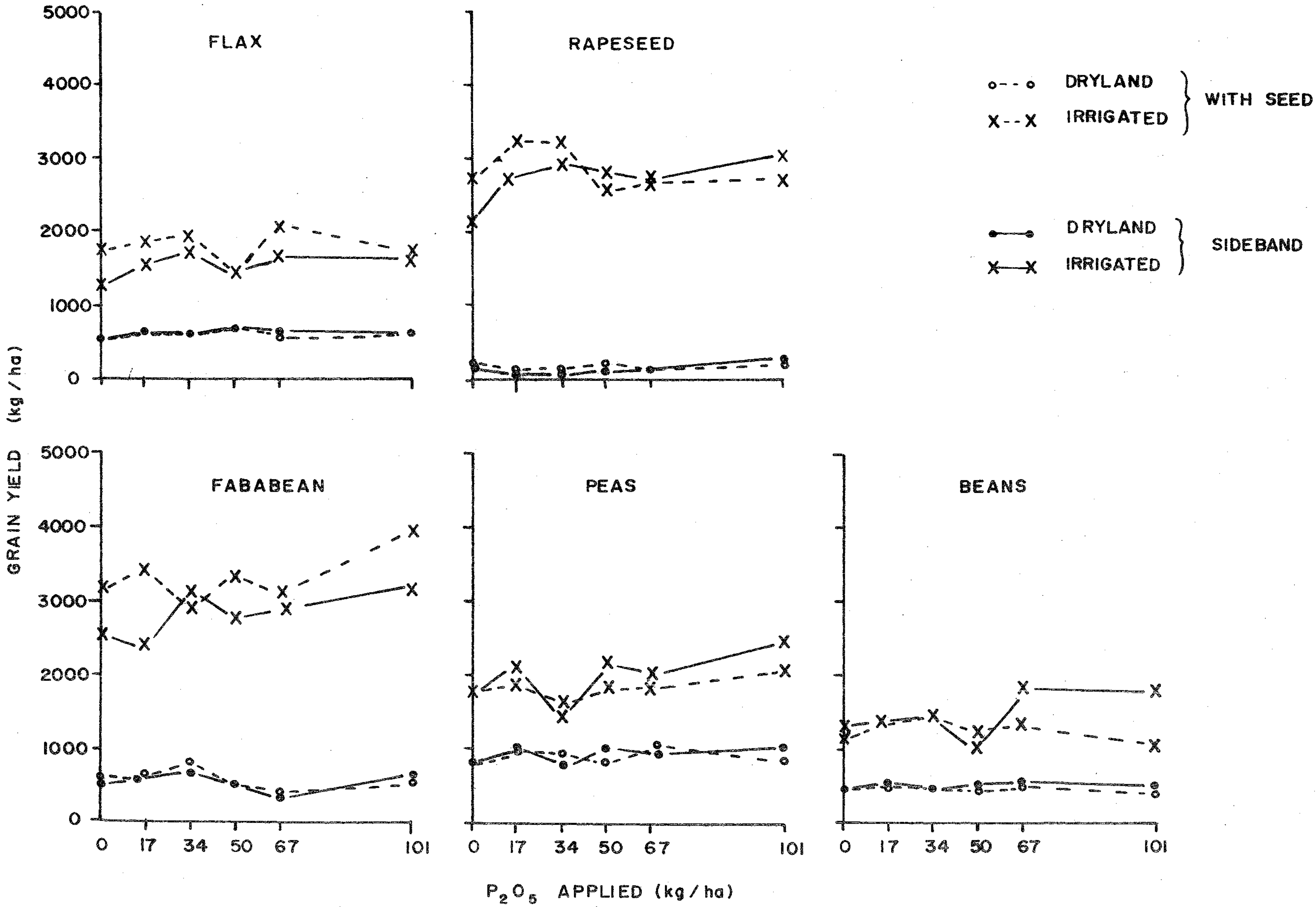

Figure 1.4.2. The effect of phosphate rate and placement on the grain yield of crops

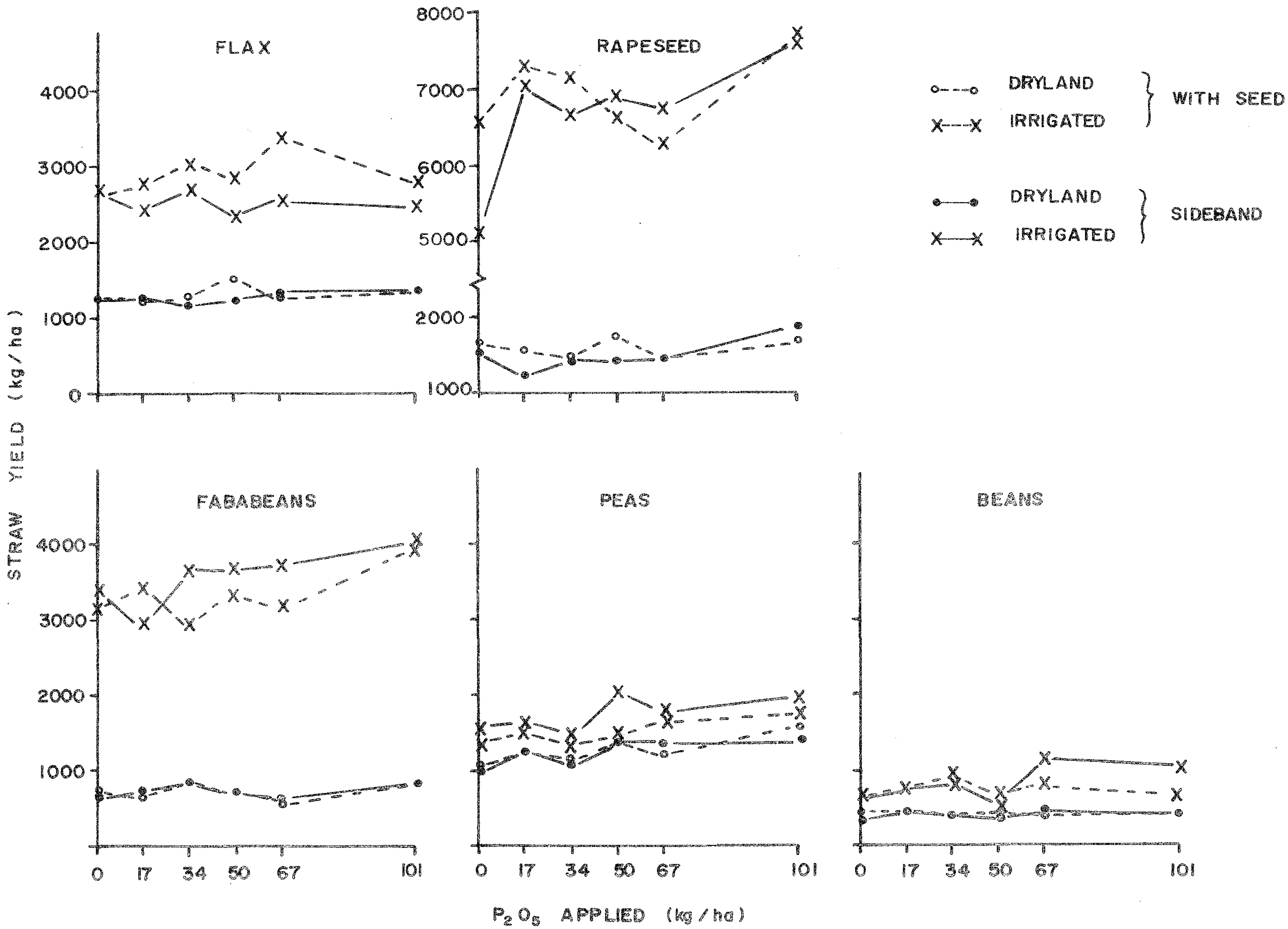

Figure 1.4.3 The effect of phosphate rate and placement on the straw yield of crops

phosphate response. For fababeans and flax the grain yields were higher for the seed-place than the sideband treatments. This was contrary to what was found in 1976 where the sideband treatments yielded greater than the seed-place treatments for these two crops. As well, the large response to phosphate by the fababeans in 1976 was not observed in 1977. For peas and beans grain yields for the sideband treatments were slightly higher than for the seed-place treatments. For rapeseed grain, yields increased at the low rates of phosphorus seed-placed and then decreased for higher phosphorus rates while a small increase in grain yield was observed at all rates of phosphorus sidebanded. For all the crops the difference between seed-placed and sidebanded phosphorus were small.

The straw yields (Figure 1.4.3) showed similar trends to that for the grain yields for all crops.

The relative responses of the crops to irrigation can also be seen in Figures 1.4.2 and 1.4.3. Both fababeans and rapeseed responded strongly to irrigation with grain yields increased by more than five and ten times that for the dryland treatments respectively. Flax, peas and beans also showed a response to irrigation but the response was less than that for fababeans and rapeseed.

Unlike the pulse crops, rapeseed and flax do not fix nitrogen but must be supplied with nitrogen from soil reserves or fertilizer applications. Previous research with rapessed has indicated that it responds strongly to irrigation and nitrogen fertilization. In 1976 both rapeseed and flax responded to the addition of 112 kg N/ha under irrigation but not under dryland. The present work also shows a response of both rapeseed and flax to fertilizer nitrogen under

Table 1.4.15. Fall soil analyses for the phosphorus placement experiment

Crop	Depth (cm)	NO_3-N	P	K
		---------- kg/ha *		----------
Irrigated Fababeans	0-15	7	7	768
	15-30	5	6	265
	30-60	9	6	415
Irrigated Peas	0-15	7	8	583
	15-30	6	4	178
	30-60	9	6	390
Irrigated Beans	0-15	9	7	413
	15-30	5	4	150
	30-60	9	6	370
Irrigated Rapeseed	0-15	5	6	388
	15-30	3	4	155
	30-60	9	5	360
Irrigated Flax	0-15	4	5	360
	15-30	4	3	165
	30-60	6	4	350
Dryland Fababeans	0-15	14	9	660
	15-30	6	6	183
	30-60	25	7	430
Dryland Peas	0-15	17	12	635
	15-30	6	6	190
	30-60	27	7	450
Dryland Beans	0-15	18	10	560
	15-30	6	6	173
	30-60	30	8	400
Dryland Rapeseed	0-15	20	12	585
	15-30	9	7	230
	30-60	30	9	455
Dryland Flax	0-15	25	10	630
	15-30	15	7	195
	30-60	36	9	440

* kg/ha = ppm x 2 for 15 cm depth and ppm x 4 for 30 cm depth

Table 1.4.16. Seasonal water use of irrigated and dryland crops for the phosphorus placement experiment

Crop	IRRIGATED Rainfall	Irrigation	ΔS*	Total** Water Use	DRYLAND Rainfall	ΔS*	Total** Water Use
	mm				mm		
Fababeans	197	480	-68	609	189	80	269
Peas	189	273	-9	453	189	98	287
Beans	153	280	-70	363	146	96	242
Rapeseed	146	535	-4	677	140	129	269
Flax	153	409	-2	560	146	131	277

* ΔS = change in soil moisture content (spring - fall)

** Total water use - rainfall + irrigation + ΔS irrigation. Likewise, as was found in 1976 no response to applied nitrogen was observed under dryland conditions.

Grain/straw ratios for all the crops showed no response to rates or placement of phosphorus under both dryland and irrigated conditions. Irrigated peas, beans, rapeseed and flax had grain/straw ratios higher than dryland. Fababeans showed little difference in grain/straw ratios between irrigated and dryland.

Grain protein was not affected by the rate or placement of phosphorus for any of the crops under study. Irrigation increased the protein content of fababeans by approximately 7%. Irrigation decreased the protein content of beans 5%, rapeseed 9% and flax 6%. There was no effect of irrigation on the protein content of peas. Similar protein levels were found for these same crops in 1976.

Straw nitrogen content was not affected by the rate or placement of phosphorus. Under irrigation straw nitrogen was increased for fababeans, peas and beans and decreased for rapeseed and flax. Similar results were observed in 1976 and it was suggested that this was possibly due to a favorable influence of irrigation on Rhizobium sp. for the pulse crops.

The results for the analyses of the Fall soil samples are presented in Table 1.4.15. Nitrate nitrogen levels decreased under irrigation from spring to fall. There was little change in NO_3-N from spring to fall for the dryland plot. Phosphorus and potassium levels were similar to the spring soil analyses.

Seasonal water use data is presented in Table 1.4.16.

1.5 Phosphorus requirements of annual crops under irrigation

INTRODUCTION

High rates of phosphate fertilizer applied to some fields in the South Saskatchewan River Irrigation Project has led to large accumulations of residual phosphorus. The extent to which this residual phosphorus meets the requirements of a growing crop and thus the need for additional phosphorus fertilizer applications is not clear at this time. Therefore, in 1976 a research project was initiated to investigate the response of annual crops under irrigation to phosphorus fertilization on land with residual phosphate from previous high rates of application.

The results from the initial year of this project were limited to one soil type (Asquith loamy sand) and one crop (Neepawa wheat) and indicated no response to added fertilizer phosphorus. In order to provide adequate information for making phosphorus fertilizer recommendations to irrigation farmers who have large accumulations of residual phosphorus in their soil, data on a wide range of soil types and crops is required. Thus, it was considered necessary to continue this work to include a wider range in soil textures and annual crops.

PURPOSE

To investigate the response of annual crops under irrigation to phosphorus fertilization on land with residual phosphate from previous high rates of application.

EXPERIMENTAL METHODS

Seven sites were selected in 1977 for the second year of this project (Table 1.5.1), five of the sites were located on Asquith sandy loam soil (Barrich Farms Ltd.) and two of the sites on a heavier textured Bradwell loam soil (B. Niska farm). Three of the sites located on the Asquith soil were seeded to potatoes in 1976 while the other two sites on the Asquith soil and the two sites on the Bradwell soil were seeded to wheat in 1976. All of the sites have had a history of large fertilizer applications. The crops seeded in 1977 were Neepawa wheat, Bananza barley, Fielder soft wheat and Dufferin flax. Thus, both a range in soil types and annual crops were included.

Soil analyses of samples taken at seeding time indicated a range in $NaHCO_3$-extractable phosphorus (0-15 cm) for the seven sites (Table 1.5.2). Three sites were in each of the high (Barrich 10, Hettrick 1, and Niska West) and medium (Barrich 15, Barrich 16 and Niska East) ranges while one site was in the low range (Barrich 14). The soil analyses also indicated a considerable quantity of phosphorus at depth for all of the sites. Nitrogen levels ranged from medium to high for the five Asquith sites and very high for the two Bradwell sites.

Small plots of randomized complete block design with four replicates and seven treatments were established at each site. The treatments included a range of phosphorus rates from 0 to 101 kg P_2O_5/ha (Table 1.5.3). Monoammonium phosphate was used as the phosphate source. The plots were rototilled then seeded using a double-disc press drill with seven rows per treatment and an 18 cm row spacing over a length of 4.6 metres. The phosphorus fertilizer was seed-placed for the cereal grains and sidebanded for the oilseeds

Table 1.5.1. Characteristics of sites selected for 1977 phosphorus correlation irrigation experiment

Crop	Co-operating Farmer	Field Designation	Previous Crop	Soil Association	Texture	Type of Irrigation
Neepawa Wheat	Barrich Farms Ltd.	Barrich 10	Potatoes	Asquith	Sandy loam	Sprinkler
Bonanza Barley	Barrich Farms Ltd.	Barrich 14	Wheat	Asquith	Sandy loam	Sprinkler
Neepawa Wheat	Barrich Farms Ltd.	Barrich 15	Wheat	Asquith	Sandy loam	Sprinkler
Neepawa Wheat	Barrich Farms Ltd.	Barrich 16	Potatoes	Asquith	Sandy loam	Sprinkler
Dufferin Flax	Barrich Farms Ltd.	Hettrick 1	Potatoes	Asquith	Sandy loam	Sprinkler
Dufferin Flax	Niska	East	Wheat	Bradwell	Loam	Sprinkler
Fielder Soft Wheat	Niska	West	Wheat	Bradwell	Loam	Sprinkler

Table 1.5.2. Spring soil analyses for the phosphorus correlation experiments

Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4-S
			------------	------ kg/ha*	------	------------
		Asquith sandy loam (Barrich 10)				
0-15	7.1	0.4	36	52	440	23
15-30	7.1	0.2	16	24	255	12
30-60	7.8	0.3	27	12	340	27
60-90	8.0	0.5	48	6	408	43
90-120	8.0	1.6	37	3	505	43
		Asquith sandy loam (Barrich 14)				
0-15	8.0	0.4	14	16	310	24+
15-30	8.0	0.4	14	31	385	24+
30-60	8.3	0.3	12	17	423	48+
60-90	8.5	0.6	16	7	475	48+
90-120	8.4	0.4	19	4	563	48+
		Asquith sandy loam (Barrich 15)				
0-15	7.4	0.3	15	25	514	20
15-30	7.3	0.3	14	27	471	19
30-60	7.6	0.2	18	19	500	20
60-90	8.1	0.3	24	8	445	36
90-120	8.0	0.4	42	4	540	43
		Asquith sandy loam (Barrich 16)				
0-15	6.9	0.3	34	34	285	15
15-30	7.0	0.2	19	15	234	10
30-60	7.4	0.2	29	11	323	11
60-90	8.0	0.2	33	8	293	9
90-120	8.2	0.3	37	4	405	27
		Asquith sandy loam (Hettrick 1)				
0-15	7.9	0.3	13	40	209	10
15-30	7.7	0.4	19	33	126	18
30-60	8.1	0.3	26	21	148	48+
60-90	8.5	0.4	19	19	205	32
90-120	8.7	0.3	10	15	220	26

..........continued

Table 1.5.2. continued

Depth (cm)	pH	Conductivity mmhos	NO_3-N	P	K	SO_4-S
			kg/ha*			
		Bradwell (Niska East) (flax)				
0-15	7.3	0.6	79	27	424	15
15-30	7.6	0.5	37	19	374	21
30-60	7.8	0.4	30	19	375	42
		Bradwell (Niska West) (soft wheat)				
0-15	7.4	0.6	90	41	356	--
15-30	7.8	0.4	30	20	213	--
30-60	8.1	0.7	28	17	278	--

* kg/ha = ppm x 2 for 15 cm depth and ppm x 4 for 30 cm depth

Table 1.5.3. Fertility treatments used in phosphorus correlation experiments

Treatment Number	P_2O_5 Applied (kg/ha)
1	0
2	17
3	34
4	50
5	67
6	84
7	101

through a set of cones while the seed was applied through the seed box. The plots were situated within the co-operating farmers field and completely surrounded by his crop.

The barley (Barrich 14) received an additional broadcast application of 112 kg N/ha as ammonium nitrate (34-0-0) after the crop had emerged and nitrogen deficiency symptoms were evident.

Post-emergent herbicides used include hoegrass for the control of wild oats and green foxtail and Buctril M for the control of broadleaf weeds in wheat and Hettrick 1 flax; 2,4-D amine and TCA tank mix for the control of broadleaf weeds and green foxtail in barley; Asulox F and Buctril M for the control of wild oats and broadleaf weeds in Niska flax; and 2,4-D and Endaven - Carbyne tank mix for the control of broadleaf weeds and wild oats in Niska soft wheat. The weed control obtained was good to excellent on all plots.

All irrigation applications were as conducted by the co-operating farmer. The timing and amounts of irrigation water applied along with the total growing season rainfall are presented in Table 1.5.4.

At harvest, yield samples were taken from all treatments by clipping at the soil surface the three centre rows over a length of 3 metres. The samples were then dried, weighed and threshed. The grain samples were cleaned and weighed. Subsamples of both grain (replicates kept separate) and straw (replicates bulked) were mixed and ground. Analyses were performed for nitrogen content of the straw and barley and flax grain by wet digestion and colorimetric analysis using an Auto Analyser II System. Protein content of the wheat was determined with a Technicon Infra Analyzer.

Table 1.5.4. Amounts and timing of irrigation applications for the phosphorus correlation experiments

Site	Growing Season Rainfall (mm)	Dates and Amounts of Irrigation Applications	Total Water (Irrigation + Rain) (mm)
Barrich 10	164	June 21, 25 mm; June 29, 27 mm; July 3, 29 mm; July 12, 37 mm; July 18, 30 mm; July 24, 25 mm; Aug. 2, 26 mm; Aug. 8, 24 mm	387
Barrich 14	167	June 13, 23 mm; July 6, 41 mm; July 27, 32 mm	263
Barrich 15	167	June 13, 26 mm; June 27, 12 mm; July 3, 12 mm; July 9, 19 mm; July 12, 15 mm; July 17, 12 mm; July 24, 12 mm; July 26, 10 mm	285
Barrich 16	170	June 13, 25 mm; June 27, 28 mm; July 3, 11 mm; July 9, 18 mm; July 12, 13 mm; July 17, 13 mm; July 24, 11 mm; July 26, 11 mm	300
Hettrick 1	169	June 7, 10 mm; June 29, 12 mm; July 10, 18 mm; July 12, 23 mm; July 14, 8 mm; July 24, 15 mm; July 27, 17 mm; July 29, 22 mm; July 31, 29 mm; Aug. 8, 50 mm; Aug. 10, 10 mm; Aug. 20, 13 mm	396
Niska (Flax)	125	June 14, 33 mm; June 27, 40 mm; July 3, 35 mm; July 6, 21 mm; July 10, 28 mm; July 12, 34 mm; July 15, 23 mm; July 18, 23 mm; Aug. 1, 44 mm; Aug. 3, 18 mm	424
Niska (Soft Wheat)	120	June 14, 20 mm; June 18, 17 mm; June 26, 27 mm; June 28, 24 mm; July 3, 21 mm; July 5, 19 mm; July 8, 22 mm; July 11, 32 mm; July 14, 27 mm; July 20, 24 mm; Aug. 1, 20 mm; Aug. 3, 23 mm	396

RESULTS AND DISCUSSION

Response of hard wheat to phosphorus fertilization

The results for the effect of phosphorus fertilization on the yield, nitrogen content and nitrogen uptake of irrigated Neepawa wheat are presented in Table 1.5.5. Hard wheat was grown at three sites: Barrich 10, 15 and 16. Barrich 10 had a high initial phosphorus content while Barrich 15 and 16 had medium initial phosphorus contents. Grain yields showed no response to phosphorus fertilization for Barrich 10 or 15. For Barrich 16 the two highest phosphorus fertilizer application rates showed an increased yield over that of the control. However, no other yield increases were observed for this site.

Differences in grain yields were observed among the three sites. Barrich 10 had an excellent yield and was higher than the yield obtained in the 1976 phosphorus correlation plots. However, Barrich 15 and 16 had very low yields for irrigated hard wheat. These two sites were seeded 7 to 10 days earlier than the co-operating farmer seeded the entire field. As a result these two plots were always further advanced in their stage of growth and did not receive irrigation when required since irrigation scheduling was conducted by the co-operating farmer to coincide with the requirements of his crop. Thus these two plots received a moisture stress early in the growing season which reduced the crop yields. The plot on Barrich 10 was seeded closer to the date that the co-operating farmer seeded his field and as a result its moisture requirements coincided with that of the entire field and it received adequate moisture throughout the growing season. Thus, the yield from the plot on Barrich 10

Table 1.5.5. The effect of phosphorus fertilization on the yield, nitrogen content and nitrogen uptake of irrigated Neepawa

P_2O_5 Applied (kg/ha)	Fertilizer Placement	Yield Grain (kg/ha)	Yield Straw (kg/ha)	Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake Grain (kg/ha)	Nitrogen Uptake Straw (kg/ha)	Nitrogen Uptake Total (kg/ha)
				Asquith: sandy loam (Barrich 10)					
0	Seed-placed	4809	7114	0.68	13.9	0.40	135.6	28.5	164.1
17		4489	6698	0.67	14.0	0.38	127.5	25.5	153.0
34		4215	6932	0.61	14.3	0.35	122.2	24.3	146.5
50		4366	6795	0.64	14.2	0.35	125.7	23.8	149.5
67		4641	7340	0.63	13.9	0.31	130.8	22.8	153.6
84		4405	7163	0.62	13.6	0.32	121.5	22.9	144.4
101		4678	8210	0.57	14.1	0.41	133.8	33.7	167.5
L.S.D. (P = 0.05)		541	976	0.07	1.5				
				Asquith: sandy loam (Barrich 15)					
0	Seed-placed	1526	2157	0.69	12.4	0.33	38.4	7.1	45.5
17		2174	3393	0.65	13.2	0.40	58.2	13.6	71.8
34		1455	2579	0.57	12.3	0.31	36.3	8.0	44.3
50		1799	3073	0.60	12.5	0.36	45.6	11.1	56.7
67		1993	3302	0.60	13.1	0.37	53.0	12.2	65.2
84		2755	3904	0.70	13.5	0.37	75.4	14.4	89.8
101		1997	3344	0.59	12.9	0.29	52.2	9.7	61.9
L.S.D. (P = 0.05)		831	998	0.15	1.3				

.... continued

Table 1.5.5. continued

P_2O_5 Applied (kg/ha)	Fertilizer Placement	Yield Grain (kg/ha)	Yield Straw (kg/ha)	Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake Grain (kg/ha)	Nitrogen Uptake Straw (kg/ha)	Nitrogen Uptake Total (kg/ha)
				Asquith: sandy loam (Barrich 16)					
0	Seed-placed	2398	3461	0.72	15.4	0.27	74.9	9.3	84.2
17		2417	3808	0.65	15.4	0.37	75.5	14.1	89.6
34		2798	4031	0.71	15.3	0.36	86.8	14.5	101.3
50		2415	4054	0.63	15.7	0.31	76.9	12.6	89.5
67		2835	4231	0.67	15.5	0.30	89.1	12.7	101.8
84		2966	4711	0.63	15.8	0.40	95.0	18.8	113.8
101		2961	5000	0.60	15.8	0.33	94.9	16.5	114.4
L.S.D. (P = 0.05)		550	1303	0.21	0.5				

[1] Grain protein based on % N at 13.5% moisture x 5.7; straw % N on oven-dry basis

should reflect that obtained for the entire field while the yield on Barrich 15 and 16 would not.

Protein content of wheat varied among the three sites with average values of 14.0%, 12.8% and 15.5% for Barrich 10, 15 and 16 respectively. This variation was probably due in part to the residual nitrogen present in the soils where the three sites were located. Barrich 10 and 16 were seeded to potatoes in 1976 which resulted in a larger carry over of nitrogen in the soil than Barrich 15 which had been seeded to wheat in 1976. This larger quantity of residual nitrogen resulted in higher protein for the wheat on Barrich 10 and 16 than Barrich 15. In 1976 high protein content (16 to 17%) was obtained with high wheat yields on the phosphorus correlation plots and was also attributed in part to the large quantities of residual nitrogen present in the soil.

Response of soft wheat to phosphorus fertilization

The results for the effect of phosphorus fertilization on the yield, nitrogen content and nitrogen uptake of Fielder soft wheat are presented in Table 1.5.6. Only one site was involved which was on a Bradwell loam soil and had a high phosphorus level (Niska West).

The grain yield of the soft wheat showed no response to the applied phosphorus. Yields were similar to those obtained in previous research plots. As well, phosphorus fertilization had no effect on grain/straw ratios, grain protein, or straw nitrogen content.

Interestingly enough the grain protein content was considered acceptable for the soft wheat even though the soil contained a large quantity of available nitrogen. Excess soil nitrogen can often lead to undesirable protein levels in soft wheat and sometimes to lodging

Table 1.5.6. The effect of phosphorus fertilization on the yield, nitrogen content and nitrogen uptake of irrigated Fielder soft wheat (Niska)

P_2O_5 Applied (kg/ha)	Fertilizer Placement	Yield Grain (kg/ha)	Yield Straw (kg/ha)	Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake Grain (kg/ha)	Nitrogen Uptake Straw (kg/ha)	Nitrogen Uptake Total (kg/ha)
				Elstow: loam					
0	Seed-placed	4464	7236	0.63	11.1	0.54	100.5	39.1	139.6
17		3990	6290	0.64	10.7	0.38	86.6	23.9	110.5
34		4291	7362	0.60	11.2	0.53	97.5	39.0	136.5
50		4391	6739	0.66	10.6	0.47	94.4	31.7	126.1
67		4694	6803	0.70	10.9	0.44	103.8	29.9	133.7
84		4547	6905	0.66	10.8	0.50	99.6	34.5	134.1
101		4565	7056	0.65	10.5	0.43	97.2	30.3	127.5
L.S.D. (P = 0.05)		644	1424	0.11	0.4				

[1] Grain protein content based on % N at 13.5% moisture x 5.7; straw % N on oven-dry basis

and reduced crop yield.

Response of barley to phosphorus fertilization

The results for the effect of phosphorus fertilization on the yield, nitrogen content and nitrogen uptake of Bonanza barley are presented in Table 1.5.7. Only one site was involved on an Asquith sandy loam soil (Barrich 14) that had a low phosphorus level.

Grain yield of the barley was similar to that found in previous irrigation studies. All phosphorus treatments had a higher yield than the control indicating that there was some response to the phosphorus fertilization. However, the differences in yield above that of the control were not statistically significant. Visual differences were also observed throughout the growing season. The control and lowest phosphate treatments always lagged behind the other treatments at various growth stages. This difference was particularly noticable at heading.

There was no effect of phosphorus fertilization on grain/straw ratios, protein content or straw nitrogen content of the barley.

Protein content was well within the level accepted for malting barley. The nitrogen level of the soil was initially in the low to medium range and even with the additional top-dress of 112 kg N/ha the protein level did not increase above acceptable levels.

Response of flax to phosphorus fertilization

The effect of phosphorus fertilization on the yield and nitrogen uptake of Dufferin flax are presented in Table 1.5.8. Two sites were involved one on an Asquith sandy loam soil (Hettrick 1) and one on a Bradwell loam soil (Niska East). The Asquith soil had a high level of phosphorus while the Bradwell soil had a medium phosphorus level.

Table 1.5.7. The effect of phosphorus fertilization on the yield, nitrogen content and nitrogen uptake of irrigated Bonanza barley (Barrich 14)

P_2O_5 Applied (kg/ha)	Fertilizer Placement	Yield (kg/ha)		Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake (kg/ha)		
		Grain	Straw				Grain	Straw	Total
				Asquith: sandy loam					
0	Seed-placed	4262	8631	0.51	11.85	0.59	80.8	50.9	131.7
17		5174	8649	0.60	12.53	0.60	103.7	51.9	155.6
34		5172	8671	0.59	12.20	0.57	101.0	49.4	150.4
50		5050	8147	0.62	12.43	0.72	100.4	58.7	159.1
67		5524	9038	0.63	12.45	0.79	110.0	71.4	181.4
84		4775	7617	0.63	12.83	0.81	98.0	61.7	159.7
101		5217	9036	0.59	12.48	0.76	104.2	68.7	172.9
L.S.D. (P = 0.05)		1405	1599	0.17	0.65				

[1] Grain protein content based on % N at oven-dry moisture x 6.25; straw % N on oven-dry basis

Table 1.5.8. The effect of phosphorus fertilization on the yield, nitrogen content and nitrogen uptake of irrigated Dufferin flax

P_2O_5 Applied (kg/ha)	Fertilizer Placement	Yield Grain (kg/ha)	Yield Straw (kg/ha)	Grain/ Straw Ratio	Grain % Protein	Straw % N	Nitrogen Uptake Grain (kg/ha)	Nitrogen Uptake Straw (kg/ha)	Nitrogen Uptake Total (kg/ha)	Grain % P
					Asquith: sandy loam (Hettrick 1)					
0	Sideband	1765	3185	0.56	22.1	0.36	76.6	11.5	88.1	.58
17		1790	3202	0.56	28.1	0.44	82.5	14.1	96.6	.60
34		1822	3116	0.59	22.6	0.46	80.5	14.3	94.8	.58
50		1818	3312	0.56	22.9	0.41	81.1	13.6	94.7	.58
67		1815	2896	0.63	27.6	0.46	80.0	13.3	93.3	.56
84		1867	3317	0.56	26.8	0.40	79.9	13.3	93.2	.58
101		2028	3267	0.65	28.1	0.47	91.3	15.4	106.7	.59
L.S.D. (P = 0.05)		232	589	0.12						
					Bradwell: loam (Niska)					
0	Sideband	2924	5302	0.55	22.3	0.29	104.1	15.4	119.5	.60
17		2573	4737	0.55	22.8	0.29	93.7	13.7	107.4	.63
34		2627	5025	0.54	23.2	0.29	97.5	14.6	112.1	.61
50		2741	5219	0.53	27.2	0.33	119.2	17.2	136.4	.58
67		2755	5435	0.51	25.8	0.31	113.8	16.9	130.7	.65
84		2692	5495	0.49	25.1	0.33	108.0	18.1	126.1	.65
101		2773	5823	0.48	27.2	0.33	120.6	19.2	139.8	.70
L.S.D. (P = 0.05)		586	1503	0.07						

Grain yields of the flax showed no response to the sidebanded phosphorus fertilization for either of the two sites. The yield on the Asquith site was lower than that on the Bradwell site. On the Asquith site differences in seeding dates between the plot and the surrounding field and irrigation scheduling conducted according to the needs of the crop in the surrounding field resulted in the plot receiving a moisture stress which resulted in the reduced yield. As a result the yield obtained for the plot would not reflect the yield for the entire field. The plot on the Elstow soil did not receive a moisture stress and should reflect the yield obtained by the co-operating farmer.

1.6 Phosphorus requirements of alfalfa

INTRODUCTION

Previous research on the nutrient requirements of irrigated alfalfa by the Department of Soil Science, University of Saskatchewan, in the South Saskatchewan River Irrigation Project indicated no response to applied nitrogen, potassium, sulfur or boron. However, a response to applied phosphorus occurred for soils with very low soil test phosphorus levels, particularly where the A horizon had been removed by levelling operations. A single large application of phosphorus (225 kg P_2O_5/ha or greater) was found to be preferable to small annual applications (84 to 112 kg P_2O_5/ha) for increasing yields of such low phosphorus areas.

This research has provided valuable information on the response of alfalfa to applied phosphorus for soils testing in the very low range. However, information for soils testing in higher ranges is required before soil test benchmarks can be refined. Therefore, in 1976 a three year project was initiated to continue this research on phosphorus soil test benchmark calibration for irrigated alfalfa.

PURPOSE

Continuation of phosphorus soil test benchmark calibration for irrigated alfalfa.

EXPERIMENTAL METHODS

Sites for investigation were selected in 1976 within the South Saskatchewan River Irrigation Project on three established alfalfa fields. The sites were selected to give some range in soil characteristics and phosphorus soil test levels, as indicated by the analyses of soil samples taken prior to plot establishment (Table 1.6.1). The Pederson site and the Gross site both had a low phosphorus soil test level. The soil potassium level at the Pederson site was just above the currently accepted sufficiency level. The Wudel site had a medium phosphorus soil test level. The Pederson and Gross sites were located in the southern part of the Irrigation Project while the Wudel site was located in the northern part of the Irrigation Project.

The experiments were established in April of 1976. The fertilizer treatments were arranged in a randomized complete block design with four replicates. Border-dyke irrigation was used at all locations and two of the replicates were placed on each of two border strips. All fertilizer material was hand broadcast. The applications took place in late April of 1976 and the annual treatments received an additional application in early April of 1977. Soil samples from selected treatments were taken from the three sites before the annual fertilizer applications in 1977.

The various treatments used for the Pederson site are presented in Table 1.6.2 and for the Gross and Wudel sites in Table 1.6.3. Triple superphosphate (0-45-0) was the source of phosphorus, potassium chloride (fine) (0-0-60), the source of potassium and granulated sulfur (0-0-0-90), (Agri-Sul) the source of sulfur.

Each plot was 1.5 metres by 6 metres. Samples were cut at a height of approximately 7.5 cm with a 60 cm Mott forage harvester over a 5 metre length of the plot. A wet weight of the samples was taken in the field immediately after cutting. A 500 gram sub-sample of each treatment was taken to the laboratory

Table 1.6.1. Site characteristics of soils selected for irrigated alfalfa study

Legal Location	Site 1 NE20-28-7-W3	Site 2 NE30-28-7-W3	Site 3 SW31-30-7-W3
Co-operator	Pederson	Gross	Wudel
Year Seeded	1971	1975	1973
Irrigation Type	-----------	Border Dyke	-----------
Soil Association	Elstow	Bradwell	Bradwell
Texture	Loam	Loam	Very fine sandy loam
Soil Analyses*:			
NO_3-N (0-60 cm)-kg/ha	27	24	59
P (0-15 cm)-kg/ha	6	9	19
K (0-15 cm)-kg/ha	220	511	401
SO_4-S (0-60 cm)-kg/ha	94	47	84

* Soil analyses are from samples taken in April of 1976

Table 1.6.2. Fertility treatments for the irrigated alfalfa experiments (Pederson site)

Treatment Number	Application	P_2O_5	K_2O	S	Other
		kg/ha			
1		0	0	0	0
2	Annual	28	0	0	0
3	Annual	56	0	0	0
4	Annual	84	0	0	0
5	Annual	112	0	0	0
6	Once only	168	0	0	0
7	Once only	336	0	0	0
8	Annual	0	28	0	0
9	Annual	0	56	0	0
10	Annual	0	112	0	0
11	Annual	0	224	0	0
12	Annual	0	0	28	0
13	Annual	0	0	56	0
14	Annual	0	0	112	0
15	Annual	0	0	224	0
16	Spare				
17	Spare				
18	Spare				

Table 1.6.3. Fertility treatments for the irrigated alfalfa experiments (Gross and Wudel sites)

Treatment Number	Application	kg/ha P_2O_5
1		0
2	Annual	28
3	Annual	56
4	Annual	84
5	Annual	112
6	Once only	84
7	Once only	168
8	Once only	252
9	Once only	336
10	Spare	0

for drying. A dry weight of the subsamples was taken and the four replicates of each treatment ground in preparation for analyses.

In 1977 soil and plant samples were also taken at two week intervals throughout the growing season from the control and 84 kg P_2O_5/ha annual treatments at both the Pederson and Gross sites. These samples were subjected to detailed analysis for various phosphorus fractions in the soil. The objective was to determine if a more reliable phosphorus soil test for alfalfa could be developed.

All irrigation applications were as conducted by the co-operating farmer.

RESULTS AND DISCUSSION

The results for the analyses of the soil samples taken in the spring of 1977 prior to the application of the annual fertilizer treatments are presented in Tables 1.6.4 to 1.6.6 for the Pederson, Gross and Wudel sites respectively. Soil samples were collected from the 0, 84 kg P_2O_5/ha annual, 168 kg P_2O_5/ha once only and 336 kg P_2O_5/ha once only treatments at all three sites. In addition, the 112 kg S/ha annual and 224 kg S/ha annual treatments at the Pederson site were sampled.

The results indicate that the broadcast phosphorus fertilizer applications increased the available phosphorus level (0-15 cm) in the soil. The majority of the increase was found in the 0-7 cm depth indicating that the applied phosphorus had not moved down into the soil to any great extent. The greatest increase in available phosphorus was found for the large applications of phosphorus fertilizer. However, these increases were small in comparison to

Table 1.6.4. Spring soil analyses of selected treatments for the Pederson alfalfa plot

Treatment (kg/ha)	Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4S
				----------	kg/ha*	----------	
0 P_2O_5	0-7	7.5	0.7	18	5	158	10
	7-15	7.8	0.5	7	2	119	9
	15-30	7.9	0.6	11	2	263	21
	30-60	8.0	1.6	16	7	690	48+
84 P_2O_5 Annual	0-7	7.6	0.6	18	9	144	10
	7-15	7.8	0.5	8	4	118	10
	15-30	7.9	0.6	13	4	270	19
	30-60	8.0	1.1	16	5	520	41
168 P_2O_5 Once	0-7	7.6	0.6	17	15	151	10
	7-15	7.7	0.5	8	5	119	10
	15-30	7.9	0.6	13	6	273	19
	30-60	7.9	2.0	20	9	605	40
336 P_2O_5 Once	0-7	7.7	0.6	18	23	148	10
	7-15	7.8	0.5	8	7	121	10
	15-30	8.0	0.5	11	11	274	19
	30-60	8.0	1.5	17	15	640	44
112 S Annual	0-7	7.6	0.8	21	6	171	12+
	7-15	7.9	0.6	8	3	130	11
	15-30	8.1	0.7	11	2	276	23
	30-60	8.0	2.2	17	8	728	48+
224 S Annual	0-7	7.7	0.7	18	4	151	12+
	7-15	7.9	0.7	7	2	120	12+
	15-30	8.0	0.7	10	2	266	22
	30-60	8.0	1.9	13	3	610	48+

* kg/ha = ppm x 2 for 15 cm depth and ppm x 4 for 30 cm depth

Table 1.6.5. Spring soil analyses of selected treatments for the Gross alfalfa plot

Treatment (kg/ha)	Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4-S
				kg/ha*			
0 P_2O_5	0-7	7.6	0.4	11	4	235	10
	7-15	7.6	0.3	7	2	213	10
	15-30	7.8	0.3	8	3	209	19
	30-60	8.1	0.3	10	5	308	36
84 P_2O_5 Annual	0-7	7.6	0.3	10	8	234	6
	7-15	7.7	0.3	7	4	195	7
	15-30	7.7	0.3	11	5	225	18
	30-60	8.1	0.3	10	6	303	37
168 P_2O_5 Once	0-7	7.6	0.3	13	20	216	6
	7-15	7.7	0.3	6	8	148	8
	15-30	7.8	0.3	11	10	194	19
	30-60	8.0	0.3	9	11	310	44
336 P_2O_5 Once	0-7	7.6	0.3	13	38	223	6
	7-15	7.7	0.3	7	9	159	9
	15-30	7.9	0.3	9	13	201	20
	30-60	8.1	0.3	10	16	310	42

* kg/ha = ppm x 2 for 15 cm depth and ppm x 4 for 30 cm depth

Table 1.6.6. Spring soil analyses of selected treatments for the Wudel alfalfa plot

Treatment (kg/ha)	Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4-S
				kg/ha*			
0 P_2O_5	0-7	7.3	0.5	8	9	188	12+
	7-15	7.5	0.7	5	4	178	12+
	15-30	7.8	0.6	7	4	408	24+
84 P_2O_5 Annual	0-7	7.2	0.6	10	9	193	12+
	7-15	7.5	0.7	5	5	161	11
	15-30	7.7	0.6	8	6	350	22
168 P_2O_5 Once	0-7	7.3	0.6	10	25	201	11
	7-15	7.6	0.4	6	7	160	11
	15-30	7.7	0.5	10	9	393	24+
336 P_2O_5 Once	0-7	7.3	0.4	10	33	211	10
	7-15	7.5	0.6	6	9	178	10
	15-30	7.7	0.7	9	11	438	22

* kg/ha = ppm x 2 for 15 cm depth and ppm x 4 for 30 cm depth

the quantity of fertilizer applied.

The soil analyses are presented for each replicate and indicate the variability that can occur in sampling field plots (see Appendix A5).

Sulfur fertilization also increased the available SO_4-S at the Pederson site. However, even those treatments sampled that received no sulfur application had an adequate supply of available sulfur present.

The yield results are presented in Table 1.6.7 for the Pederson site and Table 1.6.8 for the Gross and Wudel sites. The yields where variable; showed no consistant trends to indicate that a phosphorus response had occurred. As well, at the Pederson site no response was observed for the potassium and sulfur treatments.

The first cut at the Pederson and Gross sites was in early June and the yields obtained were markedly reduced from those in 1976. The second cut yields were equal to or greater than those obtained in 1976. The overall result was reduced total yields at both the Pederson and Gross sites as compared to the 1976 total yields.

The first cut at the Wudel site was in late June and the yields obtained were greater than for either of the other two sites. Total yields at the Wudel site were greater than those obtained in 1976. As well, total yields at the Wudel site were greater than total yields for either the Pederson or Gross sites, the differences being in the first cut yields.

The results for the protein and phosphorus content of the alfalfa are presented in Table 1.6.9 for the Pederson site and Table 1.6.10 for the Gross and Wudel sites. The results indicate that the phosphorus fertilization had no effect on the protein

Table 1.6.7. Yield results for irrigated alfalfa (Pederson site)

Treatment Number	Application Rate (kg/ha)	Dry Matter Yield (kg/ha) Cut 1 June 7/77	Cut 2 July 18/77	Total
1	0	2776	2787	5563
2	28 P_2O_5 Annual	2705	2787	5492
3	56 P_2O_5 Annual	2863	2847	5710
4	84 P_2O_5 Annual	----	----	----
5	112 P_2O_5 Annual	2770	2700	5470
6	168 P_2O_5 Once	2730	2559	5289
7	336 P_2O_5 Once	2783	2670	5453
8	28 K_2O Annual	2771	2744	5515
9	56 K_2O Annual	2796	2589	5385
10	112 K_2O Annual	2621	2414	5035
11	224 K_2O Annual	2682	2647	5329
12	28 S Annual	2770	2585	5355
13	56 S Annual	2868	2894	5762
14	112 S Annual	2594	2688	5282
15	224 S Annual	2708	2894	5602
16	Spare	----	----	----
17	Spare	2866	2689	5555
18	Spare	2884	2944	5828
L.S.D. (P = 0.05)		242	300	

Table 1.6.8. Yield results for irrigated alfalfa (Gross and Wudel sites)

Treatment Number	P_2O_5 Applied (kg/ha)	Dry Matter Yield (kg/ha)					
		Gross Site			Wudel Site		
		June 10/77 Cut 1	July 27/77 Cut 2	Total	June 20/77 Cut 1	Aug. 16/77 Cut 2	Total
1	0	2817	3091	5908	4215	3315	7530
2	28 Annual	3158	3153	6311	4024	2976	7000
3	56 Annual	2460	3268	5728	4155	3529	7684
4	84 Annual	----	----	----	4065	3302	7367
5	112 Annual	2498	3412	5910	3840	3509	7349
6	84 Once	2463	3122	5585	3847	3080	6927
7	168 Once	3036	3243	6279	3701	3239	6940
8	252 Once	3469	3096	6565	3614	3587	7201
9	336 Once	2298	3116	5414	4043	3108	7151
10	Spare	----	----	----	3803	3419	7222
L.S.D. (P - 0.05)		1327	518		464	516	

content of the alfalfa at the three sites. Likewise, potassium and sulfur fertilization at the Pederson site had no effect on the protein content of the alfalfa. Differences in the protein content among the three sites was probably due to differences in maturity when each cut was taken. Highest protein is usually obtained when approximately one-tenth of the plants are in bloom.

The phosphorus content of the alfalfa at the Pederson site was not affected by phosphorus, potassium or sulfur fertilization. However, at the Gross and Wudel sites the phosphorus content of the alfalfa increased as the rate of applied phosphorus increased. Similar results were found in 1976.

Table 1.6.9. The effect of phosphorus, potassium and sulfur fertilization on the protein and phosphorus content of irrigated alfalfa (Pederson site)

Treatment Number	Application Rate (kg/ha)	% Protein[1] Cut 1 June 7/77	% Protein[1] Cut 2 July 18/77	% P[2] Cut 1 June 7/77	% P[2] Cut 2 July 18/77
1	0	18.25	17.66	0.216	0.226
2	28 P_2O_5 Annual	19.24	16.44	0.205	0.253
3	56 P_2O_5 Annual	18.13	17.41	0.226	0.262
4	84 P_2O_5 Annual	-----	-----	-----	-----
5	112 P_2O_5 Annual	18.42	18.16	0.263	0.287
6	168 P_2O_5 Once	17.13	16.19	0.218	0.238
7	336 P_2O_5 Once	19.36	17.67	0.255	0.291
8	28 K_2O Annual	18.44	17.74	0.216	0.218
9	56 K_2O Annual	18.22	16.85	0.194	0.216
10	112 K_2O Annual	18.14	17.67	0.205	0.215
11	224 K_2O Annual	18.16	16.81	0.197	0.219
12	28 S Annual	17.78	17.42	0.201	0.215
13	56 S Annual	17.55	16.93	0.205	0.206
14	112 S Annual	18.95	17.25	0.201	0.226
15	224 S Annual	16.44	16.13	0.192	0.215
16	Spare	-----	-----	-----	-----
17	Spare	17.69	17.22	0.203	0.208
18	Spare	18.02	16.74	0.199	0.215
L.S.D. ($p = 0.05$)		1.52	1.94		

[1] Protein content based on % N at oven-dry moisture x 6.25

[2] % P on oven-dry basis

Table 1.6.10. The effect of phosphorus fertilization on the protein and phosphorus content of irrigated alfalfa (Gross and Wudel sites)

Treatment Number	P_2O_5 Applied (kg/ha)	% Protein[1] Cut 1	% Protein[1] Cut 2	% P[2] Cut 1	% P[2] Cut 2
		Gross Site			
		June 10/77	July 27/77	June 10/77	July 27/77
1	0	18.60	14.58	0.192	0.156
2	28 Annual	18.43	15.05	0.230	0.193
3	56 Annual	19.42	14.22	0.252	0.184
4	84 Annual	-----	-----	-----	-----
5	112 Annual	18.96	15.39	0.288	0.246
6	84 Once	17.98	13.55	0.196	0.165
7	168 Once	19.09	14.50	0.243	0.205
8	252 Once	17.97	14.41	0.266	0.226
9	336 Once	17.94	13.79	0.279	0.237
10	Spare	-----	-----	-----	-----
L.S.D. (P = 0.05)		1.64	1.76		
		Wudel Site			
		June 20/77	Aug. 16/77	June 20/77	Aug. 16/77
1	0	16.14	16.22	0.211	0.214
2	28 Annual	17.28	16.03	0.256	0.225
3	56 Annual	17.44	16.94	0.284	0.257
4	84 Annual	15.86	17.16	0.285	0.257
5	112 Annual	16.32	16.31	0.290	0.267
6	84 Once	17.05	17.18	0.239	0.220
7	168 Once	16.77	17.30	0.249	0.239
8	252 Once	16.94	18.11	0.265	0.267
9	336 Once	16.94	17.94	0.278	0.282
10	Spare	17.35	16.93	0.229	0.282
L.S.D. (P = 0.05)		2.04	1.27		

[1] Protein content based on % N at oven-dry moisture x 6.25

[2] % P on oven-dry basis

2. Crop utilization and fate of fertilizer nitrogen in soil

INTRODUCTION

In recent years, numerous research projects have been conducted by various agencies in Western Canada evaluating crop responsesto different rates, carriers, methods and times of applying fertilizer nitrogen. Results of these experiments have conclusively demonstrated that yields of most stubble seeded crops and a small percentage of fallow seeded crops are limited by the amounts of available nitrogen present in the soil. Hence good responses to applied fertilizer nitrogen are attainable. However, few definite statements can be made regarding the relative efficiency of different nitrogen carriers, methods and times of application.

The majority of this research has been conducted using ammonium nitrate (34-0-0) and urea (46-0-0). With the increase in the use of anhydrous ammonia (82-0-0) in the prairie provinces it was considered necessary to investigate the response of annual crops to anhydrous ammonia in comparison to one of these other nitrogen fertilizers.

2.1 Response of annual crops to different sources and times of applying nitrogen fertilizers

EXPERIMENTAL METHODS

One site was selected in the fall of 1976 to compare the response of annual crops to fall and spring applied urea (46-0-0) and anhydrous ammonia (82-0-0). This site was on a Weirdale loam in the Black-Grey soil zone (Joe Pender farm, Meath Park) which had been cropped for the past four years.

The experimental design consisted of standard strip tests the length of the field. The plot was duplicated to provide for both the fall and spring application times. Five site replicates were selected down the length of the plot for soil sampling. Two soil cores were taken to a depth of 120 cm and composited across the width of the plot at each of the five replicates. The fall and spring plots were sampled separately. Analyses of the soil samples indicated low levels of NO_3-N and extractable phosphorus (Table 2.1.1).

The two nitrogen fertilizers were applied in late October 1976 and middle April 1977 using commercial applicators. Anhydrous ammonia was applied to a depth of 10 to 15 cm with a shank-type applicator which was 14 metres wide with 41 cm shank spacings. One rate of anhydrous ammonia was applied in one pass down the field. Thus, each anhydrous ammonia strip was 14 metres wide. The rate of nitrogen applied was calculated from the total quantity of anhydrous ammonia used in one pass down the field. Urea was surface broadcast with a Gandy fertilizer spreader that was 6 metres wide. One rate of urea was applied with one pass down the field. Thus, each urea strip was 6 metres wide. The actual rate of nitrogen applied was taken as the quantity determined from a pre-calibration. The same rate of each fertilizer was placed side-by-side. Each rate was then separated by a 6 metre wide check strip. After the fertilizer had been applied the entire plot area was harrowed twice. The rates of fertilizer applied are presented in Table 2.1.2.

Three crops Glenlea wheat, Noralta flax and Beacon barley were seeded across the fertilizer strips perpendicular to the direction

Table 2.1.1. Soil analyses for the 1977 nitrogen fertilizer experiment

Time of Application	Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4-S
				------- kg/ha*			---------
Fall	0-15	7.7	0.4	11	16	270	24+
	15-30	8.0	0.6	2	7	185	24+
	30-60	8.0	1.0	4	8	400	48+
	60-90	8.0	1.0	11	4	490	48+
	90-120	8.0	0.7	12	4	560	48
Spring	0-15	7.7	0.4	9	14	325	24+
	15-30	8.1	0.7	6	6	200	24+
	30-60	8.1	0.9	8	6	460	48+
	60-90	8.1	0.9	10	4	540	48+
	90-120	7.9	1.3	18	4	500	48+

* kg/ha = ppm x 2 for 15 cm depth and ppm x 4 for 30 cm depth

Table 2.1.2. Treatments included in the 1977 nitrogen fertilizer experiment

Time of Application	N Source	N Applied (kg/ha)
Fall	Urea	45
		90
		135
	Anhydrous Ammonia	45
		90
		135
Spring	Urea	45
		90
		135
	Anhydrous Ammonia	45
		90
		135

of application. All pre-seeding tillage and seeding operations were as conducted by the co-operating farmer. Phosphate was seed-placed at the time of seeding by the co-operating farmer.

A fall application of granular Avadex-BW for wild oat control was applied and incorporated on the entire field. Wild oats were successfully controlled in the wheat and barley but not in the flax. As well, all three crops received a post-emergent application of 2,4-D Estemine for the control of broadleaf weeds. Control was excellent in the wheat and barely but not as good in the flax.

At harvest, yield samples were taken from each fertilizer treatment and checks at ten locations (replications) by clipping at the soil surface an area equal to two square metres. The samples were then dried, weighed and threshed. Grain samples were cleaned and weighed. Subsamples of straw and flax grain, replicates of individual treatments were composited, and individual wheat and barley grain samples were mixed and ground in preparation for analyses. Analyses were performed for nitrogen content of the straw, barley grain and flax grain by wet digestion and colorimetric analysis using a Technicon Auto Analyzer II system. Nitrogen content of the wheat was determined with a Technicon Infra Analyzer.

Included in the plot was a small subplot in which ^{15}N enriched fertilizer materials were utilized to allow for detailed uptake and balance measurements. The subplot consisted of 48, 60 cm long and 20 cm diameter, clyinders driven into the ground. These cylinders represented 6 treatments replicated 4 times for both fall and spring applications. Treatments included the following all applied at a rate of 56 kg/ha.:

(1) $^{15}NH_4OH$ with ATC - injected

(2) $^{15}NH_4OH$ - injected

(3) Urea - ^{15}N with ATC - injected

(4) Urea - ^{15}N - injected

(5) Urea - ^{15}N with ATC - incorporated

(6) Urea - ^{15}N - incorporated

Each of the fertilizers were applied at the same time as nitrogen was applied on the large plot. The cylinders were "hand worked" and seeded in spring. Due to dry soil conditions water was added (19 mm) to each cylinder prior to seeding. At harvest, all aboveground plant material was taken from each cylinder, dried, weighed, threshed, ground and retained for total N and ^{15}N measurements. The cylinders were dug up (frozen until processed) and the soil was removed by genetic horizons, weighed, dried and subsampled in preparation for total nitrogen and ^{15}N analyses. Resutls from this subplot are presented in a subsequent section of this report.

RESULTS AND DISCUSSION

Response of Glenlea wheat to applied nitrogen

The results for the response of the Glenlea wheat to fall and spring applied Urea and anhydrous ammonia are presented in Table 2.1.3. Grain yields increased with each increase in applied nitrogen. No differences were observed between the two nitrogen fertilizers or application times. Straw yields showed the same trend as the grain yields. No consistant trends were shown for the grain/straw ratios.

The nitrogen content of the Glenlea wheat was also affected by the nitrogen fertilization. Grain protein increased as the rate of

Table 2.1.3. The effect of different sources and times of applying nitrogen fertilizers on the yield, nitrogen content and nitrogen uptake of Glenlea wheat

Time of Application	N Source	N Applied kg/ha	Yield Grain (kg/ha)	Yield Straw (kg/ha)	Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake Grain (kg/ha)	Nitrogen Uptake Straw (kg/ha)	Nitrogen Uptake Total (kg/ha)
Fall	Urea	45	2687	3061	0.89	9.4	0.27	51.2	8.3	59.5
		90	3342	4042	0.91	9.7	0.27	65.7	10.9	76.6
		135	3649	4212	0.88	10.7	0.30	79.2	12.6	91.8
	Anhydrous	45	2384	3323	0.73	10.0	0.27	48.4	9.0	57.4
	NH_3	90	3118	3307	0.95	11.6	0.30	73.4	9.9	83.3
		135	3547	4239	0.85	11.5	0.30	82.7	12.7	95.4
Spring	Urea	45	2832	3359	0.87	9.8	0.27	56.3	9.1	65.4
		90	3158	3417	0.94	11.4	0.30	73.0	10.3	83.3
		135	3304	3538	0.94	11.6	0.39	77.7	13.8	91.5
	Anhydrous	45	2568	2909	0.89	10.1	0.30	52.6	8.7	61.3
	NH_3	90	3041	3324	0.92	12.0	0.30	74.0	10.0	84.0
		135	3407	4162	0.83	12.3	0.36	85.0	15.0	100.0
Check 1		0	1849	1830	1.21	9.0	0.21	33.8	3.8	37.6
2		0	1798	2328	0.78	8.6	0.21	31.4	4.9	36.3
3		0	1836	2031	0.91	8.7	0.24	32.4	4.9	37.3
4		0	1942	2040	0.97	9.3	0.21	36.6	4.3	40.9
5		0	1895	2147	0.88	9.2	0.24	35.4	5.2	40.6
6		0	1962	2306	0.85	9.4	0.24	37.4	5.5	42.9
7		0	2077	2386	0.87	8.8	0.24	37.1	5.7	42.8
L.S.D. (P=0.05)			382	560	0.19	0.75				

[1] Grain protein content based on % N at 13.5% moisture x 5.7; straw % N on oven-dry basis.

nitrogen was increased. Protein levels were slightly higher for the anhydrous ammonia than the urea at each time of application and for the spring application than the fall application. Straw nitrogen content also increased as the rate of nitrogen applied was increased and was similar for the two fertilizers and application times.

A direct result of increased yields and increased protein and straw nitrogen content with increased rates of fertilizer nitrogen was an overall increase in total nitrogen uptake by the Glenlea wheat.

<u>Response of Beacon barley to applied nitrogen</u>

The results for the response of the Beacon barley to fall and spring applied urea and anhydrous ammonia are presented in Table 2.1.4. The applied nitrogen increased grain yields of the Beacon barley over that of the check treatments. However, grain yields did not show a consistent trend of increasing as the rate of nitrogen applied was increased. Results were somewhat erratic for the fall applied urea and spring applied anhydrous ammonia. Straw yields on the other hand showed a general trend of increasing as the rate of nitrogen applied was increased. Grain/straw ratios showed on consistent trends.

The nitrogen content of the Beacon barley was also affected by the nitrogen fertilization. Protein content of the barley increased as the rate of nitrogen applied was increased. The protein levels were well within the acceptable limits for malting barley. Small differences between the two fertilizers indicated that slightly higher protein levels were obtained for the anhydrous ammonia than the urea at each time of application. Differences between times of application showed the spring applied urea to be greater than the fall application with the opposite true for the anhydrous ammonia. Straw nitrogen content

Table 2.1.4. The effect of different sources and times of applying nitrogen fertilizers on the yield, nitrogen content and nitrogen uptake of Beacon barley

Time of Application	N Source	N Applied kg/ha	Yield Grain (kg/ha)	Yield Straw (kg/ha)	Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake Grain (kg/ha)	Nitrogen Uptake Straw (kg/ha)	Nitrogen Uptake Total (kg/ha)
Fall	Urea	45	3516	3999	0.88	7.5	0.24	42.2	9.6	51.8
		90	5133	5880	0.89	7.9	0.27	64.7	15.9	80.6
		135	4715	5754	0.82	9.2	0.36	69.3	20.7	90.0
	Anhydrous	45	3448	3852	0.86	7.4	0.27	41.0	10.4	51.4
	NH_3	90	3578	4137	0.88	10.3	0.42	59.0	17.4	76.4
		135	4446	5297	0.86	10.3	0.48	73.4	25.4	98.8
Spring	Urea	45	3011	3799	0.80	6.8	0.21	32.5	8.0	40.5
		90	3933	5203	0.76	8.6	0.33	54.3	17.2	71.5
		135	5188	5122	1.11	9.6	0.45	79.4	23.0	102.4
	Anhydrous	45	4400	3949	0.82	6.9	0.24	48.8	9.5	58.3
	NH_3	90	3595	4643	0.95	9.4	0.36	53.9	16.7	70.6
		135	3516	5326	0.68	10.3	0.48	58.0	25.6	83.6
Check 1		0	2595	3523	0.74	7.1	0.30	29.6	10.6	40.2
2		0	2246	2601	0.87	7.1	0.27	25.6	7.0	32.6
3		0	2179	2533	0.86	6.8	0.30	23.5	7.6	31.1
4		0	2146	2205	0.97	6.6	0.27	22.5	6.0	28.5
5		0	1675	1996	0.84	6.8	0.30	18.1	6.0	24.1
6		0	1639	1781	0.92	6.6	0.27	17.2	4.8	22.0
7		0	1407	1921	0.73	6.6	0.30	14.8	5.8	20.6
L.S.D. (P=0.05)			448	654	0.15					

[1] Grain protein content based on % N at oven-dry moisture x 6.25; straw % N on oven-dry basis.

increased as the rate of nitrogen applied was increased. Generally, straw nitrogen content was greatest for the anhydrous ammonia than the urea, these differences being more apparent for the fall applied than the spring applied fertilizer. No general trends were observed for the different application times.

A direct result of increased yields and nitrogen content with increased rates of fertilizer nitrogen was an overall increase in total nitrogen uptake by the Glenlea wheat.

Response of Noralta flax to applied nitrogen

The results for the response of the Noralta flax to fall and spring applied urea and anhydrous ammonia are presented in Table 2.1.5. The applied fertilizer nitrogen increased the flax grain yield over that of the check treatments. However, the grain yields did not show a consistent trend of increasing with increases in applied nitrogen but were somewhat variable. This variability in the response of the flax could possibly be due to the problem encountered with weeds and volunteer barley. Straw yields also showed the same variability as the grain yields. No apparent differences were observed between the two fertilizers at each time of application. The spring applied nitrogen for both fertilizers tended to out yield the fall application.

The nitrogen content of the flax was increased by the nitrogen fertilization. Protein levels of the flax were increased above the check treatments but as with grain and straw yields there was no consistent trends with increasing rates of nitrogen fertilizer. No differences were observed between the two nitrogen fertilizers or times of application. Straw nitrogen content of the flax was variable and showed no consistent trends with increasing rates of applied nitrogen.

Table 2.1.5. The effect of different sources and times of applying nitrogen fertilizers on the yield, nitrogen content and nitrogen uptake of Noralta flax

Time of Application	N Source	N Applied kg/ha	Yield (kg/ha) Grain	Yield (kg/ha) Straw	Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake (kg/ha) Grain	Nitrogen Uptake (kg/ha) Straw	Nitrogen Uptake (kg/ha) Total
Fall	Urea	45	983	1974	0.51	17.7	0.60	31.8	11.8	43.6
		90	893	1508	0.60	16.2	0.51	26.5	7.7	34.2
		135	1112	1980	0.58	17.7	0.54	36.0	10.7	46.7
	Anhydrous NH_3	45	1076	2115	0.48	16.7	0.51	30.8	10.8	41.6
		90	945	2028	0.50	18.4	0.66	31.8	13.4	45.2
		135	1105	1890	0.59	16.1	0.63	32.5	11.9	46.4
Spring	Urea	45	1079	1655	0.65	18.2	0.45	35.9	7.4	43.3
		90	1212	1997	0.61	13.6	0.42	30.2	8.4	38.6
		135	1330	1940	0.80	17.6	0.51	42.7	9.0	51.7
	Anhydrous NH_3	45	1171	2048	0.56	16.7	0.57	35.8	11.7	47.5
		90	1345	2316	0.58	17.1	0.54	42.0	12.5	54.5
		135	1115	1974	0.58	17.2	0.51	35.1	10.1	45.2
Check 1		0	847	1468	0.61	15.3	0.39	23.6	5.7	29.3
2		0	824	1534	0.55	16.7	0.42	25.2	6.4	31.6
3		0	802	1643	0.52	14.9	0.54	21.9	8.9	30.8
4		0	727	1222	0.60	14.8	0.39	19.6	4.8	24.4
5		0	1147	1821	0.64	18.5	0.51	38.9	9.3	48.2
6		0	862	1595	0.55	14.9	0.60	23.5	9.6	33.1
7		0	970	1413	0.70	15.3	0.51	27.1	7.2	34.3
L.S.D. (P=0.05)			200	377	0.14					

[1] Grain protein content based on % N at 13.5% moisture x 6.25; straw % N on oven-dry basis.

For each application time the straw nitrogen content was greater for the anhydrous ammonia than the urea. As well, straw nitrogen content was greatest for the fall applied nitrogen than the spring applied nitrogen.

Nitrogen uptake by the flax was variable as the rate of nitrogen applied was increased due to the variation showed in both yields and nitrogen content.

3. Productivity Studies on Solonetzic Soils in The Weyburn Area - Summary Report

D. W. Anderson

INTRODUCTION

This brief report is a summary of data on the yield and protein content of wheat grown on third-crop on three sites in the Weyburn - Torquay areas. It covers the third and final year of the study which originally included 5 farmer cooperators. One site (Schnell) was not seeded in 1977 and a second site (Halvorson) was lost due to a misunderstanding by the farmer. Data for the 1975 and 1976 years may be found in the appropriate Plant Nutrient Research Report.

The data of this study include much more than is reported here. The additional data are stored by computer methods and is available from the Department of Soil Science.

GENERAL DISCUSSION OF RESULTS

Flaten. At the Flaten site growing season precipitation was 268 mm (10.6 inches) with an even distribution through the season. Yields were reasonably good, ranging from 1131 to 1782 kg/ha. The yields of the different series or subgroup profiles were surprisingly similar (Table 3.1) consistent with the high nitrate nitrogen content of these soils protein contents were high, with values up to 17%.

Lievaart. Growing season precipitation was 172 mm (6.8 inches) at the Lievaart site, with a particularly long drought during July. This drought period, coupled with mean weekly maximum temperatures of 30^{o}C to 32^{o}C for the last three weeks of July, severely reduced yields.

Yields were lowest on the Dark Brown Solonetz (TCS) soils, soils with thin Ap horizons and tough Bnt horizons. They were somewhat higher on the Solonetzic Dark Brown soils (DKW), soils similar to the TCS but with less tough B horizons. Yields were highest on the Dark Brown Solods, particularly those that occurred in lower areas and had deep, friable A horizons (Table 3.2).

The protein contents were lower at the Lievaart site than at Memory or Flaten, probably a consequence of lower nitrate nitrogen contents in the soils.

Memory. The comments about precipitation and temperature for the Lievaart site apply to this site as well. Yields were severely affected with most of the field considered to be a crop failure (3 to 5 bushels per acre or less) except for deep Dark Brown Solod and Chernozemic soils in lower-lying areas. Protein contents were high, reflecting reduced yields and high nitrate nitrogen contents in the soil (Table 3.3).

Table 3.1 Total and grain yields and protein content of spring wheat at the Flaten site

Plot	Soil	Total Yield kg/ha	Grain Yield kg/ha	Protein %
1	TCS	4575	1782	16.0
5	TCS	4340	1596	13.7
6	TCS	4860	1702	16.8
2	TCU	3585	1353	15.3
9	TCU	4585	1583	16.6
10	TCU	3460	1273	16.2
13	TCU	3975	1390	16.4
8	TCU	3345	1290	17.2
3	TCT	3500	1339	17.1
4	TCT	2905	1131	16.9
7	TCT	3670	1401	16.8
11	TCT	4315	1738	17.5
12	TCT	4325	1559	15.1
Means	TCS	4592	1693	15.5
	TCU	3790	1378	16.4
	TCT	3743	1402	16.7

Rainfall: May, 125 mm; June, 41 mm; July, 89 mm; August, 13 mm; Total, 268 mm (10.6 inches).

Table 3.2 Total and grain yields and protein content of spring wheat at the Lievaart site

Plot	Soil	Total Yield kg/ha	Grain Yield kg/ha	Protein %
2	TCS	1445	356	16.4
9	TCS	1825	775	11.4
13	TCS	2165	752	10.1
15	TCS	1090	477	11.4
1	BKW	2145	676	14.0
4	BKW	2275	438	13.8
5	BKW	4170	817	13.1
10	BKW	2700	655	10.5
11	BKW	1760	659	12.5
12	BKW	2155	986	10.5
6	TCU	3620	1228	9.7
8	TCU	2475	953	12.7
3	TCU	5305	1704	13.7
7	TCT	2860	686	12.0
14	TCT	1790	733	10.3
Means	TCS	1631	590	12.3
	BKW	2534	705	12.4
	TCU	3800	1295	12.0
	TCT	2325	710	11.2

Rainfall: May, 82 mm; June, 34 mm; July 1-27, none; July 27-31, 26 mm; August, 30 mm
Growing season = 172 mm (6.8 inches).

Table 3.3 Total and grain yields and protein content of spring wheat at the Memory site

Plot	Soil	Total Yield kg/ha	Grain Yield kg/ha	Protein %
1	BKY	1600	148	18.6
11	BKY	1360	317	14.5
14	BKY	1500	102	16.0
4	TCU	1400	117	18.6
7	TCU	7840	1150	13.5
8	TCU	3590	1150	16.2
13	TCU	2460	465	17.4
10	TCU	1520	279	16.3
2	TCS	1270	104	17.5
6	TCS	1025	62	18.2
12	BKW	855	193	14.5
3	TCT	3525	655	16.4
5	TCT	2255	292	17.3
9	TCT	1980	279	14.9
15	AMA	4565	1322	15.3
Means	BKY	1487	189	16.4
	TCU	3362	632	16.4
	TCS, BKW	1050	120	16.7
	TCT	2587	409	16.2
	AMA	4565	1322	15.3

Rainfall: See Lievaart site.

This cursory treatment of the data gathered in the third and final year of this study is included in this report to draw other workers' attention to this study. A much more comprehensive consideration of the large amount of data gathered is required. At any rate, the findings of the three year study all indicate the complex interactions between soil and landscape properties, precipitation and temperature that determine productivity of Solonetzic soils. Yields generally are related to soil series or subgroup profile, but relationships vary from year to year and with soil properties that are not criteria used in the soil classification.

APPENDIX Selected tables of data from the 1977 irrigation experiments

Table A1. Spring soil analyses for wheat on alfalfa breaking experiment under irrigation (R. Pederson)

Rep.	Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4-S
				kg/ha*			
1	0-15	7.4	0.3	12	10	220	8
	15-30	7.4	0.4	18	12	240	24+
	30-60	7.7	0.4	12	14	640	48+
	60-90	8.0	0.4	4	10	430	48+
	90-120	8.2	0.3	4	6	430	48+
2	0-15	7.7	0.3	18	11	270	24+
	15-30	7.7	0.4	14	7	220	24+
	30-60	8.0	0.4	10	8	550	48+
	60-90	8.3	0.4	6	6	350	48+
	90-120	8.4	0.4	8	4	430	48+
3	0-15	7.7	0.4	30	8	260	24+
	15-30	7.7	0.6	17	7	235	24+
	30-60	8.1	0.4	16	6	560	48+
	60-90	8.4	0.4	4	4	440	48+
	90-120	8.5	0.4	4	4	510	48+
4	0-15	7.9	0.3	17	7	240	11
	15-30	7.8	0.4	26	12	275	24+
	30-60	8.1	0.4	14	6	400	48+
	60-90	8.5	0.3	6	4	380	48+
	90-120	8.6	0.4	4	2	460	48+
5	0-15	7.9	1.0	30	11	275	24+
	15-30	7.9	1.5	64	14	320	24+
	30-60	8.3	1.2	28	12	460	48+
	60-90	8.5	1.2	6	6	460	48+
	90-120	8.5	1.7	4	4	580	48+
6	0-15	8.1	3.1	11	3	150	24+
	15-30	8.1	4.7	13	3	150	24+
	30-60	8.2	4.8	6	2	360	48+
	60-90	8.4	5.2	4	2	510	48+
	90-120	8.4	4.8	4	2	680	48+

* kg/ha = ppm x 2 for 15 cm depth and ppm x 4 for 30 cm depth

Table A2 Spring soil analyses for the aqua ammonia vs ammonium nitrate experiment

Rep.	Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4-S
				kg/ha*			
1	0-15	7.2	0.3	21	17	490	24+
	15-30	7.5	0.3	13	5	175	16
	30-60	7.9	0.3	12	2	280	34
2	0-15	6.9	0.3	23	17	535	24+
	15-30	7.3	0.2	13	6	260	24+
	30-60	7.5	0.2	10	4	340	32
3	0-15	7.3	0.3	23	17	380	24+
	15-30	7.6	0.3	14	3	160	18
	30-60	7.9	0.3	12	2	250	48+
4	0-15	7.3	0.3	26	18	360	19
	15-30	7.7	0.2	10	4	130	12
	30-60	7.9	0.2	12	2	230	24
5	0-15	7.3	0.3	28	11	400	23
	15-30	7.6	0.3	14	3	150	14
	30-60	8.0	0.2	14	2	240	20
6	0-15	7.3	0.4	34	16	415	24+
	15-30	7.2	0.3	14	4	150	16
	30-60	7.7	0.3	16	2	240	19

* kg/ha = ppm x 2 for 15 cm depth and ppm x 4 for 30 cm depth

Table A3 Spring soil analyses for the phosphorus correlation experiments

Rep.	Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4-S
				kg/ha*			
			Asquith: sandy loam (Barrich 10)				
1	0-15	7.0	0.4	34	53	405	24+
	15-30	7.0	0.2	19	35	310	15
	30-60	7.8	0.2	22	16	290	12
	60-90	7.9	0.3	50	6	370	40
	90-120	7.8	2.1	38	4	670	48+
2	0-15	6.9	0.3	26	58	390	24+
	15-30	7.1	0.2	10	21	195	6
	30-60	7.7	0.4	34	10	360	48+
	60-90	8.1	0.7	52	4	470	48+
	90-120	8.3	0.8	44	2	460	48+
3	0-15	7.1	0.4	50	51	485	24+
	15-30	7.1	0.3	18	19	260	16
	30-60	7.8	0.4	34	10	360	36
	60-90	8.1	0.6	56	4	440	48+
	90-120	7.8	3.0	40	2	540	48+
4	0-15	7.2	0.4	34	46	480	21
	15-30	7.0	0.2	16	22	255	10
	30-60	7.7	0.2	18	12	350	12
	60-90	8.0	0.3	34	8	350	34
	90-120	8.2	0.3	26	4	350	28
			Asquith: sandy loam (Barrich 14)				
1	0-15	8.0	0.3	13	12	300	24+
	15-30	8.0	0.3	14	14	370	24+
	30-60	8.4	0.3	12	8	480	48+
	60-90	8.4	0.6	16	4	520	48+
	90-120	8.3	0.4	16	2	610	48+
2	0-15	8.1	0.3	13	14	305	24+
	15-30	8.0	0.3	13	39	390	24+
	30-60	8.3	0.3	8	18	410	48+
	60-90	8.5	0.7	12	6	640	48+
	90-120	8.4	0.4	18	4	720	48+

.... continued

Table A3 continued

Rep.	Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4-S
				-----------	kg/ha*	-----------	
3	0-15	8.0	0.6	16	25	360	24+
	15-30	8.0	0.6	15	52	510	24+
	30-60	8.5	0.4	14	24	480	48+
	60-90	8.6	0.6	20	10	420	48+
	90-120	8.4	0.6	20	4	490	48+
4	0-15	8.0	0.4	14	13	275	24+
	15-30	7.9	0.3	12	17	270	24+
	30-60	8.1	0.3	12	16	320	48+
	60-90	8.5	0.4	16	6	320	48+
	90-120	8.5	0.4	20	4	430	48+
			Asquith: sandy loam (Barrich 15)				
1	0-15	7.4	0.2	16	34	505	24+
	15-30	7.3	0.2	9	17	420	18
	30-60	7.9	0.2	10	10	380	20
	60-90	8.2	0.2	20	6	380	28
	90-120	8.3	0.4	38	4	440	40
2	0-15	7.3	0.3	13	23	480	19
	15-30	7.4	0.3	13	33	460	13
	30-60	7.8	0.2	24	30	500	12
	60-90	8.0	0.2	18	10	440	48+
	90-120	7.2	0.4	30	4	540	48+
3	0-15	6.4	0.2	13	20	430	18
	15-30	7.4	0.3	7	13	360	20
	30-60	8.0	0.2	12	8	400	20
	60-90	8.4	0.3	20	4	500	38
	90-120	8.3	0.4	44	2	720	36
4	0-15	8.4	0.3	18	23	640	17
	15-30	7.2	0.4	26	43	645	24+
	30-60	7.5	0.2	26	28	720	26
	60-90	8.0	0.3	38	12	460	28
	90-120	8.2	0.4	54	4	460	48+
			Asquith: sandy loam (Barrich 16)				
1	0-15	6.9	0.3	31	35	280	20
	15-30	7.0	0.2	16	14	190	12
	30-60	7.7	0.2	28	12	290	12
	60-90	8.0	0.2	32	8	290	10
	90-120	8.2	0.3	38	4	400	32

..........continued

Table A3 continued

Rep.	Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4-S
				------------		kg/ha*	----------
2	0-15	6.9	0.2	28	36	250	15
	15-30	7.0	0.2	21	19	240	11
	30-60	7.5	0.2	32	12	360	14
	60-90	8.0	0.2	38	12	290	10
	90-120	8.2	0.3	44	4	420	30
3	0-15	7.1	0.3	38	30	320	11
	15-30	7.0	0.2	20	14	260	8
	30-60	7.2	0.2	28	12	320	10
	60-90	7.8	0.2	30	8	270	6
	90-120	8.1	0.3	28	4	370	24
4	0-15	6.8	0.3	40	34	290	15
	15-30	7.2	0.2	20	11	245	9
	30-60	7.5	0.2	28	8	320	8
	60-90	8.1	0.2	32	4	320	8
	90-120	8.1	0.3	36	2	430	20
			Elstow: loam (Niska East)				
1	0-15	7.3	0.6	62	36	420	24+
	15-30	7.6	0.4	31	20	315	24+
	30-60	7.9	0.4	22	20	330	38
2	0-15	7.1	0.7	120+	24	360	14
	15-30	7.4	0.6	51	19	370	19
	30-60	8.0	0.4	30	20	360	40
3	0-15	7.5	0.4	65	20	435	10
	15-30	7.8	0.4	34	17	440	22
	30-60	7.7	0.4	30	16	400	44
4	0-15	7.1	0.6	67	28	480	13
	15-30	7.4	0.4	31	20	370	19
	30-60	7.7	0.4	38	20	410	46
			Elstow: loam (Niska West)				
1	0-15	7.4	0.6	54	40	310	15
	15-30	7.7	0.4	27	26	210	22
	30-60	8.0	0.7	28	20	260	48+
2	0-15	7.4	0.6	71	52	370	17
	15-30	7.8	0.4	31	20	200	24+
	30-60	8.1	0.6	24	16	280	48+

.... continued

Table A3 continued

Rep.	Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4-S
				kg/ha*			
3	0-15	7.4	0.7	116	28	385	17
	15-30	7.8	0.4	32	14	205	24+
	30-60	8.1	0.7	32	14	280	48+
4	0-15	7.4	0.6	119	45	360	23
	15-30	7.7	0.4	29	18	235	24+
	30-60	8.2	0.7	26	16	290	48+
			Asquith: sandy loam (Hettrick 1)				
1	0-15	7.9	0.3	11	44	140	13
	15-30	7.4	0.4	19	58	175	15
	30-60	8.1	0.3	26	28	120	48+
	60-90	8.4	0.3	8	16	160	22
	90-120	8.6	0.3	8	12	240	16
2	0-15	8.0	0.3	10	25	135	6
	15-30	7.8	0.3	13	22	90	18
	30-60	8.1	0.3	24	16	140	48+
	60-90	8.5	0.2	6	16	150	8
	90-120	8.6	0.2	8	16	240	12
3	0-15	7.7	0.3	18	66	340	13
	15-30	7.7	0.4	25	31	120	24+
	30-60	8.2	0.4	26	22	170	48+
	60-90	8.5	0.6	34	22	240	48+
	90-120	8.9	0.3	16	16	200	48+
4	0-15	7.9	0.3	13	24	220	7
	15-30	7.8	0.3	17	21	120	14
	30-60	8.1	0.3	26	16	160	48+
	60-90	8.7	0.4	26	20	270	48+
	90-120	8.8	0.3	8	16	200	26

*kg/ha = ppm x 2 for 15 cm depth and ppm x 4 for 30 cm depth

Table A4 Fall soil analyses for the phosphorus placement experiment

Crop	Rep.	Depth (cm)	NO_3-N	P	K
			---------- kg/ha*	-------	
Irrigated Fababeans	1 and 2	0-15	6	5	670
		15-30	5	5	250
		30-60	6	6	410
	3 and 4	0-15	8	8	865
		15-30	4	6	280
		30-60	12	6	420
Irrigated Peas	1 and 2	0-15	7	9	600
		15-30	5	6	165
		30-60	8	8	370
	3 and 4	0-15	7	7	565
		15-30	7	2	190
		30-60	10	4	410
Irrigated Beans	1 and 2	0-15	9	6	380
		15-30	5	3	145
		30-60	12	6	360
	3 and 4	0-15	8	7	445
		15-30	4	4	155
		30-60	6	6	380
Irrigated Rapeseed	1 and 2	0-15	6	7	425
		15-30	3	4	160
		30-60	8	6	360
	3 and 4	0-15	3	5	350
		15-60	2	3	150
		30-60	10	4	360
Irrigated Flax	1 and 2	0-15	4	6	395
		15-30	4	3	180
		30-60	8	4	360
	3 and 4	0-15	3	4	325
		15-30	3	3	150
		30-60	4	4	340
Dryland Fababeans	1 and 2	0-15	13	8	680
		15-30	7	5	195
		30-60	12	6	420
	3 and 4	0-15	14	10	640
		15-30	5	6	170
		30-60	38	8	440

..........continued

Table A4 continued

Crop	Rep.	Depth (cm)	NO_3-N	P	K
			---------- kg/ha*	-------	
Dryland Peas	1 and 2	0-15	16	10	645
		15-30	6	5	190
		30-60	28	6	410
	3 and 4	0-15	18	14	625
		15-30	6	6	190
		30-60	26	8	490
Dryland Beans	1 and 2	0-15	16	9	530
		15-30	6	6	165
		30-60	34	8	400
	3 and 4	0-15	20	11	590
		15-30	6	6	180
		30-60	26	8	400
Dryland Rapeseed	1 and 2	0-15	17	12	600
		15-30	7	7	260
		30-60	12	8	460
	3 and 4	0-15	24	12	570
		15-30	10	6	200
		30-60	48	10	450
Dryland Flax	1 and 2	0-15	18	8	605
		15-30	11	6	210
		30-60	20	8	440
	3 and 4	0-15	33	12	665
		15-30	20	8	180
		30-60	52	10	440

Table A5 Spring soil analyses of selected treatments for the Pederson alfalfa plot

Treatment (kg/ha)	Rep.	Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4-S
					kg/ha			
0 P_2O_5	1	0-7	7.3	0.6	18	6	165	9
		7-15	7.7	0.4	5	3	105	8
		15-30	7.9	0.6	6	2	270	23
		30-60	8.1	0.7	12	10	780	48+
	2	0-7	7.7	0.7	24	7	155	12+
		7-15	7.8	0.4	10	3	120	11
		15-30	7.9	0.6	17	2	240	21
		30-60	8.2	0.6	18	2	600	48+
	3	0-7	7.2	0.6	16	4	135	6
		7-15	7.4	0.4	7	2	85	6
		15-30	7.6	0.6	11	2	240	17
		30-60	7.8	0.6	18	2	540	48+
	4	0-7	7.8	0.7	13	2	175	12+
		7-15	8.1	0.7	7	1	165	12+
		15-30	8.3	0.7	8	1	300	24+
		30-60	8.0	4.5	16	12	840	48+
84 P_2O_5 Annual	1	0-7	7.6	0.6	16	10	135	8
		7-15	7.7	0.6	6	4	115	11
		15-30	8.0	0.6	10	4	300	21
		30-60	8.1	0.7	18	10	690	48+
	2	0-7	7.6	0.4	19	12	155	9
		7-15	7.7	0.4	8	4	110	8
		15-30	7.7	0.6	14	2	230	17
		30-60	8.1	0.4	18	2	470	34
	3	0-7	7.5	0.6	16	6	115	9
		7-15	7.6	0.4	10	2	90	8
		15-30	7.7	0.4	14	3	195	15
		30-60	7.9	0.4	12	2	400	34
	4	0-7	7.7	0.7	20	9	170	12+
		7-15	8.0	0.7	8	4	155	12+
		15-30	8.1	0.8	14	7	355	24+
		30-60	7.8	3.0	16	6	520	48+

..........continued

Table A5 continued

Treatment (kg/ha)	Rep.	Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4-S
					----------		kg/ha	------
168 P_2O_5 once	1	0-7	7.6	0.6	17	7	140	12+
		7-15	7.8	0.6	8	3	130	12+
		15-30	7.9	0.7	10	2	285	24+
		30-60	7.7	3.1	20	8	760	48+
	2	0-7	7.6	0.4	18	13	150	7
		7-15	7.7	0.3	7	4	110	7
		15-30	7.8	0.4	10	3	235	16
		30-60	8.1	0.4	18	4	480	28
	3	0-7	7.4	0.6	18	12	125	7
		7-15	7.3	0.4	10	5	90	7
		15-30	7.6	0.4	16	6	210	13
		30-60	7.8	0.4	16	4	400	34
	4	0-7	7.8	0.6	16	27	190	12+
		7-15	8.0	0.6	8	8	145	12+
		15-30	8.2	0.7	17	13	360	24+
		30-60	8.0	3.9	24	20	780	48+
336 P_2O_5 once	1	0-7	7.6	0.6	18	36	145	12+
		7-15	7.8	0.6	8	8	115	12+
		15-30	8.0	0.6	15	16	290	24+
		30-60	8.1	0.7	18	20	700	48+
	2	0-7	7.6	0.6	23	33	150	9
		7-15	7.7	0.4	9	9	105	9
		15-30	7.9	0.3	10	8	210	13
		30-60	8.1	0.6	20	10	540	40
	3	0-7	7.5	0.6	18	2	125	6
		7-15	7.5	0.4	8	1	90	6
		15-30	7.6	0.4	10	2	210	15
		30-60	7.9	0.6	18	2	450	38
	4	0-7	7.9	0.6	11	21	170	12+
		7-15	8.1	0.7	8	10	175	12+
		15-30	8.3	0.8	10	17	385	24+
		30-60	7.9	3.9	10	26	870	48+

...........continued

Table A5 continued

Treatment (kg/ha)	Rep.	Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4-S
					-----------		kg/ha	------
112 S Annual	1	0-7	7.5	1.4	25	7	180	12+
		7-15	7.8	0.7	11	3	145	12+
		15-30	8.0	0.7	13	3	265	24+
		30-60	7.8	3.0	18	10	740	48+
	2	0-7	7.7	0.6	18	6	145	12+
		7-15	7.8	0.4	8	2	100	9
		15-30	8.0	0.6	10	2	220	18
		30-60	8.2	0.7	18	4	730	48+
	3	0-7	7.5	0.6	28	5	180	12+
		7-15	7.8	0.6	7	2	120	9
		15-30	7.9	0.6	13	1	285	24+
		30-60	8.1	0.7	20	4	620	48+
	4	0-7	7.8	0.7	13	7	180	12+
		7-15	8.1	0.6	4	3	155	12+
		15-30	8.3	0.8	9	3	335	24+
		30-60	7.9	4.2	10	12	820	48+
224 S Annual	1	0-7	7.8	0.7	15	3	150	12+
		7-15	8.0	0.9	6	2	140	12+
		15-30	8.1	0.8	8	2	320	24+
		30-60	7.8	3.0	4	4	620	48+
	2	0-7	7.8	0.6	16	6	145	12+
		7-15	7.8	0.6	6	2	105	12+
		15-30	7.9	0.4	10	2	220	21
		30-60	8.1	0.6	16	2	610	48+
	3	0-7	7.6	0.6	22	3	135	12+
		7-15	7.7	0.4	6	2	85	12+
		15-30	7.8	0.6	10	1	200	19
		30-60	8.1	0.6	8	2	490	48+
	4	0-7	7.7	0.8	17	4	175	12+
		7-15	8.0	0.7	9	1	150	12+
		15-30	8.2	0.9	11	2	325	24+
		30-60	7.9	3.4	22	4	720	48+

Table A6 Spring soil analyses of selected treatments for the Gross alfalfa plot

Treatment (kg/ha)	Rep.	Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4-S
					----------	kg/ha	----------	
0 P_2O_5	1	0-7	7.6	0.4	14	5	300	12+
		7-15	7.6	0.3	9	3	285	10
		15-30	7.7	0.3	10	3	270	19
		30-60	8.0	0.3	8	4	320	34
	2	0-7	7.8	0.4	12	3	205	7
		7-15	7.9	0.3	5	2	130	8
		15-30	8.0	0.3	10	3	160	17
		30-60	8.2	0.3	16	8	300	48+
	3	0-7	7.9	0.3	10	3	220	9
		7-15	7.7	0.2	5	2	160	10
		15-30	7.8	0.3	5	2	205	20
		30-60	8.1	0.3	8	4	350	28
	4	0-7	7.0	0.4	8	4	215	10
		7-15	7.3	0.4	7	2	180	12+
		15-30	7.6	0.3	6	2	200	19
		30-60	7.9	0.3	8	4	260	32
84 P_2O_5 Annual	1	0-7	7.6	0.3	13	16	270	5
		7-15	7.6	0.3	6	6	260	7
		15-30	7.7	0.3	9	6	245	16
		30-60	8.0	0.3	8	6	270	32
	2	0-7	7.8	0.3	10	5	230	5
		7-15	7.7	0.3	7	3	200	7
		15-30	7.7	0.3	10	4	260	15
		30-60	8.1	0.3	12	8	280	34
	3	0-7	7.8	0.3	9	4	215	5
		7-15	7.8	0.2	8	2	185	7
		15-30	7.8	0.3	14	6	215	16
		30-60	8.1	0.3	8	6	340	32
	4	0-7	7.3	0.4	8	6	220	8
		7-15	7.5	0.3	6	3	165	10
		15-30	7.7	0.4	9	3	180	24+
		30-60	8.0	0.4	12	4	320	48+

..........continued

Table A6 continued

Treatment (kg/ha)	Rep.	Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4-S
					---------- kg/ha			------
168 P_2O_5 Once	1	0-7	7.7	0.3	16	17	265	6
		7-15	7.5	0.3	8	6	235	7
		15-30	7.6	0.3	12	7	245	17
		30-60	7.9	0.3	14	10	320	40
	2	0-7	7.7	0.3	13	21	215	5
		7-15	7.9	0.3	6	7	135	8
		15-30	8.0	0.3	11	13	170	14
		30-60	8.1	0.3	8	14	300	48+
	3	0-7	7.7	0.3	11	15	185	6
		7-15	7.7	0.3	5	5	110	7
		15-30	7.9	0.3	7	6	180	19
		30-60	8.1	0.3	4	8	340	38
	4	0-7	7.4	0.4	13	26	200	8
		7-15	7.6	0.4	6	12	110	10
		15-30	7.7	0.3	14	12	180	24+
		30-60	8.0	0.4	10	12	280	48+
336 P_2O_5 Once	1	0-7	7.5	0.3	14	47	245	6
		7-15	7.6	0.3	8	13	240	8
		15-30	7.8	0.3	8	15	260	20
		30-60	8.0	0.3	8	18	300	34
	2	0-7	7.7	0.3	14	34	225	6
		7-15	7.9	0.3	7	7	130	9
		15-30	8.1	0.3	11	10	170	24+
		30-60	8.2	0.3	10	14	320	48+
	3	0-7	7.7	0.4	13	45	205	8
		7-15	7.8	0.3	5	9	120	11
		15-30	8.0	0.3	12	18	195	21
		30-60	8.2	0.3	12	20	300	46
	4	0-7	7.5	0.4	12	25	215	5
		7-15	7.6	0.3	6	8	145	8
		15-30	7.7	0.3	4	7	180	16
		30-60	8.0	0.3	10	10	320	38

Table A7 Spring soil analyses of selected treatments for the Wudel alfalfa plot

Treatment (kg/ha)	Rep.	Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4-S
					----------		kg/ha	------
0 P_2O_5	1	0-7	7.1	0.4	5	4	125	12+
		7-15	7.5	0.4	2	1	120	10
		15-30	7.7	0.4	2	2	180	24+
	2	0-7	7.4	0.6	12	9	200	8
		7-15	7.6	0.4	6	3	180	12+
		15-30	7.6	0.4	10	2	540	24+
	3	0-7	7.5	0.4	9	11	205	12+
		7-15	7.5	0.6	6	5	210	12+
		15-30	7.6	0.7	16	6	650	24+
	4	0-7	7.1	0.7	7	13	220	12+
		7-15	7.5	1.2	4	5	200	12+
		15-30	8.1	0.7	4	5	260	24+
84 P_2O_5 Annual	1	0-7	7.3	0.6	8	5	140	12+
		7-15	7.6	0.4	2	1	95	8
		15-30	7.7	0.4	2	2	180	16
	2	0-7	7.3	0.6	10	8	200	12+
		7-15	7.5	0.6	5	3	160	12+
		15-30	7.7	0.6	10	2	320	24+
	3	0-7	7.4	0.4	12	11	215	12+
		7-15	7.5	0.6	6	5	220	12+
		15-30	7.6	0.8	12	6	640	24+
	4	0-7	6.9	0.6	9	10	215	12+
		7-15	7.5	1.1	5	9	170	12+
		15-30	7.8	0.6	8	12	260	24+
168 P_2O_5 Once	1	0-7	7.4	0.4	6	7	150	10
		7-15	7.6	0.4	4	4	130	12+
		15-30	7.7	0.4	6	2	240	24+
	2	0-7	7.4	0.6	12	34	240	8
		7-15	7.5	0.4	7	7	175	9
		15-30	7.6	0.4	12	12	530	24+

..........continued

Table A7 continued

Treatment (kg/ha)	Rep.	Depth (cm)	pH	Conductivity mmhos/cm	NO_3-N	P	K	SO_4-S
					----------	kg/ha	------	
	3	0-7	7.4	0.6	13	45	245	12+
		7-15	7.5	0.4	7	9	205	12+
		15-30	7.6	0.7	14	14	580	24+
	4	0-7	7.0	0.6	10	15	170	12+
		7-15	7.6	0.6	4	6	130	12+
		15-30	7.9	0.4	6	7	220	24+
336 P_2O_5 Once	1	0-7	7.4	0.4	6	10	145	12+
		7-15	7.7	0.4	3	5	105	8
		15-30	7.8	0.4	2	4	200	17
	2	0-7	7.2	0.4	11	61	235	9
		7-15	7.5	0.4	7	13	170	12+
		15-30	7.5	0.8	12	14	560	24+
	3	0-7	7.4	0.4	12	34	255	8
		7-15	7.4	0.4	7	11	200	8
		15-30	7.6	0.4	14	14	520	24+
	4	0-7	7.2	0.6	12	25	210	12+
		7-15	7.5	1.1	8	8	235	12+
		15-30	7.8	1.0	6	12	470	24+

Table A8 Legal location and soil type of experimental field plots for 1977 irrigation trials

Farmer Co-operator	Crop Investigated	Legal Location	Soil Type
Tomasiewicz	Sinton hard wheat Glenlea utility wheat Fielder soft wheat	SW28-28-7-W3	Elstow loam
	Enfordia fababeans Trapper peas Great Northern U.S. 1140 beans Tower rapeseed Redwood 65 flax	SW28-28-7-W3	Elstow loam
R. Pederson	Glenlea wheat	SW18-28-7-W3	Asquith sandy loam
M. Larson	Betzes barley	NW26-29-8-W3	Bradwell very fine sandy loam
Barrich Farms Ltd.	Neepawa wheat	NE24-29-8-W3	Asquith sandy loam
	Bonanza barley	NW19-29-7-W3	Asquith sandy loam
	Neepawa wheat	NE19-29-7-W3	Asquith sandy loam
	Neepawa wheat	NE19-29-7-W3	Asquith sandy loam
	Dufferin flax	SE35-29-8-W3	Asquith sandy loam
B. Niska	Fielder soft wheat	NW23-27-7-W3	Elstow loam
	Dufferin flax	NW23-27-7-W3	Elstow loam
A. Pederson	Alfalfa	NE20-28-7-W3	Elstow loam
G. Gross	Alfalfa	NE30-28-7-W3	Bradwell loam
N. Wudel	Alfalfa	SW31-30-7-W3	Bradwell very fine sandy loam

Appendix Table B1. Dates of spring seeding, harvest and seasonal precipitation for the 1977 nitrogen fertilizer experiment

Crop	Seeding Date	Harvest Date	Seasonal Precipitation (mm)
Glenlea Wheat	Apr. 30	Aug. 26	243
Noralta Flax	May 6	Sept. 17	299
Beacon Barley	May 10	Aug. 12	156

Appendix Table B2. Nitrate-nitrogen content of samples taken in the fall of 1976 for the 1977 nitrogen fertilizer experiment

Rep.	Depth (cm)	NO_3-N (kg/ha)* Fall	Spring
1	0-15	54	5
	15-30	65	2
	30-60	82	2
	60-90	192	8
	90-120	132	32
2	0-15	9	8
	15-30	1	2
	30-60	2	4
	60-90	4	2
	90-120	2	24
3	0-15	12	5
	15-30	5	2
	30-60	8	2
	60-90	30	2
	90-120	30	6
4	0-15	16	7
	15-30	1	1
	30-60	2	4
	60-90	6	2
	90-120	2	6
5	0-15	7	18
	15-30	2	11
	30-60	2	6
	60-90	4	4
	90-120	14	4

* kg/ha = ppm x 2 for 15 cm depth and ppm x 4 for 30 cm depth