1978 SOIL-PLANT NUTRIENT RESEARCH REPORT

Compiled by

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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 in 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.

OBJECTIVE

To assess the effects of nitrogen fertilization and irrigation scheduling on the yield and quality of hard wheat, utility wheat and soft wheat and thus, determine if different nitrogen recommendations should be provided for these different market classes of wheat. This was the second year of a three year project.

EXPERIMENTAL METHODS

The site selected for this experiment was on an Elstow clay loam soil (Tomasiewicz farm). This site had been seeded to hard wheat in 1977 under dryland conditions.

Soil analyses from samples taken at seeding time indicated a medium level of available NO_3^--N (Table 1.1.1). It should also be noted that large quantities of NO_3^--N were present in the 30 to 120 cm. depth. As well, some salinity was present at depth.

The varieties used were Sinton hard wheat, Glenlea utility wheat and Fielder soft wheat. The site was plowed and harrowed prior to seeding with a double disc press drill with seven rows per treatment and an 18 cm. row spacing. Individual plot lengths were 4.5 meters.

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

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*			
Sinton	0-15	7.9	0.4	15	4	725	24
Water C & X	15-30	8.1	0.6	24	1	300	24
	30-60	8.4	2.2	64 103	8	590	48
	60-90	8.2	5.5	30	24	800	48
	90-120	8.0	6.3	26	20	750	48
Sinton	0-15	7.6	0.3	13	8	385	10
Water A & B	15-30	7.8	0.3	11	4	200	7
	30-60	7.9	0.6	32 56	6	390	25
	60-90	8.1	2.6	32	8	640	48
	90-120	7.7	3.3	22	8	800	48
Glenlea	0-15	7.8	0.3	13	10	580	11
Water C & X	15-30	8.0	0.4	21	4	150	17
	30-60	8.2	1.8	52 86	4	320	48
	60-90	8.2	6.1	28	28	460	48
	90-120	8.1	5.7	16	22	580	48
Glenlea	0-15	7.8	0.4	13	6	550	21
Water A & B	15-30	7.9	0.4	13	2	230	9
	30-60	8.2	0.4	24 50	4	460	26
	60-90	8.3	1.9	46	4	620	48
	90-120	8.2	3.4	34	14	385	48
Fielder	0-15	7.8	0.3	11	4	450	9
Water C & X	15-30	8.0	0.3	13	2	160	16
	30-60	8.0	1.0	30 54	4	400	48
	60-90	8.2	3.0	40	12	520	48
	90-120	8.1	4.7	34	18	620	48
Fielder	0-15	7.9	0.4	11	5	630	10
Water A & B	15-30	8.0	0.4	15	2	225	24
	30-60	8.1	2.9	50 76	6	700	48
	60-90	8.1	4.0	42	12	1340	48
	90-120	8.1	3.3	24	8	1380	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

broadcast application of ammonium nitrate (34-0-0) applied after seeding.

Post-emergent herbicides included Hoegrass for control of wild oats and green foxtail and 2, 4-D amine - Banvel LH tank mix for the control of broadleaf weeds. Weed control was excellent 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 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 meters. The samples were then dried, weighed and threshed. The grain samples were then cleaned and weighed. Subsamples of straw were taken, replicates of individual treatments bulked, mixed and ground. Subsamples of the 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	Total Water (Irrigation & Rain) (mm)
Sinton A	(Growing Season Rainfall = 123 mm) June 19, 72 mm; June 24, 64 mm; July 4, 80 mm; July 17, 32 mm; July 26, 17 mm; July 27, 18 mm; July 28, 52 mm.	458
B	(Growing Season Rainfall = 112 mm) June 6, 28 mm; June 7, 47 mm; June 24, 41 mm; July 4, 73 mm; July 17, 64 mm; July 26, 11 mm; July 27, 16 mm; July 28, 35 mm.	427
C	(Growing Season Rainfall = 112 mm) June 3, 61 mm; June 14, 78 mm; June 23, 56 mm; July 1, 72 mm; July 11, 53 mm; July 24, 84 mm.	516
Glenlea A	(Growing Season Rainfall = 123 mm) June 19, 92 mm; June 24, 77 mm; July 4, 83 mm; July 17, 26 mm; July 26, 22 mm; July 27, 21 mm; July 28, 63 mm.	507
B	(Growing Season Rainfall = 112 mm) June 6, 19 mm; June 7, 47 mm; June 24, 77 mm; July 4, 97 mm; July 17, 73 mm; July 26, 24 mm; July 27, 22 mm; July 28, 57 mm.	528
C	(Growing Season Rainfall = 112 mm) June 3, 67 mm; June 14, 83 mm; June 23, 57 mm; July 1, 83 mm; July 11, 76 mm; July 24, 85 mm.	563
Fielder A	(Growing Season Rainfall = 123 mm) June 19, 75 mm; June 24, 78 mm; July 4, 89 mm; July 17, 38 mm; July 26, 23 mm; July 27, 17 mm; July 28, 59 mm.	502
B	(Growing Season Rainfall = 112 mm) June 6, 24 mm; June 7, 43 mm; June 24, 71 mm; July 4, 85 mm; July 17, 70 mm; July 26, 17 mm; July 27, 20 mm; July 28, 58 mm.	500
C	(Growing Season Rainfall = 112 mm) June 3, 63 mm; June 14, 102 mm; June 23, 50 mm; July 1, 75 mm; July 11, 56 mm; July 24, 88 mm.	546

Differences in Growing Season Rainfall are due to different harvest dates.

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 results reported are the mean of four replicates.

Grain yields for the three wheat varieties, grown on the Elstow clay loam soil which had a low to medium NO_3^--N content (0-60 cm), 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. There was no response to nitrogen fertilization under dryland conditions.

A moisture stress late in the growing season (Water B) reduced the response to fertilizer nitrogen more than a moisture stress early in the growing season (Water A). This was the opposite to what was found in 1977 for this same experiment. The reason for this discrepancy is believed to be due to a second growth in the Water A treatment. In 1977 this second growth was lost at harvest time due to it being green and immature. On the other hand, in 1978 the second growth was saved by harvesting the Water A treatment two weeks later than the Water B treatment and thus allowing the second growth to reach maturity. Obviously the early water stress provided was not severe enough to kill off the tillers as evidenced by the second growth.

The differences in grain yield for the three irrigation schedules (Water A, B, and C) were most pronounced for the Fielder soft wheat followed in turn by the Glenlea utility wheat then the Sinton hard wheat. Highest grain yields were found where little or no moisture stress was

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 the Elstow soil.

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)
				Water A				
0	1843	2051	0.90	13.0	0.61	48.6	12.5	61.1
56	3206	4053	0.81	13.2	0.74	85.8	30.0	115.8
84	3319	4291	0.78	13.5	0.59	90.9	25.3	126.2
112	3818	5107	0.75	13.8	0.85	106.9	43.4	150.3
168	3649	4860	0.76	14.4	0.98	106.6	47.6	154.2
224	3555	4641	0.77	14.5	0.74	104.5	34.3	138.8
L.S.D. (P=0.05)	670	777	0.15					
				Water B				
0	1918	2309	0.90	11.6	0.29	45.1	6.7	51.8
56	2624	3664	0.72	12.7	0.45	67.6	16.5	84.1
84	2632	3925	0.69	13.6	0.43	72.6	16.9	89.5
112	3132	4620	0.69	13.8	0.51	87.7	23.6	111.3
168	3113	4310	0.73	14.8	0.53	93.4	22.8	116.2
224	3346	4683	0.74	14.8	0.50	100.4	23.4	123.8
L.S.D. (P=0.05)	760	1129	0.26					
				Water C				
0	2743	3008	0.92	11.9	0.29	66.2	8.7	74.9
56	4015	5144	0.78	11.7	0.46	95.3	23.7	119.0
84	4000	5317	0.75	11.9	0.37	96.5	19.7	116.2
112	4119	5879	0.71	12.5	0.51	104.4	30.0	134.4
168	4872	6489	0.75	13.1	0.51	129.4	33.1	162.5
224	4310	6079	0.72	13.7	0.39	119.8	23.7	143.5
L.S.D. (P=0.05)	729	1084	0.09					
				Dryland				
0	597	870	0.69	14.3	0.81	17.3	7.0	24.3
56	741	1089	0.69	14.4	0.83	21.6	9.0	30.6
84	721	1006	0.71	14.8	0.88	21.6	8.9	30.5
112	688	1064	0.72	14.8	0.78	20.7	8.3	29.0
168	725	744	1.08	15.4	0.91	22.6	6.8	29.4
224	718	981	0.73	15.0	0.90	21.8	8.8	30.6
L.S.D. (P=0.05)	199	322	0.42					

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

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 Grain ---(kg/ha)---	Yield Straw ---(kg/ha)---	Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake Grain -------(kg/ha)---------	Nitrogen Uptake Straw	Nitrogen Uptake Total
				Water A				
0	2057	2130	0.97	11.2	0.45	46.7	9.6	56.3
56	3097	3656	0.87	12.1	0.61	76.0	22.3	98.3
84	3475	4128	0.84	12.5	0.39	88.1	16.1	104.2
112	3315	4280	0.78	13.0	0.59	87.4	25.3	112.7
168	3478	4394	0.79	13.1	0.72	92.4	31.6	124.0
224	3680	4699	0.82	13.4	0.44	100.0	20.7	120.7
L.S.D. (P=0.05)	649	921	0.15					
				Water B				
0	1905	2317	0.82	10.2	0.28	39.4	6.5	45.9
56	3019	4427	0.69	11.5	0.37	70.4	16.4	86.8
84	3028	4619	0.66	12.7	0.37	78.0	17.1	95.1
112	2652	4539	0.58	14.2	0.30	76.4	13.6	90.0
168	3373	5123	0.66	13.9	0.29	95.1	14.9	110.0
224	3139	4968	0.64	14.2	0.48	90.4	23.8	114.2
L.S.D. (P=0.05)	373	660	0.09					
				Water C				
0	3240	3428	0.96	9.1	0.27	59.8	9.3	69.1
56	4674	6865	0.68	9.6	0.27	91.0	18.5	109.5
84	4976	6889	0.73	10.5	0.27	106.0	18.6	124.6
112	4841	7103	0.68	11.4	0.30	111.9	21.3	133.2
168	4687	7756	0.61	12.4	0.38	117.9	29.5	147.4
224	4910	6795	0.73	12.8	0.36	127.5	24.5	152.0
L.S.D. (P=0.05)	691	902	0.11					
				Dryland				
0	436	911	0.47	14.8	0.75	13.1	6.8	19.9
56	502	1107	0.45	15.7	0.74	16.0	8.2	24.2
84	532	1119	0.47	15.7	0.83	16.9	9.3	26.2
112	315	1246	0.29	16.1	0.78	10.3	9.7	20.0
168	471	1209	0.37	16.3	0.82	15.6	9.9	25.5
224	348	1024	0.33	16.8	0.93	11.9	9.5	21.4
L.S.D. (P=0.05)	224	393	0.16					

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

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 Grain	Yield Straw	Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake Grain	Nitrogen Uptake Straw	Nitrogen Uptake Total
	---(kg/ha)---					------(kg/ha)	--------	
				Water A				
0	2345	2299	1.01	10.5	0.49	49.9	11.3	61.2
56	3599	3347	1.09	10.8	0.74	78.8	24.8	103.6
84	3776	3801	1.00	11.2	0.47	85.8	17.9	103.7
112	3513	3424	1.03	11.6	0.72	82.7	24.7	107.4
168	3769	4049	0.93	11.7	0.83	89.4	33.6	123.0
224	3456	3614	0.97	11.8	0.60	82.7	21.7	104.4
L.S.D. (P=0.05)	612	547	0.11					
				Water B				
0	1924	2298	0.87	9.3	0.42	36.3	9.7	46.0
56	2770	3907	0.71	11.6	0.64	65.2	25.0	90.2
84	2522	3974	0.64	12.6	0.62	64.5	24.6	89.1
112	4584	2514	2.02	12.6	0.67	117.1	16.8	133.9
168	3042	4184	0.73	12.7	0.72	78.4	30.1	108.5
224	2875	4335	0.68	12.8	0.67	74.6	29.0	103.6
L.S.D. (P=0.05)	979	670	0.57					
				Water C				
0	2979	2689	1.11	9.0	0.34	54.4	9.1	63.5
56	4651	5057	0.93	9.4	0.50	88.7	25.3	114.0
84	5181	5368	0.98	10.1	0.40	106.1	21.5	127.6
112	3605	7425	0.53	10.0	0.64	73.1	47.5	120.6
168	5499	5619	0.98	11.1	0.74	123.8	41.6	165.4
224	5314	5298	1.01	11.0	0.65	118.6	34.4	153.0
L.S.D. (P=0.05)	719	1259	0.18					
				Dryland				
0	658	861	0.78	11.7	0.57	15.6	7.4	23.0
56	635	793	0.80	13.8	0.86	17.8	6.8	24.6
84	676	773	0.90	14.0	0.82	19.2	6.3	25.5
112	663	744	1.15	14.1	0.93	19.0	6.9	25.9
168	648	749	0.87	14.3	0.88	18.8	6.6	25.4
224	718	847	0.85	14.3	0.84	20.8	7.1	27.9
L.S.D. (P=0.05)	130	216	0.52					

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

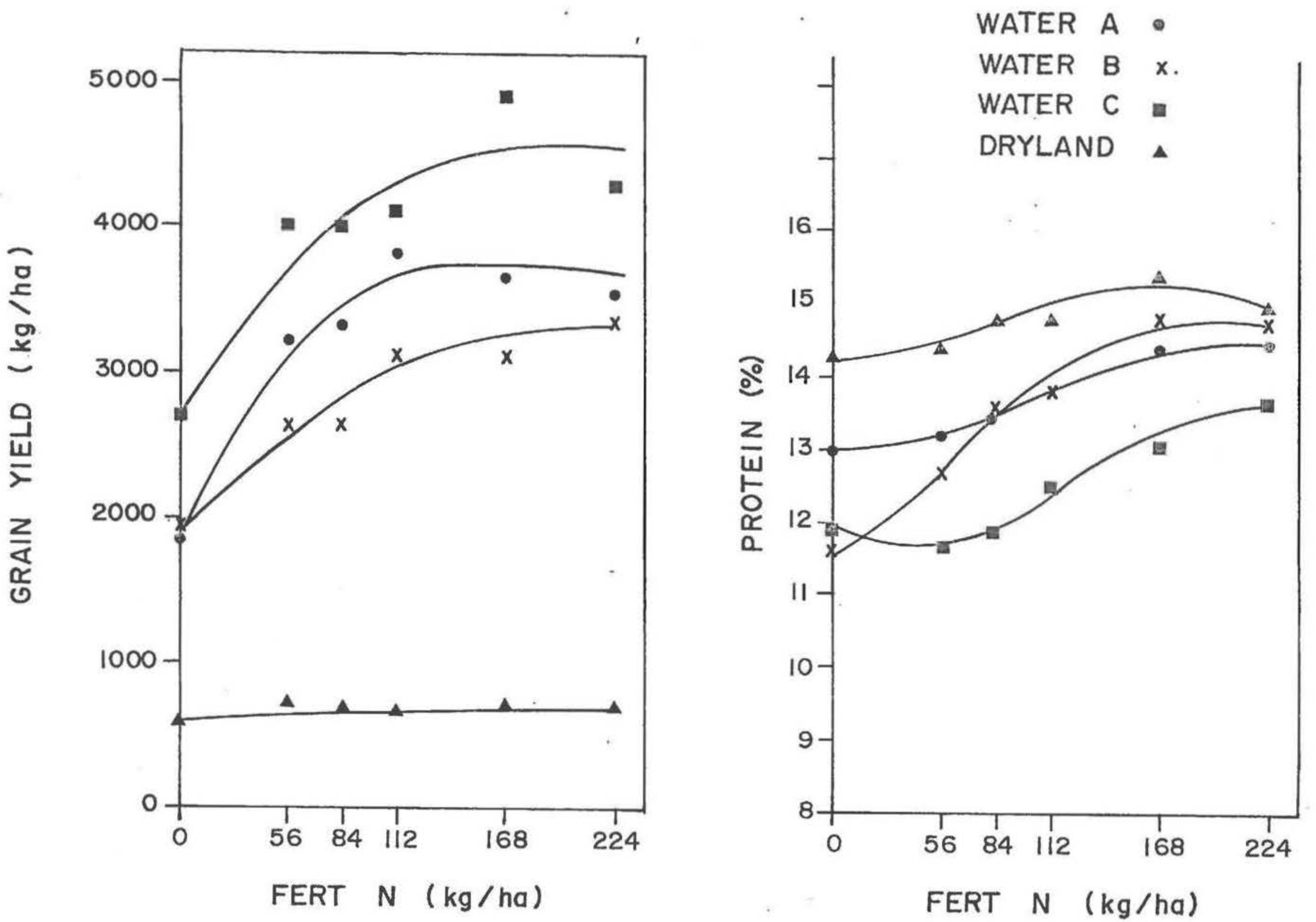

Figure 1.1.1. The effect of nitrogen fertilization on the yield and protein content of Sinton hard wheat.

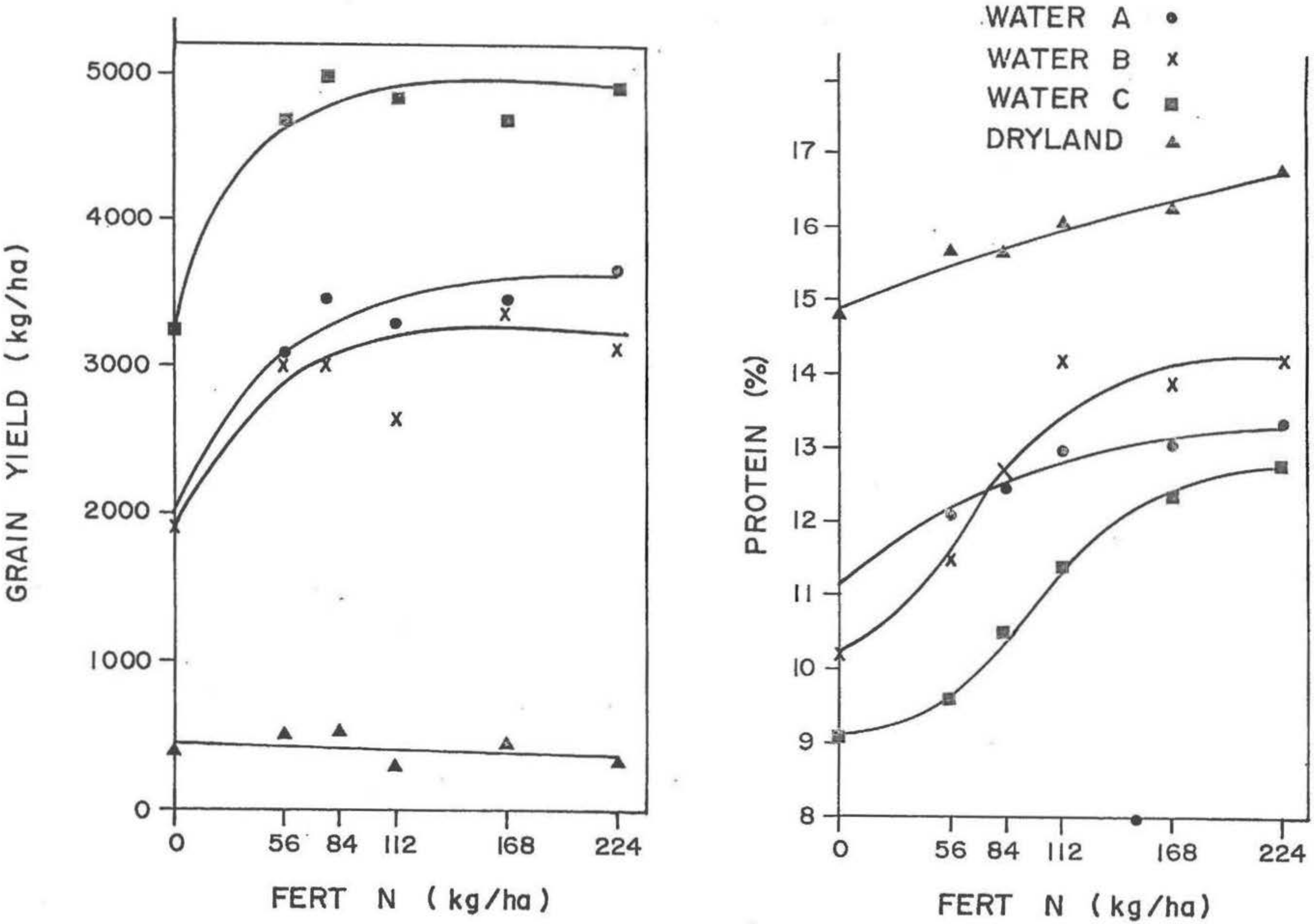

Figure 1.1.2. The effect of nitrogen fertilization on the yield and protein content of Glenlea utility wheat.

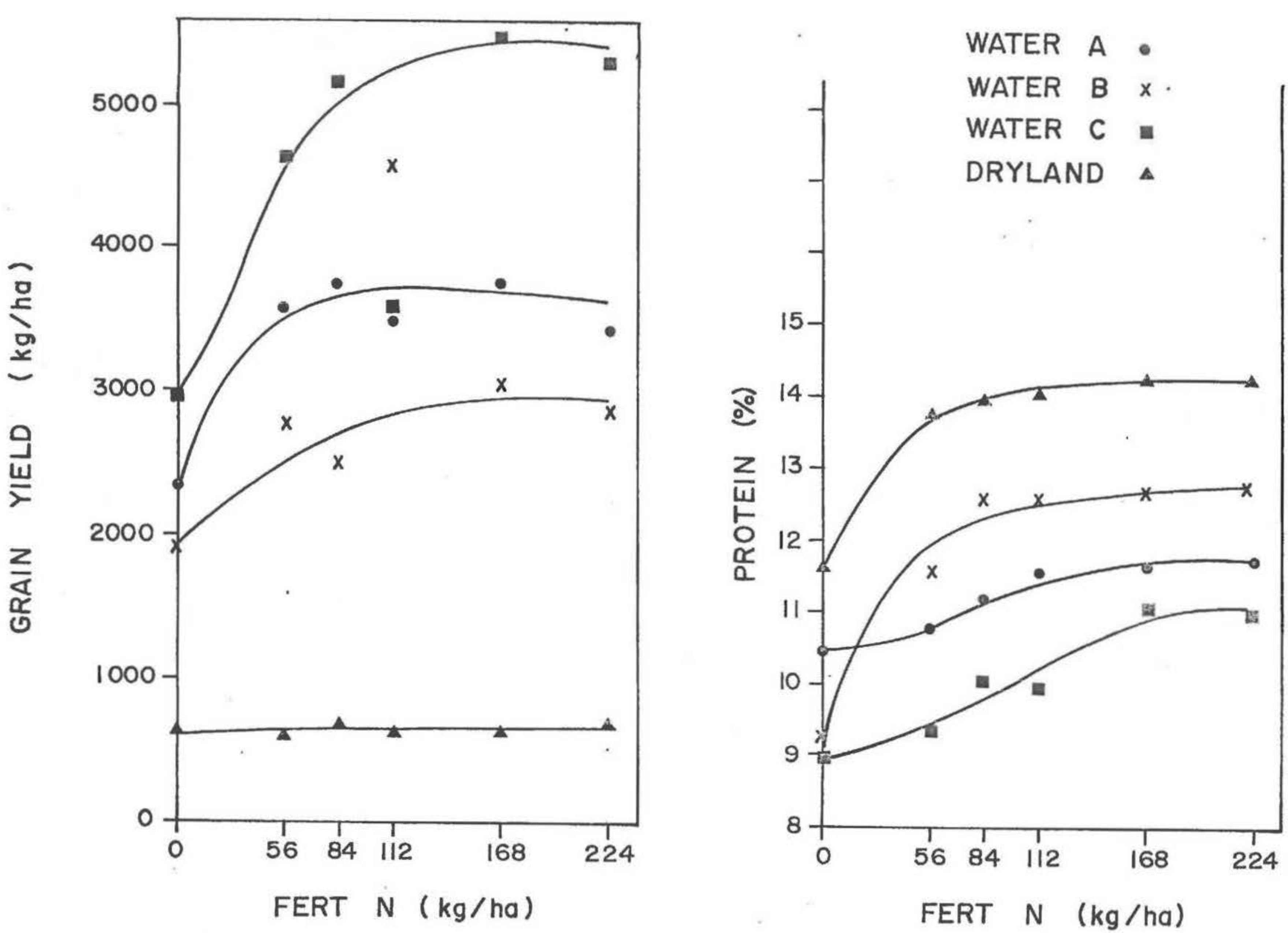

Figure 1.1.3. The effect of nitrogen fertilization on the yield and protein content of fielder soft wheat.

involved and high rates of nitrogen were applied for all three wheat varieties. Under these conditions the highest grain yield obtained was approximately 5500 kg/ha for the Fielder soft wheat. This yield for the Fielder soft wheat is higher than that found in 1977 (4100 to 4200 kg/ha) for the same experiment but of a similar magnitude (5300 kg/ha) found in previous research in the South Saskatchewan River Irrigation Project. The Sinton hard wheat and Glenlea utility wheat produced yields of approximately 4900 kg/ha under the same conditions. The Sinton hard wheat yield showed an increase over that obtained in 1977 for the same experiment while the yield for the Glenlea utility wheat was similar to that obtained in 1977 for the same experiment.

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 applied. 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, the exception being for the Sinton and Fielder dryland treatments where little change was observed. 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 showed a similar trend for the three wheat varieties. Generally, grain/straw ratios were greater where water was applied than on the dryland plots. This same trend was not observed in 1977 for the same experiment but has been found in previous research with soft wheat. This suggests that grain production is more efficient when more moisture is available for crop growth.

Grain protein content and straw nitrogen content increased with increases in nitrogen fertilization. This trend was most noticeable where the wheat was subjected to a moisture stress. The greater the moisture stress, the higher were both grain protein and straw nitrogen contents 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 was an overall increase in total nitrogen uptake by the wheat varieties. As well, greater nitrogen uptake occurred where little or no moisture stress was involved, and it decreased the greater was the moisture stress.

The seasonal water use data for the three wheat varieties and different irrigation treatments are presented in Table 1.1.8. The amount of irrigation water applied was greater for Water C than either Water A or Water B, the latter two irrigation treatments being similar. This was expected since both Water A and Water B missed one of the irrigation applications to provide a water stress to the plants at different points in the growing season. There was excess water present in the soil in the fall compared to that in the spring for the three irrigation treatments indicating that not all the water applied was used by the crops. However, there was a deficit situation for the change in soil moisture content for the dryland cropping treatment indicating that the soil had been dried out providing a large water stress to the crop. The overall water use pattern was of the order Water C > Water A > Water B >> Dryland which was the same as the yield pattern indicating greater water use with increased yield. Total water use was similar for the Glenlea utility wheat and Fielder soft

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	123	335	-24	434
	B	112	315	-58	369
	C	112	404	-53	463
	X	108	0	27	135
Glenlea	A	123	384	-27	480
	B	112	416	-69	459
	C	112	451	-35	528
	X	108	0	42	150
Fielder	A	123	379	-22	480
	B	112	388	-42	458
	C	112	434	-40	506
	X	108	0	39	147

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

** Total water use = rainfall + irrigation + ΔS wheat which was greater than that for the Sinton hard wheat. Somewhat similar results were found in 1977 for the same experiment.

The residual NO_3^--N levels in the soil after harvest of the crops for the 0 and 224 kg N/ha application rates under the Water A, Water C, and Dryland irrigation treatments are presented in Table 1.1.9. The results for the individual replicates are presented in Appendix Table A2. The results, though somewhat variable, indicate greater levels of residual NO_3^--N for the Dryland than for either the Water A or Water C treatments. The majority of the NO_3^--N for the Dryland treatment was found in the 0-15 cm depth while for the Water A and Water C treatments, greater NO_3^--N levels were found at lower depths. This indicates movement downward of the NO_3^--N with the irrigation applications. Obviously, more of the applied fertilizer nitrogen was used by the crop when irrigated.

The residual NO_3^--N levels in the 0-15 cm depth for all of the fertilizer nitrogen application rates for the Dryland treatment are presented in Table 1.1.10. The results for the individual replicates are presented in Appendix Table A3. The results indicate that as the rate of fertilizer nitrogen applied was increased more residual NO_3^--N was found in the 0-15 cm depth at the end of the growing season. More nitrogen was being supplied to the crop than could be utilized under the Dryland growing conditions.

Table 1.1.9. Residual NO_3^--N levels from selected rates of nitrogen application and irrigation treatments.

Depth (cm)	Water A N Rate (kg/ha) 0	Water A N Rate (kg/ha) 224	Water B N Rate (kg/ha) 0	Water B N Rate (kg/ha) 224	Dryland N Rate (kg/ha) 0	Dryland N Rate (kg/ha) 224
	kg NO_3^--N/ha*					
Sinton						
0-15	11	12	11	12	13	215
15-30	8	10	7	13	7	19
30-60	12	31	10	49	30	39
60-90	12	49	14	47	32	29
90-120	27	44	26	24	42	29
Glenlea						
0-15	10	11	9	12	8	158
15-30	8	24	6	25	6	18
30-60	11	80	9	106	20	36
60-90	18	67	17	49	18	24
90-120	19	46	19	22	16	21
Fielder						
0-15	8	8	10	14	11	173
15-30	5	14	6	9	6	19
30-60	13	106	12	90	13	31
60-90	25	71	12	51	16	20
90-120	38	36	25	30	17	32

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

Table 1.1.10. Residual NO_3^--N levels in the 0-15 cm depth for the dryland treatment.

N Applied (kg/ha)	Residual NO_3^--N (kg/ha)*		
	Sinton	Glenlea	Fielder
0	13	8	11
56	44	33	44
84	56	61	65
112	80	58	80
168	194	160	183
224	215	158	173

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

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

INTRODUCTION

Established fields of irrigated alfalfa in the South Saskatchewan River Irrigation Project have been found to become less productive with time. For this reason these alfalfa fields are taken out of production by breaking them up. In most cases the alfalfa breaking is seeded to an annual crop. The nitrogen status of alfalfa breaking under irrigation has not been adequately studied with the result that nitrogen recommendations are based on those for stubble seeded crops. Therefore, it was considered necessary to carry out a research project to determine the modifications that should be made to existing soil test nitrogen benchmarks to take into account nitrogen mineralized when alfalfa is broken and seeded to an annual crop in the same year. This project was initiated in 1977 with one field experiment conducted in that year.

OBJECTIVE

To assess the response of irrigated annual crops to nitrogen fertilization on alfalfa breaking and thus determine the contribution alfalfa breaking makes to supplying nitrogen to the growing crop.

EXPERIMENTAL METHODS

Two sites were selected in the spring of 1978, one on an Asquith sandy loam soil (Pederson site) and the other on an Elstow loam soil (Mathison site). Both fields were broken in the spring of 1978. Gravity irrigation was used at both sites.

The results of the analyses of the soil samples taken prior to seeding are presented in Table 1.2.1 with the results for the individual replicates presented in Appendix Table A4. The results indicate low levels of NO_3^--N present in the top 60 cm at both sites. Phosphorus and potassium levels were also low while sulfur was adequate.

The Pederson site was seeded to Glenlea wheat and the Mathison site was seeded to Betzes barley. All pre-seeding tillage and seeding operations were as conducted by the cooperating farmers. Phosphate was applied by the cooperating farmer with the seed during the seeding operation.

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

All herbicide applications for weed control and irrigation applications were as conducted by the cooperating farmers.

One of the control treatments which received no additional nitrogen (Treatment 8) was used for time-step plant 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 meter. Total above ground dry matter production was recorded and then samples were ground in preparation for total nitrogen and phosphorus analyses.

At harvest, yield samples were taken from all treatments, except

Table 1.2.1. Spring soil analyses for the alfalfa breaking experiment under irrigation

Depth (cm)	pH	Conductivity mmhos/cm	NO_3^--N	P	K	$SO_4^=$-S
			------------	------------ kg/ha*	------------	------------
		Pederson Site				
0-15	8.1	0.4	9	4	188	24
15-30	8.2	0.4	7	3	182	24
30-60	8.3	0.4	15	7	460	48
		Matheson Site				
0-15	7.5	1.3	10	6	163	24
15-30	8.0	2.1	7	6	136	24
30-60	8.2	2.9	13	12	320	48
60-90	8.5	3.9	16	15	443	48
90-120	8.3	5.6	19	17	562	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 annual crops on alfalfa breaking experiment under irrigation

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

[1]Treatment number 8 used for time-step sampling

[2]Nitrogen applied as surface broadcast ammonium nitrate (34-0-0) after seeding

Treatment 8, by clipping at the soil surface three rows over a length of 3 meters. 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 protein content of the grain using a Technicon Infra Analyzer while nitrogen content was determined by wet digestion and colorimetric analysis using a Technicon Auto Analyzer II System.

RESULTS AND DISCUSSION

The results for the time-step sampling are presented in Table 1.2.3. Total above ground yield increased with each growth stage for both the Glenlea wheat and Betzes barley. The nitrogen and phosphorus content of the plant material decreased with time but both nitrogen and phosphorus uptake increases with time due to the yield increases. Similar results were found for Glenlea wheat grown on alfalfa breaking in 1977, however, larger yields and greater nitrogen and phosphorus uptake were found in the 1977 results.

The results for the effect of nitrogen fertilization on the yield, protein content and nitrogen uptake of the Glenlea wheat and Betzes barley are presented in Tables 1.2.4 and 1.2.5 respectively. Both grain yield and straw yield showed a small increase for the Glenlea wheat and Betzes barley where fertilizer nitrogen was applied. As well, grain/straw ratios were lowered at the high rates of fertilizer nitrogen application an indication of a yield increase in the above ground plant material. Grain protein content and straw nitrogen content also increased at the higher fertilizer nitrogen application rates.

Table 1.2.3. The yield, nitrogen content and nitrogen uptake of irrigated Glenlea wheat and Betzes barley at five growth stages on alfalfa breaking

Crop	Growth Stage	Number of Days After Seeding	Yield (kg/ha)	% N	Nitrogen Uptake (kg/ha)	% P	Phosphorus Uptake (kg/ha)
		Pederson Site (Asquith Sandy loam)					
Glenlea Wheat	Tillering	37	954	3.46	33.0	0.18	1.7
	Flagleaf	44	1897	2.02	38.3	0.22	4.2
	Heading	52	2754	1.78	49.0	0.20	5.5
	Early milk	67	4880	1.07	52.2	0.15	7.3
	Maturity	90	6749	0.74	49.4	0.11	7.4
		Matheson Site (Elstow loam)					
Betzes Barley	Tillering	23	295	6.10	18.0	0.35	1.0
	Flagleaf	38	2120	2.91	61.7	0.32	6.8
	Heading	47	3057	2.24	68.5	0.28	8.6
	Early milk	61	5485	1.24	68.0	0.20	11.0
	Maturity	102	9045	0.86	77.8	0.14	12.7

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 (Pederson site)

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)
0	2413	3419	0.71	9.9	0.41	48.5	14.0	62.5
28	3065	3985	0.77	10.5	0.37	65.3	14.7	80.0
56	3080	4551	0.69	10.9	0.41	68.1	18.7	86.8
84	2916	4597	0.66	11.5	0.44	68.0	20.2	88.2
112	3187	5209	0.62	11.2	0.53	72.4	27.6	100.0
168	2767	5059	0.59	12.4	0.54	69.6	27.3	96.9
224	3130	4918	0.65	12.8	0.56	81.3	27.5	108.8
0	2698	3380	0.80	10.1	0.38	55.3	12.8	68.1
0	2981	3982	0.77	10.3	0.38	62.3	15.1	77.4
L.S.D. (P = 0.05)	538	854	0.11					

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

Table 1.2.5. The effect of nitrogen fertilization on the yield, nitrogen content and nitrogen uptake of irrigated Betzes barley grown on alfalfa breaking (Matheson site)

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)
0	3650	4890	0.81	8.4	0.58	56.7	28.4	85.1
28	3225	6920	0.47	8.0	0.50	47.7	34.6	82.3
56	4017	6776	0.60	8.7	0.81	64.6	54.9	119.5
84	4440	7153	0.64	8.8	0.79	72.3	56.5	129.8
112	4021	7093	0.59	10.3	0.97	76.6	68.8	145.4
168	4176	9502	0.46	10.4	1.03	80.3	97.9	178.2
224	3053	7138	0.47	11.4	1.34	64.4	95.6	160.0
0	4816	4953	0.98	7.3	0.53	65.0	26.3	91.3
0	5180	5107	1.05	7.1	0.52	68.0	26.6	94.6
L.S.D. (P = 0.05)	911	1621	0.23					

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

This work indicates that the release of mineral nitrogen in the year of alfalfa breaking under irrigation is sufficiently rapid enough to meet a large portion of a cereal crop's nitrogen requirements. Some response was observed to applications of fertilizer nitrogen. Further investigations to obtain more data are required before changes in the present nutrient requirement guidelines are recommended.

1.3 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, beans, lentils, rapeseed, and flax under irrigated and dryland conditions.

This was the third and final year of a joint project between the Crop Development Center and the Department of Soil Science, University of Saskatchewan.

EXPERIMENTAL METHODS

The site selected for the final year of this experiment was on an Elstow clay loam soil in the South Saskatchewan River Irrigation Project. This site had been seeded to wheat in 1977. The plot was duplicated to provide a dryland and an irrigated treatment.

The results of the soil analyses of soil samples taken in the spring prior to establishing the plot are presented in Table 1.3.1. The results indicate low levels of soil phosphorus (0-15 cm) and medium levels of soil NO_3^--N (0-60 cm) were present.

The cultivars used were: fababeans-Erfordia; peas-Trapper; beans-Great Northern U.S. 1140; lentils-P.I. 179307 (Eston); flax-Redwood 65;

Table 1.3.1. Spring soil analyses for the phosphorus placement experiment

Treatment	Depth (cm)	pH	Conductivity (mmhos/cm)	NO_3^--N	P	K	SO_4-S
				-----------		kg/ha*	--------
Dryland	0-15	7.7	0.3	12	8	460	9
	15-30	7.8	0.4	13	3	200	24
	30-60	8.1	1.4	20	4	340	48
	60-90	8.4	2.0	20	20	600	48
	90-120	8.1	4.4	8	18	810	48
Irrigated	0-15	7.6	0.3	11	7	650	9
	15-30	7.9	0.3	11	2	240	7
	30-60	8.2	0.4	18 40	6	420	25
	60-90	8.4	2.0	22	14	380	48
	90-120	8.1	5.0	20	20	720	48

*kg/ha = ppm x 2 for 15 cm depth and ppm x 4 for 30 cm depth and rapeseed-Tower.

The entire plot area was plowed and harrowed prior to seeding with a hoe-press drill with eight rows per plot and an 18 cm row spacing. This hoe-press drill was specially designed by the Crop Development Center, 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 meters.

The fertilizer treatments used are presented in Table 1.3.2. The phosphorus source utilized was monoammonium phosphate (11-55-0) for all treatments. No additional nitrogen was utilized for the pulse crops which were innoculated with commercial rhizobium prior to seeding. The flax and rapeseed received an additional 112 kg N/ha for all treatments except Number 7. This nitrogen was applied as surface broadcast ammonium nitrate (34-0-0) at seeding time. As well, the irrigated rapeseed received an additional 112 kg N/ha on July 10 applied as surface broadcast ammonium nitrate.

Avadex/Treflan tank mix was spring applied and double-harrow incorporated pre-plant for fababeans, peas, beans, and rapeseed, and post-plant pre-emerge for lentils and flax. Dinoseb amine was used for post-emerge weed control in fababeans, peas, and lentils. Some additional handweeding was done in all plots.

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

Irrigation of the plot designated for this purpose was conducted using a specially designed sprinkler system for small plot work. The

Table 1.3.2. The treatments 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	side band
9	34	side band
10	50	side band
11	67	side band
12	101	side band

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

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 0.7 atm. The amount of water to apply was determined by the readings obtained by the deep tensiometers as indicated in Table 1.3.3. The timing and amounts of irrigation water applied are presented in Table 1.3.4.

Neutron access tubes were installed to a depth of 120 cm in fertility treatment 10 of all four 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 seeding time, at two week 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 four replicates in all crops of the dryland plot.

At harvest yield samples were taken by hand cutting at the soil surface the four center rows of the eight row plot over a length of 2.3 m for the irrigated and 3 m for the dryland fababeans, lentils, and rapeseed; the eight rows over a length of 2.3 m for the irrigated beans and dryland flax; and the entire eight row plot for the irrigated peas and dryland peas and beans. The samples were then dried, weighed,

Table 1.3.3. 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 1.3.4. 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	120	June 7, 73 mm; June 19, 86 mm; July 4, 82 mm; July 17, 69 mm; July 26, 17 mm; July 28, 56 mm; Aug. 5, 61 mm; Aug. 11, 54 mm.	618
Peas	120	June 9, 17 mm; June 12, 28 mm; June 13, 40 mm; June 25, 68 mm; July 6, 88 mm; July 20, 80 mm; Aug. 3, 64 mm.	505
Beans	120	June 9, 16 mm; June 12, 30 mm; June 13, 46 mm; June 27, 90 mm; July 18, 73 mm; Aug. 3, 58 mm; Aug. 12, 48 mm.	481
Lentils	111	June 14, 67 mm; July 2, 94 mm; July 20, 67 mm.	339
Rapeseed	117	June 8, 71 mm; June 20, 80 mm; July 2, 83 mm; July 12, 66 mm; July 25, 86 mm; Aug. 6, 54 mm.	557

and threshed. All grain samples were cleaned and weighed. Subsamples of grain for the pulse crops (replicates kept separate) and straw (replicates bulked) of each treatment were ground in preparation for nitrogen and phosphorus analysis. Nitrogen was determined on the grain by the Udy-dye binding method using a Udy analyzer[1]. Straw nitrogen and phosphorus contents were determined by wet digestion and colorimetric analysis using a Technicon Auto Analyzer 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 fertilizer that was placed with the seed at seeding time.

RESULTS AND DISCUSSION

The results of the effect of phosphate rate and placement on the stand of crops is presented in Figure 1.3.1. The irrigated and dryland plots were averaged as the two moisture treatments had been handled identically up to the time that plant counts were taken. No results for flax are presented since poor stands were established and the irrigated flax plot was eventually discontinued.

For fababeans and rapeseed there was no effect of phosphate placement on plant counts. However, for rapeseed, stand counts decreased as the rate of phosphate applied increased.

For peas, beans, and lentils the placement of phosphate did effect the stand of the crop. Seed-placed phosphate reduced the stand for all

[1]Bernard, C. M. 1980. The effect of phosphate fertilizer placement and rates on pulse crops in Saskatchewan. M. Sc. Thesis. Department of Crop Science, University of Saskatchewan, Saskatoon, Saskatchewan.

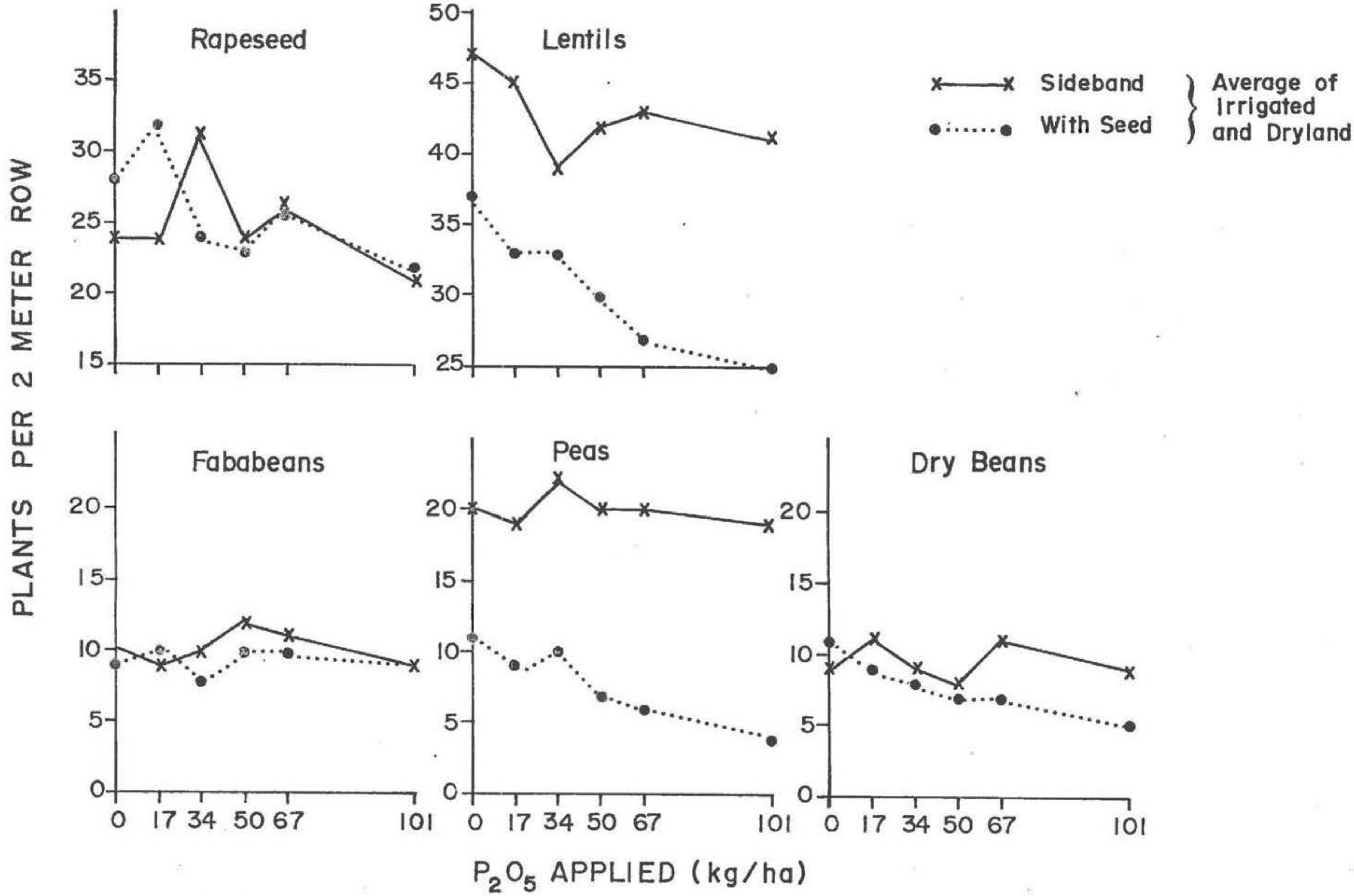

Figure 1.3.1. The effect of phosphate rate and placement on the stand of crops.

three crops over that of the side-band phosphate. This effect was noticeable more so for the peas and lentils than the beans. As well, as the rate of seed-placed phosphate increased, plant counts decreased for the three crops. This same effect was not observed with the side-band phosphate.

Similar results for plant counts were found in both 1976 and 1977.

The results of the effect of phosphate rate and placement on the yield, protein content, nitrogen uptake and phosphorus content of the crops are presented in Tables 1.3.5 to 1.3.15. Grain and straw yields are also presented graphically in Figures 1.3.2 and 1.3.3 respectively.

Under dryland conditions grain yields showed no response to either the rate or placement of the phosphate fertilizer for all of the crops. Similar results were found in 1976 and 1977.

Under irrigated conditions grain yields of some of the crops showed a response to the applied phosphate. Both peas and beans showed an increase in grain yield to the side-band phosphate application. No response was observed for these two crops to seed-placed phosphate. Fababean grain yield increased with the rate of phosphate application for both methods of placement but no differences were observed between the methods of placement. Lentils and rapeseed showed a small response to the rate of phosphate applied but showed little difference between the two methods of placement.

Straw yields showed similar trends to that of the grain yields for all the crops (Figure 1.3.3).

The relative responses of the crops to irrigation can also be seen in Figures 1.3.2 and 1.3.3. Grain yields were increased from 5 to 10 times for the irrigated plots over those for the dryland plots with

Table 1.3.5. The effect of phosphorus fertilizer rate and placement on the yield and nutrient uptake of 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 % P	Straw % P
0	Seed-placed	3272	2875	1.17	24.8	1.62	129.8	46.6	176.4	0.227	0.077
17		3797	3624	1.05	25.8	2.22	156.7	80.5	237.2	0.268	0.104
34		4699	4126	1.15	26.0	1.76	195.5	72.6	268.1	0.313	0.096
50		4614	4682	0.99	26.5	1.38	195.6	64.6	260.2	0.314	0.075
67		4901	4630	1.06	26.8	1.62	210.2	75.0	285.2	0.370	0.089
101		4820	5274	0.91	27.2	1.58	209.8	83.3	293.1	0.437	0.111
0	Side-banded	3522	3428	1.03	25.1	1.35	141.4	46.3	187.7	0.248	0.060
17		4465	4111	1.09	25.7	1.35	183.6	55.5	239.1	0.263	0.066
34		4714	4244	1.12	26.3	1.50	198.4	63.7	262.1	0.308	0.077
50		5059	4932	1.03	26.4	1.58	213.7	77.9	291.6	0.314	0.078
67		5351	5012	1.07	26.4	1.38	226.0	69.2	295.2	0.341	0.074
101		5050	5254	0.97	26.6	1.68	214.9	88.3	303.2	0.399	0.093
L.S.D. (P = 0.05)		805	751	0.13							

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

Table 1.3.6. The effect of phosphorus fertilizer rate and placement on the yield and nutrient uptake of 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 % P	Straw % P
0	Seed-placed	604	521	1.23	24.8	1.44	24.0	7.5	31.5	0.433	0.089
17		693	849	0.83	24.3	1.65	26.9	14.0	40.9	0.458	0.099
34		664	687	0.98	24.4	1.51	25.9	10.4	36.3	0.470	0.092
50		821	822	1.02	24.3	1.39	31.9	11.4	43.3	0.478	0.099
67		692	727	0.97	24.7	1.55	27.3	11.3	38.6	0.475	0.099
101		615	784	0.78	24.8	1.59	24.4	12.5	36.9	0.488	0.098
0	Side-banded	632	690	0.93	24.6	1.56	24.9	10.8	35.7	0.420	0.084
17		665	764	0.87	24.7	1.43	26.3	10.9	37.2	0.430	0.077
34		672	608	1.12	25.0	1.37	26.9	8.3	35.2	0.440	0.084
50		797	781	1.08	24.7	1.44	31.5	11.2	42.7	0.455	0.084
67		708	746	0.97	24.8	1.34	28.1	10.0	38.1	0.468	0.083
101		665	573	1.17	24.4	1.28	26.0	7.3	33.3	0.458	0.090

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

Table 1.3.7. The effect of phosphorus fertilizer rate and placement on the yield and nutrient uptake of 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 % P	Straw % P
0	Seed-placed	2609	1966	1.33	24.5	1.18	102.3	23.2	125.5	0.313	0.098
17		2549	1921	1.34	23.9	0.98	97.5	18.8	116.3	0.345	0.081
34		2393	1880	1.28	24.5	1.14	93.8	21.4	115.2	0.375	0.102
50		2619	2382	1.33	23.8	1.14	99.7	27.2	126.9	0.405	0.111
67		2418	2130	1.18	24.7	1.21	95.6	25.8	121.4	0.403	0.117
101		2374	1936	1.23	23.9	1.39	90.8	26.9	117.7	0.405	0.138
0	Side-banded	2890	2091	1.39	24.7	0.84	114.2	17.6	131.8	0.318	0.045
17		2931	2231	1.32	24.3	1.11	114.0	24.8	138.8	0.338	0.072
34		3247	2367	1.38	24.2	1.32	125.7	31.2	156.9	0.370	0.102
50		3424	2844	1.21	24.2	1.02	132.6	29.0	161.6	0.395	0.095
67		3789	2616	1.51	24.8	1.45	150.3	37.9	188.2	0.405	0.135
101		3415	2852	1.21	24.2	1.14	132.2	32.5	164.7	0.430	0.093
L.S.D. (P = 0.05)		443	569	0.27							

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

Table 1.3.8. The effect of phosphorus fertilizer rate and placement on the yield and nutrient uptake of 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 % P	Straw % P
0	Seed-placed	597	687	0.87	18.6	0.78	17.8	5.4	23.2	0.323	0.042
17		562	633	0.89	17.9	0.75	16.1	4.7	20.8	0.343	0.042
34		540	664	0.82	17.8	0.82	15.4	5.4	20.8	0.350	0.044
50		519	642	0.82	18.3	0.81	15.2	5.2	20.4	0.345	0.048
67		519	665	0.78	17.6	0.85	14.6	5.7	20.3	0.360	0.054
101		444	533	0.83	17.7	0.88	12.6	4.7	17.3	0.363	0.054
0	Side-banded	611	940	0.67	19.8	0.90	19.4	8.5	27.9	0.308	0.048
17		636	834	0.77	18.9	0.85	19.2	7.1	26.3	0.333	0.045
34		698	997	0.71	19.1	0.99	21.3	9.9	31.2	0.353	0.065
50		569	871	0.68	20.6	0.91	18.8	7.9	26.7	0.348	0.050
67		654	1036	0.64	19.3	0.80	20.2	8.3	28.5	0.390	0.047
101		669	927	0.73	19.9	0.89	21.3	8.3	29.6	0.373	0.062
L.S.D. (P = 0.05)		85	146	0.12							

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

Table 1.3.9. The effect of phosphorus fertilizer rate and placement on the yield and nutrient uptake of 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 % P	Straw % P
0	Seed-placed	2447	1541	1.61	18.6	0.91	72.8	14.0	86.8	0.368	0.086
17		2427	1114	1.48	17.3	1.26	67.2	14.0	81.2	0.418	0.131
34		2506	1673	1.51	17.6	1.20	70.6	20.1	90.7	0.463	0.131
50		2393	1491	1.62	17.1	0.92	65.5	13.7	79.2	0.448	0.108
67		2734	1792	1.53	17.5	0.80	76.6	14.3	90.9	0.442	0.087
101		2508	2021	1.29	17.5	0.85	70.2	17.2	87.4	0.495	0.117
0	Side-banded	2365	1521	1.55	18.0	1.02	68.1	15.5	83.6	0.350	0.101
17		2559	1695	1.52	18.1	1.04	74.1	17.6	91.7	0.443	0.119
34		3117	2246	1.39	17.5	1.00	87.3	22.5	109.8	0.428	0.111
50		3070	2193	1.44	17.9	0.96	87.9	21.1	109.0	0.443	0.100
67		3264	2214	1.47	18.1	0.84	94.5	18.6	113.1	0.450	0.096
101		3778	2436	1.56	17.2	0.89	104.0	21.7	125.7	0.470	0.105
L.S.D. (P = 0.05)		587	609								

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

Table 1.3.10. The effect of phosphorus fertilizer rate and placement on the yield and nutrient uptake of 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 % P	Straw % P
0	Seed-placed	592	461	1.29	23.1	0.96	21.9	4.4	26.3	0.460	0.084
17		613	466	1.32	21.7	0.86	21.3	4.0	25.3	0.455	0.071
34		544	491	1.12	22.0	0.91	19.1	4.5	23.6	0.450	0.078
50		491	375	1.32	22.6	1.07	17.8	4.0	21.8	0.453	0.098
67		568	428	1.33	22.1	1.02	20.1	4.4	24.5	0.458	0.092
101		558	387	1.46	22.2	1.03	19.8	4.0	23.8	0.493	0.101
0	Side-banded	637	589	1.10	22.6	1.12	23.0	6.6	29.6	0.463	0.066
17		634	626	1.02	22.8	1.20	23.1	7.5	30.6	0.485	0.063
34		697	597	1.18	22.3	1.07	24.9	6.4	31.3	0.465	0.083
50		568	583	0.98	23.1	1.36	21.0	7.9	28.9	0.498	0.116
67		701	633	1.11	22.1	1.18	24.8	7.5	32.3	0.500	0.102
101		641	600	1.07	22.4	1.25	23.0	7.5	30.5	0.518	0.117
L.S.D. (P = 0.05)		146	133	0.19							

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

Table 1.3.11. The effect of phosphorus fertilizer rate and placement on the yield and nutrient uptake of irrigated lentils.

P_2O_5 Applied (kg/ha)	Fertilizer Placement	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	Grain % P	Straw % P
0	Seed-placed	2294	2084	1.09	19.4	1.10	71.2	22.9	94.1	0.320	0.101
17		2357	1865	1.27	20.2	0.98	76.2	18.3	94.5	0.368	0.093
34		2218	2126	1.04	18.7	1.10	66.4	23.4	89.8	0.430	0.129
50		3283	2651	1.25	21.1	1.07	110.8	28.4	139.2	0.418	0.100
67		2370	2163	1.09	19.6	1.20	74.3	26.0	100.3	0.448	0.132
101		2949	2473	1.18	20.4	1.02	96.3	25.2	121.5	0.458	0.120
0	Side-banded	2086	1912	1.08	19.2	1.10	64.1	21.0	85.1	0.338	0.100
17		2267	2013	1.15	20.8	0.87	75.4	17.5	92.9	0.353	0.087
34		2463	2096	1.17	19.9	1.11	78.4	23.3	101.7	0.383	0.111
50		3075	2315	1.33	21.3	1.25	104.8	28.9	133.7	0.390	0.114
67		2296	2280	1.00	19.1	1.29	70.2	29.4	99.6	0.433	0.129
101		2320	2321	1.03	19.5	1.53	72.4	32.5	104.9	0.440	0.150
L.S.D. (P = 0.05)		842	544	0.28							

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

Table 1.3.12. The effect of phosphorus fertilizer rate and placement on the yield and nutrient uptake of dryland lentils.

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 % P	Straw % P
0	Seed-placed	507	879	0.59	16.3	0.98	13.2	8.6	21.8	0.385	0.078
17		504	863	0.63	16.3	0.98	13.1	8.5	21.6	0.418	0.081
34		522	895	0.59	16.7	1.06	13.9	9.5	23.4	0.430	0.087
50		596	861	0.75	16.2	0.96	15.4	8.3	23.7	0.425	0.084
67		574	877	0.66	16.1	0.97	14.8	8.5	23.3	0.418	0.084
101		560	867	0.64	16.4	1.04	14.7	9.0	23.7	0.465	0.102
0	Side-banded	530	863	0.62	16.8	1.06	14.2	9.1	23.3	0.395	0.089
17		528	911	0.59	16.9	1.08	14.3	9.8	24.1	0.408	0.098
34		553	688	0.84	17.0	1.03	15.0	7.1	22.1	0.415	0.084
50		517	884	0.60	16.5	1.09	13.6	9.6	23.2	0.418	0.108
67		542	792	0.76	16.4	1.08	14.2	8.6	22.8	0.433	0.100
101		577	1024	0.57	16.1	0.93	14.9	9.5	24.4	0.465	0.099
L.S.D. (P = 0.05)		115	260	0.24							

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

Table 1.3.13. The effect of phosphorus fertilizer rate and placement on the yield and nutrient uptake of 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 % P	Straw % P
0	Seed-placed	3650	5641	0.66		0.92					0.050
17		3474	5238	0.66		0.76					0.047
34		3666	5417	0.69		0.69					0.042
50		4268	6865	0.62		0.69					0.035
67		3771	5457	0.70		0.75					0.039
101		3828	6167	0.62		0.92					0.074
0	Side-banded	2407	3942	0.62		1.07					0.054
17		2644	3983	0.71		0.98					0.045
34		3171	4996	0.64		0.74					0.033
50		3245	5421	0.63		0.90					0.056
67		3509	5687	0.64		0.67					0.035
101		3261	4851	0.67		0.78					0.069
L.S.D. (P = 0.05)		1110									

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

Table 1.3.14. The effect of phosphorus fertilizer rate and placement on the yield and nutrient uptake of dryland 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 % P	Straw % P
0	Seed-placed	228	1125	0.20		1.76					0.161
17		261	1365	0.18		1.70					0.164
34		177	1054	0.17		2.30					0.291
50		260	1342	0.18		2.31					0.285
67		316	1162	0.26		1.74					0.225
101		325	1211	0.27		1.76					0.245
0	Side-banded	200	841	0.22		1.90					0.146
17		230	944	0.22		2.04					0.197
34		109	908	0.12		2.64					0.314
50		131	939	0.15		2.56					0.324
67		239	1148	0.19		1.97					0.257
101		143	999	0.13		2.43					0.360
L.S.D.	(P = 0.05)	123	310	0.08							

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

Table 1.3.15. The effect of phosphorus fertilizer rate and placement on the yield and nutrient uptake of 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 % P	Straw % P
0	Seed-placed	605	1122	0.55		0.61					0.020
17		663	1150	0.58		0.50					0.020
34		648	1140	0.58		0.67					0.023
50		645	1186	0.55		0.69					0.027
67		668	1336	0.51		0.86					0.042
101		720	1326	0.55		0.84					0.036
0	Side-banded	558	1066	0.53		0.42					0.018
17		541	916	0.59		0.59					0.027
34		648	1064	0.65		0.67					0.036
50		606	990	0.62		0.55					0.030
67		613	1187	0.53		0.44					0.030
101		603	1142	0.56		0.73					0.042
L.S.D. (P = 0.05)		146	311	0.14							

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

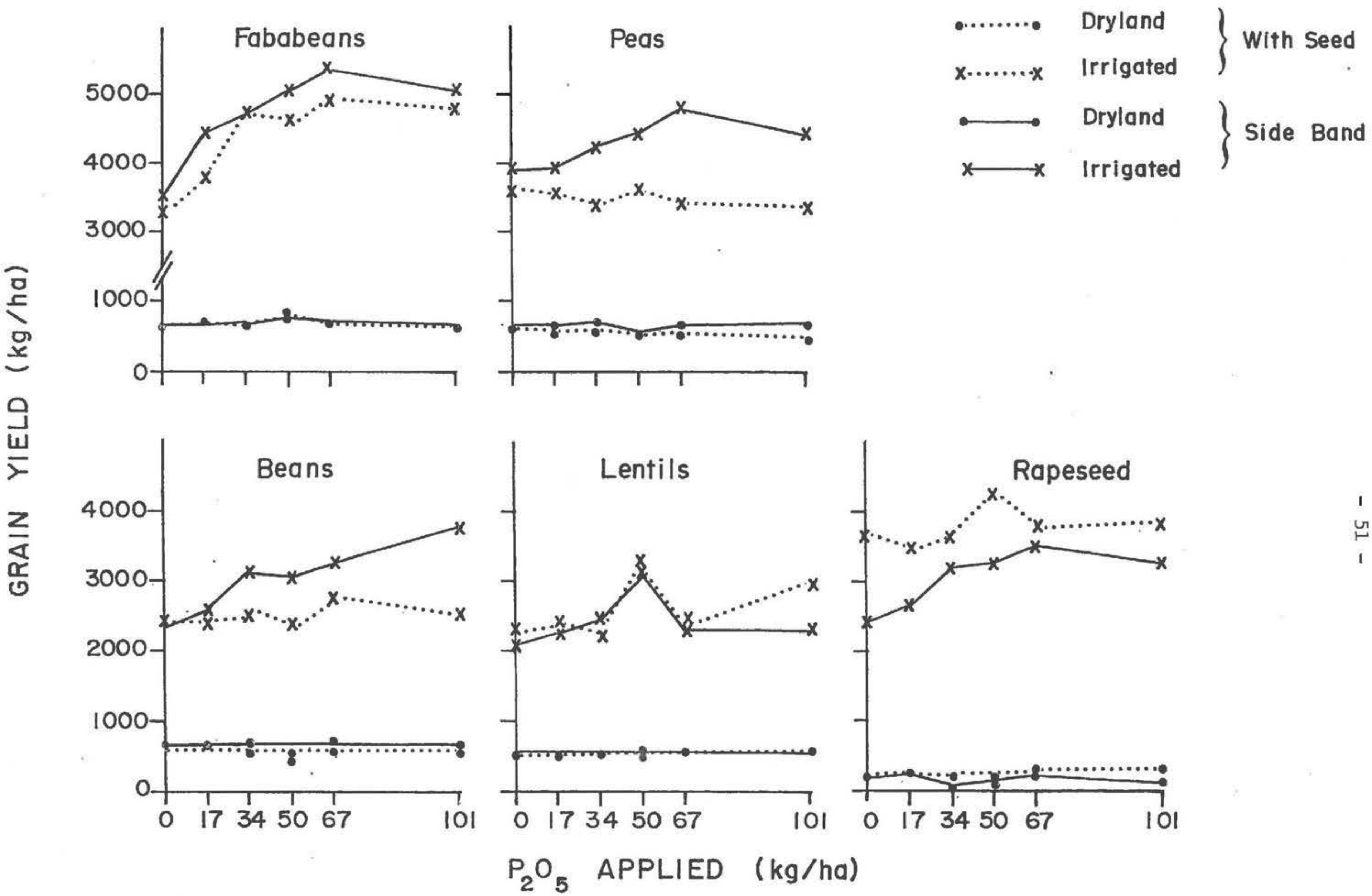

Figure 1.3.2. The effect of phosphate rate and placement on the grain yield of crops.

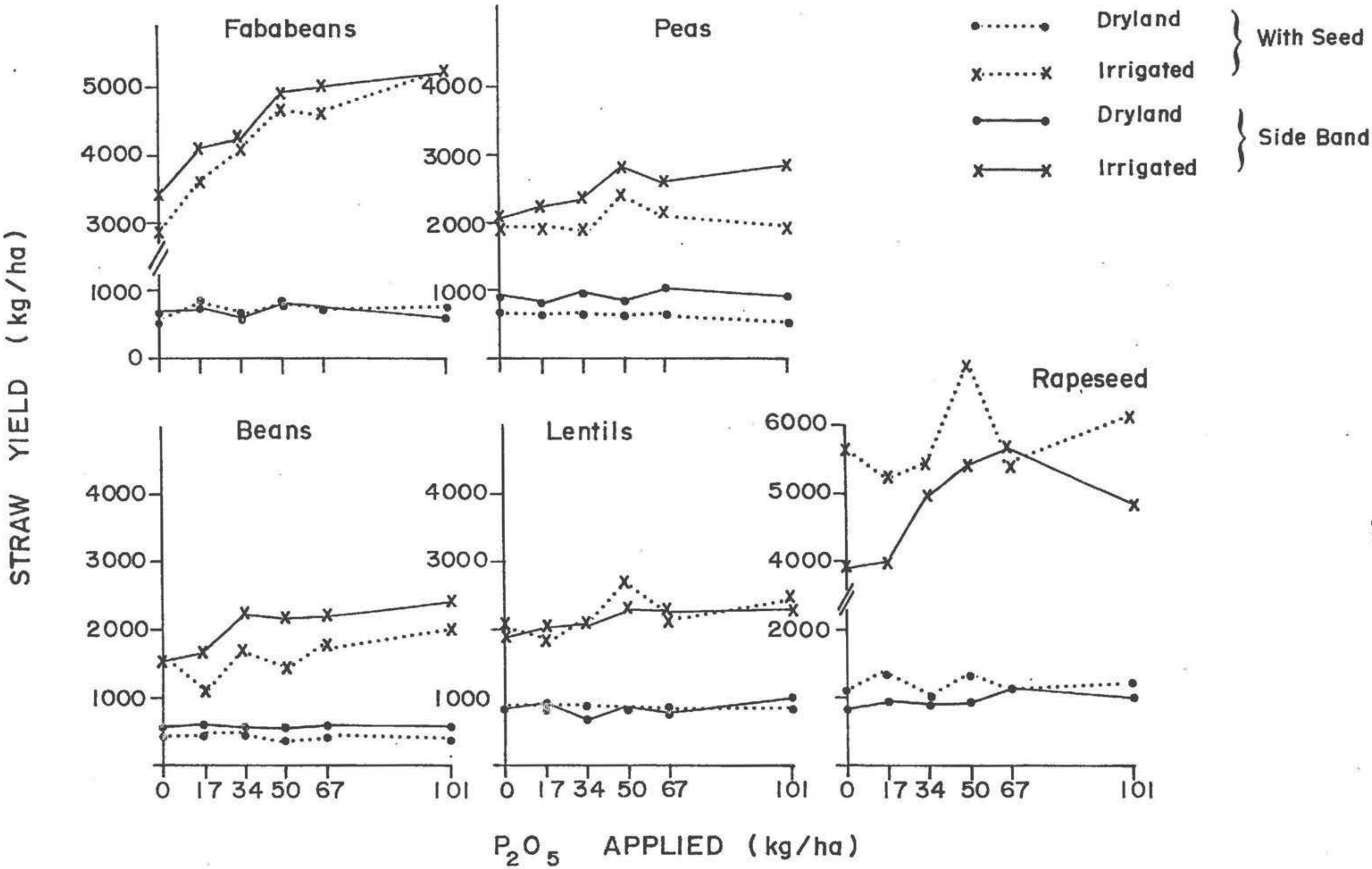

Figure 1.3.3. The effect of phosphate rate and placement on the straw yield of crops.

fababeans and rapeseed showing the greatest response to irrigation.

Grain/straw ratios generally showed no response to either the rate or placement of phosphate except for dryland peas and beans where grain/straw ratios were greater for seed-placed than side-band phosphate. All crops except fababeans had higher grain/straw ratios under irrigated than dryland conditions. Fababeans showed little difference in grain/ straw ratios between irrigated and dryland conditions.

Grain protein was not affected by the rate or placement of phosphate for any of the pulse crops. No results are available for the grain protein of the rapeseed and flax. The protein content of the fababeans, peas, and lentils was greater under irrigation than dryland conditions by 1%, 5%, and 3% respectively. On the other hand, bean protein content was 5% higher under dryland than irrigated conditions.

Straw nitrogen content was not affected by the rate or placement of phosphate. Peas and lentils had a higher straw nitrogen content under irrigation than dryland while rapeseed had a higher straw nitrogen content under dryland than irrigation conditions. Fababeans and beans showed little difference in straw nitrogen content between irrigated and dryland conditions.

Grain phosphorus content of the pulse crops was not affected by the placement of phosphate but showed an increase as the rate of phosphate applied was increased. Fababeans, beans, and lentils had a higher grain phosphorus content under irrigated than dryland conditions while the opposite was observed for peas.

Straw phosphorus content as well was not affected by the placement of phosphate and showed some increase as the rate of phosphate applied was increased. Peas and lentils had a greater straw phosphorus content under irrigation than dryland conditions while for fababeans and beans, straw phosphorus content was similar for irrigated and dryland conditions. The straw content of rapeseed was greater under dryland than irrigated conditions.

The seasonal water use for the crops under study for both irrigated and dryland conditions is presented in Table 1.3.16. A greater total water use was found for each crop under irrigated than dryland conditions. All the crops studied showed a yield increase when irrigated indicating they all responded to the irrigation applications.

For the irrigated crops the total water use was of the order fababeans > rapeseed > beans > peas > lentils and followed the order of the amounts of water applied as irrigation applications. The fababeans and rapeseed used the most water and produced the highest yields indicating they are well suited for production under irrigation conditions.

Under the dryland conditions the total water use for the crops was much less than that found under the irrigated conditions as could be expected. A deficit occurred in soil moisture content from spring to fall indicated that the crops had used all the water received as rainfall plus a small amount of stored soil moisture.

The results for the analyses of the soil samples collected in the fall from the plot after harvest of the crops are presented in Table 1.3.17. The NO_3^--N levels were decreased to a small extent under irrigation but remained similar under dryland conditions from spring to fall for the pulse crops. This indicates that there was no increase in soil available NO_3^--N immediately after the harvest of the pulse crops. NO_3^--N levels increased from spring to fall in the 0-15 cm depth for the dryland rapeseed and flax plots and in the 30-60 cm depth for the

Table 1.3.16. Seasonal water use of irrigated and dryland crops for the phosphorus placement experiment.

Crop	Irrigated Rainfall	Irrigated Irrigation	Irrigated ΔS*	Irrigated Total** Water Use	Dryland Rainfall	Dryland ΔS*	Dryland Total** Water Use
	mm				mm		
Fababeans	120	498	-67	551	108	89	197
Peas	120	385	-82	423	108	49	157
Beans	120	361	-52	429	112	50	162
Lentils	111	228	17	356	95	97	192
Rapeseed	117	440	-42	515	108	118	226
Flax	-	-	-	-	114	74	188

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

**Total water use = rainfall + irrigation + ΔS.

Table 1.3.17. Fall soil analyses for the phosporus placement experiment.

Crop	Rep.	Depth (cm)	pH	Conductivity (mmhos/cm)	NO_3^--N	P	K	$SO_4^=$-S
					------- kg/ha*			-------
Dry Fababeans	1 and 2	0-15	7.7	0.2	18	6	610	5
		15-30	7.9	0.2	5	3	155	4
		30-60	8.2	0.6	16	6	300	48+
	3 and 4	0-15	7.8	0.2	24	6	610	8
		15-30	8.0	0.2	6	4	180	5
		30-60	8.2	0.7	20	8	360	48+
Dry Peas	1 and 2	0-15	7.6	0.2	29	5	600	7
		15-30	7.7	0.2	10	2	180	4
		30-60	8.0	0.3	18	4	300	12
	3 and 4	0-15	7.6	0.3	26	4	480	5
		15-30	7.8	0.2	10	3	200	3
		30-60	8.1	0.4	18	4	360	48+
Dry Beans	1 and 2	0-15	7.6	0.2	17	6	460	6
		15-30	7.8	0.2	4	3	150	5
		30-60	8.0	0.6	12	4	280	48+
	3 and 4	0-15	7.6	0.2	19	6	505	6
		15-30	7.8	0.2	3	3	170	4
		30-60	8.0	0.4	14	4	280	48+
Dry Lentils	1 and 2	0-15	7.4	0.3	28	5	490	7
		15-30	7.6	0.2	11	3	210	3
		30-60	8.0	0.4	12	4	340	32
	3 and 4	0-15	7.6	0.2	26	5	575	5
		15-30	7.7	0.2	6	2	190	4
		30-60	8.1	0.4	16	4	360	48+
Dry Rapeseed	1 and 2	0-15	7.5	0.3	63	7	560	6
		15-30	8.0	0.2	8	2	150	4
		30-60	8.0	0.3	24	4	260	48+
	3 and 4	0-15	7.6	0.4	51	7	630	6
		15-30	7.9	0.2	8	3	190	4
		30-60	8.1	0.6	14	4	400	30
Dry Flax	1 and 2	0-15			71	8	560	
		15-30			8	3	205	
		30-60			24	6	410	
	3 and 4	0-15			55	7	660	
		15-30			5	2	250	
		30-60			14	4	540	

Table 1.3.17, continued

Crop	Rep.	Depth (cm)	pH	Conductivity (mmhos/cm)	NO_3^--N	P	K	$SO_4^=$-S
					kg/ha*			
Irrigated Fababeans	1 and 2	0-15			8	6	570	
		15-30			5	3	270	
		30-60			18	6	560	
	3 and 4	0-15			7	4	615	
		15-30			6	3	260	
		30-60			12	4	480	
Irrigated Peas	1 and 2	0-15			10	5	545	
		15-30			7	3	275	
		30-60			10	6	440	
	3 and 4	0-15			9	6	560	
		15-30			6	3	250	
		30-60			20	8	530	
Irrigated Beans	1 and 2	0-15			9	6	660	
		15-30			6	3	285	
		30-60			18	4	420	
	3 and 4	0-15			7	4	590	
		15-30			6	2	230	
		30-60			14	4	460	
Irrigated Lentils	1 and 2	0-15			7	6	870	
		15-30			5	3	460	
		30-60			12	6	570	
	3 and 4	0-15			6	5	685	
		15-30			5	3	260	
		30-60			10	4	460	
Irrigated Rapeseed	1 and 2	0-15			10	7	715	
		15-30			14	4	370	
		30-60			44	4	520	
	3 and 4	0-15			6	5	560	
		15-30			10	2	260	
		30-60			32	6	560	

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

irrigated rapeseed plot. This increase was residual NO_3^--N from the spring fertilizer nitrogen application on these two plots.

Conclusions

The following conclusions are based on three years of field data (1976, 1977 and 1978) and should provide reasonable guidelines to production of pulse crops, rapeseed, and flax.

1. All crops produced higher yields under irrigated than dryland conditions.
2. Seed placed phosphorus resulted in serious stand reductions for peas, beans, lentils, rapeseed, and flax. For peas and beans these stand reductions were so serious as to almost preclude yield response to seed placed phosphorus. Yield responses to seed placed phosphorus were so small that the economics is questionable and such recommendations should be closely examined with a view to eliminating the recommendation of seed placed phosphorus for peas and beans.
3. Seed placed phosphorus resulted in significant stand reduction of lentils, rapeseed, and flax but useful yield increases were still obtained. It is probable that the current recommendation of a low rate of application of seed placed phosphorus is justified.
4. Placement of phosphorus away from the seed provided economic yield increases for peas, beans, lentils, rapeseed, and flax.
5. Fababean stands were not affected by phosphate placed with the seed. In irrigated agriculture phosphate applications at least as great as that for cereals is essential to maximizing production of fababeans.

6. Fababeans and rapeseed are definitely irrigated crops and beans and flax also respond well to irrigation. While increases in yield of both peas and lentils were obtained under irrigation it is doubtful whether these two crops could be considered as a high priority for irrigated acreage in a farm unit containing both dryland and irrigated portions.

1.4 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 1.4.1). 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 and again in April of 1978. Soil samples from selected treatments were taken from the three sites before the annual fertilizer applications in 1977. No spring soil samples were taken in 1978.

The various treatments used for the Pederson site are presented in Table 1.4.2 and for the Gross and Wudel sites in Table 1.4.3. 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 subsample

Table 1.4.1. Site characteristics of soils selected for irrigated alfalfa study.

	Site 1	Site 2	Site 3
Legal Location	NE20-28-7-W3	NE30-28-7-W3	SW31-30-7-W3
Cooperator	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 (0-60cm)kg/ha	27	24	59
P (0-15cm)kg/ha	6	9	19
K (0-15cm)kg/ha	220	511	401
SO_4-S (0-60cm)kg/ha	94	47	84

*Soil analyses are from samples taken in April/1976.

Table 1.4.2. Fertility treatments for the irrigated alfalfa experiment (Pederson site).

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

Table 1.4.3. Fertility treatment for the irrigated alfalfa experiments (Gross and Wudel sites).

Treatment Number	Application	P_2O_5 Applied (kg/ha)
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

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

In 1977 and 1978 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 cooperating farmer.

RESULTS AND DISCUSSION

The yield results for the Pederson alfalfa plot are presented in Table 1.4.4 and for the Gross and Wudel plots are presented in Table 1.4.5. Two cuts were taken from each site with first cut yields larger than second cut yields. The reduction in yield from first cut to second cut was greater at the Gross site than either the Pederson or Wudel sites. As well, it was observed that the entire alfalfa stand on the Gross field was poor at the time of the second cut. The reason for this is not known. However, total yields for the Gross and Wudel sites were similar since a greater first cut yield was obtained at the Gross site. Total yields for each of the sites was similar to total yields found in 1977.

The yields obtained were variable and showed no consistant response to the applied fertilizer treatments. For the Pederson and Wudel sites those treatments receiving a phosphate application had yields higher than the control for the first cut, but no yield differences were observed for the second cut. For the Gross site a yield response was observed for the highest annual phosphate applications for both the first and second cuts. No yield response was observed at the Pederson site for the potassium and sulfur fertilizer treatments.

The results for the protein and phosphorus content of the alfalfa for the Pederson site are presented in Table 1.4.6 and for the Gross and Wudel sites are presented in Table 1.4.7. The results indicate that the phosphorus fertilization had no effect on the protein content of the alfalfa at the three sites. Likewise, potassium and sulfur fertilization had no effect on the protein content of the

Table 1.4.4. Yield results for irrigated alfalfa (Pederson site).

Treatment Number	Application Rate (kg/ha)	Dry Matter Yield (kg/ha) Cut 1 (June 23/78)	Cut 2 (Aug. 25/78)	Total
1	0	2665	2762	5427
2	28 P_2O_5 Annual	3002	2885	5887
3	56 P_2O_5 Annual	3344	2970	6314
4	84 P_2O_5 Annual	2411	2825	5236
5	112 P_2O_5 Annual	3161	2931	6092
6	168 P_2O_5 Once	3075	2851	5926
7	336 P_2O_5 Once	3226	2714	5940
8	28 K_2O Annual	2649	2565	5214
9	56 K_2O Annual	2771	2695	5466
10	112 K_2O Annual	2587	2471	5058
11	224 K_2O Annual	2874	2410	5284
12	28 S Annual	2849	2543	5392
13	56 S Annual	2711	2505	5216
14	112 S Annual	2931	2574	5505
15	224 S Annual	2876	2766	5642
16	Spare	2213	2544	4757
17	Spare	2358	2287	4645
18	Spare	2866	2581	5447
L.S.D. (P=0.05)		359	450	

Table 1.4.5. Yield results for irrigated alfalfa (Gross and Wudel sites).

Treatment Number	P_2O_5 Applied (kg/ha)	Dry Matter Yield (kg/ha) Gross Site Cut 1 (June 19/78)	Gross Site Cut 2 (Aug. 9/78)	Gross Site Total	Wudel Site Cut 1 (June 27/78)	Wudel Site Cut 2 (Aug. 24/78)	Wudel Site Total
1	0	4030	1959	5989	3410	3583	6993
2	28 Annual	4264	2371	6635	4071	3585	7656
3	56 Annual	4614	2631	7245	3792	3502	7294
4	84 Annual	3348	1789	5137	3943	3257	7200
5	112 Annual	5539	2711	8250	4147	3907	8054
6	84 Once	4497	2276	6773	3720	3495	7215
7	168 Once	4221	2411	6632	3973	3559	7532
8	252 Once	4482	2719	7201	3960	3731	7691
9	336 Once	4478	2696	7174	3978	3563	7541
10	Spare	3383	2082	5465	3447	3193	6640
L.S.D. (P=0.05)		1180	380		604	553	

Table 1.4.6. 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	% Protein[1] Cut 2	% P[2] Cut 1	% P[2] Cut 2
1	0	17.99	16.22	0.197	0.149
2	28 P_2O_5 Annual	17.31	16.85	0.210	0.161
3	56 P_2O_5 Annual	17.91	17.20	0.233	0.176
4	84 P_2O_5 Annual	17.38	19.17	0.292	0.232
5	112 P_2O_5 Annual	17.47	17.19	0.272	0.196
6	168 P_2O_5 Once	17.36	16.25	0.204	0.157
7	336 P_2O_5 Once	18.94	17.19	0.233	0.171
8	28 K_2O Annual	17.39	16.50	0.191	0.151
9	56 K_2O Annual	16.96	17.80	0.181	0.161
10	112 K_2O Annual	18.13	17.47	0.194	0.155
11	224 K_2O Annual	17.55	16.63	0.183	0.151
12	28 S Annual	17.00	16.63	0.180	0.146
13	56 S Annual	17.11	15.82	0.186	0.150
14	112 S Annual	17.08	16.31	0.177	0.140
15	224 S Annual	17.43	16.71	0.183	0.153
16	Spare	17.46	17.72	0.189	0.170
17	Spare	18.00	16.77	0.194	0.152
18	Spare	17.32	16.99	0.181	0.160
L.S.D. (P=0.05)		1.22	1.70	0.023	0.022

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

[2]%P on oven-dry basis.

Table 1.4.7. 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		
1	0	16.56	19.92	0.172	0.234
2	28 Annual	16.92	20.14	0.188	0.235
3	56 Annual	16.89	19.11	0.193	0.224
4	84 Annual	17.80	19.67	0.223	0.266
5	112 Annual	18.42	19.27	0.269	0.270
6	84 Once	16.53	20.11	0.158	0.221
7	168 Once	16.25	19.46	0.172	0.213
8	252 Once	17.75	18.17	0.218	0.219
9	336 Once	17.60	18.55	0.220	0.238
10	Spare	15.91	18.69	0.148	0.197
L.S.D. (P=0.05)		1.38	1.80	0.031	0.033
			Wudel Site		
1	0	15.75	19.84	0.184	0.227
2	28 Annual	17.39	20.06	0.223	0.247
3	56 Annual	17.21	21.13	0.255	0.282
4	84 Annual	17.84	20.24	0.269	0.282
5	112 Annual	18.02	20.63	0.293	0.314
6	84 Once	16.61	20.70	0.196	0.251
7	168 Once	16.69	19.64	0.206	0.250
8	252 Once	17.07	20.41	0.239	0.274
9	336 Once	17.49	19.91	0.251	0.277
10	Spare	16.66	20.32	0.188	0.221
L.S.D. (P=0.05)		1.06	1.23	0.029	0.034

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

[2]%P on oven-dry basis.

alfalfa at the Pederson site. Protein content decreased at the second cut for the Pederson site, but increased at the second cut for the Gross and Wudel sites. Differences in 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 was affected by the phosphorus fertilizer treatments at the three sites. At the Pederson site phosphorus content of the alfalfa increased with increases in the annual phosphate applied for both the first and second cuts. At the Gross and Wudel sites the phosphorus content of the alfalfa increased with increases in both the annual and once only phosphate applied for the first and second cuts. The phosphorus content of the alfalfa increased with the second cut for the Gross and Wudel sites and decreased with the second cut for the Pederson site. These results indicate that the applied phosphate was utilized by the alfalfa plants with greater utilization taking place with higher phosphate applications. However, the increased phosphorus utilization was not always transferred into a greater alfalfa yield.

In the spring of 1979, the year following the completion of the alfalfa experiment, soil samples were collected from all treatments at the three sites. The soil samples were collected to determine the effect of the fertilizer treatments on the available nutrient status of the soil after the three year experimental period. The results of the soil analyses are presented in Tables 1.4.8 to 1.4.10. The soil analysis indicated that there was little if any change in

Table 1.4.8. Spring soil analyses for the Pederson alfalfa plot following completion of the experiment (1979).

Application Rate (kg/ha)	Depth (cm)	pH	Conductivity (mmhos/cm)	NO_3^--N	P	K	$SO_4^=$-S
				-------	kg/ha*	--------	
0	0-15	8.1	0.5	14	5	250	18
	15-30	8.1	1.1	12	3	245	24
	30-45	8.2	1.7	8	4	315	24
	45-60	8.2	2.1	6	6	353	24
28 P_2O_5 Annual	0-15	7.9	1.0	15	5	307	19
	15-30	8.1	0.8	11	5	251	22
	30-45	8.2	1.2	7	3	258	20
	45-60	8.1	1.9	5	4	311	24
56 P_2O_5 Annual	0-15	7.9	0.8	15	6	283	17
	15-30	8.2	0.9	12	3	266	21
	30-45	8.1	1.7	8	4	313	23
	45-60	8.1	2.0	7	5	341	24
84 P_2O_5 Annual	0-15	7.9	0.9	15	12	296	18
	15-30	8.1	0.7	10	4	260	21
	30-45	8.3	0.6	8	4	306	21
	45-60	8.2	1.1	6	4	360	24
112 P_2O_5 Annual	0-15	8.1	0.5	14	13	331	16
	15-30	8.3	0.6	10	6	274	21
	30-45	8.2	1.4	6	5	335	23
	45-60	8.3	1.7	7	7	413	24
168 P_2O_5 Once	0-15	7.9	1.0	15	4	308	15
	15-30	8.1	0.7	12	3	264	17
	30-45	8.2	1.5	7	4	293	20
	45-60	8.3	1.7	7	5	338	23
336 P_2O_5 Once	0-15	7.9	0.9	15	4	276	19
	15-30	8.1	0.7	12	3	246	21
	30-45	8.2	1.6	8	4	290	24
	45-60	8.3	1.5	8	5	371	24
28 K_2O Annual	0-15	8.0	0.9	14	3	279	17
	15-30	8.1	0.8	10	2	274	19
	30-45	8.2	1.9	6	4	331	21
	45-60	8.1	2.3	7	5	374	24
56 K_2O Annual	0-15	7.8	1.2	14	3	300	18
	15-30	8.1	0.7	12	2	273	20
	30-45	8.1	1.5	6	3	295	21
	45-60	8.1	2.0	6	4	351	21

continued

Table 1.4.8 continued

Application Rate (kg/ha)	Depth (cm)	pH	Conductivity (mmhos/cm)	NO_3^--N	P	K	$SO_4^=$-S
				------ kg/ha*			------
112 K_2O Annual	0-15	8.0	0.8	13	3	336	18
	15-30	8.2	0.7	9	3	289	21
	30-45	8.2	1.4	5	4	309	21
	45-60	8.0	2.4	5	4	325	22
224 K_2O Annual	0-15	8.0	0.9	13	5	356	20
	15-30	8.3	0.7	11	3	270	23
	30-45	8.3	1.1	5	3	355	24
	45-60	8.0	2.6	5	5	413	24
28 S Annual	0-15	7.9	1.0	14	5	333	22
	15-30	8.2	0.7	11	3	279	22
	30-45	8.1	1.4	6	3	291	24
	45-60	8.1	2.0	4	6	350	24
56 S Annual	0-15	8.0	1.1	12	4	315	24
	15-30	8.2	0.7	9	4	299	24
	30-45	8.2	1.7	4	6	340	24
	45-60	8.1	2.1	5	6	383	24
112 S Annual	0-15	7.9	1.1	15	5	340	23
	15-30	8.2	0.8	11	3	278	24
	30-45	8.2	1.3	8	5	353	24
	45-60	8.2	1.8	5	6	350	24
224 S Annual	0-15	7.9	1.0	14	5	326	24
	15-30	8.2	0.9	12	4	313	24
	30-45	8.3	1.4	7	5	370	24
	45-60	8.2	1.6	5	7	391	24
0	0-15	7.9	0.9	13	9	346	22
	15-30	8.3	0.6	10	4	283	22
	30-45	8.2	1.1	6	5	295	22
	45-60	8.0	1.6	8	6	373	23
0	0-15	8.0	0.6	14	9	306	18
	15-30	8.2	0.6	10	5	280	20
	30-45	8.1	2.2	6	6	324	24
	45-60	8.1	2.0	6	7	379	24
0	0-15	7.8	0.7	15	5	308	17
	15-30	8.1	0.6	12	4	268	19
	30-45	8.2	1.2	7	5	280	21
	45-60	8.1	1.9	5	6	324	24

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

Table 1.4.9. Spring soil analyses for the Wudel alfalfa plot following completion of the experiment (1979).

P_2O_5 Applied (kg/ha)	Depth (cm)	pH	Conductivity (mmhos/cm)	NO_3^--N	P	K	$SO_4^=$-S
				kg/ha*			
0	0-15	7.9	0.6	15	11	320	24
	15-30	8.1	0.6	11	5	343	24
	30-45	8.4	0.6	7	5	364	24
	45-60	8.7	0.6	7	6	360	24
28 Annual	0-15	8.2	0.7	15	5	360	24
	15-30	8.1	0.6	10	4	308	24
	30-45	8.3	0.5	7	5	293	24
	45-60	8.7	0.5	6	6	343	24
56 Annual	0-15	8.1	0.9	14	4	319	24
	15-30	7.9	0.8	10	3	360	22
	30-45	8.1	0.6	7	3	338	24
	45-60	8.5	0.6	7	5	344	24
84 Annual	0-15	8.1	0.8	12	6	363	24
	15-30	8.0	0.7	9	4	378	24
	30-45	8.4	0.6	7	4	406	24
	45-60	8.7	0.5	6	6	405	24
112 Annual	0-15	8.1	0.9	15	9	409	24
	15-30	7.9	0.8	12	5	366	24
	30-45	8.3	0.6	9	6	408	24
	45-60	8.4	0.7	8	5	380	24
84 Once	0-15	8.2	0.7	12	9	310	24
	15-30	7.9	0.8	9	3	301	24
	30-45	8.3	0.6	8	3	288	24
	45-60	8.5	0.6	7	4	308	24
168 Once	0-15	8.1	0.5	12	10	328	24
	15-30	8.0	0.5	9	5	374	24
	30-45	8.1	0.5	7	4	394	24
	45-60	8.4	0.5	7	7	386	24
252 Once	0-15	8.1	0.5	12	5	326	24
	15-30	8.0	0.5	10	4	340	24
	30-45	8.2	0.5	8	4	343	24
	45-60	8.4	0.5	8	5	331	24
336 Once	0-15	8.1	0.9	16	7	338	24
	15-30	7.9	0.7	11	4	365	23
	30-45	8.3	0.5	9	3	403	24
	45-60	8.5	0.5	8	4	364	24
0	0-15	8.2	0.5	14	6	326	24
	15-30	8.0	0.4	10	3	369	24
	30-45	8.3	0.4	6	3	280	24
	45-60	8.6	0.4	6	4	310	24

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

Table 1.4.10. Spring soil analyses for the Gross alfalfa plot following completion of the experiment (1979).

P_2O_5 Applied (kg/ha)	Depth (cm)	pH	Conductivity (mmhos/cm)	NO_3^--N	P	K	$SO_4^{=}$-S
				----------	kg/ha*	---------	
0	0-15	8.0	0.4	7	2	369	24
	15-30	8.1	0.3	3	1	215	21
	30-45	8.2	0.3	3	1	179	20
	45-60	8.4	0.3	2	2	173	21
28 Annual	0-15	7.9	0.4	8	3	339	24
	15-30	8.1	0.3	3	1	206	23
	30-45	8.3	0.3	3	2	154	24
	45-60	8.4	0.3	2	2	168	22
56 Annual	0-15	7.9	0.4	8	3	281	23
	15-30	8.1	0.3	3	1	191	21
	30-45	8.3	0.3	3	1	156	22
	45-60	8.4	0.3	2	1	149	21
84 Annual	0-15	7.9	0.3	6	4	335	24
	15-30	8.0	0.3	3	2	214	18
	30-45	8.1	0.3	2	2	169	17
	45-60	8.4	0.3	3	2	164	17
112 Annual	0-15	7.9	0.3	8	5	309	18
	15-30	8.0	0.3	3	2	196	20
	30-45	8.2	0.3	2	3	166	20
	45-60	8.4	0.3	2	2	165	23
84 Once	0-15	7.9	0.4	9	3	344	23
	15-30	8.0	0.3	3	2	220	22
	30-45	8.2	0.3	3	2	159	23
	45-60	8.4	0.3	3	2	160	21
168 Once	0-15	7.9	0.4	8	3	260	22
	15-30	8.1	0.3	4	1	173	18
	30-45	8.3	0.3	4	2	153	18
	45-60	8.5	0.3	3	2	154	20
252 Once	0-15	8.0	0.3	8	3	274	17
	15-30	8.1	0.3	4	2	180	19
	30-45	8.3	0.3	3	2	154	24
	45-60	8.5	0.3	3	2	175	21
336 Once	0-15	7.9	0.4	11	5	304	22
	15-30	8.1	0.3	4	2	190	19
	30-45	8.3	0.4	3	2	159	22
	45-60	8.5	0.3	3	2	163	16
0	0-15	7.9	0.4	8	3	351	21
	15-30	8.0	0.3	4	2	211	19
	30-45	8.3	0.3	3	2	183	18
	45-60	8.4	0.3	3	2	198	17

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

the available phosphorus levels at the three sites at the completion of the experiment in comparison to levels at the start of the experiment, a period of three years. This is contrary to what was expected since some of the treatments received large applications of phosphate over the three year period (up to 336 kg P_2O_5/ha). In the spring of 1977, one year after the start of the experiment, analyses of soil samples collected from selected treatments indicated some increase in available phosphorus levels at high application rates of phosphate. However, this increase in available phosphorus levels was not evident at the end of the experiment. As well, at the Pederson site there was little change in the available soil potassium levels where potassium had been applied, but a small increase in $SO_4^{=}$-S was observed where sulfur was applied.

Appendix A. Selected tables of data from the 1978 irrigation experiments.

Appendix Table A1. Farmer cooperator, legal location and soil type of experimental field plots for the 1978 irrigation trials.

Farmer Cooperator	Crop Investigated	Legal Location	Soil Type
	N x Wheat Varieties x Water Scheduling Experiment		
Tomasiewicz	Sinton hard wheat Glenlea utility wheat Fielder soft wheat	SE30-28-7-W3	Elstow Clay Loam
	N Status of Alfalfa Breaking		
Pederson	Glenlea utility wheat	SE18-28-7-W3	Asquith Sandy Loam
Mathison	Betzes barley	SE33-28-7-W3	Elstow Loam
	Phosphate Placement x Water Scheduling x Selected Crops		
Tomasiewicz	Erfordia Fababeans Trapper Peas Great Northern U.S. 1140 Beans Eston Lentils Redwood 65 Flax Tower Rapeseed	SE30-28-7-W3	Elstow Clay Loam
	Phosphate Fertilization of Alfalfa		
Pederson	Alfalfa	NE20-28-7-W3	Elstow Loam
Gross	Alfalfa	NE30-28-7-W3	Bradwell Loam
Wudel	Alfalfa	SW31-30-7-W3	Bradwell Very Fine Sandy Loam

Appendix Table A2. Residual NO_3^--N levels from selected rates of nitrogen application and irrigation treatments for the nitrogen x wheat varieties x water scheduling experiment.

Depth	Residual NO_3^--N (kg/ha)*											
(cm)	Water A				Water C				Dryland			
	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Rep.1	Rep. 2	Rep. 3	Rep. 4	Rep. 1	Rep. 2	Rep. 3	Rep. 4
	Sinton 0 kg N/ha											
0-15	10	12	12	11	11	10	11	11	14	15	12	12
15-30	8	10	7	8	8	6	7	8	10	7	6	4
30-60	12	12	6	16	12	10	6	12	44	38	22	14
60-90	18	8	10	10	10	16	16	14	18	48	34	26
90-120	38	6	54	8	26	28	24	24	18	90	36	24
	Sinton 224 kg N/ha											
0-15	13	10	14	11	13	10	11	13	118	240	270	230
15-30	10	7	10	11	12	6	8	26	18	15	22	22
30-60	18	22	30	52	34	46	22	44	44	34	46	32
60-90	24	76	48	46	28	76	48	34	22	20	30	44
90-120	18	78	56	22	20	22	28	24	18	26	32	38
	Glenlea 0 kg N/ha											
0-15	13	9	8	9	8	9	10	10	10	8	8	6
15-30	9	7	7	7	6	5	6	8	9	4	4	5
30-60	8	8	12	16	10	6	8	10	46	16	10	8
60-90	8	6	42	14	26	14	12	14	22	20	20	8
90-120	16	10	26	24	24	20	12	20	16	16	24	8
	Glenlea 224 kg N/ha											
0-15	15	5	10	13	16	10	11	10	270	220	58	85
15-30	15	5	33	41	76	7	6	9	23	14	12	19
30-60	38	84	116	80	206	64	40	112	54	50	20	20
60-90	60	130	46	30	36	62	44	54	24	22	26	22
90-120	60	64	28	30	20	22	20	24	18	20	24	22

Appendix Table A2. continued

Depth (cm)	Residual NO_3^--N (kg/ha)*											
	Water A				Water C				Dryland			
	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Rep. 1	Rep. 2	Rep.3	Rep. 4
					Fielder 0 kg N/ha							
0-15	8	9	3	10	13	8	10	9	11	9	12	12
15-30	6	6	2	4	8	4	6	7	5	6	5	6
30-60	12	18	10	12	12	8	12	14	14	10	14	12
60-90	34	20	32	12	16	10	8	12	16	18	16	14
90-120	76	22	28	26	24	22	34	18	12	24	20	12
					Fielder 224 kg N/ha							
0-15	10	7	8	8	11	11	16	16	200	210	83	200
15-30	12	4	23	16	10	6	8	11	16	15	16	30
30-60	152	62	108	100	88	20	60	192	36	32	30	24
60-90	164	40	38	42	38	64	36	64	22	15	20	22
90-120	68	20	30	26	26	36	24	34	44	34	20	28

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

Appendix Table A3. Residual NO_3^--N levels in the 0-15cm depth for the dryland treatment for the nitrogen x wheat varieties x water scheduling experiment.

N Applied (kg/ha)	Residual NO_3^--N (kg/ha)* Rep. 1	Rep. 2	Rep. 3	Rep. 4
		Sinton		
0	14	15	12	12
56	44	39	72	22
84	55	62	65	43
112	102	77	80	62
168	200	240	250	84
224	118	240	270	230
		Glenlea		
0	10	8	8	6
56	35	34	-	30
84	74	-	68	40
112	67	56	64	46
168	200	-	119	-
224	270	220	58	85
		Fielder		
0	11	9	12	12
56	33	23	74	45
84	52	38	67	101
112	55	101	82	80
168	180	190	93	270
224	200	210	83	200

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

Appendix Table A4. Spring soil analyses for the alfalfa breaking experiment under irrigation.

Rep.	Depth (cm)	pH	Conductivity (mmhos/cm)	NO_3^--N	P	K	$SO_4^=$-S
				-------	kg/ha*		--------
			Pederson				
1 and 2	0-15	8.0	0.4	13	3	225	24
	15-30	8.1	0.6	9	2	250	24
	30-60	8.3	0.7	14	4	720	48
3 and 4	0-15	8.3	0.4	4	2	160	24
	15-30	8.3	0.3	5	3	150	24
	30-60	8.1	0.3	16	12	340	48
5 and 6	0-15	8.1	0.4	9	8	180	24
	15-30	8.2	0.3	6	3	145	24
	30-60	8.4	0.3	14	6	320	48
			Mathison				
1	0-15	6.9	0.3	13	8	165	24
	15-30	7.4	0.6	7	7	160	24
	30-60	7.7	0.8	6	12	350	48
	60-90	8.3	1.9	14	14	310	48
	90-120	8.2	3.7	14	12	420	48
2	0-15	7.5	1.1	8	5	180	24
	25-30	8.1	1.7	6	5	120	24
	30-60	8.2	4.2	14	10	350	48
	60-90	8.5	4.3	18	14	640	48
	90-120	8.1	5.6	16	16	610	48
3	0-15	7.7	0.4	10	5	135	24
	15-30	8.1	0.3	6	6	100	24
	30-60	8.4	0.4	12	10	240	48
	60-90	8.7	0.6	4	6	310	48
	90-120	8.2	2.9	6	10	610	48
4	0-15	7.8	1.1	9	4	180	24
	15-30	8.2	1.4	7	5	150	24
	30-60	8.7	1.7	10	8	380	48
	60-90	8.6	3.7	14	18	560	48
	90-120	8.3	6.1	22	20	640	48
5	0-15	7.7	1.3	11	6	150	24
	15-30	8.1	3.7	7	8	135	24
	30-60	8.0	3.7	12	14	310	48
	60-90	8.3	4.3	14	10	400	48
	90-120	8.3	6.4	26	18	550	48
6	0-15	7.1	3.4	11	6	165	24
	15-30	7.8	4.8	10	7	150	24
	30-60	8.2	6.5	22	20	290	48
	60-90	8.5	8.6	30	26	440	48
	90-120	8.4	8.8	30	24	540	48

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