SOIL PLANT NUTRIENT RESEARCH REPORT

compiled by

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ACKNOWLEDGEMENTS

This report summarizes the field research investigations carried out during the 1968 growing season.

The financial assistance of all the agencies who contributed funds in support of this research is gratefully acknowledged. It would have been impossible to conduct the investigations reported herein without this support.

The V.L.A. co-operative project provides a coverage of the province which would otherwise be impossible without greatly adding to costs. This portion of the program also provides an excellent evaluation as to the performance of the soil test recommendations. Grateful acknowledgement is extended to the V.L.A. credit advisors and veteran farmers.

Almost all the investigations reported herein were conducted on individual farms throughout the province. Without the generous co-operation of the many farmers involved it would be impossible to carry out research of this type.

The major responsibility for the field work connected with the School of Agriculture trials was carried by Mr. G. Kowalenko. Mr. H. Schappert accepted similar responsibilities for the nitrogen trials on summerfallow and the potassium trials. Other assistants who aided in the various projects were D. McKenzie, L. Rygh, T. Marshall, E. Czarnecki, G. Herndier, M. Greenshields, G. Shaw and D. Cowie.

Highlights of the 1968 Soil Fertility Research Program

1. The nitrate soil test continues to provide a good basis for predicting the nitrogen fertilizer requirements of stubble seeded crops. The relationship of nitrogen response to soil nitrate-nitrogen levels is excellent for soils in the very low soil test range. However, some inconsistencies in response were found for soils testing in the higher ranges. This years results, together with those obtained in previous years are being analyzed to determine if there is a necessity to adjust the range of the benchmarks which are currently in use.

2. Crops seeded on summerfallow fields with low levels of nitrate-nitrogen responded well to nitrogen fertilization. For three trials on which the nitrogen soil tests were in the low or very low soil test range, the average response to 40 pounds of nitrogen per acre was 8.2 bushels.

The data obtained from these summerfallow tests support the current nitrogen fertilizer practice recommended by the Soil Testing Laboratory for summerfallow seeded cereals.

3. Ammonium polyphosphate (15-60-0) was found to be equal to monoammonium phosphate (11-48-0) in terms of availability and yield response for wheat and brome-alfalfa mixtures. The results of the 1968 investigations together with those conducted in 1967 indicate that ammonium polyphosphate is a suitable source of fertilizer phosphorus for our conditions.

4. The potassium soil test has proven useful in delineating areas of severe potassium deficiencies. Barley appeared to respond much better than wheat to potash fertilization. However, one trial with wheat located on a very low potassium soil showed excellent visual response in the early growth stages. The final yields at this site were depressed by a severe frost. Therefore,

the exact nature of the differential response of wheat and barley to added potassium is still to be determined.

1968 SOIL-PLANT NUTRIENT RESEARCH REPORT

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1. SOIL TEST CORRELATION STUDIES

1.1 Nitrogen

1.1.1 Nitrogen requirements of fallow seeded crops

PURPOSE

To assess the soil test benchmarks for nitrogen on summerfallow seeded crops.

EXPERIMENTAL METHODS

Summerfallow fields which tested very low, low or medium in nitrate-nitrogen were selected from samples submitted to the Soil Testing Laboratory in the fall of 1967.

A standard plot design was used at all of the 13 sites at which a plot was seeded. Phosphorus in the form of monoammonium phosphate (11-48-0) was applied with the seed to the entire plot area at the rate recommended on the basis of the phosphorus soil test. Ammonium nitrate (34-0-0) was broadcast in strips at rates to supply 20, 30, 40 and 60 lb/acre of nitrogen in addition to the nitrogen in the 11-48-0. The nitrogen was broadcast, prior to seeding, with a trailer mounted Cominco 70 fertilizer attachment. All other operations were done with the farmer's equipment.

Composite soil samples, from the width of the plot, were taken at each of ten sampling sites. The sampling sites were selected on the basis of slope position to obtain sites representative of the plot area. The three standard depths (0-6". 6-12" and 12-24") were used.

Two square-yard or three square-yard samples were cut at each of the 10 sampling sites for yield determination. Twelve of the 13 plots were harvested.

RESULTS

The comparison of fall (field) and spring (plot area) soil sampling (Table 1) show that some wide variations occurred. Of the 13 comparisons, 4 could be considered to be essentially the same; in 3 trials the difference was small enough to be attributable to mineralization but in the remaining 6 the fall and spring results differed markedly. These wide differences could result if:

1) the trial area selected was not representative of the field as a whole or,

2) the sample submitted in the fall was not representative of the field.

The trial area selected was usually one-half mile in length or the length of the field and site selection was such as to approach representation of the field. Therefore, the possibility of fall sampling errors should not be overlooked. This serves to reemphasize the point that the samples submitted for analysis must be representative of the field to which the recommendation is to be applied.

The nitrogen response patterns of wheat seeded on summerfallow land are shown in Table 2. In general, the highest and most consistent responses to nitrogen were obtained for soils in the very low and low soil test ranges but some significant yield increases were obtained in the other soil test ranges.

The relationship of yield response to cost of application (Figure 1) shows that for soils in the very low and low nitrogen soil test ranges, the maximum profit was obtained, on the average, with an application of 40 lb N/acre. The cost line in Figure 2 was calculated assuming a price of $1.60 per bushel for wheat and a cost of 13.2 cents per pound for nitrogen.

Table 1 Comparison of fall and spring soil test data*
for nitrogen trials on summerfallow land

Farmer Co-operator	Soil Type	Nitrate Nitrogen lb/acre to 24"		$NaHCO_3$ - P lb/acre to 6"		Exchangeable K lb/acre to 6"	
		Fall/67	Spring/68	Fall/67	Spring/68	Fall/67	Spring/68
Bandet	W:cl	39	86	8	12	850	544
Chapman	W:l	35	43	19	37	640	889
Hamm	A:vl	27	26	10	16	610	569
Halstead I	A:fl	30	55	9	13	670	830
Halstead II	A:fl	34	50	11	18	550	637
Hartz	Br:vl	16	59	21	14	950	725
Heggie I	A:vl	23	18	8	11	670	462
Heggie II	A:vl	20	18	7	6	500	544
Lockwood	A:fl	25	71	7	16	420	662
Lucyshyn	Cd:sil	27	90	18	26	940	784
Presnell	W:l	34	77	12	15	470	804
Stephan	A:fl	25	44	11	17	420	490
Stone	E:cl	21	70	28	12	760	735
		27	54				

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* Note that these data compare the field sampling in the fall of 1967 to the sampling of the plot area in the spring of 1968.

Table 2 Yield response to nitrogen fertilization of wheat seeded on summerfallow land

Farmer	Soil Type	Spring Nitrogen lb/acre to 24"	11-48-0 Yield bu/acre	Yield Increase Over 11-48-0			
				11-48-0 + 34-0-0 @			
				60	90	120	180
				lb/acre			
		Very Low and Low Nitrogen Tests[1]					
Hamm	A:vl	26	20.0	6.5	4.4	4.7	7.5
Heggie I	A:vl	18	21.7	3.4	4.6	12.3	9.0
Heggie II	A:vl	18	17.3	1.9	6.1	7.7	9.3
			Average	3.6	5.0	8.2	8.6
		High and Very High Nitrogen Tests					
Chapman	W:l	43	27.4	1.9	2.5	2.7	6.2
Halstead I	A:fl	55	35.6	5.5	5.3	2.0	3.0
Halstead II	A:fl	50	34.7	2.7	7.3	1.9	3.1
Stephan	A:fl	44	26.0	-1.7	9.5	5.8	11.6
			Average	2.1	6.1	3.1	5.9
		Nitrogen Tests 70 lb/acre and Greater					
Bandet	W:cl	86	26.7	-0.3	2.6	0.6	3.8
Lockwood	A:fl	71	22.5	2.6	2.2	1.8	5.8
Lucyshyn	Cd:Sil	90	35.3	4.0	8.5	1.3	3.2
Presnell	W:l	77	43.9	3.5	6.1	2.3	5.7
Stone[2]	E:cl	70	26.6	-0.6	2.6	-1.7	0.0
			Average	1.8	4.4	1.1	3.7

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[1] Nitrogen ratings are from the September/68 soil test benchmarks

[2] Durum wheat was the test crop

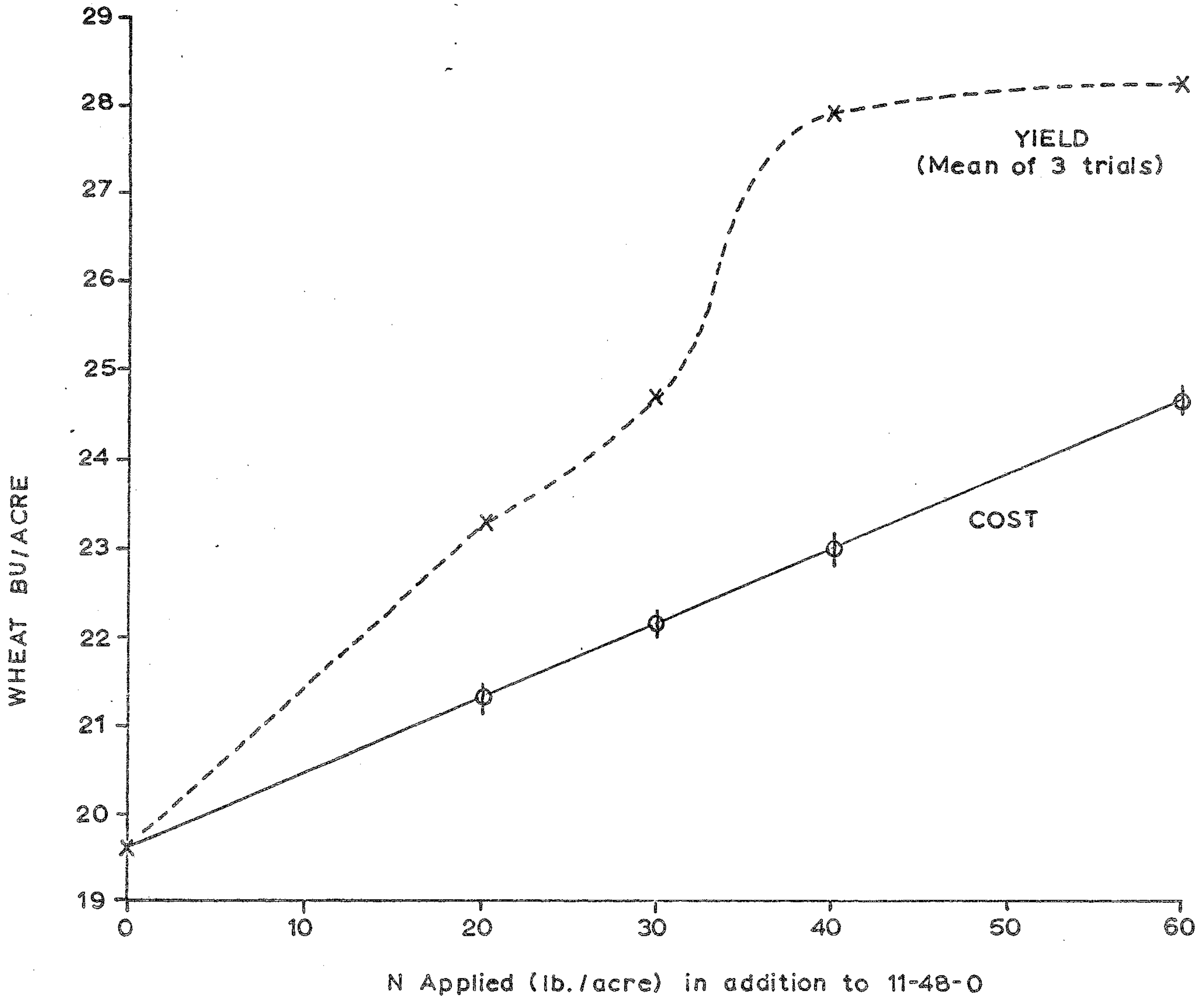

FIGURE 1. Yield increases and cost of N application for summerfallow fields in the low and very low soil test ranges. (average of 3 trials)

These data indicate that the soil test benchmarks as established for summerfallow seeded crops are relatively sound. No alteration of these benchmarks could be recommended on the basis of the 1968 field trials. Unfortunately, no trials were laid down on fields in the medium (31-40 lb N/acre) range.

CONCLUSIONS

1. Response to applications of nitrogen on soils which tested greater than 40 lb/acre were not as consistent as for soils with lower soil test levels.

2. These data indicate that the soil test benchmarks currently in use for summerfallow seeded crops are relatively sound.

1.1.2 Nitrogen requirements of stubble seeded crops

1.1.2.1 School of Agriculture trials

PURPOSE

To evaluate and refine the current soil test benchmarks for nitrogen on stubble seeded crops.

EXPERIMENTAL METHODS

Twelve trials were laid down on the farms of former students of the School of Agriculture. Of these trials 9 were with wheat, 2 with barley and 1 with oats. Ammonium nitrate (34-0-0) was broadcast in strips to supply a total of 20, 30, 40, 60 and 80 lb/acre of nitrogen. Monoammonium phosphate (11-48-0) was applied at 60 lb/acre to all strips receiving the nitrogen. The nitrogen supplied by the monoammonium phosphate was taken into account in calculating the total nitrogen supplied. The 11-48-0 was all seed placed using the farmer's equipment and the ammonium nitrate was applied with a truck mounted Cominco 70 fertilizer attachment. Sampling sites were selected on the basis of slope position as for N on summerfallow (see section 1.1.1). Two plots were not harvested, one wheat and one barley.

In addition to the 12 School of Agriculture trials, 4 trials of an identical design were conducted on Waitville soils in the general Lintlaw-Okla area. In these trials all seeding and fertilizing operations were conducted with department equipment.* Sampling sites were selected on the basis of subgroup profile distribution.

RESULTS

The patterns of yield response to nitrogen for soils in the various soil test ranges (Table 3) confirmed that wheat seeded in soils testing in the very low range shows quite consistent response to the application of nitrogen. The one trial in the very low nitrogen range which did not show good nitrogen response had only 12" of moist soil at seeding time and, therefore, seeding of stubble would not have been recommended. The data also shows that rates of nitrogen greater than 60 lb/acre (i.e. 11-48-0 @ 62 + 34-0-0 @ 160) did not result in further significant yield increases.

As would be expected soils in the medium and high N soil test ranges did not exhibit a sharp N response pattern. However, soils testing in the low range for N would be expected to exhibit a response curve intermediary to the very low and very high soil test ranges. On the average, this was not the case. One of the three trials for this group exhibited an extremely erratic response pattern and this undoubtedly had an adverse effect on the results. Very low precipitation in the early growth stages and severe second growth at later stages probably contributed to the erratic response pattern.

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*In 1968 the department equipment consisted of:

1) a Ford 3000 diesel tractor
2) a Massey Ferguson #36, 9 foot discer
3) an International Harvester Company #10, 8 foot double disc drill
4) 2 four-foot Flexicoil packers

Table 3

Yield response to nitrogen fertilization of crops seeded on stubble land

(Yields in bu/acre and rates of fertilizer application in lb/acre)
(All wheat unless stated otherwise)

Farmer	Soil Type	Nitrate Nitrogen lb/acre to 24"	Check Yield	11-48-0 @ 62 Yield	Increase over 11-48-0 Yield 11-48-0 @ 62 + 34-0-0 @				
					40	70	100	160	220
Very Low Nitrogen Tests									
Hult	Wa:l	19	6.7	10.0	0.1	0.1	2.3	0.0	1.1
Kowalenko	E:cl-A:sl	18	6.9	7.7	6.2	7.4	6.6	8.0	8.8
George	Wv:l	16	12.9	12.8	5.8	9.1	12.6	21.3	19.5
Minky	Wv:l	6	5.9	8.8	2.7	5.0	8.8	12.9	17.2
Weinhandl	Wv:l	12	8.4	10.6	2.5	4.8	6.7	9.1	6.3
				Average	3.5	5.3	7.4	10.3	10.6
Low Nitrogen Tests									
R. Bruce	R:hvc	34	24.8	29.0	3.3	8.2	7.5	7.6	7.4
Coolidge	Wa:l	23	17.5	29.4	-4.8	-1.9	-1.9	-7.6	0.5
Wallace	W:l	27	12.1	13.0	5.0	4.2	3.5	4.5	1.0
				Average	1.2	3.5	3.0	1.5	3.0
B. Bruce Oats	R:hvc	29	40.3	40.6	14.1	10.9	-4.7	-3.7	15.3
Medium Nitrogen Tests									
Froh	W:cl	43	8.6	7.2	3.8	0.6	2.9	2.2	2.0
Raven	Wv:l	43	21.8	23.4	4.3	1.8	4.2	8.3	2.2
				Average	4.0	1.2	3.5	5.3	2.1
Latrace Barley	E:Sicl	45	46.1	53.5	0.8	2.4	8.9	13.6	5.7
High and Very High+ Nitrogen Tests									
Hamilton	W:l	53	14.5	14.2	5.9	2.0	1.3	1.3	9.5
Wallin	Y:l	78	22.6	28.6	-0.7	-1.5	4.1	5.0	5.4
				Average	2.6	0.2	2.7	3.7	7.4

The 1968 data indicates that the soil test benchmarks for soils in the very low range are sound but that refinement in other ranges may be justified. However, modification and refinements of benchmarks should not be based on the results of a single year and the compilation of other data for previous years will be required. If data from a series of years gave results similar to the 1968 results then some modification of soil test benchmarks would be justified.

The profit structure (Figure 2) from nitrogen fertilization of soils in the very low soil test range indicates that profit maximization occurred at about 60 lb N/acre rate for Grey Wooded soils but at a much lower rate for Chernozemic soils. Recall that the curve for Chernozemic soils is the average of two trials, one of which had very low reserve soil moisture. The data presented in Figure 2 is based on a price of $1.60 per bushel for wheat and a cost of 13.2¢ per pound of N. No application costs or interest charges were included so the profit from the 60 lb N/acre application, on Grey Wooded soils, would be somewhat less than the $15 per acre that would be concluded from Figure 2.

CONCLUSIONS

1. Correlation of yield response to nitrogen with the nitrogen soil test was good for soils in the very low soil test range but the correlations were not good in the low and medium soil test ranges.

2. A compilation of several years data is required so that the nitrogen soil test benchmarks can be fully assessed.

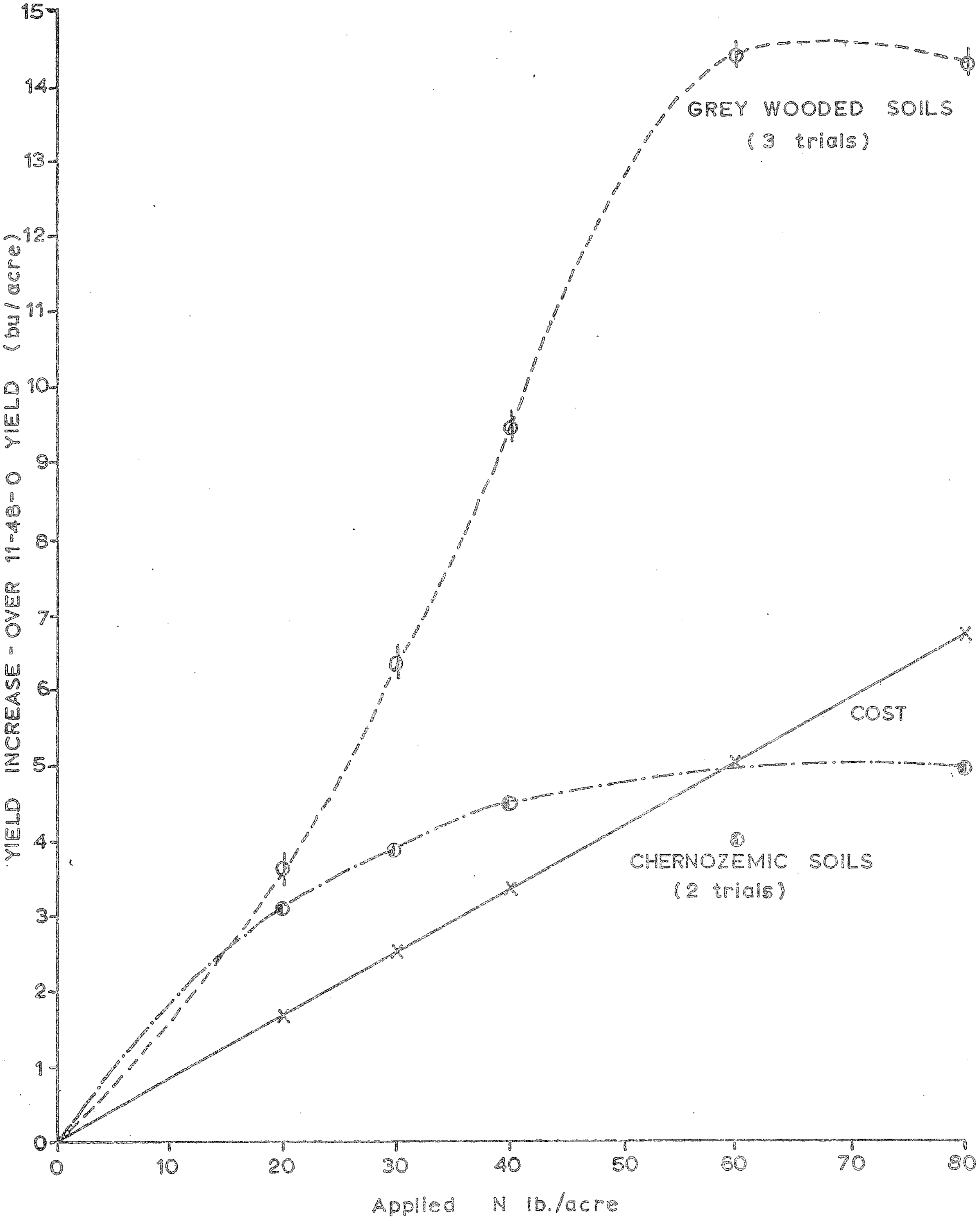

FIGURE 2. Yield increases to and cost of application of nitrogen for stubble seeded wheat with soil tests in the very low range.

1.1.2.2 V.L.A. Co-operative tests

The V.L.A. co-operative stubble fertilizer project is designed to provide information on the performance of soil test recommendations in comparison with the general recommendations. Twenty-five strip tests were seeded. The farmers equipment was used for all seeding and fertilizing operations and the V.L.A. credit advisors aided the farmers in the seeding of the tests. Soil samples were taken from the plot area in the fall of 1967 and again in the spring of 1968. Soil test recommendations were based on the fall sampling and these recommendations were one of the treatments used in these trials. The depth of moist soil at seeding time was estimated, with a probe. Of the 25 tests seeded, 24 were harvested and yield data obtained. Three of the trials were combine harvested and the remainder were harvested by the square yard technique.

The comparison of fall and spring sampling (Table 4) indicates that the difference between the nitrogen values of the two sampling dates was not great in most instances. Of the 22 plots for which the comparison can be made, a difference in the recommendation of greater than 10 lb N/acre would have occurred in only 6 cases. However, in some individual cases serious discrepancies occurred between the spring and fall samplings.

The V.L.A. tests are located in widely scattered areas throughout the entire province and the results should give some indication of fertilizer responses on a broad provincial basis. The average yield results (Table 5) in general show good responses. The data for the individual plots is given in Appendix B . A comparison with 1967 results (Figure 3) indicates quite close agreement between the two years. The largest volume of supporting data is available for wheat and the data in Figure 3 shows that check and fertilized wheat yields were slightly greater in 1968 than in 1967.

Table 4

Comparison of spring and fall sampling
V.L.A. co-operative tests

Advisor-Farmer	Nitrate-Nitrogen lb/acre 0-24" Fall/67	Spring/68	P lb/acre 0-6" Fall/67	Spring/68	K lb/acre 6" Fall/67	Spring/68
Baker-Hayward	13	--	24	--	870	--
Cox-Ford	28	56	25	26	540	720
White-Hooper	21	27	17	12	460	500
Dennis-Peach	118	92	34	25	660	930
Draftenza-Denis	41	43	34	47	1340	1630
Fisher-Currie	48	35	18	27	760	870
Kendel-Tosh	40	43	16	34	520	710
King-Craig	16	25	13	13	950	1000
Laing-Boechler	--	61	--	26	--	420
McDonald-Yakubowich	55	90	19	27	560	500
MacKay-Stadnick	50	51	37	59	1040	1550
McLeod-Beddome	45	56	15	8	650	670
Morrow-Young	16	36	6	13	230	260
Murch-Adair	71	59	15	13	1220	1050
Peace-Freeman	63	133	46	44	1470	1250
Puckey-Nowasad	26	36	20	18	1500	1290
Salkeld-Keith	89	115	51	42	1042	1210
Sherwin-Sharp	38*	113	11	30	580	750
Sikora-Kulovany	55	28	44	124	670	960
Simpson-Zunti	35	37	15	21	950	1300
Steabner-Peckham	12	23	29	26	960	1010
Steenson-Frolek	10	29	7	10	350	350
Stewart-McLeod	27	160	34	26	1440	970
Welwood-Lindstrom	96	75	19	21	410	380
Zinkhan-Powell	28	48	15	30	1190	1860

* Indicates that spring and fall samples were from different fields.

Table 5 Average yield and yield increases
(bu/acre)
for V.L.A. co-operative tests

Crop	Check Yield	Increases 11-48-0 @ 40*	 23-23-0 @ 85	 11-48-0 @ 40 + 33.5-0-0 @ 100
Wheat (14)	18.8	3.5	3.5	6.8
Barley (3)	21.9	3.9	2.5	3.7
Oats (2)	36.2	7.2	11.6	13.6
Flax (1)	15.0	2.7	2.9	1.9
Durum (1)	23.9	6.9	4.7	3.5

* The actual rates of application varied somewhat from test to test but were close to the rate stated. (see Appendix for individual data)

A comparison of soil test and general recommendations was available in 17 of the V.L.A. tests. Fourteen of the tests were with wheat, 1 each with durum, oats and barley. The average yield increases obtained (Table 6) indicate that the application of the soil test recommended rates resulted in an additional 3.9 bushels/acre over that obtained using the general recommendations. At current prices* this would mean an increased profit of approximately $4.00 per acre from the soil test application as compared to the general recommendation. In 13 of the 17 tests the yield was greater for the soil test recommended rate while the general recommendation gave greater yields in 2 tests and 2 tests showed no response to either application. The soil test recommendation resulted in greater profits in 11 of the 17 tests, in 2 tests the general recommendation gave greater returns, in 2 tests the returns were similar for both applications and 2 tests showed a loss from both the soil test and general recommendations.

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* Wheat $1.60/bushel, Oats $0.50/bushel, Barley $1.00/bushel
11-48-0 $111.00/ton, 33.5-0-0 $89.50/ton, 23-23-0 $103.00/ton

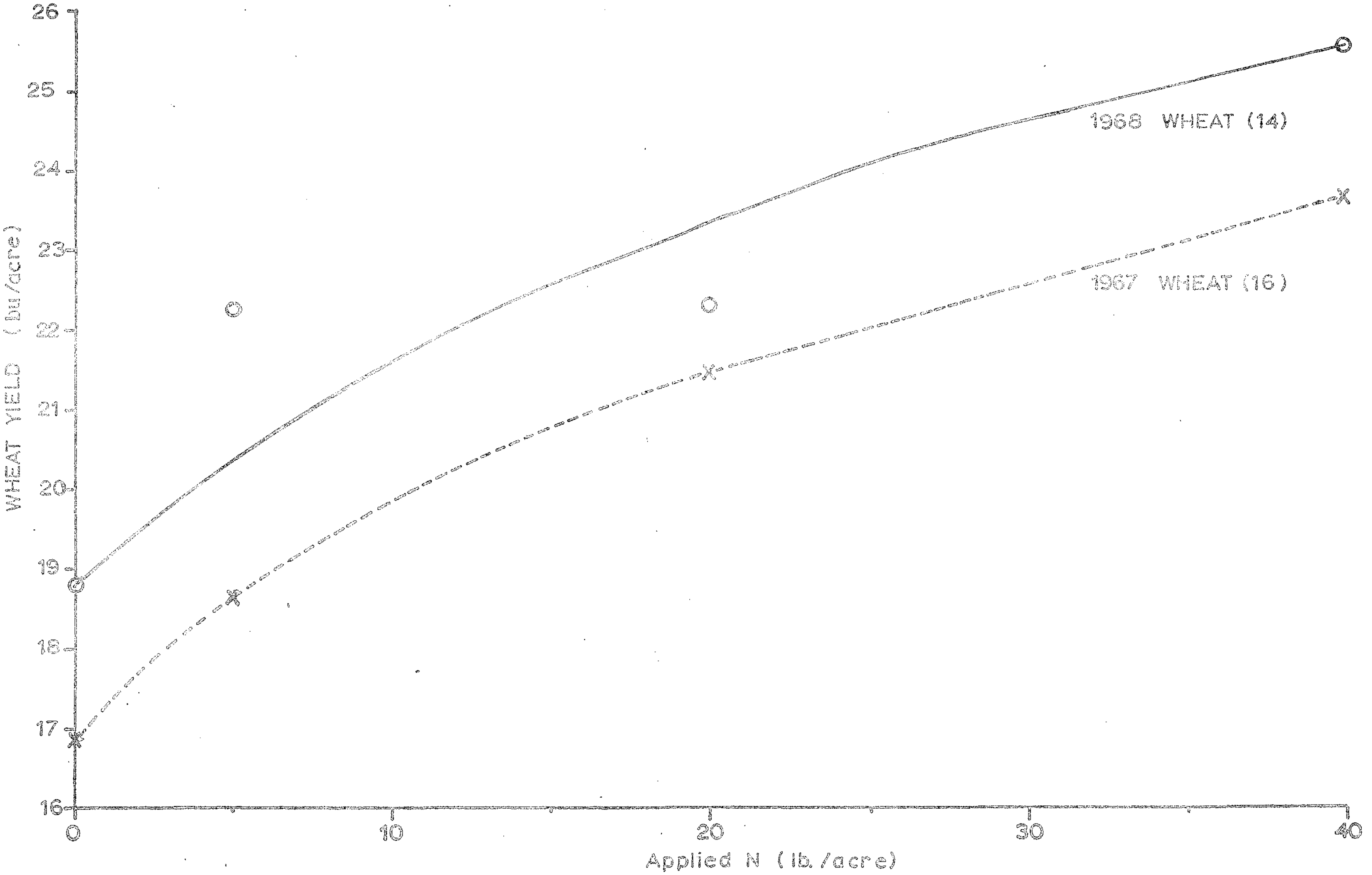

FIGURE 3. Response of wheat to nitrogen in 1967 and 1968 — V.L.A. co-operative tests.

Table 6 Comparison of increases and profits
from soil tests and general recommendation
V.L.A. co-operative tests
(Yield in bu/acre and wheat was test crop unless otherwise indicated)

Advisor-Farmer District	Check Yield	Yield Increase Soil Test Recom.	Yield Increase General Recom.	Increase Soil Test Over Gen.Recom.	Profit Soil Test Over Gen.($/acre)
Baker-Hayward Assiniboia	7.5	1.7	0.9	0.8	-2.55
Cox-Ford Humboldt	18.5	14.3	3.4	10.9	13.00
Fisher-Currie Strasbourg	13.6	10.3	5.1	5.2	8.16
King-Craig Tuxford(Durum)	23.9	3.5	4.7	-1.2	-4.86
MacKay-Stadnick Weyburn	7.9	4.1	3.1	1.0	2.21
McLeod-Beddome Prince Albert	22.1	8.3	6.3	2.0	2.50
Morrow-Young Nipawin	13.3	20.8	9.3	11.5	14.68
Murch-Adair Milden(Barley)	33.0	4.2	1.7	2.5	2.91
Puckey-Nowosad Meacham	19.4	10.9	5.5	5.4	8.36
Salkeld-Keith Yorkton	27.7	6.2	6.9	-0.7	1.50
Simpson-Zunti Unity	22.6	7.2	6.4	1.2	0.38
Steabner-Peckham Hearts Hill	11.7	0.0	0.0	0.0	-4.18
Steenson-Frolek Battleford	7.2	3.8	2.5	1.3	-0.68
Stewart-McLeod Carlyle	19.0	12.5	-1.0	13.5	22.00
Welwood-Lindstrom Wadena	33.2	4.6	2.5	2.1	4.60
White-Hooper Tisdale(Oats)	47.0	32.1	22.5	9.6	4.00
Zinkham-Powell Rosetown	26.8	-0.2	-1.0	0.8	-2.83
Average	20.8	8.5	4.6	3.9	4.06

1.2 Potassium

PURPOSE

To establish response patterns and to evaluate current soil test benchmarks for potassium.

EXPERIMENTAL METHODS

Fields low in potassium were selected for study from samples submitted to the Soil Testing Laboratory in the fall of 1967. The plot area (about 60' x ½ mile) was selected within the field and 10 sampling sites were selected on the basis of slope position. Composite soil samples (0-6", 6-12", and 12-24") were taken in the spring at each of the 10 sampling sites which also served as sites for yield measurements. Nitrogen and phosphorus were applied to the entire plot area at the soil test recommended rate and 0-0-60 was broadcast, prior to seeding at 100, 200 and 400 lb/acre. The potash was broadcast with the same equipment as that for the nitrogen on summerfallow trials (see section 1.1.1). If broadcast nitrogen was required it was applied with department equipment but the phosphorus (as 11-48-0) was applied with the farmer's equipment. Ten trials were seeded and nine were harvested. Three of the plots were permanently staked so that the residual response could be followed.

RESULTS

The comparison of fall and spring sampling (Table 7) for the potassium trials show reasonable agreement for potassium and phosphorus. In examining these data it should be recalled that this is a comparison of the field samples obtained in the fall of 1967 to the values obtained from sampling the trial area in the spring of 1968. The comparison for nitrogen shows close agreement in some cases but very wide divergences in other cases. Most of the trials were placed on Carrot River soils which are

Table 7 Comparison of spring and fall soil test data for potassium trials[1]

Farmer	Nitrate Nitrogen lb/acre to 2' Fall/67	Spring/68	Available P lb/acre to 6" Fall/67	Spring/68	Exchangeable K lb/acre to 6" Fall/67	Spring/68	Soil Type
A. N. Gentner I	113	26	19	16	120	71	Cr:vl
A. N. Gentner II	-	91	-	24	-	238	We:cl
B. Gentner	-	196	-	19	-	182	Cr:vl
Harrison I	26	50	6	15	130	144	Cr:vl
Harrison II	59	88	12	13	70	101	Cr:vl
E. Kozun	19	48	11	10	60	67	Cr:vl
N. Kozun	167	174	19	15	80	61	Cr:vl
Lang	22	36	19	19	210	172	Wf:vl
Rediger I	91	93	15	16	90	104	Cr:vl
Rediger II	40	36	12	16	70	89	Cr:vl

[1] Note that these data compare the fall field values to those obtained from the trial area in the spring.

characterized by inclusions of peaty areas. Examination of the data on the basis of an individual site within the trial area (data not reported) showed that the peaty areas were characterized by a very high nitrate nitrogen status. Therefore, the number of peaty areas included in the sampling pattern would have a pronounced effect on the value obtained for the nitrogen status of a particular field.

The yield results (Table 8) show that excellent responses to potassium were obtained in most trials. In the best response recorded (E. Kozun plot) a yield of 10.9 bu/acre of barley was obtained with N and P applied at the soil test recommended rate while the yield was increased to 57.7 bu/acre by the addition of 400 lb/acre of 0-0-60.

The yield response curves (Figures 4 and 5) show that barley responds better to potassium fertilization than wheat. In one of the wheat trials (Gentner I plot, see Figure 4) excellent visual response was recorded during the growing season. However, a severe early frost resulted in serious yield reduction and undoubtedly affected the response pattern. Therefore, the response levels of wheat may not be as low as indicated by the data as presented in Figure 4.

Two different types of response patterns were observed for barley. In one type (Figure 4) yield increases were recorded for each additional increment of potassium added. In the other type (Figure 5) the 60 lb/acre rate of K_2O gave sharp increases but higher additions of potassium resulted in yield decreases from that obtained with the 60 lb K_2O/acre rate. No explanation is evident for the type of response shown in Figure 5.

The response patterns of barley appear to be related to the K soil test levels. The best responses (Figure 4) were recorded for soils with very low exchangeable potassium levels. The response curve for the

Table 8 Yield response of barley, wheat and rapeseed to potassium fertilization (yield in bu/acre)

Farmer Co-operator	Soil Type	Crop	Nitrogen*+ Phosphorus Yield	Yield Increase 0-0-60 @ 100 lb/acre	200	400	Potassium -Soil Test** lb/acre (spring)
E. Kozun	Cr:vl	Barley	10.9	27.0	37.6	46.8	67
N. Kozun	Cr:vl	Barley	24.1	14.8	26.6	27.8	61
Rediger II	Cr:vl	Barley	44.7	18.6	13.5	9.1	89
Harrison I	Cr:vl	Barley	39.4	2.8	9.4	19.8	144
Lang	Wf:vl	Barley	44.9	17.6	5.3	5.1	172
A. N. Gentner	Cr:vl	Wheat	5.4	9.5	12.8	15.0	71
Rediger I	Cr:vl	Wheat	35.8	7.6	7.5	2.4	104
A. N. Gentner II	We:cl	Wheat	45.5	0.0	-1.0	2.1	238
Harrison II	Cr:vl	Rapeseed	26.2	0.3	2.9	3.5	101

* Note - Nitrogen and phosphorus were applied to the entire plot area at the rates recommended on the basis of the soil test.

** Ammonium acetate extraction

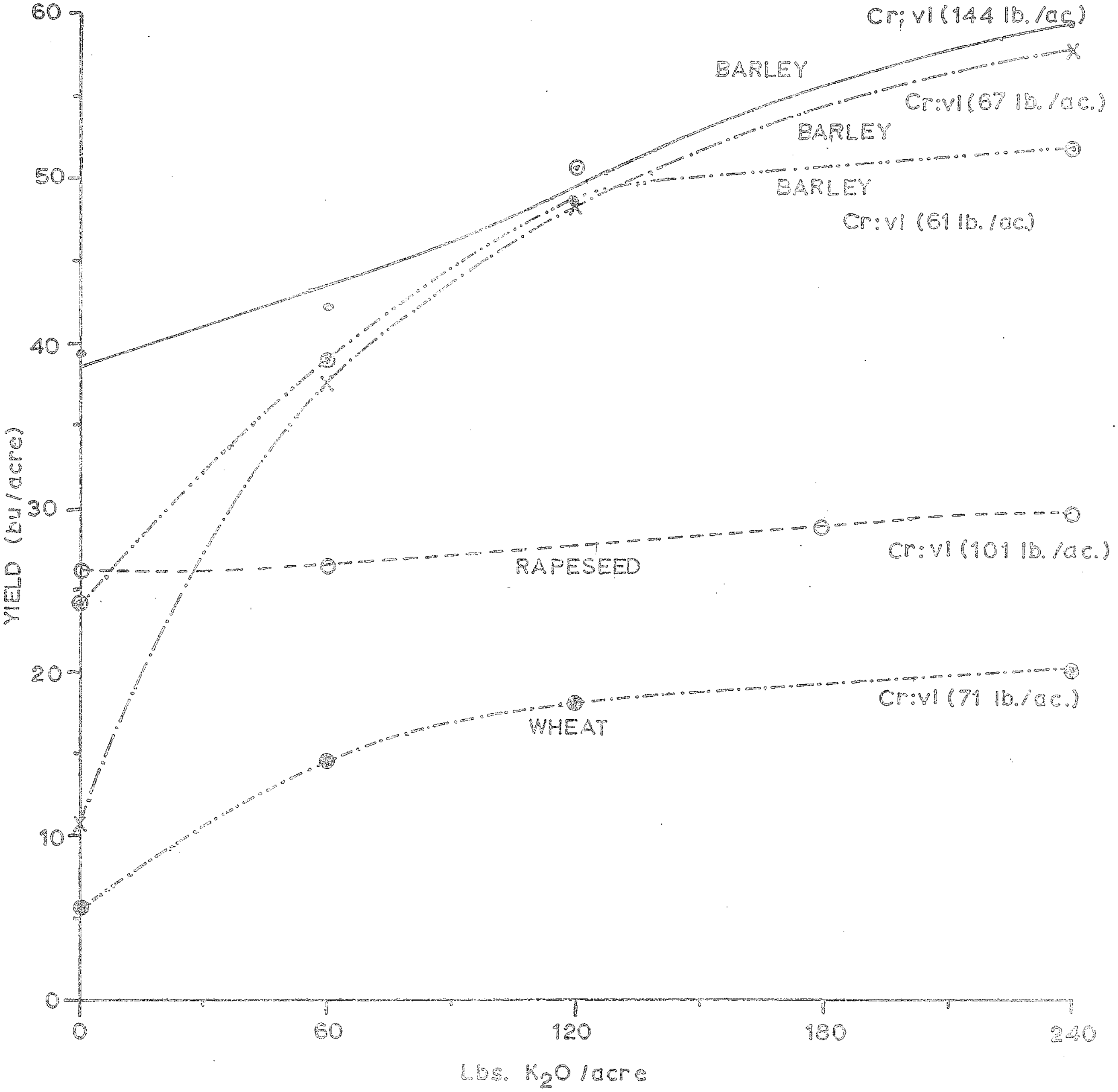

FIGURE 4. Response of wheat, barley, and rapeseed to potassium fertilization.

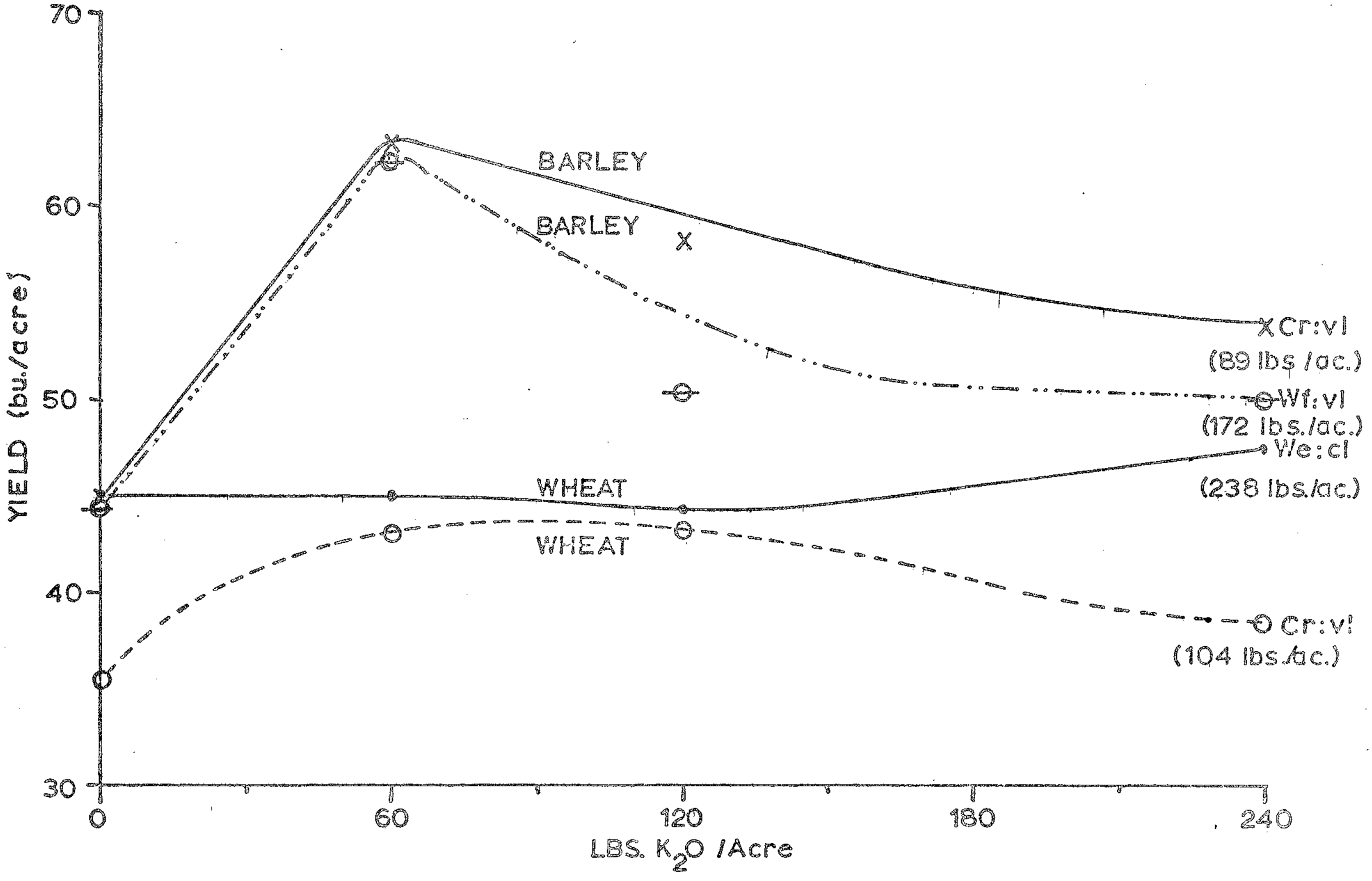

FIGURE 5. Response of wheat and barley to potassium fertilization.

trial with 144 lb exchangeable K/acre was not as sharp as for the two trials with soil K values of 67 and 61 lb exchangeable K/acre.

CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

1. The soil test for potassium is successful in delineating areas of potassium deficiency. However, further research will be required to evaluate and refine current soil test benchmarks.

2. The 1968 results appear to corroborate the 1967 evidence that barley responds better to potash fertilization than does wheat.

3. Potassium research should be expanded to include other soil types such as Sylvania, Whitefox, Shellbrook, LaCorne and some calcareous soils.

4. Further field trials on soils testing very low in potassium should include a large number of rates so an accurate determination of the yield response curve can be obtained. The 3 rates used in 1968 are probably satisfactory for exploratory projects where response is not certain.

2. COMPARATIVE AVAILABILITY OF AMMONIUM POLYPHOSPHATE AND MONOAMMONIUM PHOSPHATE

2.1 Wheat

2.1.1 Field scale trials

Five field scale trials were laid down in the Dark Brown and Black Soil Zones, in which monoammonium phosphate (11-48-0) was compared to ammonium polyphosphate (15-60-0). Department equipment described previously (see section 1.1.2) was used for all the seeding operations. Standard strip tests formed the experimental design and 10 sites were selected, according to subgroup profile distribution, for all soil sampling and yield measurements. All fertilizer was seed placed to supply 15, 25 and 40 lb P_2O_5/acre. The strips with 11-48-0 and 15-60-0 at the same rate of P_2O_5

Table 9 Yield results - polyphosphate strip tests
(Yields in bushels/acre and rates of application of fertilizer in lb/acre)

				Yield Increase over Adjacent Check					
Farmer Co-operator	Soil Type	P lb/acre	Check Yield	11-48-0 @ 31	15-60-0 @ 25	11-48-0 @ 52	15-60-0 @ 42	11-48-0 @ 83	15-60-0 @ 67
Bellamy* (Birch Hills)	M:sicl	12	19.9	2.6	6.6	-1.1	2.5	2.4	1.2
Hoey (Hoey)	M-B:cl	18	34.8	0.9	0.3	0.5	-0.6	5.7	3.1
Jensen (Milden)	R:hvc	15	34.6	-0.5	1.4	-0.5	1.3	-0.5	2.5
Popoff (Saskatoon)	E:cl	41	33.8	7.2	4.0	2.7	1.0	8.6	3.6
Wagner* (Hague)	O:1	20	26.7	2.0	-0.4	2.7	4.1	8.5	7.3

* The rates of application as stated are in doubt for these 2 trials. Visual response in the early growth stages suggested that the fertilizer attachment on the drill was not delivering uniformly.

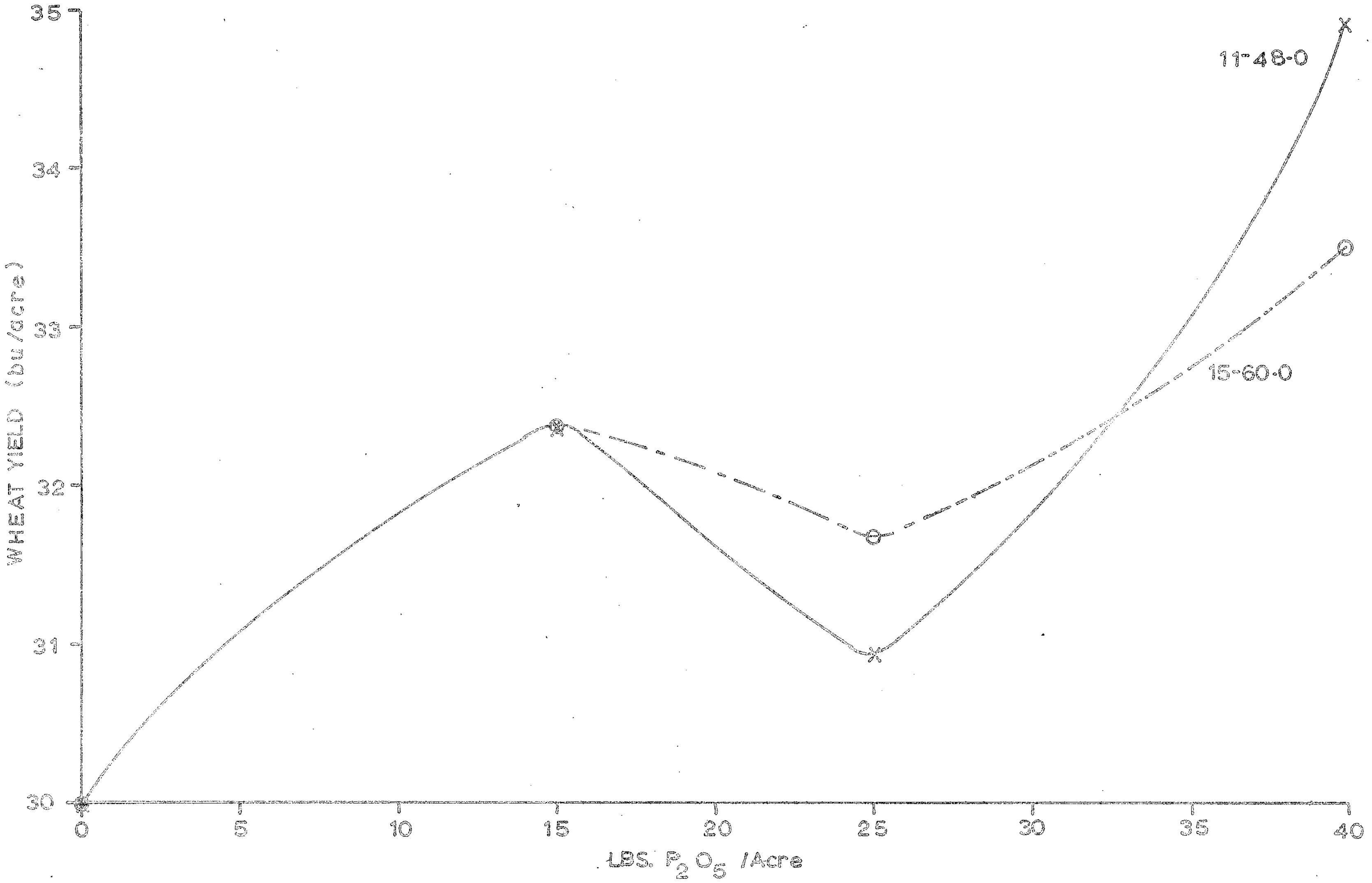

FIGURE 6. A comparison of the response patterns from 11-48-0 (monoammonium phosphate) and 15-60-0 (ammonium polyphosphate) - Average of 5 trials.

per acre were placed adjacent to one another.

The results (Table 9) indicate that no consistent difference exists between the response patterns of 11-48-0 and 15-60-0. In some instances the 11-48-0 was superior while others showed that 15-60-0 gave greater responses. The averaged results, plotted as the yield response surve (Figure 6) indicate that there is very little, if any, difference in the effectiveness of the 2 sources of phosphorus.

2.1.2. Rod-row experiments using P^{32}

PURPOSE

To compare the availability of monoammonium phosphate and ammonium polyphosphate for wheat using the A value technique.

EXPERIMENTAL METHODS

Five experiments were laid down in which monoammonium phosphate (MAP) and ammonium polyphosphate (APP) were compared using P^{32} labelled fertilizer materials. All the fertilizer materials were prepared in powder form in the laboratories of T.V.A. At one site a slightly more condensed ammonium polyphosphate (CAPP) was also used.(see Appendix F for chemical analysis of fertilizers).

The plots were selected on individual subgroup profile sites to give a wide range in soil and climatic conditions. One experiment was laid down on each of Calcareous Dark Brown, Orthic Dark Brown and Orthic Gleysol profiles which occurred within a 20 acre portion of a field of Weyburn loam (Stevenson farm - Saskatoon). The other two experimental sites were on a Calcareous Black profile of the Yorkton Association and a Dark Grey Wooded profile of the Whitewood Association (Ekman farm - Okla). The Yorkton and Whitewood soils occurred as a complex in the same field.(see Appendix E for chemical analysis of soils).

A multi-rate design, with no replication, was employed. The monoammonium phosphate and ammonium polyphosphate were applied at rates to supply 4, 6, 8, 10, 12, 14, 16, 18, 20, 23, 26, and 30 lb P/acre. All fertilizer materials were seed placed in 25 foot row lengths using a Bolens Ridemaster V-Belt seeder. Two foot row lengths were sampled for spring (6 week) A value determination and fifteen foot row lengths were sampled for fall A value and yield determinations. Manitou wheat was the test crop at all experimental sites.

RESULTS

The A values are shown in Table 10. For purposes of comparison of the MAP, APP and CAPP the A values for all rates of application, for a single source, were averaged and the mean and standard deviation of the mean are reported. As A values are considered to be somewhat independent of the rate of application the above method of presentation of results should serve for the comparison of the availability of sources of fertilizer P.

The yields were somewhat variable and it was difficult to establish the response pattern from the multiple rates used. It appears that the single row yield measurement was not sufficiently precise to distinguish between the small rate increments used in these experiments. Therefore, an averaging procedure was employed in order to allow the yield response pattern to be determined. Thus the yields of the 4, 6, and 8 lb P/acre rates were averaged and plotted as the yield for the 6 lb P/acre rate of application. The yield response curves plotted in the manner described above, are presented in Figures 7 and 8.

CONCLUSIONS

From the data in Table 10 and Figures 7 and 8 the following conclusions are drawn:

1. The availability of the APP carrier is at least as great as that of MAP. It should be noted that low A values[1] indicate a high degree of uptake of the

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[1] $A = \frac{\text{soil P in plant}}{\text{fert. P in plant}} \times \text{rate of application of P}$

Table 10 A-values from monoammonium phosphate (MAP), ammonium polyphosphate (APP) and condensed ammonium polyphosphate (CAPP) carriers

		A value (lb P/acre) Spring							A value (lb P/acre) Fall					
		MAP		APP		CAPP			MAP		APP		CAPP	
Farmer Soil Type	Profile	Mean	$S_{\bar{x}}$	Mean	$S_{\bar{x}}$	Mean	$S_{\bar{x}}$	Available P lb/acre to 6"	Mean	$S_{\bar{x}}$	Mean	$S_{\bar{x}}$	Mean	$S_{\bar{x}}$
Stevenson Weyburn:loam	Calc. Dk. Br.	38.6	3.8	33.1	2.8			19	81.0	5.3	90.2	4.7		
	Orthic Dk. Dr.	15.6	2.1	8.8	0.8			14	28.8	2.9	28.2	2.4		
	Orthic Gleysol	22.2	3.0	30.7	5.8	25.8	5.7	42	46.9	3.4	60.8	5.3	66.9	11.1
Ekman														
Whitewood:loam	Dark Grey Wooded	53.9	7.6	33.7	3.7			12	148.4	30.5	100.7	18.8		
Yorkton:loam	Calc. Black	16.3	1.3	7.1	1.3			7	57.2	4.2	54.1	3.2		

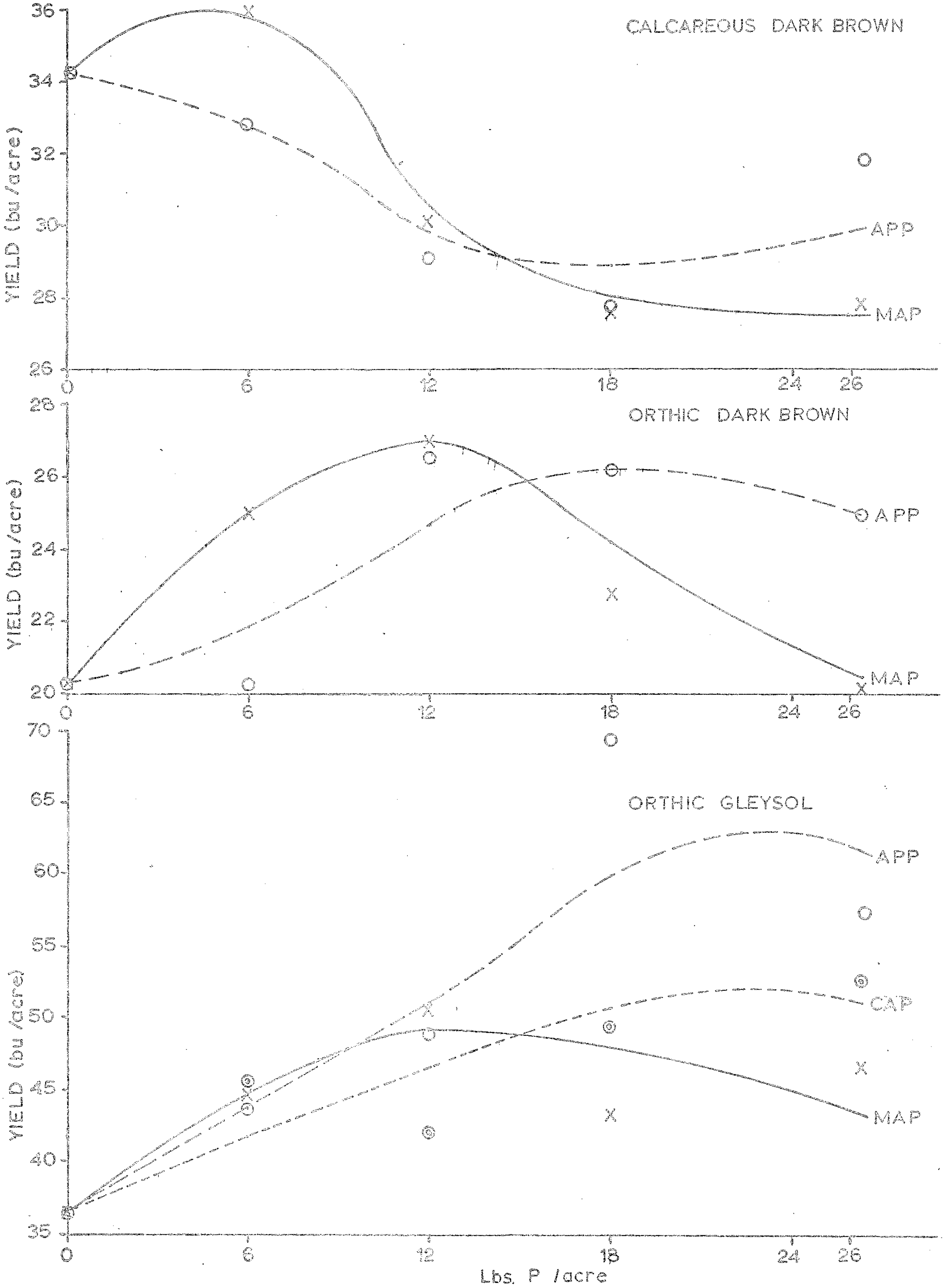

FIGURE 7. Response of wheat to ammonium polyphosphate (APP), monoammonium phosphate (MAP) and condensed ammonium polyphosphate (CAP) on three soil profiles of the Weyburn association (Stevenson farm, Saskatoon)

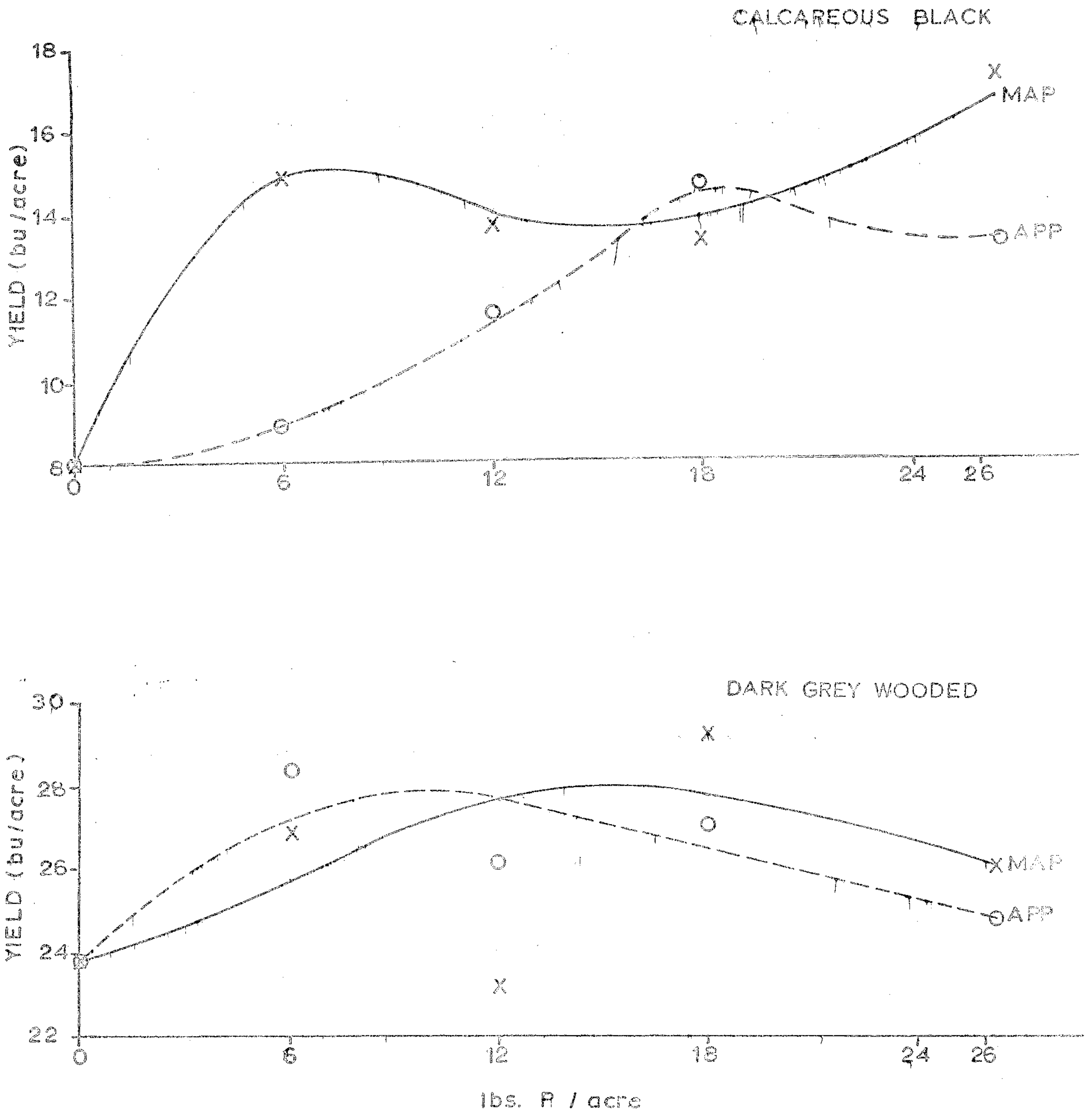

FIGURE 8. Comparison of response of wheat to ammonium polyphosphate (APP) and monoammonium phosphate (MAP) on a Calcareous Black (YORKTON ASSOCIATION) and a Dark Grey Wooded (WHITEWOOD ASSOCIATION) profile. (Ekman farm, Okla)

fertilizer phosphorus. The spring A values for the APP were lower than those for the MAP in 4 of the 5 subgroup profile sites. This trend was reversed for the Orthic Gleysol profile of the Weyburn Association. The fall A values, however, showed the availability of the APP to be greater at only one of the subgroup profile sites, while on the remainder of the sites there was either little difference between the 2 sources, or the MAP availability was greater. Therefore, it could be concluded from the results of this study that the availability of MAP and APP are very similar.

2. The yield response curves show no consistent difference in the response of wheat to MAP and APP. This is consistent with results obtained in the field scale trials (see section 2.1.1). For the upland soils the high yield responses (i.e. Calcareous Black and Orthic Dark Brown sites) are associated with low A values and low available soil phosphorus as measured by the $NaHCO_3$ extraction. The yield depression on the Calcareous Dark Brown profile is difficult to explain.

3. The low availability of soil phosphorus in the Gleysolic profile is shown by the strong yield response and relatively low A values.

2.2 Forage Crops (Brome-Alfalfa)

PURPOSE

To compare the availability of monoammonium phosphate (MAP) and ammonium polyphosphate (APP) for brome-alfalfa crops under irrigated and dryland conditions.

EXPERIMENTAL METHODS

Two experiments were laid down, on established stands of brome-alfalfa in which MAP was compared to APP using P^{32} labelled fertilizer materials. Both sites were on the University farm; the dryland site was on Bradwell loam and the irrigated site was on Asquith fine sandy loam.

A randomized complete block design with 4 replicates was used. Two rates of application, 20 and 40 lb P_2O_5/acre, were used to compare the availability and response patterns of the two sources. All fertilizer materials were broadcast, by hand, on plots 2 feet by 20 feet. The fertilizer was broadcast on May 16 and the forage samples for yield and A value determinations were taken on June 28 (spring) and September 18 (fall).

RESULTS AND CONCLUSIONS

The A value and yield results (Table 11) indicate that there is no significant difference between the availability of MAP and APP for brome-alfalfa. The very low spring A values for the irrigated site indicate that a very high proportion of the added phosphorus was taken up within a short period of time. It should be noted that negative A values are theoretically impossible. However, under the conditions of very high uptake of fertilizer phosphorus, such as that experienced on the irrigated site, a small error in any of the measurements could result in the negative A values which were observed.

Table 11 A-values (lb P/acre) and yields (cwt/acre) from forage plots (average of 4 reps.).

	IRRIGATED				DRYLAND			
	A-value (lb P/acre)		Yield (cwt/acre)		A-value (lb P/acre)		Yield (cwt/acre)	
Treatment lb P_2O_5/acre	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Check	-	-	30.47	33.34	-	-	21.62	20.10
MAP @ 40	6.7	53.8	33.70	33.90	45.0	44.8	26.65	30.96
MAP @ 80	-3.8	68.9	41.76	37.00	42.5	47.8	25.62	19.08
APP @ 40	12.8	49.8	40.05	35.04	63.3	38.2	25.57	21.31
APP @ 80	-3.2	55.8	36.79	36.41	59.0	29.9	25.76	23.29
L.S.D. (0.05)	12.4	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

The spring A values from the dryland plot were considerably higher than for the irrigated plot; which is undoubtedly a reflection of the very low precipitation in the early portion of the growing season. The higher uptake under moist conditions, for broadcast phosphorus is in direct contrast to results for seed placed phosphorus with wheat, where low A values are associated with dry conditions. With broadcast materials a certain amount of precipitation would be required to move the fertilizer into the root zone.

The fall A values for the dryland plot were somewhat lower than the spring A values of the same plot and lower than the fall A values of the irrigated plot. The precipitation was much greater in the latter part of the growing season and this undoubtedly affected the uptake pattern.

Yield increases were recorded for all treatments on the irrigated plot and all but one treatment on the dryland plot. However, these increases were not significant at the 5% level.

There did not appear to be any significant differences in the uptake or response patterns of the two phosphorus sources compared in these experiments.

3. THE PHOSPHATE FEEDING POWER OF SELECTED WHEAT VARIETIES

PURPOSE

To measure the relative phosphate feeding capacities of selected wheat varieties and to indirectly measure rooting habits of the varieties using the A value technique.

EXPERIMENTAL METHODS

Two experiments were laid down, one under sprinkler irrigation and one under dryland conditions. Nine wheat varieties were selected for study. Six of the varieties (Manitou, Selkirk, Pitic 62, Nainari, Webster and 17-20-1) were hard red spring wheats. The Pitic 62 and Nainari are high yielding varieties developed in Mexico. Two of the varieties (Stewart 63 and DT191) were durum wheat and Lemhi is a soft white wheat.

The 9 varieties were arranged in a balanced triple lattice design with 4 replications to give a total of 36 sub-plots at each experimental site. The sub-plots consisted of 7 rows which were 24 feet in length with a 6" row spacing. The P^{32} labelled monoammonium phosphate was applied to the centre row at 20 lb P_2O_5/acre with a V-belt seeder. The adjacent rows on each side were sown, without fertilization, at the same time and with the same seeder. The outer guard rows (2 on each side) were sown with a cone seeder.

Two foot row lengths were taken from the fertilized rows of both the irrigated and the dryland sites on June 28, for determination of spring A values. At the irrigated site the remainder of the fertilized row and one of the check rows were sampled on September 23. The unusually wet and cool conditions in the latter part of the growing season prevented some of the varieties from reaching full maturity at the time of harvesting.

At the dryland site, poor germination and severe drought in the early part of the growing season resulted in very uneven stands. Therefore, samples were taken but no yield evaluations were possible. As well, due to the extremely small sample size it was necessary to composite the grain samples from the 4 replicates to obtain sufficient material for radioactivity readings and total P analysis. Therefore, it was not possible to conduct statistical analysis of the fall A values or total P values from the dryland site.

RESULTS AND CONCLUSIONS

The results of the yield, A value and total phosphorus determinations are presented in Table 12. As explained in the Methods section, no yield determinations were made on the dryland plot and no statistical analysis was possible for the fall measurements from the dryland plot.

The A value determinations showed that the rooting habits and phosphate feeding power of all the hard red spring varieties tested (Manitou, Selkirk, Webster, Pitic 62, Nainari and L.-20-1) were very similar. The fall A value (irrigated) of Lemhi, a soft white wheat, was slightly higher than other varieties, indicating a somewhat greater ability to exploit soil phosphorus reserves. However, this difference was not significant at the 5% level.

The fertilized yields of Pitic 62 and Nainari (high yielding Mexican varieties) were higher than all other varieties tested. However, the check yields of these two varieties were just equal or slightly inferior to Manitou and other hard red spring wheats. The Pitic 62 and Nainari are later maturing varieties and as noted previously the cool, damp weather conditions severely retarded maturity. The excellent phosphate response to Pitic 62 and Nainari was probably due, in part at least, to the earlier maturity associated with phosphate fertilization. The variety Webster, under the conditions of this experiment, was definitely inferior to all other varieties tested.

Table 12 Yield, A values and total phosphorus content of selected wheat varieties under irrigated and dryland conditions

	A Value lb P/acre		Total P mgm P/gm		Yield bu/acre	
Variety	Fall	Spring	Fall	Spring	Check	8.7 lb P/acre
			Irrigated			
Manitou	66.1	36.1	3.71	4.31	52.6	50.8
Selkirk	63.0	32.3	4.09	4.10	48.7	47.1
Pitic 62	64.6	30.6	3.16	3.89	46.6	61.8
Nainari	64.5	37.3	3.59	4.09	51.4	55.9
17-20-1	63.5	35.7	3.44	4.09	46.0	49.6
Stewart	72.7	36.6	3.56	4.10	44.0	48.3
DT 191	67.3	25.2	3.90	4.23	43.5	45.3
Lemhi	80.8	38.3	3.40	3.64	43.5	44.8
Webster	62.0	26.1	3.95	3.75	32.2	30.1
L.S.D. (0.05)	N.S.	N.S.	0.33	0.50	N.S.	8.1
			Dryland			
Manitou	43.0	26.1	4.20	3.80		
Selkirk	41.1	32.1	4.20	3.88		
Pitic 62	38.1	11.9	4.00	3.33		
Nainari	42.9	38.1	4.15	4.04		
17-20-1	41.6	18.1	4.10	3.71		
Stewart 63	52.4	20.6	4.15	3.66		
DT 191	47.6	21.3	4.30	3.66		
Lemhi	30.9	25.6	4.00	3.40		
Webster	47.4	30.4	4.30	3.66		
L.S.D. (0.05)	-	N.S.	-	N.S.		

4. RESIDUAL EFFECTS OF APPLIED NITROGEN

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A. INTRODUCTION

Residual effects may be defined in the broadest sense as changes in a crop caused by fertilizer nitrogen remaining in the soil after application to a previous crop. They may include increases in yield or quality, or changes in species composition such as weed content or changes of dominance in a mixed pasture. Residual N must, therefore, be considered to be any fertilizer-N causing a residual effect. Thus it may be composed of any of several chemical components, including mineral-N, humic-N, N in plant residues and roots, and possibly fixed ammonium.

Residual mineral-N will be present when N is applied in excess of the requirements of a crop. Unless conditions are unfavorable for nitrification, it will occur mostly as nitrate. Residual N present in the humus and in plant residues probably account for most of the N causing residual effects. It is difficult to assess the role of fixed ammonium, however, logically, applied N that is truly fixed probably cannot contribute to residual effects.

Fixed ammonium could exert a negative residual effect. Obviously if a considerable quantity of ammonium added to the soil is fixed in an unavailable form, it will reduce the effectiveness of the fertilizer and hence, both initial and residual effects will be reduced. Similarly, it should be apparent that any of the N loss mechanisms in soil, if of sufficient magnitude, could reduce residual effects of added N. This will apply with losses that occur soon after fertilizer application such as ammonium volatilization and to denitrification of residual nitrate, both of which could limit residual effects. Fortunately, denitrification would appear to be of little importance in prairie soils. Under laboratory conditions, Saskatchewan wheat growing soils have a much lower ability to denitrify added nitrate than their Australian counterparts (Myers, unpublished results).

B. RESIDUAL EFFECTS IN NATIVE AND SOWN GRASSLANDS

About 30 million acres remain as grassland in Western Canada, mainly on the poorer soil types. Due to inherent infertility, substantial responses have been obtained with added fertilizers, particularly N. A significant proportion of the research into fertilizer responses on grassland has included studies of residual responses.

1. Scott Experimental Farm (Ukrainetz, 1965)

A thorough series of field trials has enabled comparisons to be made of residual effects between different soil types, pasture species and N carriers. On Scott loam, a slightly acid Dark Brown Chernozemic soil, one application of broadcast ammonium nitrate to bromegrass produced significant responses in the first year and in two subsequent years (Table 1).

Table 1 Residual effects from one application of ammonium nitrate on yield of bromegrass on Scott loam.

	Yield (lb/acre D.M.)[1]		
Rate lb N/acre	One applic. (1959-65)	1st yr. resid. (1963-65)	2nd yr. resid. (1963-65)
0	1091	1132	878
20	1506	1127	850
40	1668	1341	795
80	2051	1728	926
160	2312	2385	1092

[1] Mean of several years data and mean of fall and spring application. (Ukrainetz, 1965)

The results demonstrate a considerable response in the year of application at all fertilizer levels. There were large residual responses in the second year at 40, 80, and 160 lb N/acre and smaller residual responses in the third year at 80 and 160 lb N/acre. The magnitude of the residual response increased with the rate of fertilization.

Smaller but essentially similar responses were obtained with crested wheatgrass on Scott loam. In both cases, the economic response to the fertilizer was at 40 lb N/acre. In a similar experiment on an Elstow silty clay loam, a slightly saline Dark Brown soil, large initial and first year residual responses were obtained. At 160 lb N/acre, yield was increased by 2100 lb/acre of dry matter in the initial year and by 1000 lb/acre in the first residual year. In this trial, ammonium nitrate and urea were compared as N carriers. The results showed that ammonium nitrate was more effective in both the initial and residual years. In this experiment, the economic rate of application was again 40 lb N/acre.

On Whitewood loam, a Degraded Black Chernozemic soil, the effect of ammonium nitrate and urea on initial and two years residual yields of bromegrass were compared (Table 2).

Table 2 Residual effects from one application of N fertilizer on yield of bromegrass on Whitewood loam.

	Yield (lb/acre D.M.)		
Rate lb N/acre	One applic. (1959-65)[1]	1st yr. resid. (1960-65)	2nd yr. resid. (1960-65)
0 A.N.[2]	1340	1120	550
20	1878	1010	745
40	2335	1184	745
80	2836	1480	876
160	3523	2320	1085
40 Urea	2077	1234	693
80	2523	1240	748
160	3119	1689	980
Mean A.N.	2898	1661	905
Mean Urea	2573	1387	806

---

[1] Means of several years data and mean of fall and spring application.

[2] Ammonium nitrate

(Ukrainetz, 1965)

Large initial responses to both fertilizers were obtained at all applied levels. Residual responses were obtained in both residual years. There were larger initial and residual responses to ammonium nitrate than to urea. This indicates that significant losses occurred from the broadcast application of urea. A toxic effect would not be expected to carry over into the residual years because the possible toxic factors (biuret, ammonia and nitrite) are rapidly transformed in soil. This suggests that ammonium volatilization from the broadcast urea is substantial and greater in magnitude than from ammonium nitrate. If this interpretation is correct, it demonstrates that N losses can be important in governing the magnitude of residual effects.

Smaller residual effects were obtained in a similar trial on Loon River loam, a Grey-Wooded soil. Ammonium nitrate was applied once to bromegrass (Table 3).

Table 3 Residual effects from one application of ammonium nitrate on yield of bromegrass on Loon River loam

	Yield (lb/acre D.M.)		
Rate lb N/acre	One applic. (1962-65)[1]	1st yr. resid. (1963-65)	2nd yr. resid. (1963-65)
0	927	766	441
20	1522	683	584
40	2040	896	591
80	2603	1068	592
Av. Fall[2]	2244	878	619
Av. Spring	2465	991	642

[1] Mean of several years data and mean of fall and spring application

[2] Includes other treatments not tabulated here

(Ukrainetz, 1965)

There was a tendency for the spring-applied fertilizer to be more effective than the fall-applied fertilizer. This demonstrates either N losses from the fall application or stabilization of the added N during the fall and early spring. The economic rate of application for both Whitewood and Loon River soils was 80 lb N/acre.

In another trial with bromegrass/alfalfa on Whitewood loam, there was an initial increase in production of dry matter up to 800 lb N/acre in the first year but no residual yield response in subsequent years. However, there were residual effects on species composition at the high rates of N where the proportion of alfalfa in the mixture remained low even in the third year after application.

At higher rates of N application even larger residual responses were obtained (Table 4).

Table 4 Residual responses of bromegrass to high rates of ammonium nitrate

Rate lb N/acre	Yield (lb/acre D.M.) Whitewood loam	Loon River loam
80	1095	1015
240	2315	2347
320	2660	2446
500	4224	4814
LSD 5%	1269	793

(Ukrainetz, 1965)

This shows the effects of 500 lb/acre of added N on Whitewood loam and Loon River loam. If we consider the 80 lb treatment as a check, then fourfold increases in yield occurred in the second residual year. However, the practical aspects are doubtful as applying 80 lb N/acre for three consecutive years gave yields of the order of 4400 lb/acre of dry matter.

The above results give no indication of the form of the residual N. Residual nitrate from the various treatments appeared to be unimportant (Table 5).

Table 5 Residual nitrate in Scott loam - applied fall 1963; sampled spring 1964

	NO3-N (lb/acre)			
Depth (in.)	Check	20 lb/acre	80 lb/acre	160 lb/acre
0-3	0	0	3	2
3-6	1	2	4	3
6-12	0	2	6	18
12-18	0	3	0	2
18-24	0	6	5	3
Total	1	13	18	28

As ammonium-N was not determined, the results from the 20 lb/acre treatment are difficult to interpret; but at 80 and 160 lb/acre there was obviously a decline in soil nitrate even if there had been no nitrification of the added ammonium. Assuming that denitrification was small, this shows that considerable quantities of added mineral-N must have been incorporated into the organic matter of the soil. Similar results were obtained from Whitewood loam (Table 6).

Table 6 Residual nitrate in Whitewood loam in spring 1965

	NO_3^--N (lb/acre)				
Depth (in.)	4 x 160 lb/ac (fall)	1 x 160 lb/ac (fall) 3 yrs. res.	3 x 160 lb/ac (spring)	1 x 160 lb/ac (spring) 3 yrs. res.	Check
0-12	36	0	4	0	11
12-24	1	2	0	0	0

(Ukrainetz, 1965)

Even after four consecutive years of fall-applied N, only 37 lb/acre NO_3^--N was recovered in the soil in the spring. Negligible quantities of nitrate were found in three year residual plots.

To summarize the work at Scott Experimental Station, it would seem that there is a general tendency throughout for responses and residual effects to be greater from spring-applied fertilizers. There was considerable variation between years. Some years showed very little effect while in other years the residual effect was quite large. The magnitude of residual effects increased with rate of fertilization. Greater responses and residual effects occurred from using ammonium nitrate compared with urea. There was a marked inability of nitrate-N to accumulate in soils even at higher rates of fertilizer. This suggests that these residual effects are caused by remineralization of immobilized fertilizer-N.

2. Results of Other Workers

Kilcher et al. (1965) and Kilcher (1961, 1963) reported results from experiments at ten sites from Manitoba through to British Columbia, all on native grassland. Residual-N responses were obtained at Brandon, Indian Head, Swift Current, and Manyberries to 60 lb N/acre broadcast as ammonium nitrate (Table 7).

Table 7 Residual nitrogen effects on native grass yields

Location	Treatment (lb N/acre)	Yield (lb/acre D.M.)			
		1st yr.	2nd yr. resid.	3rd yr. resid.	4th yr. resid.
Brandon	Check	615	745	775	1000
	60	785	890	765	1010
Indian Head	Check	425	570		
	60	620	990		
Swift Current	Check	330	225	365	
	60	460	350	445	
Manyberries	Check	110	55	120	
	60	160	125	220	

(Kilcher, 1963)

Looking at all ten sites, only 33% of the total yield increase occurred in the first year, 45% in the second, and 17% in the third year. At two sites, where fourth year measurements were taken, Manyberries, Alberta and Summerland, B.C., the response to N was as great as it had been during some of the previous years. Fourth year grass production response at Manyberries accounted for nearly 40% of the total four year increase in production. Residual effects were less sustained in weeds in these trials; that is, weeds responded to the initial N application but showed less response to residual-N.

Smith et al. (1968) at Lethbridge also noted residual effects on weed growth. Large residual responses in the second and third years after addition of up to 1000 lb N/acre were due to the invasion of the sward by various forbs and shrubs of little nutritive value, and also by the increase in size and area of the surviving grass species. Some desirable species were favoured while others were eliminated. Two further residual effects were observed, those of increased palatability and greater persistence of greenness into the fall. An economic assessment of this trial showed that the application of N was uneconomic at all levels. The additional animal unit months of grazing in the four years represented only a 10% return of the total fertilizer investment.

Other materials containing N may also cause residual effects. An example of their use was given by Smoliak (1965) at Manyberries, Alberta. He found large residual responses to heavy application of straw and of manure. However, it is not possible to speak of these effects entirely as N responses as other nutrients undoubtedly are involved.

Smika et al. (1961) at North Dakota have presented soil analyses for N after fertilizer addition of nine annual applications of 0, 30, and 90 lb N/acre (Table 8). These workers showed that the applied N increased the N content of the surface soil. When they included the extra N taken off in herbage, all the applied N was accounted for in the 30 lb treatment and 88% in the 90 lb treatment.

Table 8 Total soil N in native grass plots fertilized annually for 9 years.

Depth (in.)	Nitrogen (lb/acre) 0 lb N/acre	 30 lb N/acre	 90 lb N/acre
0-6	5400	5820*	6020**
6-12	2940	3040*	3200**
Total (6 ft.)	17700	17940	18260
Increase		240	560
% recovery of added N		89%	69%

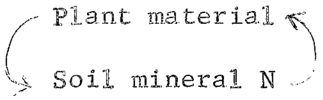
* 5% level

** 1% level

(Smika et al., 1961)

The work of Power (1967, 1968) provides some insight into the fate of applied N in grassland soils. He added nitrate to bromegrass and measured plant and nitrate nitrogen levels throughout two seasons under irrigated and dryland conditions (Figure 1). Added nitrate-N declined rapidly under irrigated conditions to levels close to check by mid-summer. In the dryland plot, nitrate-N declined but held constant when moisture stress conditions prevailed. There was no detectable leaching beyond three feet. Analyses of the root material from these plots showed that N fertilization increased the N content of the roots from 0.8-0.9% N in unfertilized roots to 1.2-1.3% N in fertilized roots. Power also showed that mineralization of the N in the roots during decomposition was dependent on the N content of the roots. When incubated with soil, the roots containing 0.8% N from the unfertilized plot mineralized significantly less mineral N (+8.8 ppm) than the roots containing 1.4% N from the fertilized plot (+19.5 ppm).

These results suggest that N fertilization of grassland results in a temporary tie-up or immobilization of fertilizer-N in the root. Upon senescence this N will be mineralized and much of the N made available during the growing season will come from this source. This suggests that soil humus is less important than once thought. This hypothesis helps explain the extremely large residual responses on grassland as due to a cycling of N through the following type of system:



The large amount of nitrogen contained in roots at the end of the second season tends to confirm this hypothesis (Table 9).

Table 9 Nitrogen content of bromegrass roots

Treatment	Nitrogen (lb/acre) Fertilized	Nitrogen (lb/acre) Check
Irrigated	247	102
Dryland	184	132

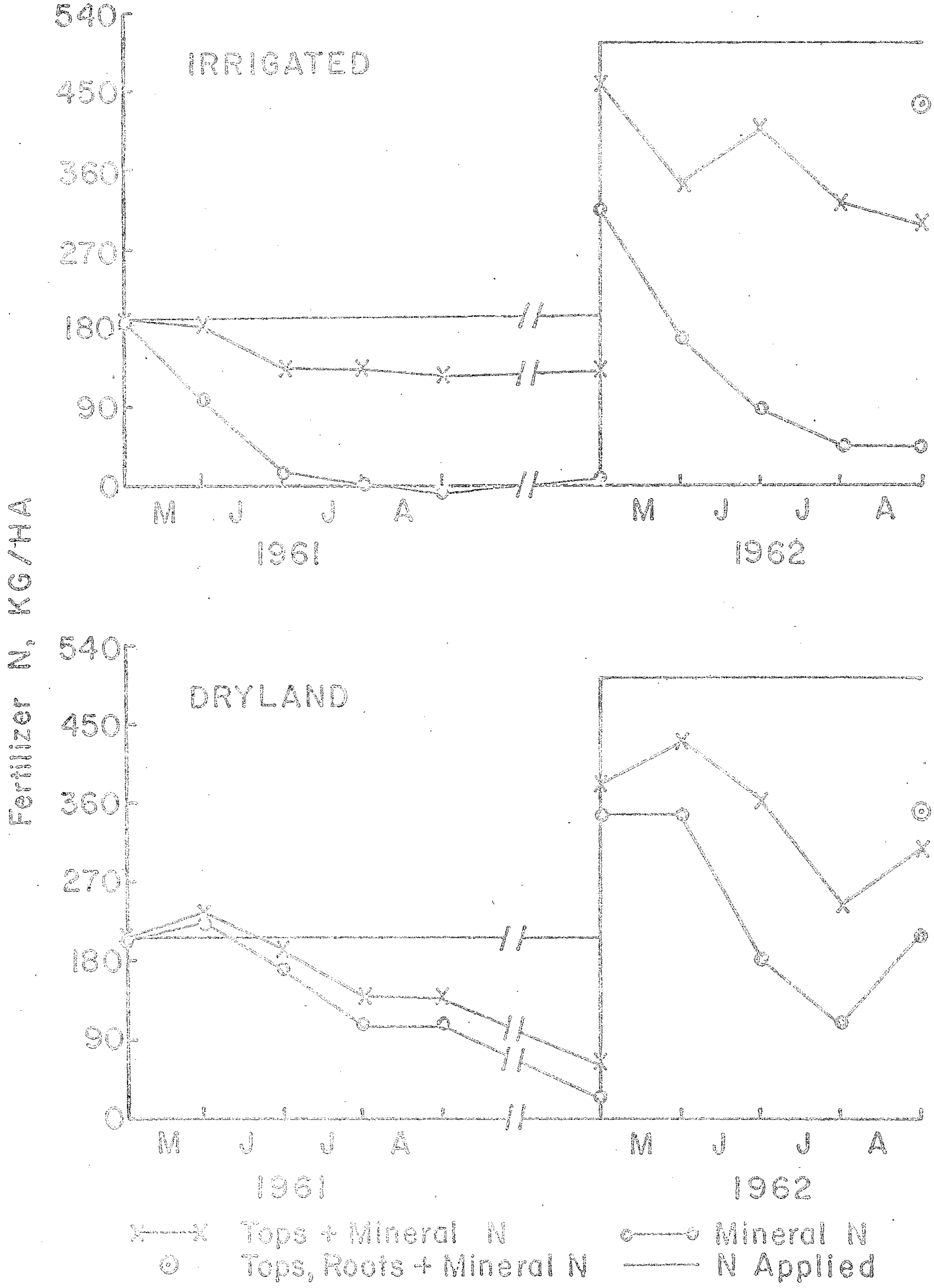
(Powers, 1967)

Some relevant figures for Saskatchewan virgin grassland soils have been obtained (IBP Matador Project unpublished results) for May, 1968 (Table 10).

Table 10 Dry matter content of vegetation on virgin pasture at Matador, Saskatchewan.

Grass	Dry matter (lb/acre)
Green	482
Dead	3490
Roots	
0-4 inches	16356
4-12 inches	22176

Figure 1. Fertilizer N accounted for in bromegrass tops, roots, and mineral soil N as affected by time. Fertilizer applied at 224 and 336 lb N/acre in 1961 and 1962, respectively.



This shows that contrary to the situation in annual crops, most of the N in plant material in grassland is below the soil surface.

Further evidence for the importance of roots in residual responses was obtained by Barnes (1961) in Rhodesia. He found that in uncut pasture, the root weight was large and the residual response was large. In pasture that was cut frequently, the root weight was low and the residual response was also small.

C. RESIDUAL EFFECTS ON GRAIN CROPS

In the prairie provinces in 1967, the application of 150,000 tons of fertilizer-N probably produced an extra 75 million bushels of grain. If the residual effect of this N was only 5% of the original effect, a residual yield increase of 3 3/4 million bushels of grain would be expected. Even if residual effects in cereals are small, a large overall effect may occur.

There is a scarcity of published material for residual N effects in Canada. Most of the work so far reported has been from Europe with a small amount from the U.S.A.

White (1957) in Iowa found that after applying 180 lb N/acre as nitrate to corn, a maximum residual response of +29 bu/acre was obtained on a following oats crop. He considered this response was due to residual nitrate which amounted to 88 lb N/acre in the soil after the first crop.

Pearson et al. (1961) in the southeast of the United States obtained data for N uptake (Table 11).

Table 11 Recovery of NH_4NO_3-N by 3 successive crops

N applied	N recovered (%)			
lb N/acre	1-corn	2-oats	3-corn	Total
50	59	6	12	77
100	55	7	13	75
200	40	13	17	70

(Pearson et al., 1961)

They showed that the recovery of ammonium nitrate fertilizer by three successive crops was large and that the second and third crops were able to recover measurable quantities of applied N.

Widdowson and Penny (1965) in England found that N applied to potatoes consistently increased the yield of the following wheat. The residual effect of 160 lb N/acre was equivalent to a direct application of 60 lb N/acre to wheat. They obtained no significant second year residual effect.

Nommik (1966) in Sweden studied the effect of a single application of 224 lb N/acre on cereals and found significant effects in the second and third year crops. This, he thought, was due to carry over of nitrate-N in the subsoil.

Van der Paauw (1963) in Holland found that with various crops over seven years, the average residual effect was 5.6% of the effect of a corresponding fresh application. The residual effect of N not taken up by the crop averaged 13.5%. The fact that a wet winter reduced the size of the residual effect would suggest that these responses were due to nitrate carry over.

The probable reason for lack of reports of residual effects of N on wheat is that residual effects are small and also that in field experiments, variability is large and it is difficult to detect a statistically significant residual effect. Our standard field methods are not sufficiently precise for this type of study. To study effectively residual N in cereals, we need to use tracer N so that we can assess accurately the partition of the fertilizer N into mineral N, organic matter, and plant meterial.

A growth chamber experiment carried out by Paul (unpublished data) at the University of Saskatchewan provides an example of this approach. Wheat was grown in pots on two soils under three moisture regimes using ammonium nitrate labelled on the ammonium radical (Table 12). Half to three-quarters of the added N was taken up by the plant (roots included). About 20-36% remained in the soil.

That remaining in the soil (residual N) was present as organic N (15-20%) and as nitrate-N (0-18%). Maximum residual nitrate occurred at high moisture stress while the maximum N immobilized in the soil organic matter occurred at low moisture stress. The last line of this table shows why it is necessary to account for all forms of N. This treatment has the least residual N and also has the highest loss of N during the experiment. By contrast, where residual N is highest, there has been little loss of N. This demonstrates the dependence of residual N and N losses but does not indicate any causal relationship.

Table 12 Nitrogen balance of labelled $N^{15}H_4NO_3$ in 2 soils under 3 moisture regimes

		N^{15} recovery (%)			
Soil	Treatment (atm.)	Plant	Soil OM	Soil NO_3-N	Total
Oxbow	0.23-1	71	28	nil	99
	0.23-4	69	21	9	99
	0.23-10	59	15	18	92
Melfort	0.23-1	60	36	nil	96
	0.23-4	68	20	5	93
	0.23-10	63	15	5	83

Jansson (1963) performed a residual N experiment using N^{15} in pots which, however, were left outside in the natural environment and, therefore, shows some similarity to field conditions (Table 13).

Table 13 Residual uptake of N fertilizer by oats

		N uptake (mg/pot)						
Harvest at	N source	1956	1957	1958	1959	1960	1961	Total
Maturity	NH_4	207	8	5	5	5	6	236
	NO_3	283	5	6	5	4	3	306
Earing	NH_4	178	41	4	4	3	8	238
	NO_3	287	11	6	4	4	5	317

(Jansson, 1963)

He showed that residual N became available in small quantities through five residual crops. The first residual crop removed the most N and thereafter uptake of fertilizer-N was small. He estimated that the half-life of the residual N was approximately 20 years. More N was recovered from nitrate in the first crop but residual N from ammonium and nitrate additions were similar.

Growth chamber and greenhouse experiments have provided much information relating to the incorporation of fertilizer N into soil organic matter and its subsequent release. To discuss it all in detail would be impossible. To summarize some of the main findings:

(a) Jansson (1958) elaborated the concept of an active and passive phase of organic matter. The active phase comprised 10-15% of the total organic N.

(b) More N enters the organic matter when straw is present in the soil (Broadbent and Nakashima, 1967).

(c) Immobilization of ammonium-N tends to be greater than that of nitrate-N (Jansson, 1958).

(d) Most of the immobilized N enters a fraction known as the non-distillable, acid-solution nitrogen (Stewart, Porter and Johnson, 1963). Most of the N remineralized is then derived from this fraction (Stewart, Johnson and Porter, 1963). In a pot experiment, they found that 75% of the residual N taken up by four successive crops was derived from the non-distillable, acid-solution N.

(e) Residual soil N is progressively stabilized and slowly converted to more resistant fractions (Broadbent and Nakashima, 1967).

Despite the excellence of greenhouse and growth chamber studies with regard to soil N, very little is known of N reactions under field conditions. It took soil scientists a very long time to realize the possibilities of N^{15}. It has taken still longer for them to use it in the field. The principle objections namely the cost of N^{15} and the excessive mobility of N in small plots can no longer be justified.

In May, 1967 we set up a field experiment using doubly labelled ammonium nitrate on wheat on two soil types near Saskatoon. The purpose was to study the effect of two rates, 50 and 100 lb N/acre with and without straw at 2 ton/acre on Bradwell soil and 100 lb N/acre with and without straw on a Sutherland soil. Ammonium nitrate at 6.14% enrichment was used. Large steel pipes 12 inches in diameter and 36 inches long were pressed down into the soil to a depth of 36 inches. The pipe was used to provide a boundary between labelled and unlabelled areas, to prevent movement of N laterally, and to prevent uptake of labelled N by plants outside the experimental area. In one extra treatment, straw labelled with N^{15} was applied to the Bradwell soil to determine the availability of the straw N. Two crops of wheat were grown. Small soil samples (0-3 inches) were taken in August 1967 and May 1968. In September 1968, the entire soil sample was removed and subsampled according to depth.

The analytical work is as yet incomplete but the results so far obtained provide some information on residual N effects. Table 14 shows the quantity of fertilizer N remaining in the 0-3 inch layer of the soil after various periods of time. Residual nitrogen in the 0-3 inch depth declined with time. More fertilizer N remained in the surface of the lighter-textured Bradwell soil than the heavy-textured Sutherland soil initially, but the N in the Sutherland soil declined more rapidly. Little labelled mineral-N remained in the 0-3 inch soil at sampling, so these figures represent mostly organic N.

Table 14 Residual fertilizer-N in surface soil (0-3 in.) in the field

Soil	Treatment (lb N/acre)	August 67	May 68	September 68
			(N lb/acre)	
Bradwell	100[1]	18.5	14.4	12.8
	100 + S[2]	27.3	23.6	18.9
	50	11.1	8.3	7.7
	50 + S	15.9	15.0	12.5
	S*(41)[3]	27.0	25.6	n.d.
Sutherland	100	14.6	8.3	7.7
	100 + S	24.3	13.6	14.1

[1] lb N/acre

[2] straw 2 ton/acre

[3] N15 labelled straw at 2 ton/acre containing 41 lb N/acre

The presence of 2 ton/acre of straw markedly increased the retnetion of fertilizer-N as residual N at both fertilizer levels. This is not unexpected as it has been shown frequently in the pot experiments that straw enhances N immobilization.

The N balance is not yet complete, however, the following partial balance sheet has been set up (Table 15).

Table 15 Recovery of fertilizer-N by 2 wheat crops and surface soil

Soil	Treatment	lb N/acre Wheat 1967	Wheat 1968	Soil 0-3 in.
Bradwell	100[1]	14.6	6.2	12.8
	100 + S[2]	10.5	9.0	18.9
	50	12.4	1.8	7.7
	50 + S	8.3	1.6	12.5
	S* (41)[3]	2.3	1.4	n.d.
Sutherland	100	39.6	9.5	7.7
	100 + S	46.0	4.8	14.1

[1] lb N/acre

[2] straw 2 ton/acre

[3] N15 labelled straw at 2 ton/acre, containing 41 lb N/acre.

This shows that the rates of application chosen were probably a little high considering the seasonal conditions in the first year. In the Sutherland soil which had more favourable moisture conditions, wheat recovered more fertilizer-N than from the Bradwell soil. There tended to be more uptake of labelled N in the absence of straw.

There was partial mineralization of the N in the N^{15}-labelled straw. Straw N clearly was more stable than the fertilizer N.

In this partial balance, the total recovery so far amounts to 34-45% from the Bradwell soil and 57-65% from the Sutherland soil.

Basically the same kind of results have been obtained in a Russian field experiment using tracer N (Koritskaya, 1968). In the first year, uptake of labelled N by wheat amounted to 30-38% of that added as three different N sources. In the second year, uptake by oats was only 2.2 - 7.0%. Tracer N remaining in the soil at the end of the experiment amounted to 19-35% of that added.

This type of approach is required to obtain information on the residual effects of N under field conditions. Obviously, in Western Canada N fertilization is extensive and increasing in use. We should know more about what is happening to it.

D. CONCLUSIONS

It should be obvious that when we are considering the question of residual N uptake we have to think of it in terms of two separate systems, the grassland and the annual cereal crop.

In the grassland, we have a system in which there is an extremely large mass of root material. When N fertilizer is added to this system, a large quantity ends up in the root fraction. The total mass of roots is increased and the concentration of N in the roots is also increased. The very large residual responses that result from applied N in grassland must be largely due to a turnover of root N. As roots slough off and senesce they decompose and part of the N is mineralized. The mineral-N released is in turn taken up by plants and the cycle continues.

In the cereal crops, the root system is much smaller and residual responses will depend more on the nitrate-N remaining in the soil and/or on the release of immobilized N from the soil organic matter. Another factor is the return of residues to soil. These may immobilize added N and subsequently release part of this for later crops. However, there is no evidence that this immobilization/remineralization reaction has a significant effect on wheat yields. It is probable that most observed residual yield increases in wheat have been caused by residual nitrate and that this has occurred when N has been applied at rates higher than required for maximum yield response. When recommended rates of N are applied, residual effects on yield are not evident and uptake of residual N can only be detected using tracer techniques. Residual effects on cereals are probably not of great magnitude because of the relatively greater removal of applied N by the initial crop.

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APPENDIX

Appendix A Legal locations and rainfall records of all experimental sites

Farmer	Legal Location	Rainfall Records (in.)					Total
		May	June	July	Aug 1-15	After Aug 15	To Aug 15
	Nitrogen Trials on Summerfallow						
Bandet	NW 22-38-28-2	1.51	0.78	4.32	0.60	3.85	7.21
Chapman	W 21-31-18-2	0.83	1.16	3.09	0.27	2.39	5.35
Halstead I	SE 18-30-22-2	0.48	0.40	3.93	0.96	1.40	5.77
Halstead II	SW 19-30-22-2	0.48	0.40	3.93	0.96	1.40	5.77
Hamm	SE 10-35-5-3	1.50	1.10	4.20	1.83	2.39	8.63
Heggie I	NW 17-35-4-3	1.93	1.88	3.74	1.33	6.12	8.88
Heggie II	SW 17-35-4-3	1.93	1.88	3.74	1.33	6.12	8.88
Lockwood	SE 31-27-27-2	0.50	0.60	2.10	0.68	2.00	3.88
Lucyshyn	SE 26-39-27-2	-	-	-	-	-	-
Presnell	SW 17-32-3-3	1.09	2.35	3.79	1.36	4.61	8.59
Stephan	SW 6-34-22-2	1.22	1.08	4.25	3.30	1.00	9.85
Stone	E 12-27-1-3	1.46	0.55	1.65	0.85	1.46	4.51
	Nitrogen Trials on Stubble						
B. Bruce	SE 2-19-26-2	1.60	0.70	0.90	1.60	-	4.80
R. Bruce	N 1-19-26-2	1.75	0.75	0.75	2.00	2.00	5.25
Coolidge	SW 19-49-25-3	0.70	2.03	5.69	1.28	2.27	9.70
Froh	SE 23-7-19-2	1.30	0.80	1.05	2.80	2.75	5.95
Hamilton	NE 21-33-17-3	3.00	0.00	1.56	1.45	1.30	6.01
Hult	N 17-47-24-3	0.76	1.95	3.75	3.00	0.45	9.46
Latrace	N 34-33-11-3	4.73	0.90	2.37	1.52	-	9.52
Wallace	SE 29-39-24-3	-	-	-	-	-	-
Wallin	SE 30-33-9-2	0.75	1.50	1.79	1.00	1.00	5.04
Kowalenko	NW 18-38-11-3	4.05	0.35	4.87	1.12	2.20	10.39
George	NW 2-36-9-2	0.74	1.75	3.90	1.00	1.60	7.39
Minky	SW 4-38-10-2	0.90	2.40	6.60	0.30	3.30	9.20
Raven	SW 18-37-9-2	1.90	1.85	5.25	1.00	3.07	10.00
Weinhandl	N 33-36-9-2	0.58	1.75	4.54	1.17	2.15	8.04
	Potassium Trials						
Gentner I	SW 3-50-12-2	1.10	3.22	2.82	0.31	3.19	7.45
Gentner II	SW 16-49-12-2	1.69	3.10	2.85	-	3.68	7.64
Harrison I	SW 6-53-13-2	2.47	1.25	2.63	0.61	4.85	6.91
Harrison II	SE 6-53-13-2	2.47	1.25	2.63	0.61	4.85	6.91
E. Kozun	NW 34-49-11-2	-	-	-	-	-	-
N Kozun	SW 19-50-11-2	-	-	-	-	-	-
Lang	NE 23-49-13-2	2.00	2.96	2.73	0.61	3.13	8.30
Rediger I	SW 11-49-12-2	2.44	3.10	2.60	0.37	2.17	8.51
Rediger II	SE 11-49-12-2	2.44	3.10	2.60	0.37	2.17	8.51

Appendix A Continued

		Rainfall Records					
Farmer	Legal Location	May	June	July	Aug 1-15	After Aug 15	Total To Aug 15
Polyphosphate - Field Scale							
Bellamy	NE 24-46A-25-2	3.47	1.15	4.07	0.96	3.24	9.65
Hoey	NW 32-44-26-2	2.71	1.12	4.34	0.86	2.22	9.03
Jensen	NW 3-30-12-3	3.20	0.56	1.83	1.95	1.60	7.54
Popoff	SW 5-36-3-3	1.79	1.85	3.47	0.95	2.10	8.06
Wagner	SE 26-41-5-3	-	-	-	-	-	-
Polyphosphate - Rod Row - P^{32}							
Stevenson	SW 3-37-4-3	1.67	1.45	3.73	2.85	1.14	9.74
Ekman	SW 32-34-8-2	1.08	2.71	3.39	1.00	2.14	8.18
Polyphosphate - Forage							
Dryland	U.Farm	2.10	1.39	3.95	0.93	4.37	8.37
*Irrigated	U.Farm	2.10	5.59	5.15	0.93	4.37	13.77
Straw Incorporation							
Honey	SE 6-37-9-2	1.25	2.69	2.16	2.61	3.01	8.71
Roth	NW 36-42-4-3	1.62	0.51	4.59	0.98	1.16	7.70
Wheat Varieties							
Dryland	U.Farm	2.10	1.39	3.95	0.93	4.37	8.37
*Irrigated	U.Farm	5.85	5.14	7.70	0.93	4.37	19.62
V.L.A. Trials							
**Baker							
***Hayward	SE 22-8-30-2	0.00	1.63	0.95	1.80	-	4.38
Cox							
Ford	SW 28-37-23-2	1.51	1.83	3.41	0.85	4.06	7.60
Draftenza							
Denis	SE33-11-5-3	0.65	0.51	1.50	0.00	-	2.66
Fisher							
Currie	NE 1-24-23-2	0.62	1.26	2.60	1.12	-	5.60
Kendel							
Tosh	SW 22-14-3-2	0.30	0.97	1.90	1.30	4.69	4.47
King							
Craig	SE 5-19-26-2	1.10	1.70	2.50	1.80	1.80	7.10
Laing							
Boechler	NW 9-50-8-3	4.00	1.90	3.20	0.30	1.80	9.40

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* Data includes natural rainfall and irrigation

** Credit Advisor

*** Farmer

Appendix A Continued

Credit Advisor Farmer	Legal Location	Rainfall Records May	June	July	Aug 1-15	After Aug 15	Total To Aug 15
MacKay Stadnick	NW 31-6-18-2	0.30	0.10	0.90	4.60	4.20	5.90
McDonald Yakubowich	N½ 20-25-5-2	0.25	1.97	2.74	0.55	3.43	5.51
McLeod Beddome	30-46-26-2	2.75	1.16	4.16	0.91	2.83	9.00
Morrow Young	NE 13-51-15-2	3.28	1.98	2.61	0.41	4.14	8.28
Murch Adair	SW 26-30-11-3	2.69	0.99	1.13	2.23	-	7.04
Peace Freeman	NE 31-44-21-2	2.20	2.42	3.28	1.11	3.60	9.01
Puckey Nowosad	SE 32-36-27-2	1.35	1.50	3.50	0.80	4.20	7.15
Salkeld Keith	SE 33-26-3-2	0.69	1.61	3.25	0.95	1.86	6.50
Sherwin Sharp	NW 17-10-18-3	0.00	1.00	0.00	0.00	-	1.00
Sikora Kulovany	SE 15-19-2-2	3.50	1.00	5.40	2.20	3.20	12.10
Simpson Zunti	NW 34-38-25-3	0.00	2.05	1.82	0.69	4.45	4.56
Steabner Peckham	SW 32-36-26-3	0.00	2.33	3.14	1.42	4.05	6.89
Steenson Frolek	SW 9-44-17-3	0.06	0.90	4.06	0.90	3.01	5.92
Stewart McLeod	SW 14-8-3-2	0.03	0.81	1.73	2.10	4.18	4.67
Welwood Lindstrom	SE 4-35-13-2	1.50	1.36	3.10	0.85	4.00	6.81
White Hooper	NE 34-43-14-2	1.90	1.97	3.75	0.69	2.67	8.31
Zinkhan Powell	NW 3-31-15-3	2.20	0.79	2.39	1.27	1.65	6.64

Appendix B Yield results: Department of Soil Science - V.L.A. co-operative trials on stubble land (Yields in bushels/acre)

Credit Advisor Farmer	Soil Type	Check Yield	11-48-0		23-23-0		11-48-0 + 33.5-0-0		NO_3-N
			Rate lb/A	Yield Increase	Rate lb/A	Yield Increase	Rate lb/A	Yield Increase	lb/A - 2' Spring/68
Baker-Hayward Assiniboia Wheat	Hv:1	7.5	43	1.3	76	0.9	43+120	1.7	--
Cox-Ford Humboldt Wheat	O:1	18.5	44	3.9	90	3.4	44+80 30+80 23-23-0@41 +34-0-0@80	14.3 11.5 14.7	56
White-Hooper Tisdale Oats	Ti:sicl	47.0	36	13.0	80	22.5	50+110	32.1	27
Draftenza-Denis Gravelbourg Durum	Fx:sicl	11.6	42	3.6	87	3.5			43
Fisher-Currie Strasbourg Wheat	W:1	13.6	42	4.6	94	5.1	42+60	10.3	35
Kendel-Tosh Langbank Flax	O:1	15.0	38	2.7	80 120	2.9 -0.1	38+110	1.9	43
King-Craig Tuxford Durum	Tu:c	23.9	40	6.9	87	4.7	40+120 60+90 33.5-0-0@25 (with seed)	4.0 3.5 3.9	25
Laing-Boechler Shell Lake Barley	Wh-P:cl	24.8	53	6.4	67	3.7	53+100	19.8	61
MacKay-Stadnick Weyburn Wheat	Hv:1	7.9	45	1.5	80	3.1	35+35*	4.5	51
McDonald-Yakubowich Yorkton Wheat	Me:fsl	19.9	53	9.2	70	1.6	53+90	2.5	90
McLeod-Beddome Prince Albert Wheat	Sb:vfsl	22.1	40	1.4	90	6.3	40+85* 56+50*	11.3 8.3	56

Morrow-Young									
Nipawin	Wf:vfsl	13.3	46	2.4	89	9.3	46+60	9.6	36
Wheat							53+120	20.8	
Murch-Adair									
Milden	E:sicl	33.0	40	0.4	76	1.7	40+76	-7.0	59
Barley			52	8.1					
Peace-Freeman									
Kinistino	M:sicl	37.8	49	1.2	83	0.8	16-20-0@83	4.8	133
Wheat									
Puckey-Nowosad							41**+50*	10.9	36
Meacham	E:sicl	19.4	41**	2.9	82	5.5	41**+86*	17.5	
Wheat							16-20-0@82	5.3	
Salkeld-Keith									
Yorkton	Ca:sil	27.7	41	6.2	95	6.9	41+120	-0.3	115
Wheat									
Sherwin-Sharp									
Shaunavon	Cy:l	8.0	37	0.8	73	2.2	37+105	-1.5	113
Barley									
Sikora-Kulovany									
Esterhazy	O:l	22.5	44	1.4	97	0.6	44+120	-5.0	28
Oats									
Simpson-Zunti									
Unity	W:cl	22.6	40	2.8	90	6.4	40+120	11.0	37
Wheat							55**+70	7.2	
Steabner-Peckham									
Hearts Hill	E:cl	11.7	53	-0.7	80	0.0	53+120	0.0	23
Wheat									
Steenson-Frolek									
Battleford	Me:fsl	7.2	38	2.7	87	2.5	38+120	-1.2	29
Wheat							50+100	3.8	
Stewart-McLeod									
Carlyle	Cd:sil	19.0	38**	1.7	90	-1.0	38**+120	-0.4	160
Wheat							38**+70	12.5	
Welwood-Lindstrom									
Wadena	Y:l	33.2	40	3.7	60	1.6	52+120	5.8	75
Wheat			52	4.6	80	2.5			
Zinkhan-Powell									
Rosetown	R:hvc	26.8	43	5.6	114	-0.8	43+100	-0.2	48
Wheat					78	-1.0			

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* Indicates 46-0-0 was used in pl[illegible]-0-0 ** Indicates 11-55-0 was used in place of 11-48-0

Appendix C Protein content of wheat for various rates of nitrogen of selected stubble trials

Farmer	Soil Zone	Protein (%)						
		Check	lbs N/acre applied					
			7	20	30	40	60	80
Ron Bruce	Dark Brown	13.4	14.9	13.6	14.7	14.4	15.1	15.2
Kowalenko	Dark Brown	14.5	13.9	14.7	15.2	14.2	15.5	15.7
Coolidge	Black	14.7	14.6	14.1	14.3	15.1	14.7	15.0
Wallin	Black	15.6	15.3	14.6	15.4	15.8	15.8	15.6
George	Grey	13.2	13.8	13.8	13.5	12.5	12.5	14.2
Weinhandl	Grey	12.7	13.2	11.9	12.8	12.8	12.7	15.1

Appendix D Soil test results (spring) for School of Agriculture trials

Farmer	NO_3^--N lbs/acre to 2'	Available P lbs/acre to 6"	Exchangeable K lbs/acre to 6"
Bob Bruce	29	21	1502
Ron Bruce	33	22	1278
Coolidge	23	21	645
Froh	43	13	835
Good	135	41	1211
Hamilton	54	22	1204
Huit	19	11	444
Latrace	45	19	819
Wallace	30	23	767
Wallin	78	24	563
Turvey	45	85	610
Kowalenko	18	11	528
George	16	39	394
Minky	6	22	377
Raven	43	36	409
Weinhandl	14	11	337

Appendix E Chemical analyses of soils on which the rod-row polyphosphate trials were placed.

Soil	Depth	NO_3^--N (lb/acre)	Avail. P (lb/acre)	Exch. K (lb/acre)	pH	Cond. mmhos/cm
Weyburn	0-6	25	19	920	7.8	0.5
Calcareous	6-12	30	7	370	8.0	0.5
Dark Brown	12-24	84	4	880	8.1	2.5
Weyburn	0-6	49	14	950	6.9	0.6
Orthic	6-12	34	3	710	7.6	0.7
Dark Brown	12-24	150	6	1220	8.2	1.4
Weyburn	0-6	83	42	1400	6.5	0.6
Orthic	6-12	26	10	550	6.2	0.4
Gleysol	12-24	18	16	1220	6.5	0.5
Whitewood	0-6	11	12	450	7.7	0.4
Dark Grey Wooded	6-12	11	12	450	7.6	0.5
	12-24	8	8	520	8.2	0.4
Yorkton	0-6	30	7	360	8.1	0.6
Calcareous	6-12	20	4	330	8.1	0.6
Black	12-24	16	6	520	8.1	0.8
Forage Irrigated	0-6	8	12	540	7.2	0.4
Asquith	6-12	8	4	370	7.5	0.4
	12-24	14	12	500	8.3	0.4
Forage Dryland	0-6	4	17	660	7.2	0.3
Bradwell	6-12	2	8	420	7.4	0.3
	12-24	4	8	680	8.0	0.3

Appendix F Chemical characterization of phosphate fertilizers used in rod-row experiments with P32

Fertilizer	Analysis (%) N	Analysis (%) P_2O_5	Analysis (%) K_2O	P_2O_5 as Orthophosphate	% P_2O_5 as Polyphosphate
Monoammonium Phosphate	-	59.5	0	100	0
Ammonium Polyphosphate	16.8	63.4	0	40-50	50-60
Condensed Ammonium Polyphosphate	16.7	62.2	0	5-10	90-95