The Fertility Balance in a Ten-Year Sugar Beet Rotation After Forty-two Years of Cropping

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History of the Rotation

Crop rotations on irrigated land have been carried on at the Experimental Station, Lethbridge, Alberta, since 1910. Rotation "U," a 10-year rotation which was laid down on one acre plots in that year, is still in progress and is thought to be the oldest irrigated crop rotation in North America (1)[2].

This rotation originally consisted of six continuous years of alfalfa and one year each of oats, barley, potatoes, and spring wheat seeded down to alfalfa. Barnyard manure was applied at the rate of 12 tons per acre once in the rotation cycle. As conditions and crops changed with advancing years, it became necessary to make certain adjustments in the rotation. The first of these was the substitution of sugar beets for potatoes in 1923. By 1933 the yields of alfalfa had begun to decline, presumably because of phosphorus deficiency, and hence triple superphosphate (0-43-0) at the rate of 100 pounds per acre was applied to the south half of each plot for three of the ten crop years. The north half of each plot has never received any commercial fertilizers. In 1938 ammonium phosphate (11-48-0) was substituted for triple superphosphate.

By 1910 it was evident again that the yields were declining. Hence, the manurial application was increased to 30 tons in 1942. Since then, each plot has received 15 tons of manure twice in the rotation cycle.

Within recent years, bacterial wilt has reduced the yields of the fourth, fifth and sixth years of alfalfa to such an extent that it became necessary to revise the rotation. In 1951 the six continuous years of alfalfa were broken up into two 3-year periods with two other crop years intervening. No changes were made in the crops grown, and the fertility treatments have been maintained.

The crop sequence and fertilization plan of the rotation prior to the revision in 1951, together with the yields for the first 22-year period before fertilizer was applied and for the fertilized and unfertilized halves for the last 20-year period, are shown *in* Table 1.

The records of the yields of the crops, including the weights of straw from these plots, have made it possible to calculate the quantities of the three principal plant nutrients—nitrogen, phosphoric acid and potash—that were removed by these crops. This was done using the average amounts of these three constituents in the various crops. The amounts of these fertilizer constituents returned to the soil were calculated from periodic analyses of the barnyard manure and the guaranteed content of the commercial fertilizer applied. The fertility balances per acre per year for the three periods, for which the yield data are given in Table 1, are shown in Figures 1, 2 and 3.

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Numbers in parentheses refer to literature cited.

Soil analyses have been carried out on samples taken from each plot at approximately 10-year intervals, the first samples being taken in 1911. Table 2 shows the results of recent analyses on stored remnants of the samples taken in **1911** and 1951.

Table 1.—Crop Yields[1] Per Acre on Rotation "U" for the First 22-Year Period Before Commercial Fertilizer Was Applied and for the Unfertilized and Fertilized Halves for the Last 20-Year Period.

		Experimental Station—Lethbridge, Alberta		
Crop	Treatment	No Fertilizer 1911-1932	No Fertilizer 1933-1952	Fertilizer 1933-1952
Alfalfa 1	100 lb. 11-48-0	2.29	2.60	3.00
Alfalfa 2	15 tons manure	3.46	2.62	4.10
Alfalfa 3		3.64	2.63	3.69
Alfalfa 4	100 lb. 11-48-0	3.67	2.50	**3.58**
Alfalfa 5		3.77	1.98	2.80
Alfalfa 6		3.95	1.70	2.11
Oats		92.8	100.0	104.2
Barley	15 tons manure	57.5	72.5	74.2
Sugar beets	100 lb. 11-48-0	13.582	16.48	18.46
Wheat seeded down to alfalfa		49.4	56.0	58.6

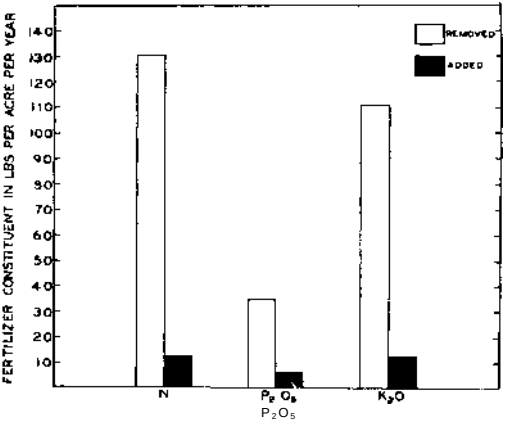

Figure 1. Fertility balance on Rotation "U" for the first 22-year period 1911-1932, when barnyard manure was applied at 12 tons per acre once every ten years.

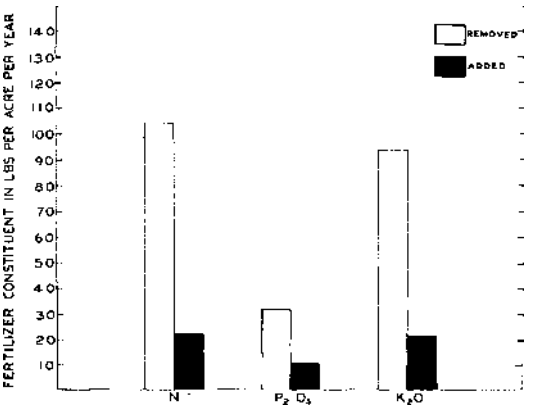

Figure 2. Fertility balance on Rotation "U" for the 20-year period 1933-1952. In 1942 the manurial application was increased from 12 to 30 tons per acre per rotation cycle.

Table 2.—Analyses of Soil Samples[1] Taken from Rotation "U" in 1911 and 1951.

	N. (%)		O.M. (%)		K_2O (%)		P. (p.p.m.)	
	1911	1951	1911	1951	1911	1951	1911	1951
No fertilizer	0.18	0.20	4.17	4.68	.039	.035	37.4	35.2
Fertilizer	0.18	0.20	4.17	4.82	.039	.035	37.4	39.7

Method of Analysis

N—Kjeldahl method.
OM—Loss on ignition—heating at 450° C. for 3 hours.
K—Exchangeable, using neutral normal ammonium acetate.
P—Soluble in 1 percent solution of $K2CO_3$.

[1] Analyses were made by the Soil Chemistry Unit, Division of Chemistry, Science Service, Ottawa. Soil samples were taken from 0- to 6-inch depths.

Nitrogen

Figures 1, 2 and 3 show a definite deficit in nitrogen for each of the three periods. However, the nitrogen that is returned to the soil by the alfalfa must be considered. Lyon and Buckman (2) state that an average crop of alfalfa fixes from 200 to 250 pounds of nitrogen per acre yearly. Since alfalfa is grown during six of the ten crop years, it may be assumed that an average of 120 to 150 pounds of nitrogen would be fixed every year for each acre of the rotation. This would more than balance any deficit, and it would seem that the nitrogen balance was at least maintained. The slightly higher percentages of nitrogen in 1951, as revealed by the soil analyses, substantiate this.

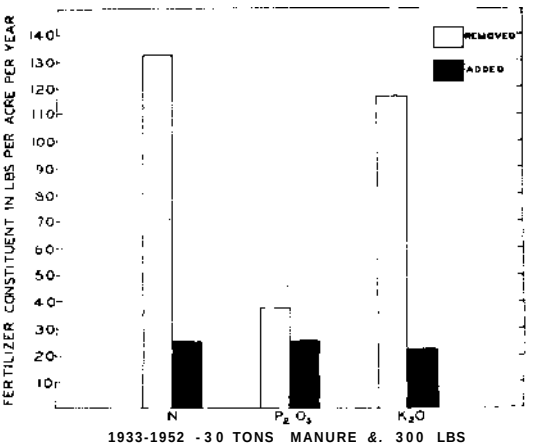

Figure 3. Fertility balance on Rotation "U" for the 20-year period 1933-1952. In 1942 the manurial application was increased from 12 to 30 tons per acre per rotation cycle. In 1933 commercial fertilizer (0-43-0 from 1933 to 1937, 11-48-0 from 1938 to 1952) was applied at 100 pounds per acre for three of the ten crop years.

Organic Matter

Table 2 indicates that the organic matter content of the soil has increased since 1911. In the light of the heavy manure applications and the return of the crop residues from the high-yielding crops, it is reasonable to expect such a change.

Phosphorus

A comparison of Figures 1, 2 and 3 shows that the greatest deficit of phosphoric acid occurred during the early period when only 12 tons of manure per cycle were added to the rotation and no phosphate fertilizer was used. Although high crop yields were obtained, the original fertility of the soil probably was reduced. This reduction is evidenced in Figure 2 and by the lower yields of the subsequent crops.

Increasing the manurial rate to 30 tons per acre per rotation cycle improved the phosphoric acid balance, but production of crops, especially alfalfa, was not as high in the early years of the rotation. The relatively higher average cereal crop yields, as compared with yields of alfalfa and

sugar beets, during the period following the increase in manurial rate may have occurred because the cereals are less sensitive to a mild deficiency of phosphorus than are alfalfa and sugar beets.

The highest yields of all crops were obtained on the plots which received commercial fertilizer along with the barnyard manure. Figure 3 shows the most favorable phosphoric acid balance. Results of the soil analyses show slightly higher amounts of phosphorus being made available in 1951 than in 1911. The reason for this may be due to the available form of phosphorus that is provided by the fertilizer. Nevertheless, a deficit *in* phosphorus does exist from year to year and, under the present fertilization program, it will be interesting to note the effect of additional cropping in future years on this condition.

Potassium

The deficit of potassium follows closely the apparent deficit of nitrogen. Wyatt et al (3) report that the potassium content of soils in the Lethbridge area is between 1.25 and 1.75 percent. This may be represented as about 30,000 pounds of potassium per acre in the top six inches of soil. The soil analyses show a slight decrease in exchangeable potassium since 1911. Since the exchangeable potassium is believed to be in balance with non-exchangeable potassium and potassium in soil solution, a small decrease in one form may be an expression of a proportional decrease in the other forms. Although a decided yearly deficit in potassium exists, it seems to be of no immediate concern in view of the large amount present in the soil. No response to potash fertilizers has been obtained on soils in this area.

Summary

The results from this long-term rotation show that a highly productive level of soil fertility can be maintained under irrigation with proper rotation, barnyard manure and commercial fertilizers. The three principal fertilizer elements—nitrogen, phosphorus and potassium—appear to be in fairly good balance in the soil after forty-two years of cropping. However, phosphorus and potassium are showing deficits. The immediate application of additional phosphorus may be warranted as a safeguard toward future reserves.

Literature Cited

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