1959 TRACER FERTILIZER RESEARCH REPORT

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CONTENTS

SOIL MEMBER INVESTIGATIONS

Purpose - To determine whether crop yield differences within an area that has had uniform cultural and cropping practices in the past can be related to pedogenic differences used to separate soils into differing units. This project is a cooperative study with the Saskatchewan Soil Survey, (Mr. J. S. Clayton, Senior Pedologist).

Methods - Plot sites were selected in the fall of 1958 at three locations within the Regina map sheet area. (The soil survey of this area, comprising some 5 M acres, was completed during the 1958 season.) The location of the sites, together with a brief description of the catenary groups of soils belonging to the Weyburn and Aberdeen soil associations, is as follows: (member profiles of the Regina Association were also included in the study, but due to excessive wind erosion in the spring, followed by prolonged drought, the crop was not harvested).

Weyburn Catena - Soils developed on medium textured brownish grey to yellowish brown, moderately calcareous and moderately stony glacial till deposite. The surface texture is predominately loam but sandy clay loams are frequently encountered. Sub-group profiles studied included the (1) orthic dark brown (2) calcareous dark brown (3) eluviated dark brown, and (4) degraded meadow member profiles of the Weyburn catena. The field plot sites were located within an area of approximately 10 acres on the N.W. 28-22-26 W3 (Mr. Joe Hager, Chamberlain).

Aberdeen Catena - Soils developed on moderately calcareous, fine textured, and slightly saline glacial lacustrine deposits. Surface textures are predominately clays. Sub-group profiles included in the study were the (1) solonetz dark brown (2) solodized-solonetz - dark brown, and (3) degraded meadow member profiles of the Aberdeen catena. The field plot sites were located within a 60 acre area on the N.W.29-19-26 W2, (Mr. W. J. Franks, Tuxford).

The soil in the vicinity of both catenary groups of soils had been fallowed during the 1958 growing season. Four treatments, consisting of a 20 and 40 lb. P_2O_5 per acre application of $NH_4H_2PO_4$*, 20 lb. per acre of a 1:1 mix of $NH_4H_2PO_4$* and NH_4NO_3, and a check, arranged in a randomixed block design (six replicates) were laid down on each individual soil member site. In each instance, care was taken to insure that the plot site represented only the selected sub-group profile.

Composite soil samples were taken from the Ap horizon from all plot sites for chemical analysis. The analytical data obtained are given in Table 1.

Table 1. Analytical data from composite surface samples taken from the plot area.

Soil member	Texture	pH	Conductivity mmhos/cm.	Field Capac. %	% Inorganic C	% O.M. (Cx1.724)	Available-P ppm.-p NaHCO$_3$	H$_2$CO$_3$
Weyburn								
-calcareous Dark Brown	SL	7.6	1.12	25.8	0.34	6.9	7.4	10.0
-orthic Dark Brown	L	6.9	1.20	25.4	0.03	5.6	9.0	10.2
-eluviated Dark Brown	SL	6.3	1.14	26.4	0.00	5.9	7.0	7.9
-degraded meadow	SiCL	5.5	0.79	32.1	0.03	10.5	35.2	15.0
Aberdeen								
-solonetz Dark Brown	HvC	7.5	0.75	31.2	0.12	4.4	10.4	10.2
-solodized s. Dark Brown	C	5.6	1.49	25.7	0.00	4.8	20.6	10.9
-degraded meadow	C	5.9	0.66	30.6	0.00	5.6	26.6	19.1
Regina								
-cloddy (s) granular	HvC	7.6	0.49	-	0.33	5.5	3.8	6.5
-cloddy (sf) granular	HvC	7.5	0.77	-	0.21	6.1	5.0	7.5
-rego-glysolic (sf)	HvC	7.5	0.81	-	0.13	6.6	11.4	12.7
-rego-glysolic (s)	HvC	7.5	0.60	-	0.17	6.6	11.6	12.7

* level of activity = 150 μc.P32/g.P_2O_5

Table 2. Analytical data obtained on member profiles of the Weyburn catena. (W. K. Janzen, Sask. Soil Survey)

Horizon and depth	pH	Cond.	% N	% Organic Carbon	Total Exch.Cap. me/100g.	Exchangeable bases me/100 g. Ca	Mg	Na	K	H	Mechanical Analysis % by wt. Sand	Silt	Clay	Fine Clay	% $CaCO_3$
A. Orthic Dark Brown															
Ap 0 - 5	6.9	0.7	0.20	2.25	18.2	13.8	4.6	T	1.6	-	48.1	30.5	21.4	13.7	-
B_1 5 - 9	6.1	0.7	1.12	1.12	21.2	13.1	7.7	0.1	1.0	-	39.3	29.9	31.3	22.2	-
B_2 9 - 13	6.9	0.8	0.11	1.7	13.5	9.6	4.8	T	0.5	-	56.8	22.7	20.4	12.1	-
Bca 13 - 25	7.7	0.6									55.9	25.2	18.9	8.6	17.25
C_1 25 - 33	8.1	0.9									47.5	29.4	23.1	13.9	21.60
C_2 33^+	8.2	1.6									47.6	27.9	25.0	12.2	17.40
B. Calcareous Dark Brown															
Ap 0 - 5	7.2	0.7	0.19	2.01	17.3	14.1	5.4	0.1	1.2	-	50.7	29.2	20.1	14.0	-
Bca 5 - 7	7.5	0.7		1.52							61.9	21.3	16.9	12.5	3.67
Bca 7 - 15	7.6	0.8									55.4	24.1	20.5	12.1	25.50
C_1 15 - 26	7.9	0.6									57.4	23.9	18.1	10.1	18.65
C_2 26^+	8.1	0.5									64.3	20.1	15.7	7.1	14.40
C. Eluviated Dark Brown															
Ap 0 - 5	6.3	0.9	0.26	2.93	23.1	12.6	4.4		2.6	3.5					
A_2 5 - 10	6.3	0.7	0.07	0.80	14.8	7.9	3.8	T	0.6	2.5	44.6	32.3	22.1	13.0	-
A-B 10 - 15	6.3	0.8	0.08	0.80		12.0	8.1	0.2	0.8	-	22.0	32.3	45.8	19.6	-
B_1 15 - 21	7.0	0.5	0.08	0.91		18.0	10.2	0.2	1.1	-	22.9	31.3	45.9	27.2	-
Bca 21 - 28	7.8	0.5									48.7	27.7	23.8	15.6	21.5
C 28^+	7.9	0.5									43.7	28.9	27.9	16.5	16.5
D. Degraded Meadow															
Ap 0 - 5	6.0	0.7	0.23	2.78	22.4	11	4.9	T	2.1	4.4	20.2	51.2	28.5	15.7	-
A_2 5 - 11	5.4	0.9	0.23	2.72	22.4	10.3	5.1	T	1.2	5.8	18.1	51.4	29.3	20.9	-
AB 11 - 13	5.3	0.7	0.11	1.02	22.1	9.3	7.2	0.3	0.8	4.5	13.5	51.6	34.1	25.1	-
B_1 13 - 23	5.6	0.3	0.09	0.81		12.8	10.4	0.7	1.0	-	13.2	40.1	46.7	33.6	-
B_{1-2} 23 - 28	6.2	0.3	0.08	0.67	27.4	10.7	0.9	0.9	2.7	2.7	21.0	37.2	41.8	33.2	-
B_2 28 - 33	7.3	0.6									45.9	27.4	26.3	17.3	-
Bca 33 - 38	7.8	0.6									55.0	25.5	20.0	10.7	18.0
C 38^+	7.8	1.7									48.3	31.0	20.7	12.3	20.0

Samples were taken from the various horizons of the four member profiles of the Weyburn catena. The detailed analytical data which characterize the chemical and physical differences between these related soil members are listed in Table 2.

The four member profile sites of the Weyburn catena were sampled to a depth of 30 inches (deeper sampling would have been preferable, but due to a 'pavement of stones' at approximately 30 to 40 inches, it was practically impossible to sample to a greater depth) for moisture content at time of seeding and at harvest. In order to convert percentage moisture by weight to inches of water it was necessary to determine the bulk density of the various soil horizons. The moisture and density figures given in Tables 3 and 4 represent the average of four individual samples taken at random within each plot site.

In order to obtain an approximate measure of moisture consumption at each of the Weyburn plot sites, rain guages were installed at seeding time. Table 5 includes precipitation data obtained at the Weyburn site and, in addition, at the Aberdeen soil site.

Moisture sampling, conducted at the Aberdeen soil sites at seeding time indicated all three members contained approximately 9.5 inches of available water to a depth of 42 inches, (the moisture content of each member site was markedly uniform). Unfortunately, it was not possible to resample the sites after harvest, however, with a total rainfall of 4.30 inches, the growing crop had approximately 13.7 inches of water for growth (assuming no evaporation from the soil).

Results

The various criteria used to assess the relative productivity of the member profile sites included yield of grain with and without fertilization, uptake of applied fertilizer-P, ratio of fertilizer-P to total-P in the grain, available soil-P and consumptive use of water. These data are given in Table 6 for the Weyburn Catena.

On the basis of check yields, the productivity of the eluviated Dark Brown member can be classified as low, the degraded meadow high, and the well-drained

Table 3. Density of horizons of the four Weyburn sub-group profiles.

Depth (inches)	Degraded Meadow	Calcareous Dk. Brown	Orthic Dk. Brown	Eluviated Dark Brown
0 - 8	1.01	1.18	1.12	1.12
8 - 12	1.31	1.30	1.30	1.35
12 - 18	1.43	1.31	1.27	1.43
18 - 24	1.50	1.39	1.35	1.49
24 - 30	1.48	1.40	1.45	1.35

Table 4. Inches of water present at various depths, at seeding and harvest time. Weyburn sub-group profiles (Chamberlain)

	Degraded Meadow		Calcareous Dark Brown		Orthic Dark Brown		Eluviated Dark Brown	
(inches)	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
0 - 8	2.80	2.43	1.82	1.94	1.52	2.02	1.81	2.18
8 - 12	1.26	0.73	0.96	0.57	0.90	0.86	0.92	0.73
12 - 18	2.08	1.17	1.34	0.61	1.14	0.72	1.28	0.69
18 - 24	2.19	1.34	1.23	0.67	1.01	0.58	1.22	0.64
24 - 30	1.76	1.18	1.15	0.77	1.03	0.71	1.00	0.59
Total	10.09	6.85	6.50	4.56	5.60	4.89	6.23	4.83
Water used by crop (inc. rainfall)	11.52		10.22		8.99		9.68	

Table 5. Rainfall at the Weyburn and Aberdeen catena sites.

Date	(Inches) Weyburn	(Inches) Aberdeen
June 7-10	0.10	0.26
June 15	0.01	0.23
June 16	0.16	0.07
June 23	0.29	0.12
June 24	-	0.37
June 26-30	4.20	2.28
July 4-7	0.27	0.15
July 9	-	0.05
July 22	0.50	0.33
July 28-Aug. 2	-	0.27
Aug. 28	2.50	0.17
Sept. 7	0.25	-
Total	8.28	4.30

Table 6. Comparative data obtained on four member profiles of the Weyburn Catena (Hagen, Chamberlain)

(a) Yield of grain, bu/ac.

		Fertilizer treatment, lb. P_2O_5/ac.				
		11-48-0		23-23-0	L.S.D.	%* Yield
Soil Member	Check	20	40	20	(P = .05)	Inc.
Degraded Meadow	38.9	43.4	51.8	48.4	5.1	22
Calc. Dark Brown	28.3	34.8	37.0	34.8	1.8	27
Orthic Dark Brown	27.1	32.7	33.1	34.1	2.5	17
Eluviated Dark Brown	23.5	33.4	38.7	35.4	3.2	41
L.S.D. (P = .05)	4.2	6.5	4.7	5.1		

*based on the average of the 20 and 40 lb. P_2O_5 yield increase.

(b) Percentage uptake of applied fertilizer (grain only)

Degraded Meadow	14.2	14.8	21.0
Calc. Dark Brown	18.2	15.0	19.7
Orthic Dark Brown	24.2	18.8	29.8
Eluviated Dark Brown	25.7	25.6	30.2
L.S.D. (P = .05)	4.0	4.7	6.4

(c) Fertilizer-P as a percentage of total P (grain only)

Degraded Meadow	10.9	19.2	15.2
Calc. Dark Brown	19.6	31.9	21.2
Orthic Dark Brown	27.4	40.5	29.7
Eluviated Dark Brown	31.7	45.8	33.3
L.S.D. (P = .05)	3.6	5.2	4.1

(d) Available-P, lb. P/ac.

				Extractable-P		
	Field 'A' Values			H_2CO_3	$NaHCO_3$	Greenhouse 'A' Value
Degraded Meadow	73.1	65.4	50.7	29.9	70.4	55.0
Calc. Dark Brown	37.9	39.6	33.7	22.0	14.3	28.8
Orthic Dark Brown	24.0	25.6	21.3	20.4	18.0	35.0
Eluviated Dark Brown	21.0	21.0	17.5	15.8	14.0	40.5
L.S.D. (P = .05)	8.0	13.7	5.0	-	-	4.1

(e) Water Consumption, Weyburn Catena

Soil Member	Inches water used by crop	Av. yield on plot bu/ac	Evapo-trans. Ratio
Degraded Meadow	11.52	45.9	945
Calc. Dark Brown	10.22	33.5	1149
Orthic Dark Brown	8.99	31.5	1075
Eluviated Dark Brown	9.68	32.5	1121

upland members intermediate, but of similar productivity.

The 'low' level of available phosphorus in the eluviated profile may in part account for its low productivity in relation to yields recorded from the other three sites. Field 'A' values, which represent an integrated soil profile level of available phosphorus, together with H_2CO_3 extractable-P (surface soil) suggest this soil is more deficient in available-P than the other three soils investigated. (The 41% yield increase due to phosphate fertilization confirms the soil test data.) With fertilization, yields on all but the degraded meadow soil, were practically the same. The relatively high uptake of applied fertilizer, and high content of fertilizer-P in the grain, also lend further confirmatory evidence to the suggestion that the low yields obtained on the check (eluviated) treatment reflect a rather marked deficiency of soil-P.

The orthic Dark Brown profile can be classified as a soil only moderately deficient in phosphorus. Maximum yields were obtained with an application of 20 lb. P_2O_5. Where 40 lb. P_2O_5 were applied, this member profile was the least productive of the four studied. A possible explanation for the levelling off of the yield curve at the 20 lb. P_2O_5 rate is evident in the moisture use data; the inches of water used by the crop grown on the orthic site were less than on any other site, hence, it is possible that yields were partially restricted by a shortage of water. The relatively high percentage of fertilizer-P in the grain (fertilizer-P as a % of total P increases as soil moisture stress increases) would tend to confirm this.

The marked yield increases resulting from phosphorus fertilization on the degraded meadow site would appear to refute all measurements of available soil-P given in Table 6 (d). While such results are frequently encountered, no satisfactory explanation can be suggested at this time. It is of interest to note that the soil in the vicinity of the degraded meadow was also somewhat deficient in nitrogen; the 23-23-0 treatment significantly increased yields above those obtained where 11-48-0 was applied at a similar rate of P_2O_5.

From the pedogenic (thin A horizon and shallow profile) and chemical data (low O.M., high lime content) presented in Table 2 for the calcareous Dark Brown profile, this soil would be expected to be characterized by a lower level of productivity than the orthic soil. The yield data would tend to refute this. However, it is to be noted that the water used by the crop is appreciably higher, and the fertilizer-P content in the grain significantly lower than that recorded for the grain grown on the orthic site.

Table 7. Comparative data obtained on three member profiles of the Aberdeen Catena (Kettlewell, Tuxford).

(a) Yield of grain bu/ac.

		Fertilizer treatment, lb. P_2O_5/ac.			
		11-48-0		23-23-0	L.S.D.
Soil Member	Check	20	40	20	(P = .05)
Solonetz D.K.	29.1	37.5	34.9	36.0	6.7
S.S. Dark Brown	18.5	25.0	26.9	23.8	3.9
Degraded Meadow	32.8	48.1	56.6	48.8	8.7
L.S.D. (P = .05)					

(b) Percentage uptake of applied fertilizer (grain only)

	11-48-0 20	11-48-0 40	23-23-0 20
Solonetz D.K.	23.4	21.3	28.6
S.S. Dark Brown	19.7	15.1	27.9
Degraded Meadow	14.3	12.5	16.1
L.S.D. (P = .05)			

(c) Fertilizer-P as a percentage of total P (grain only)

	11-48-0 20	11-48-0 40	23-23-0 20
Solonetz D.K.	20.8	32.6	28.3
S.S. Dark Brown	20.4	31.3	27.8
Degraded Meadow	25.1	37.5	27.5
L.S.D. (P = .05)	3.6	4.0	N.S.

(d) Available soil-phosphorus

				Extractable-P		Greenhous[e]
	11-48-0 20	11-48-0 40	23-23-0 20	H_2CO_3	$NaHCO_3$	'A' value
Solonetz D.K.	33.7	36.7	23.6	20.4	20.8	33.1
S.S. Dark Brown	36.5	38.9	23.6	39.2	53.2	38.8
Degraded Meadow	26.7	29.5	23.6	21.9	41.2	53.5
L.S.D. (P = .05)	6.5	5.8	N.S.	-	-	

The various criteria used to assess the productivity of the three member profiles of the Aberdeen catena are given in Table 7. Since moisture data obtained at time of seeding indicated that the amount of available moisture to a depth of 42 inches was approximately the same at all three sites, it can be tentatively concluded that the crop yield differences are likely not due to differences in available moisture supply ('run off' measurements were not taken). On the basis of check yields, the solodized solonetz member site was characterized by the lowest yield, followed, in order of increasing yield, by the solonetz and the degraded meadow; while fertilization (11-48-0 or 23-23-0) changed the magnitude of yield for all three sites, this order of productivity was not altered.

The yields obtained for the degraded meadow were still climbing steeply at the highest rate of phosphorus application - 40 lb. P_2O_5 per acre, while the 20 lb. P_2O_5 application resulted in a maximal yield on both other member sites. The marked yield increases due to phosphorus fertilization on the degraded meadow site were complemented by relatively low field 'A' values; other tests for available P, including chemical extractants, and greenhouse 'A' values, did not indicate the 'lowest' level of available P on this particular soil. However, field 'A' values, represent an integrated profile level of available P, while the laboratory and greenhouse tests were conducted on the Ap horizon only.

There is no evidence in the yield data that any of the member sites were deficient in nitrogen.

The comparative productivity of the three member profiles recorded in this study could probably have been predicted from their respective 'physical' characteristics. The heavy textured, dense and intractable B horizon of the solodized solonetzic Dark Brown member, together with the tendency of the leached, plate-like Ap horizon to form a hard compact crust following rainstorms would certainly be expected to adversely affect productivity. Although the physical structure of the Ap and B horizon of the solonetzic member is similar to the solodized-solonetzic soil, the degree of development of a tough intractable B horizon is less, and the 'tilth' of the Ap horizon is much more favorable for plant growth.

Root Studies

Roots play a vital role in the life of plants. Under natural environments, the extent and activity of the root system might be expected to reflect the moisture, nutrient and physical characteristics of the soil profile.

Three inch diameter cores were taken at four locations on each of the check, and fertilized (40 lb. P_2O_5/ac.) treatments of three sub-group profile sites--Calcareous Dark Brown, Orthic Dark Brown and eluviated Dark Brown sites (Weyburn catena). The quantity of roots measured at depths up to 24 inches are illustrated in Figure 1.

Fertilization (40 lb. P_2O_5 using $NH_4H_2PO_4$ as source of phosphate) in every instance increased root growth. The increase on the eluviated Dark Brown and Orthic Dark Brown sites occurred throughout the depth sampled, while the increase in root density due to fertilization on the Calcareous Dark Brown site occurred only in the 0 to 3 inch depth.

Each of the three sub-group profiles were characterized by different quantities of roots; the least amount of roots were measured in cores taken from the check-orthic site and the maximum from the check-calcareous site. With fertilization, the relative order of the soils arranged in order of increasing quantity of roots was altered, i.e., orthic - calcareous - eluviated, however, differences between the quantity of roots to a 24 inch depth between the fertilized eluviated and calcareous sites were small. The close relationship between yield of grain and quantities of roots is illustrated in Figure 2. While the easiest interpretation of this relationship is that the greater the yield, the greater the root development--and consequently root studies should be discontinued as they only reflect top growth--it would be hazardous to draw such definite conclusions from the limited data obtained.

No attempt can be made, at this time, to relate these data on plant root systems to specific soil characteristics. These studies will be continued during the 1960 growing season. As studies of this type are difficult to carry out, investigations are underway, using a P32 injection technique, with a view to developing a more rapid and less laborious means of detecting root distribution in soils.

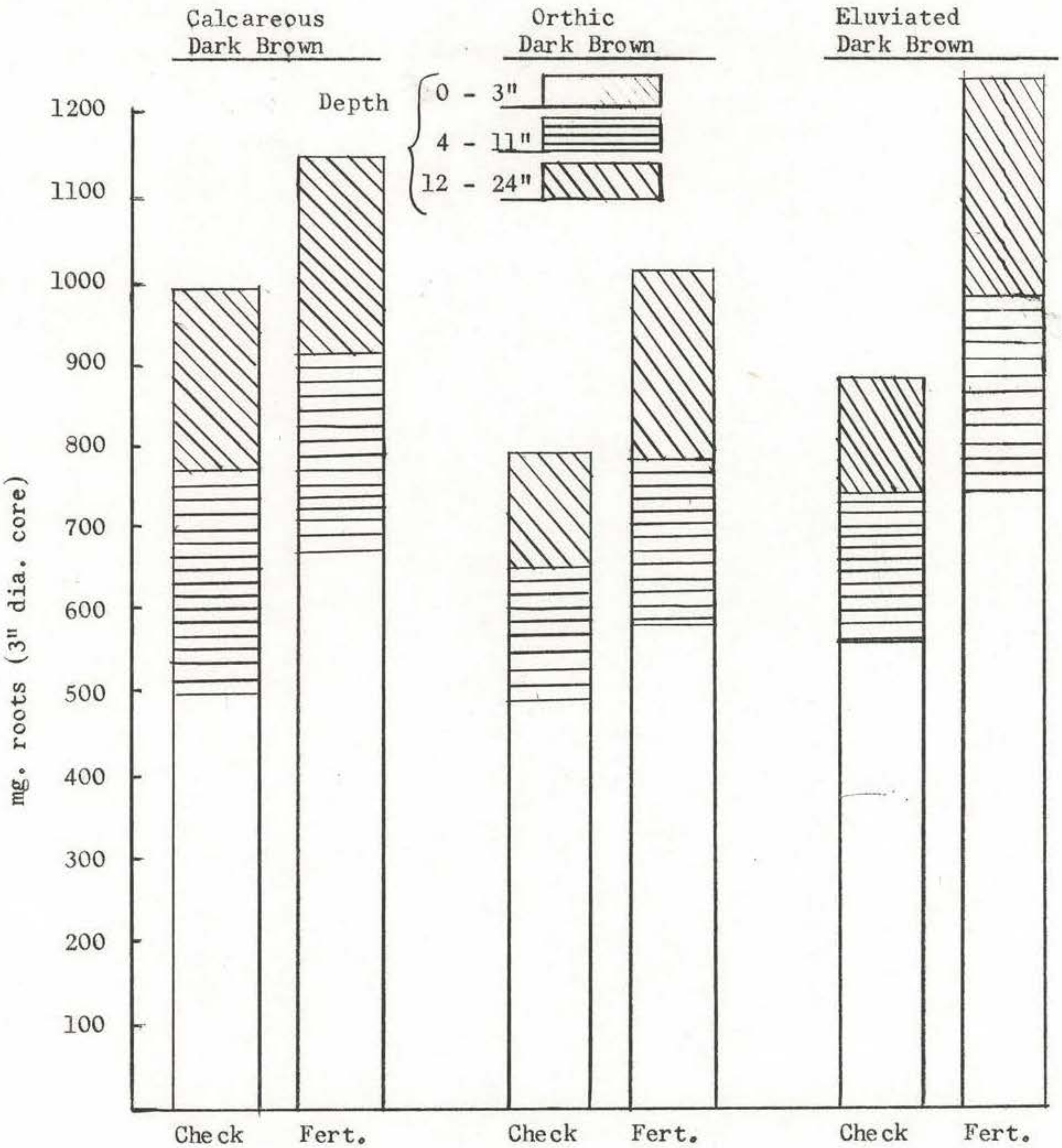

Fig. 1 The effect of soil type and phosphate fertilization on quantity of roots of wheat to a depth of 24 inches.

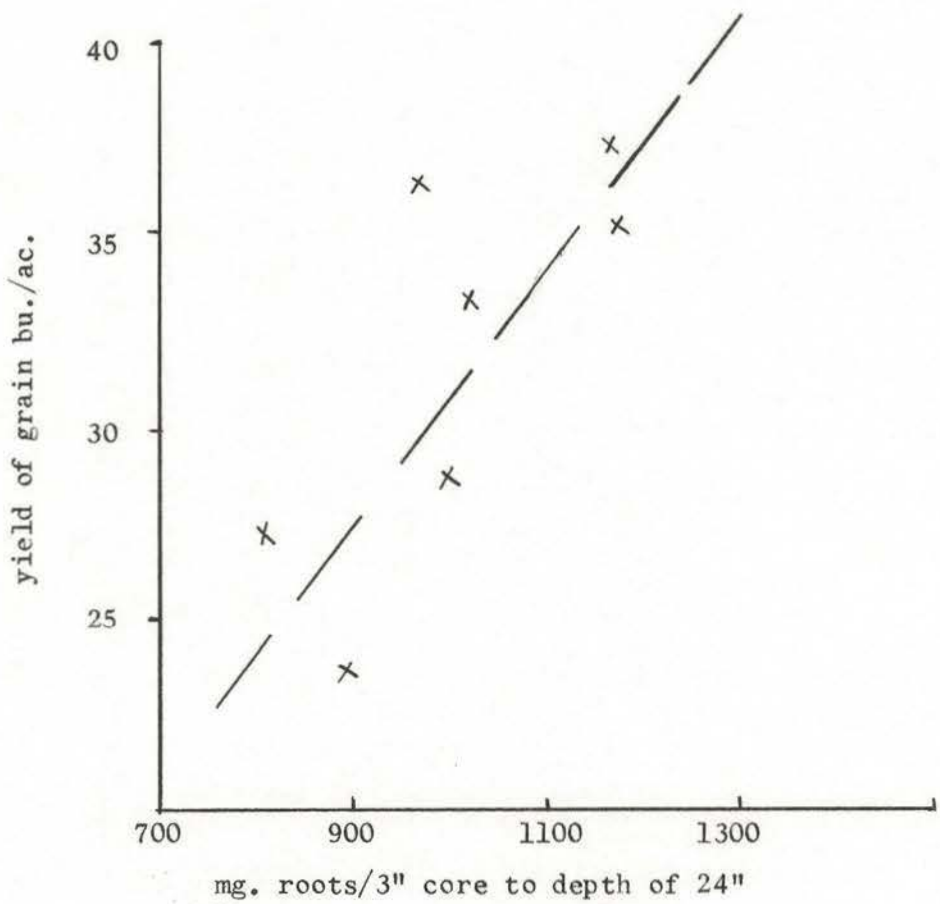

Fig. 2 The relationship between yield of grain and quantities of roots measured to a depth of 24 inches.

General Comments

The studies reported above suggest that, under the climatic conditions prevailing in the vicinity of the plot sites, certain of the member sites were characterized by widely differing levels of productivity. Two of the many factors affecting growth of plants were shown to be of importance in explaining, in part, the reasons for the differences in yields, namely, phosphate fertility level, and supply of soil moisture.

In some instances, the differences in productivity between member sites were eliminated when phosphate fertilizers were applied; however, in other instances, application of phosphate enhanced the differences in yield between closely related sites. It is significant that field 'A' values appeared to reflect the level of available phosphorus more closely (as indicated by response curves) than greenhouse 'A' values or 'quick tests'.

The preliminary, and rather incomplete moisture data obtained, appeared to be of considerable significance as a means of accounting for differences in productivity. However, the labor and time required to obtain moisture consumption data limits, rather drastically, the application of this technique to field fertility studies. Studies currently under way, investigating the application of the neutron moisture meter to field fertility studies should, if positive results are obtained, make possible the collection of frequent and extensive soil moisture data in the vicinity of field test plots, and thus enable more extensive application of soil moisture data in interpreting productivity studies on soil types.

Table 8. Weyburn Soil Catena - *Percentage Protein in the Grain.

		Fertilizer treatment (lb. P_2O_5/ac.				Av.
		11-48-0		23-23-0	L.S.D.	Protein
Soil Member	Check	20	40	20	(P = .05)	%
Degraded meadow	17.2	17.2	16.8	17.4	N.S.	17.2
Calcareous Dark Brown	18.3	18.5	18.3	18.4	N.S.	18.4
Orthic Dark Brown	18.1	18.4	18.4	18.4	N.S.	18.3
Eluviated Dark Brown	18.7	18.3	18.3	18.9	N.S.	18.7
L.S.D. (P = .05)	0.3	0.2	0.5	0.3		0.4

*based on grain dried at 60°C for 48 hrs. (% N x 5.7 = % protein)

Protein Content of Wheat Samples from Tracer and Field Strip Tests

Grain samples from the Weyburn and Aberdeen soil catena studies (168 samples) and 44 field strip tests (315 samples) were analysed for protein content (N x 5.7).

Protein content of wheat (Thatcher) grown on differing member sites.

The percentage protein of grain samples grown on the Weyburn and Aberdeen soil catenas are given in Tables 8 and 9, respectively. Fertilization did not, in any instance, alter the protein content of the grain. (The small increases in protein content, compared to the check or 11-48-0 treatments, where 23-23-0 was applied, for grain grown on the solonetzic Dark Brown and degraded meadow (Aberdeen catena), and the leached meadow and solodized Dark Brown (Weyburn catena), were not significant at the 5% probability level.)

Grain grown on the degraded meadow (Weyburn catena) site was characterized by absolute protein content of approximately 1% less than that recorded for the three well drained members. Similarly, grain samples from the solodized solonetzic (Aberdeen) site contained approximately 3% more protein than the degraded meadow or solonetzic Dark Brown sites.

Protein content of grain from the field strip fertilizer tests.

The protein content of composite grain samples from 44 field strip fertilizer tests laid down on fallow land are listed in Table 10. While small increases, or decreases, in percentage protein between the check and fertilized treatments were recorded for individual tests, the average data obtained from the 44 trials indicates that the 40 lb. of 11-48-0 has not changed the protein content of the grain. Thus, the data confirm similar experimental data obtained from the 1958 and 1957 field test plots.

Table 9. Aberdeen Soil Catena - *Percentage Protein in the Grain

		Fertilizer treatment (lb. P_2O_5/ac.)				Av.
		11-48-0		23-23-0	L.S.D.	Protein
Soil Member	Check	20	40	20	(P = .05)	%
Solonetz Dark Brown	15.2	14.9	15.1	15.9	N.S.	15.3
S.S. Dark Brown	18.5	18.2	18.3	18.5	N.S.	18.4
Degraded Meadow	15.8	15.6	15.8	16.3	N.S.	15.9
L.S.D. (P = .05)	0.9	0.9	1.1	1.1		0.7

*based on grain dried at 60°C for 48 hrs. (% N x 5.7 = % protein)

The protein content of the unfertilized grain grown at the 44 sites ranged from a low of 12.6 (Waitville soil, Wynyard) to a high of 20.8 (Elstow soil, Asquith). The average protein content of the grain grown at these 44 locations, 16.5%, is identical to that obtained from the same locations in 1958 (16.5%), and only slightly less than the average protein content of grain from the 1957 tests (16.8%).

The protein data obtained from the field strip test trials during the 1957-59 period are currently being summarized, and will be presented by R. McKercher to the technical sessions of the Canadian Society of Soil Science, Guelph, Ontario, in June.

The variation in the protein content of grain samples taken from each of the 20 replicates from the fertilized and check treatments of six field trials are outlined in Table 11. The wide variability in percentage protein of the 'square yard' grain samples at any one site is of similar magnitude to that recorded for composite samples taken from widely scattered locations (Table 10). These data indicate that differences in micro-climate and soil type within any one field can very markedly affect the protein content of the grain. In addition, the data emphasize the care that must be taken in attempting to assess the protein content of grain grown in any one field; samples should be taken according to soil variability (which reflects differences in micro climate) and not on an arbitrary grid basis.

Soil Testing

The 'available phosphorus content of approximately 250 soil samples taken from the 1959 field strip fertilizer tests was determined using three extracting solutions (1) H_2CO_3, (2) .5M $NaHCO_3$ and (3) H_2CO_3 + 20 ppm P. In the latter test, the decrease in concentration of phosphorus in the carbonated solution reflects the available-P in the soil. In addition, approximately 550 soil samples

Table 10. Influence of 11-48-0 (40 lb./ac.) on percentage protein of wheat grown on fallow land.

Co-operator	Location	Soil Type	Percentage Protein Check	Percentage Protein Fertilized	Yield of Grain Check	Yield of Grain Fertilized
Penrose	Watrous	WL	14.3	13.3	22.1	26.5
Measner	Holdfast	WL-LL	14.5	16.4	22.4	28.4
Spratt	Davidson	WL	17.9	17.7	22.3	28.6
Myrah	Holdfast	WL-LL	16.0	16.7	28.4	37.4
Gieselman	Davidson	WL	16.7	17.2	22.5	27.4
Holm	Watrous	WL	16.0	14.5	37.4	45.2
Willner	Davidson	WL	17.6	18.7	23.0	29.6
Nielsen	Adanac	W + OL	18.1	17.5	14.2	21.1
Junop	Asquith	E SiL-SiCL	20.8	21.6	20.4	24.7
Latrace	Tessier	E SiL-SiCL	19.4	18.5	26.7	31.6
Lawton	Tessier	E SiL	16.4	17.3	31.8	31.0
Carr	Laura	E SiL-SiCL	17.6	15.5	24.8	30.2
Cummings	Adanac	E SiCL	19.0	19.1	25.4	31.8
Featherstone	Kinley	E SiCL-SiC	19.8	20.7	25.3	30.4
Rugg	Elstow	E SiC	17.1	17.0	30.7	39.7
Eley	Colonsay	E SiC	18.2	17.9	24.4	28.8
McMillan	Asquith	AFL	15.2	15.3	23.4	26.8
McGowan	Asquith	AFL	16.9	16.5	24.5	34.2
McGowan	Asquith	AFL	18.8	19.3	18.6	22.6
Sakundiak	Regina	RHvC	15.5	15.4	20.5	28.5
Muggli	Muenster	OL	15.3	16.0	33.6	38.8
Bergerman	Muenster	OL	14.8	15.0	30.8	41.0
Hansen	Neilberg	OL	16.6	16.9	26.4	29.6
Hauser	Neudorf	OL	18.8	18.0	28.3	34.6
Stoll	Neudorf	OL	15.0	14.3	32.8	36.7
Foisey	Cutknife	OL	16.8	18.1	14.9	19.1
Lorenz	Marsden	BL	17.9	18.1	32.3	37.0
Duval	Bellevue	BSiL	16.1	17.1	30.1	36.3
Johnson	Radisson	BL	16.6	16.9	23.1	31.3
Flint	Speers	BC	15.0	15.3	23.0	31.8
Wohlberg	Speers	BC	14.2	14.1	32.3	42.1
Erickson	Wynyard	YL-LL	16.6	16.1	28.0	32.5
Brice	Wadena	YL	18.2	17.8	23.4	26.5
Kuryluk	Yorkton	CaSiL	16.6	16.7	34.4	39.6
Harris	Yorkton	CaSiCL	15.4	15.3	32.3	39.6
Weinmeister	Yorkton	CaSiCL	15.2	15.1	42.5	46.0
Weinmeister	Yorkton	CaSiCL	15.0	14.9	47.3	52.9
Molstad	Domremy	CdSiL	18.9	18.8	26.7	29.7
Smith	Hagen	MSiCL	15.0	16.3	44.9	50.0
Zelenski	Birch Hills	MSiCL	16.0	16.0	36.5	47.4
Marynariski	Paynton	MeLL	15.4	16.3	27.6	34.1
Hall	Lashburn	WaL	18.0	18.8	21.5	24.6
Byblow	Sheho	WvL	14.1	11.7	19.1	35.0
Popowich	Wynyard	WvL	12.6	12.1	33.5	40.7
Average (44 samples)			16.5	16.6	27.6	33.7

from the 1957 and 1958 field fertilizer tests were extracted using .5M $NaHCO_3$, and 450 samples from these earlier tests analysed using the carbonated phosphorus solution.

Correlation coefficients calculated to measure the relationship between H_2CO_3 and $NaHCO_3$ soluble phosphorus, and yield increases from phosphorus fertilization have, in general, been less than .3. In summary, it appears that neither the H_2CO_3 or the $NaHCO_3$ test are satisfactory 'quick tests' for use in estimating the need for phosphorus fertilization on the 19 soil associations included in this three year study. (Approximately 2800 H_2CO_3 and 800 $NaHCO_3$ extraction tests have been completed.) The data obtained from the carbomated-phosphorus solution tests have not been compiled. A more detailed summary of these data will be available in the near future.

Table 11. Range in percentage protein of grain samples taken from six field fertilizer tests.

Co-operator	Location	Soil type	Fertilizer treatment	*Range in Protein percentage	Av. % Protein
Carr	Laura	ESiL-SiCL	Check	12.5 - 19.4	15.5
			Fert.	13.7 - 20.8	17.6
Willner	Davidson	WL	Check	16.7 - 19.5	17.6
			Fert.	16.8 - 22.8	18.7
Featherstone	Kinley	ESiCL-SiC	Check	15.8 - 23.0	19.8
			Fert.	16.1 - 23.3	20.7
Junop	Asquith	ESiL-SiCL	Check	17.5 - 23.3	20.8
			Fert.	18.4 - 23.6	21.6
Spratt	Davidson	WL	Check	15.5 - 19.6	17.9
			Fert.	15.6 - 18.9	17.7
Latrace	Tessier	ESiL-SiCL	Check	16.3 - 23.3	19.4
			Fert.	16.3 - 22.3	18.5

*High and low percentage protein of 20 grain samples taken from the check and fertilized strips, respectively.

The Organic Phosphorus Content of Selected Soils

A preliminary (and broad) survey of the 'organic phosphorus' content of the Ap horizon of selected soils in Saskatchewan was conducted by K. Blackburn. The ignition method of Saunders and Williams (J. Soil Sci. 6: 254-267, 1955) was used to determine organic-P. This method involves extraction of the phosphorus with .2 N H_2SO_4 (16 $\frac{1}{2}$ hrs.) before and after ignition (550°C for 1 hr.). The difference between the inorganic-P in the extract before and after ignition represents organic phosphorus. The Na_2CO_3 fusion method was used for total-P determination.

Soil samples used in the study were taken from (a) the Ap horizons of soils developed on heavy textured lacustrine deposits in the Brown, Dark Brown, Black, Grey Black and Grey soil zones, (b) the Ap horizon of four member profiles of the Oxbow Association (Black soils developed on glacial till), (c) the Ap horizon of three member profiles of the Amulet Association (Dark Brown soils developed on till modified by upper cretaceous shales, (d) the Ap horizon of three member profiles of the Ardill Association (Brown soils developed on till modified by upper cretaceous shales), (e) the Ap horizon of three Black soils of differing texture - Meota FL (developed on sandy alluvial deposits, Hoey L developed on medium textured lacustrine deposits, and Blaine Lake CL developed on silty clay lacustrine deposits) and (f) two samples each from residual-P plots on the Regina HvC (Dark Brown) and Elstow CL (Dark Brown) soils.

The data obtained from these studies are given in Table 12.

The amount of organic-P in the 22 soils varied from a low of 130 ppm. (degraded member of the Oxbow catena) to a high of 890 ppm. (Hoey SiL). The average content of organic-P, expressed as a percentage of total-P, was 49.6%; approximately half the total soil P was present in the organic form. The significance of the organic-P to the phosphorus fertility level of soils is presumably dependent on the "turnover rate" of soil organic matter. While it might be presumed that a partial mineralization of the organic-P in 'virgin' soils would occur on cultivation (note the

Table 12. The organic phosphorus content of selected soils

Soil Association	Zone	.2N H_2SO_4 ext-P (ppm.) before ignition	.2N H_2SO_4 ext-P (ppm.) after ignition	Organic P ppm.	Total-P (Na_2CO_3 fusion) ppm.	Organic-P as % of total-P
I Arborfield C	Grey	120	520	400	640	62.5
Tisdale C	Grey Black	280	850	570	790	72.2
Melfort SiCL	Black	170	640	470	820	57.3
Regina HvC	Dark Brown	210	770	560	930	60.2
Sceptre HvC	Brown	230	560	330	700	47.1
II Oxbow L (catena)	Black					
-dark grey glysolic - Degraded		270	400	130	570	22.8
-orthic Black		210	700	490	970	50.5
-calcareous Black		220	650	430	870	49.4
-orthic black (virgin)		120	870	750	880	85.2
III Amulet (catena)	Dark Brown					
-solod		240	500	260	850	30.6
-solonetz		210	610	400	670	59.7
-calcareous Dark Brown		230	510	280	850	32.9
IV Ardill (catena)	Brown					
-solod		290	550	260	860	30.2
-solonetz		220	540	320	800	40.0
-calcareous Dark Brown		260	580	320	800	40.0
V Meota FL	Black	150	520	370	710	52.1
Hoey SiL	Black	250	1140	890	1110	80.2
Blaine Lake CL	Black	200	680	480	930	51.6
Melfort SiCL	Black	170	640	470	820	57.3
VI Elstow CL (Check)	Dark Brown	160	460	300	580	51.7
Elstow CL (1280 lb.P_2O_5/ac.)		420	630	210	850	24.7
Regina HvC (Check)	Dark Brown	290	600	310	695	44.6
Regina HvC (1280 lb.P_2O_5/ac.)		620	890	270	978	27.6
Average		241	644	403	812	49.6

higher organic-P content of the uncultivated as compared to the cultivated orthic Black member of the Oxbow catena), the rate of mineralization of organic-P in cultivated soils under the climatic conditions prevailing in Saskatchewan is not known.

The following additional observations can be drawn from the data:

(1) The organic-P content of the member profiles of catenary groups of soils varied widely. In general, the depressional members (i.e. solod) contained

the least amount of O.P. (and the lowest percentage of O.P. expressed as a % of total-P); the members occupying the intermediate slope position (solonetzic and orthic) the most O.P.; the organic-P content of the Ap horizon of the columnar calcareous profiles was, in general, slightly less than the members on the intermediate slope positions.

(2) The Grey and Brown zonal soils contained the least amount of organic-P; the differences between the Black and Dark Brown soils were, in general, very small.

(3) Addition of inorganic-P to an Elstow and Regina soil (the 1280 lb. P_2O_5/ac., equivalent to 280 ppm-P had been equilibrated under greenhouse conditions for a period of one year, then the samples air dried and stored for two years), resulted in a decrease in the organic-P content in both soils. An explanation for this decrease (possibly mineralization of O.P.) must await further investigation.

(4) Approximately 80% of the total-P content of the 22 soils was extracted by the Saunders and Williams Ignition Procedure. (The 20% not extracted is presumably insoluble in .2 NH_2SO_4.)

(5) A fractionation analysis using the procedure of Chang and Jackson (Soil Sci. 84: 133, 1957) had previously been carried out on the Elstow and Regina soils. These data, together with the organic-P data obtained in this study, are outlined in Table 13.

Table 13. The nature of the indigeneous and residual phosphate compounds in two Dark Brown soils.

Soil	Loosely bound P (ppm.)	Al-P (ppm.)	Fe-P (ppm.)	Ca-P (ppm.)	Organic-P (ppm.)	Total-P (ppm.) Na_2CO_3 fusion	% total-P accounted for
I Regina HvC	2.1	32.5	27.2	203	310	695	83
" " plus *280 ppm. P	43.5	170.0	67.0	226	270	978	80
I Elstow CL	1.4	26.0	35.8	134	300	580	86
" " plus *280 ppm. P	30.0	172.0	95.3	136	210	850	76

*Phosphorus added in the form of $NH_4H_2PO_4$ and wet and dried for a period of one year prior to analysis.

It is significant that the sum of the loosely bound, aluminum, iron, calcium and organic phosphorus represents approximately 80 per cent of the total phosphorus present in the two soils. The non-extractable-P is probably "reductant soluble" or "occluded" phosphate.

Graduate Student Research Project

Mr. E. Spratt, who has been studying the influence of soil and climate factors on 'A' values, received his M.Sc. degree during the May Convocation ceremonies. The following summarizes the data he has obtained during the past two years. (A portion of these data has been included in a paper which will be presented during the 7th International Society of Soil Science meetings, August 14-28, 1960, Madison Wisconsin.)

The 'A' value has become universally known as a relative measure of available soil phosphorus. Since it is calculated from the relative content of soil and fertilizer phosphorus in the plant, it represents an integrated value for the relative supply of all sources of phosphorus in the soil. However, the 'A' value is dependent on experimental techniques and the soil and plant environment. The effect of phosphate fertilizer (standard) placement (mixed throughout the soil or banded with the seed), type of standard (water soluble or water insoluble), plant environment (temperature), and soil environment (moisture levels and nitrogen fertilization) on 'A' values were determined in this study. A constant temperature growth chamber was used.

Initial experiments were designed to determine the effect of placement of the phosphate fertilizer on 'A' values. The 'A' values were high when the water soluble fertilizer ($NH_4H_2PO_4$) was mixed throughout the soil, but were considerably lower when the insoluble fertilizer (resin-phosphorus) was mixed throughout the soil. This indicated fixation of the $NH_4H_2PO_4$ fertilizer (standard). However, when the $NH_4H_2PO_4$ was banded with the seed, the limited soil: fertilizer contact restricted fertilizer phosphorus fixation (lower 'A' values were obtained).

The 'A' values obtained from the mixed and banded placements of resin-phosphorus were not significantly different (no fixation of the phosphate fertilizer). It was concluded that both soil and fertilizer phosphorus were equally accessible to the plant regardless of placement.

When the phosphate fertilizer (standard) was mixed throughout the soil, the 'A' values increased as the rate of phosphate fertilization increased. This was attributed to isotopic exchange. When the phosphate fertilizers were banded with the seed, the 'A' values remained constant as the rate of phosphate fertilization increased, thus indicating limited isotopic exchange.

Mixed placement resulted in very high 'A' values when there was high microbiological activity due to the presence of organic residues (straw). The high 'A' value could give the misleading conclusion that available phosphorus was being released from the straw. However, it was more reasonable to assume that immobilization of the fertilizer standard caused the high 'A' value. When the phosphate standard was banded with the seed, the lower 'A' value indicated immobilization (microbiological fixation) of the soil phosphorus.

It was concluded that 'A' values obtained from mixed placement of the phosphorus standard resulted in an estimation of both fertilizer phosphorus fixation and isotopic exchange in addition to the relative amount of available soil phosphorus. The limited soil:fertilizer contact afforded by band placement minimized the effects of fertilizer phosphorus fixation and isotopic exchange, thereby giving a more valid estimation of soil phosphorus availability. For the above reasons, band placement of the phosphate fertilizer (standard) was utilized in all subsequent experiments.

Experiments were set up to determine the effect of small differences in temperature on 'A' values. Data from a crop grown on ten different soils at 65°F. were compared to subsequent data obtained from a crop grown at 70°F. The differences in 'A' values obtained from the two growth chamber experiments were not significant and within the limit of expected experimental error. Since the growth chamber temperature can be controlled to $\pm$ 2°F., it would be possible to compare 'A' values and yield data obtained from experiments grown at the same temperature but at different times.

Two experiments were set up to determine the effect of soil moisture stress on 'A' values. When the plants were subjected to an increased soil moisture stress, lower 'A' values were obtained. The 'A' values were lower than the low stress treatments, to varying degrees, regardless of time, or intensity of stress. The low 'A' values were a result of low soil phosphorus uptake. The low soil phosphorus uptake resulting from high moisture stress was attributed to root damage (limited exploitation of the soil volume) as well as the low soil phosphorus availability (lack of capillary flow may limit nutrient flow). When comparing the relative phosphorus supplying power of various soils, it would be advisable to grow the test crops at relatively low moisture stress, thus limiting root damage.

One moisture stress experiment was repeated since the differences in 'A' values due to the moisture treatments were masked by a soil nitrogen deficiency. In the subsequent experiment, two high rates of nitrogen fertilization were used. Large differences in 'A' values due to the moisture stress treatments were found, thereby illustrating the need for adequate nitrogen fertilization.

This study points to the need for: (1) band placement of the phosphate fertilizer standard (preferably ammonium phosphate), (ii) a relatively constant temperature, (iii) constant watering practices, and (iv) a constant but adequate rate of nitrogen fertilization, when using the 'A' value to compare the phosphorus supplying power of various soils.

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Mr. G. Racz, graduate student, assisted with most of the investigations reported. Mr. R. McKercher was responsible for the field strip-protein and soil test correlation data. All protein analyses were conducted by the Department of Chemistry, University of Saskatchewan.