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Ten-year irrigated rotation U. 1911-1980

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Ten-year irrigated rotation U. 1911-1980

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The late Dr. W. H. Fairfield, first superintendent of the Lethbridge Experimental Station, started rotation U. The late Dr. Frank T. Shutt, Dominion Chemist, Ottawa, established the practice of taking soil samples at the beginning of each rotation cycle. The rotation continued under the supervision of Drs. A. E. Palmer and K. W. Hill until 1951.

The author is indebted to the late Dr. H. J. Atkinson, Head of the Soil Chemistry Unit, Ottawa, under whose supervision the first soil analyses were performed in 1951.

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SUMMARY

Started in 1911, Rotation U is believed to be the oldest continuous irrigated crop rotation in North America. It occupies ten 0.4-ha plots and consists of six years of alfalfa, wheat, oats, barley, and sugar beets. Each plot receives barnyard manure at 67 t/ha in a 10-year cycle, and three crops (Alfalfa 1, Alfalfa 1a, and Sugar beets) receive 11-48-0 fertilizer at 112 kg/ha each year on the south half of the plots. The rotation has provided the following information:

- Crop yields have continued to increase with time. The regression coefficients of sugar beets, barley, hard red spring wheat, and oats on advancing years are 0.250, 0.061, 0.020, and 0.034 t/ha/yr.
- The record crop yields are as follows: Sugar beets 62.97, alfalfa 14.07, barley 8.62, hard red spring wheat 4.97, and oats 6.99 t/ha.
- Alfalfa was plagued with diseases for about three decades, but the problem has now been largely overcome.
- The pH in the top 15 cm of soil increased gradually from 7.1 to 7.6 during the first 60 years and appears to have stabilized.
- Organic matter decreased slightly from 2.62 to 2.25% in the top 15 cm of soil but increased from 1.50 to 2.07% in the 15- to 30-cm layer.
- Total nitrogen increased from 0.18 to 0.20% in the 0- to 15-cm layer and from 0.13 to 0.18% in the 15- to 30-cm layer.
- Available phosphorus has remained relatively low (10 ppm) in the 0- to 15-cm depth of the unfertilized plots but has increased to 15 ppm in the plots that received fertilizer.
- Exchangeable potassium decreased from 376 to 306 ppm in the 0- to 15-cm layer and from 272 to 225 ppm in the 15- to 30-cm layer but critical levels have not been reached.
- The improved productivity of the soil is attributed to the use of barnyard manure, alfalfa, and fertilizer.
- The rotation will continue to provide new information relative to the permanency of irrigated agriculture for decades to come.

RÉSUMÉ

Amorcée en 1911, la Rotation U est considérée comme la plus ancienne rotation continue de cultures irriguées en Amérique du Nord. Elle occupe dix parcelles de 0,4 ha chacune et se compose de cultures de luzerne, de blé, d'avoine, d'orge et de betterave à sucre réparties sur six ans. Chaque parcelle reçoit du fumier d'étable à raison de 67 t/ha dans un cycle de 10 ans et trois cultures (luzerne 1, luzerne 1a et betterave à sucre) reçoivent de l'engrais 11-48-0 à raison de 112 kg/ha chaque année dans la moitié sud des parcelles. Le régime cultural a permis d'obtenir des données suivantes:

- Les rendements ont continué d'augmenter au fil du temps. Les coefficients de régression de la betterave, de l'orge, du blé vitreux roux de printemps et de l'avoine au fil des ans sont de 0,250, 0,061, 0,020 et 0,034 t/ha par année.

- Les rendements maximaux s'établissent comme suit: betterave 62,97, luzerne 14,07, orge 8,62, blé vitreux roux de printemps 4,97 et avoine 6,99 t/ha respectivement.

- La luzerne a été assaillie par des maladies pendant trois décennies environ, mais le problème est en grande partie résolu maintenant.

- Le pH dans les 15 premiers centimètres du sol est passé graduellement de 7,1 à 7,6 au cours des 60 premières années et semble s'être stabilisé depuis.

- La teneur en matière organique a légèrement diminué de 2,62 à 2,25% dans les 15 premiers centimètres, mais s'est accru de 1,5 à 2,07% dans la couche de 15 à 30 cm.

- L'azote total est passé de 0,18 à 0,20% dans la couche de 0 à 15 cm et de 0,13 à 0,18% dans celle de 15 à 30 cm.

- La teneur en phosphore assimilable est demeurée relativement faible (10 ppm) dans les 15 premiers centimètres du sol des parcelles qui n'ont pas reçu d'engrais, mais a atteint 15 ppm dans les parcelles fertilisées.

- La teneur en potassium échangeable a baissé de 376 à 306 ppm dans la couche de 0 à 15 cm et de 272 à 225 ppm dans celle de 15 à 30 cm, mais les concentrations seuils n'ont pas été atteintes.

- La productivité accrue du sol est due à l'utilisation du fumier, de la luzerne et de l'engrais.

- La rotation ne cessera pas de fournir de nouvelles données sur la permanence de l'agriculture irriguée dans les décennies à venir.

HISTORY AND GENERAL PROGRESS

The Lethbridge Research Station was established in August, 1906, as the sixth facility of the Experimental Farms Service. It originally consisted of 162 ha of unbroken prairie land that was donated to the Government of Canada by the Alberta Railway and Irrigation Company. During the fall of the first year, 4 ha of land were broken and by the following summer an additional 60 ha were put to the plow. The first crops were grown in 1908. Cereals, alfalfa, and potatoes were grown during the first few years. Alfalfa hay was a major cash crop then as it was required for the many horses and mules that were used in railroad and irrigation works construction at the time.

Rotation U, a 10-year rotation comprised of ten 0.4-ha plots, was begun in 1911. It is believed to be the oldest continuous irrigated rotation in North America. The original crop sequence was as follows: six years of alfalfa, then one year each of potatoes, wheat, oats, and barley. Eleven tonnes of manure (27 t/ha) were applied annually in the fall to the plot growing the 5th year of alfalfa. Thus, each plot received 11 tonnes of manure once in 10 years. The rotation progressed unchanged until 1923.

Typical of land preparation and cultural practices that were in use is the following information gleaned from the 1913 records concerning the potato crop that was grown in the rotation in that year.

> In September, 1912, the plot was plowed 8-10 cm deep, packed and double-disced with a four-horse-team. In the spring of 1913, the plot was plowed 20-23 cm deep and harrowed twice. Six hundred and seventy kilograms of potatoes (cv. Gold Coin) were planted on May 20 and 21 with a two-horse planter in 71-cm rows with tubers spaced 35 cm apart. It took one man three days to carry out the first hoeing in mid-June but the second hoeing required only one day. The crop was cultivated on June 17 and July 5, and was hilled and flood-irrigated on July 14. On July 18, the crop was sprayed with 0.4 kg of Paris Green, and on July 28 with 0.3 kg. On August 22, one man (an inmate from the nearby Provincial Gaol) pulled weeds out of the crop. The potatoes were harvested on October 2 and 3 with a four-horse digger. A yield of 14,392 kg of marketable tubers and 1050 kg of unmarketable tubers was realized from the 0.4-ha plot.

By 1920, the rotation had completed its first cycle and had become fully established. Yields fluctuated between years but the 50.85 t/ha of potatoes harvested in 1912, 4274 kg/ha of hard red spring wheat in 1914, 4436 kg/ha of oats, and 13.66 t/ha of alfalfa in 1916, attested to the high yields that were attainable with irrigation. With the impending re-establishment of the sugar beet industry (a factory was opened at Raymond in 1925), sugar beets were substituted for potatoes in 1923. This was the only change in crops made in the rotation.

By 1924, alfalfa yields began to decrease and continued to decline into the third decade as evidenced in the five-year average yields in t/ha of fourth-year alfalfa.

1913-17	1918-22	1923-27	1928-32
9.39	10.04	6.88	6.09

Because it was thought that phosphorus was lacking in the soil, in 1933 triple superphosphate (0-43-0) at 110 kg/ha was applied to the south half of each of three plots, viz., first-year alfalfa, fourth-year alfalfa, and sugar beets. When the manufacture of triple superphosphate was discontinued in western Canada, ammonium phosphate (11-48-0) fertilizer was substituted in 1938 and has been used since.

The benefits of the phosphorus fertilizer were soon apparent on the alfalfa and sugar-beet crops as shown below in the 5-year average yields in tonnes/ha.

	1933-37		1938-42	
	Fertilizer	No fertilizer	Fertilizer	No fertilizer
Alfalfa - fourth-year	8.00	5.26	9.77	5.67
Sugar beets	41.19	35.80	43.43	36.31

In 1942, the manure application was increased from 27 t/ha to 67 t/ha. Starting that year, a 33.5-t/ha application was applied to two of the ten plots. Thus, in the course of 10 years each plot (0.4 ha) received 27 tonnes of manure. The rate of manure was increased to replace the nutrients removed by the crops, particularly those of the unfertilized half of the plots.

About 1939, bacterial wilt spread into southern Alberta and infected the alfalfa plots on Rotation U. The cultivar Grimm, grown at the time, was very susceptible to the disease. Periodic surveys of the plots showed that about half of the plants were infected with the disease by the fourth year and in the sixth year almost 90% of the plants were infected (Peake and Cormack, 1955). Consequently, alfalfa yields, particularly those of the fourth, fifth, and sixth years, declined rapidly during the 1940's. Yields of less than 2 t/ha were recorded from some plots. Crown bud rot, a complex disease of alfalfa, also made its appearance about this time and contributed to depressed yields. As a result of the declining alfalfa yields, a major change in the cropping sequence was made in 1951. The new sequence, which still maintained the manure and fertilizer treatments, follows.

Crop	Treatment
Wheat and alfalfa	none
Alfalfa 1a	11-48-0 at 110 kg/ha to south half
Alfalfa 2a	manure at 33.5 t/ha
Alfalfa 3a	none
Barley	none
Oats and alfalfa	none
Alfalfa 1	11-48-0 at 110 kg/ha to south half
Alfalfa 2	none
Alfalfa 3	manure at 33.5 t/ha
Sugar beets	11-48-0 at 110 kg/ha to south half

After three years, the new alfalfa series (1, 2, and 3) became established, and the other alfalfa series (1a, 2a, and 3a) continued as part of the previous 6-year series.

In 1959, the cultivar Vernal, which showed some resistance to bacterial wilt, was substituted for Grimm. In 1971 the last change in cropping sequence was made. The positions of wheat and sugar beets were interchanged to facilitate early cultivation of beets without interference from alfalfa root remnants. Also, starting in that year, alfalfa was seeded without a companion crop and one cut of hay was taken. Two cuts of hay are normally taken with established alfalfa. Finally, in 1974, the cultivar Trek, highly resistant to bacterial wilt and to the alfalfa stem nematode, was used. Thus, every effort was made to improve the alfalfa yield and in the 1970's the yields (t/ha) did improve as shown below.

	1966-70		1971-75		1976-80	
	Fert.	No fert.	Fert.	No fert.	Fert.	No fert.
Alfalfa 2a	7.39	6.16	9.16	7.37	11.67	9.27
Alfalfa 3a	8.29	7.62	8.15	4.79	10.37	8.33

The disease problems that plagued alfalfa for three decades have been largely overcome with changes in management practices and with the introduction of disease-resistant cultivars. As a consequence of the improved recovery of the rotation, alfalfa yields and N_2 fixation should continue to increase, and better yields as well as improved soil properties should result in the decades ahead.

Throughout the years, sugar beet tops have been returned to the land but the straw from the cereal crops has been hauled off the plots.

Surface irrigation was practised until 1966. Each surface application consisted of 10 to 15 cm of water and, in most years, all of the plots were irrigated after harvest in the fall. The number of irrigations

during the growing season varied, depending on the crop and the amount of precipitation. Generally, sugar beets received 3 to 4 irrigations, alfalfa 2 to 3 irrigations, and the cereal crops 1 to 2 irrigations.

The quality of irrigation was likely improved with the introduction of sprinklers in 1967. The sprinkler method used smaller amounts of water and provided a more uniform application. In general, irrigation was practised to maintain soil water in the upper half of the available range.

SOIL SAMPLING AND SOIL ANALYSES

The soil is classified as an Orthic Dark Brown Chernozem (Lethbridge series) developed on alluvial lacustrine parent material. The texture of the surface 30 cm of soil is generally a loam (48% sand, 32% silt, and 20% clay).

In October, 1911, the first soil samples were taken from the 0- to 15- and 15- to 30-cm depths from all plots. Similar samples were taken in 1922. Starting in 1933, samples were taken from both halves (north half, unfertilized; south half, fertilized since 1932) from each plot for the two depths. This was repeated in 1941 and 1951. In 1953, two additional depths (30-60 and 60-90 cm) were taken and analyzed for total N and organic matter at Ottawa, but no further analyses were performed on these samples and they were not returned to Lethbridge. In 1961 and 1971, samples were taken from 0- to 15-, 15- to 30-, 30- to 60-, and 60- to 90-cm depths from both halves of all plots. Finally, in 1981, the depth of sampling was increased to 180 cm, the last four depths composed of 30-cm layers.

All of the samples from 1911, 1922, 1933, 1941, and 1951 were analyzed in 1951 for pH, total N, loss on ignition, exchangeable K, and available P by the Science Service, Soil Chemistry Unit, at Ottawa. Data from only three of the ten plots were recorded for 1933. The results of the Ottawa analyses were reported by Hill (1951) and Dubetz (1954). After analysis the remaining soils (except those of 1933) were returned to Lethbridge where they were stored. Because data from only three plots of the 1933 samples were reported and the samples were not available for further analyses, none of the 1933 data are presented.

During the 70-year period, some methods of analyses had changed which made direct comparisons inappropriate. For example, on samples taken between 1911 and 1951, organic matter was estimated by loss on ignition (450°C for 3 h), and available phosphorus (P) was analyzed by the K_2CO_3 method. Consequently, these samples were analyzed by the newer methods ($K_2Cr_2O_7$ method for organic matter and $NaHCO_3$ method for P) in 1981. Also in 1981, the 1961, 1971, and 1981 soil samples were analyzed for pH, electrical conductivity, nitrogen, O.M., available P, and exchangeable K. The following methods were used:

1. pH and electrical conductivity - saturated paste
2. Nitrogen - Kjeldahl method (Association of Official Agricultural Chemists, 1970)
3. O.M. - $K_2Cr_2O_7$ method, described by Walkley and Black (1934)
4. Available P - sodium bicarbonate method (Olsen et al., 1954)
5. Exchangeable K - 1N ammonium acetate method as outlined in the Association of Official Agricultural Chemists (1970)

RESULTS AND DISCUSSION

Crop Yields

The average yields of crops grown in the rotation from 1911 to 1950 (prior to the revision) are shown in Table 1 and the yields from 1911 to 1980 are shown in Table 2. The yields of most crops presented in Table 2 are higher than those in Table 1, which indicates that crop yields improved with time. Regression coefficients calculated for the period 1911 to 1980 show that barley, wheat, and oats increased on average 0.061, 0.020, and 0.030 t/ha/yr (1.13, 0.30, and 0.89 bu/ac/yr). Sugar beets have increased on average by 0.25 t/ha/yr (0.11 tons/ac/yr) during the 58 years that they have been grown. Similar comparisons for alfalfa are more difficult to obtain because of the many years the crop was plagued with bacterial wilt and other diseases.

Table 1. Cropping sequence, treatments, and long-term yields of crops grown on Rotation U from 1911-1950

	All yields in tonnes/ha		Yields of cereals in bu/acre, alfalfa and sugar beets in tons/acre	
	Fert. 1933-1950	Unfert. 1911-1950	Fert. 1933-1950	Unfert. 1911-1950
Oats	4.08	3.71	107.2	97.5
Barley*	3.95	3.44	73.5	63.9
Sugar beets+	42.11	34.65	18.8	15.47
Wheat	3.96	3.52	58.9	52.4
Alfalfa 1+	6.45	5.35	2.88	2.39
Alfalfa 2*	9.27	6.88	4.14	3.07
Alfalfa 3	8.44	7.19	3.77	3.21
Alfalfa 4+	8.31	7.12	3.71	3.18
Alfalfa 5	6.36	6.65	2.84	2.97
Alfalfa 6	4.66	6.63	2.08	2.96

*Barnyard manure at 33.5 t/ha to entire plot.

+11-48-0 at 110 kg/ha to south half of plot.

Table 2. Cropping sequences, treatments, and long-term yields of crops grown on Rotation U from 1911-1980

	All yields in tonnes/ha		Yields of cereals in bu/acre, alfalfa and sugar beets in tons/acre	
	Fert.	Unfert.	Fert.	Unfert.
	1933-1980	1911-1980	1933-1980	1911-1980
Barley	5.09	4.39	94.6	81.7
Oats	4.54	4.14	119.2	108.6
Alfalfa 1+§§	5.64	4.48	2.52	2.00
Alfalfa 2§§	7.80	5.31	3.48	2.37
Alfalfa 3*§§	6.18	4.12	2.76	1.84
Wheat	4.21	3.94	62.7	58.7
Sugar beets+§	45.23	37.95	20.19	16.94
Alfalfa 1a+	6.23	5.31	2.78	2.37
Alfalfa 2a	8.53	6.59	3.81	2.94
Alfalfa 3a*	7.80	6.65	3.48	2.97

*Barnyard manure at 33.5 t/ha to entire plot.

+11-48-0 at 110 kg/ha to south half of plot.

§Since 1923.

§§Since 1951.

Sugar beets and alfalfa, the crops that receive the fertilizer, have benefitted substantially from it. A 110 kg/ha application of fertilizer has resulted in an average yearly increase of 7280 kg/ha of sugar beets. Similarly, the average increase for each of the 3-year alfalfa periods has been 4860 kg/ha. In addition, the benefits from the residual fertilizer are apparent in the yields of the cereal crops.

The record crop yields from this rotation are as follows: barley, 8623 kg/ha (160.4 bu/ac); hard red spring wheat, 4973 kg/ha (74.0 bu/ac); oats, 6988 kg/ha (183.5 bu/ac); sugar beets, 62,966 kg/ha (28.11 tons/ac); and alfalfa, 14,067 kg/ha (6.28 tons/ac).

Five-year moving average yields and the cultivars grown for barley, oats, and wheat are shown in Figs. 1, 2, and 3, respectively. The increase in yield for barley has been greater than for either of the

other two cereals. The introduction of each new cultivar, with the exception of Jubilee, resulted in an increase in barley yield, and the cultivar Galt contributed most to the increased yield (Fig. 1). Introduction of the new cultivars Eagle and Sioux increased the mean yields of oats (Fig. 2).

Only three hard red spring wheat cultivars, Red Fife, Marquis, and Thatcher, were grown during the first 60 years of the rotation. Mean yields increased with the introduction of Marquis, and Thatcher increased yields only slightly over those of Marquis. Utility wheats were grown during the last 10 years and their yields, especially those of Pitic, were substantially higher than those of the hard red spring wheats (Fig. 3).

Fig. 4 shows the 5-year moving average yields of sugar beets from the fertilized and unfertilized plots. Yields increased sharply during the first 10 years that sugar beets were grown (1923-1932), and generally have climbed steadily since about the mid-1950's. Similar data for third-year alfalfa are shown in Fig. 5. As explained earlier, alfalfa diseases depressed yields for three decades starting about 1940. During the last decade, alfalfa yields improved dramatically.

Increased crop yields can be attributed to several factors such as improved cultivars, better management, and improved soil conditions. Because some of these improvements occurred simultaneously, it is difficult to establish the specific contribution of any individual factor.

More detailed discussions on the yields of sugar beets and cereal crops were reported in 1976 and 1979, respectively, by Dubetz and Oosterveld.

The rotation has apparently not suffered from a buildup of diseases other than those that plagued alfalfa, or from pests, weeds or harmful chemicals. Soil erosion has not been a problem.

Soil analyses

The changes in soil chemical properties with time are shown in Table 3. The pH of the surface soil increased gradually from 7.1 to 7.6 during the first 60 years and appears to have stabilized. The pH, however, is still within the range for proper growth of all crops.

Table 3. Changes in soil chemical properties on Rotation U with time (means of ten plots)*

	1911	1922	1941	1951	1961	1971	1981
pH							
0-15 cm	7.1	7.2	7.1	7.5	7.4	7.6	7.6
15-30 cm	7.3	7.6	7.2	7.5	7.5	7.7	7.7
30-60 cm					7.8	7.8	7.8
60-90 cm					8.0	8.0	7.8
Organic matter (%)							
0-15 cm	2.62	2.16	2.78	2.75	2.48	2.30	2.25
15-30 cm	1.50	1.59	2.25	2.42	2.08	2.06	2.07
30-60 cm				1.52	1.16	1.24	1.20
60-90 cm				0.80	0.64	0.69	0.73
Nitrogen (%)							
0-15 cm	0.18	0.17	0.19	0.20	0.21	0.20	0.20
15-30 cm	0.13	0.14	0.17	0.18	0.18	0.17	0.18
30-60 cm				0.11	0.10	0.10	0.10
60-90 cm				0.07	0.06	0.06	0.06
Available phosphorus (ppm)							
0-15 cm - unfert.	11	16	8	11	9	10	8
- fert.			8	12	12	11	15
15-30 cm	6	7	6	8	7	6	6
30-60 cm					3	2	2
60-90 cm					2	2	2
Exchangeable potassium (ppm)							
0-15 cm	375	332	342	314	283	298	306
15-30 cm	272	200	278	238	226	200	225
30-60 cm					112	132	132
60-90 cm					99	111	122

*Since 1941, means of 20 plots (north and south), except available P for the 0- to 15-cm depth, where means of ten plots (unfertilized and fertilized) are shown.

After 70 years of cropping, the organic matter content in the 0- to 15-cm layer of soil decreased from 2.62 to 2.25%, but that of the 15- to 30-cm depth increased markedly from 1.50 to 2.07%. These changes may be due in part to the dilution of the top layer with the lower layer through cultivation. However, the average organic matter content of the two layers showed an increase from 2.06% in 1911 to 2.16% in 1981, which indicates that there was a net increase in the top 30 cm of soil.

Total nitrogen increased slightly from 0.18% to 0.20% in the top 15 cm of soil but increased markedly from 0.13 to 0.18% in the 15- to 30-cm layer. This increase is attributed to the six years of alfalfa and to the application of barnyard manure.

Available phosphorus has remained relatively low (10 ppm) in the 0- to 15-cm depth of the unfertilized plots, but has increased to 15 ppm in the plots that receive fertilizer. The crops could probably benefit from larger applications of phosphorus fertilizer but continued monitoring of crop yields and soil phosphorus will dictate any future action.

Exchangeable potassium (K) decreased from 375 to 306 ppm in the 0-to 15-cm layer and from 272 to 225 ppm in the 15- to 30-cm layer, but critical levels have not yet been reached. The results of analysis for total, exchangeable and extractable K were reported by Dubetz and Dudas (1981). The total K content of this soil is relatively high ($\simeq$ 13,000 ppm in the 0- to 15-cm depth), and has changed little with time. Readily extractable K, derived from micaceous minerals and feldspars, remains relatively constant and apparently is being converted to exchangeable K at a rate that is sufficient to meet crop needs.

Sampling of the additional soil depths, started in 1961 and in 1981, and the additional analysis (electrical conductivity) of all samples started in 1961, will provide new benchmarks for future comparisons.

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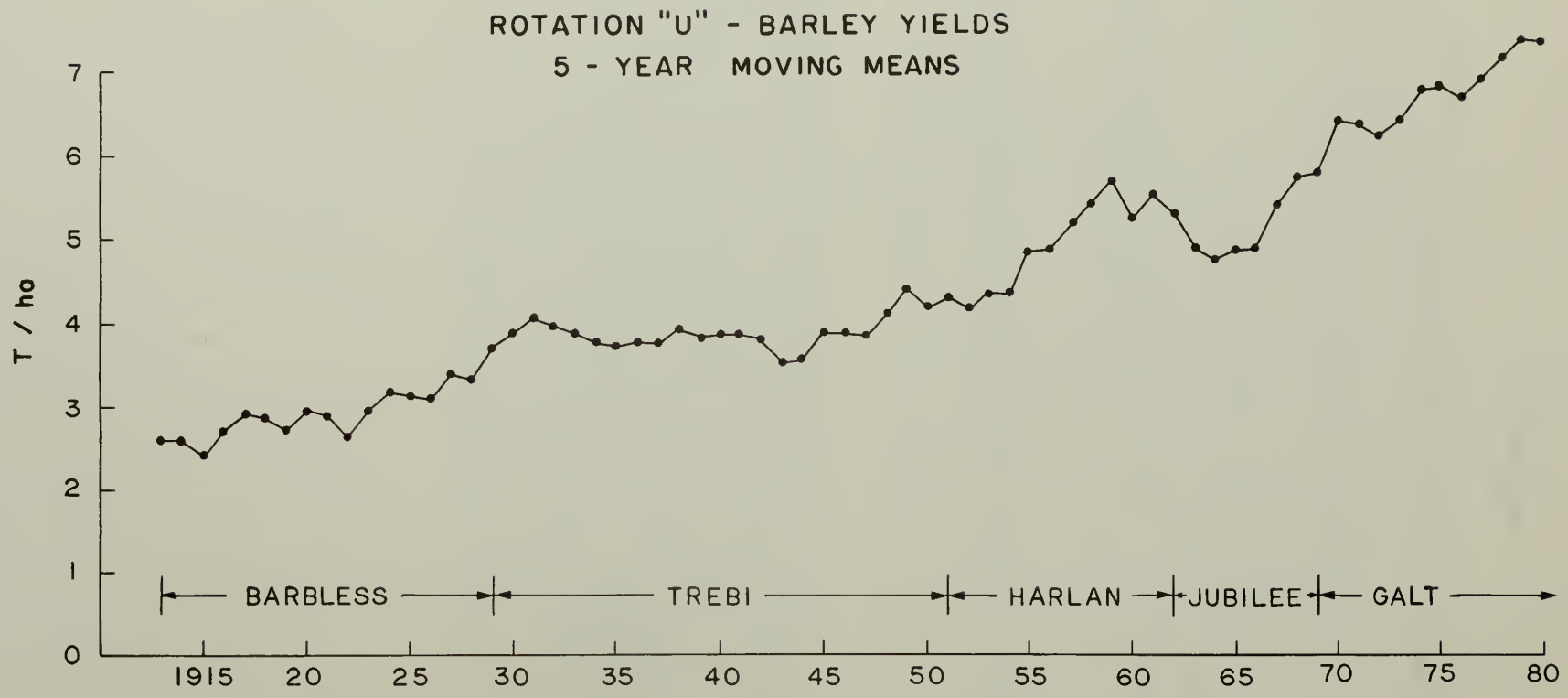

Fig. 1. Long-term yield trends of barley grown on Rotation U. All points are 5-yr moving averages. The cultivars and period during which they were grown are also shown.

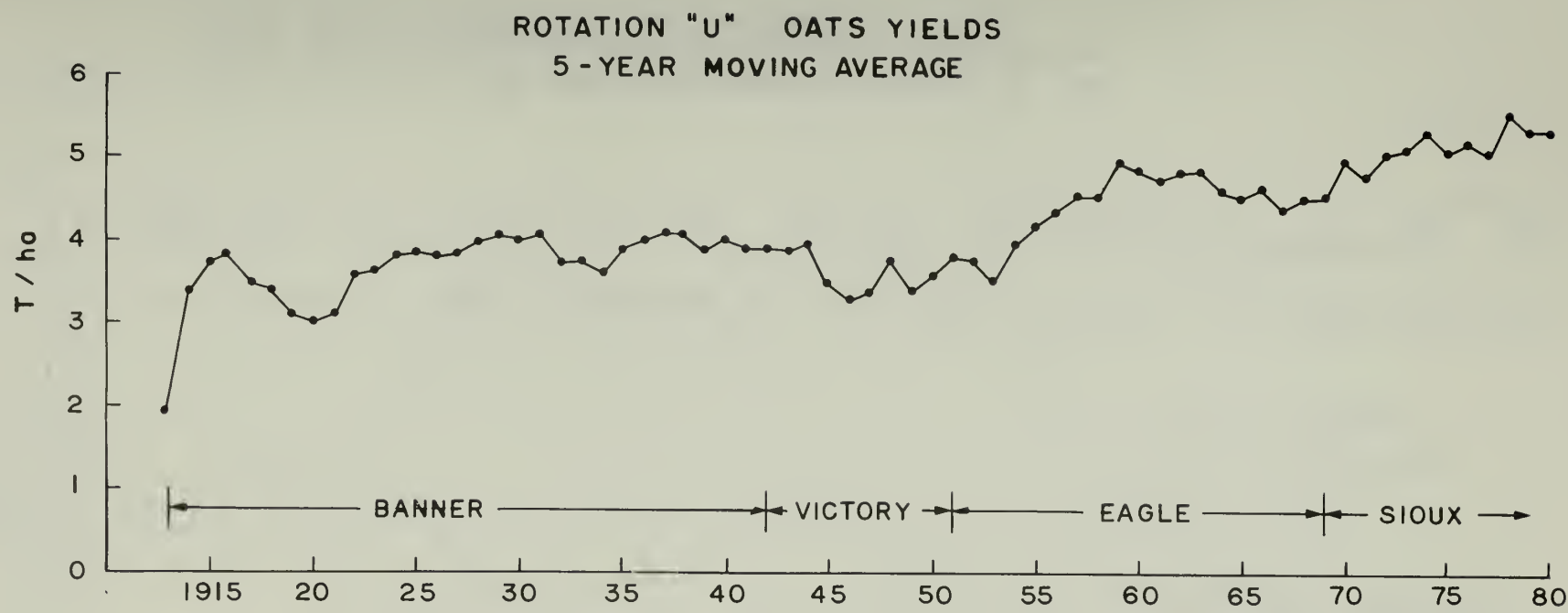

Fig. 2. Long-term yield trends of oats grown on Rotation U. All points are 5-yr moving averages. The cultivars and periods during which they were grown are also shown.

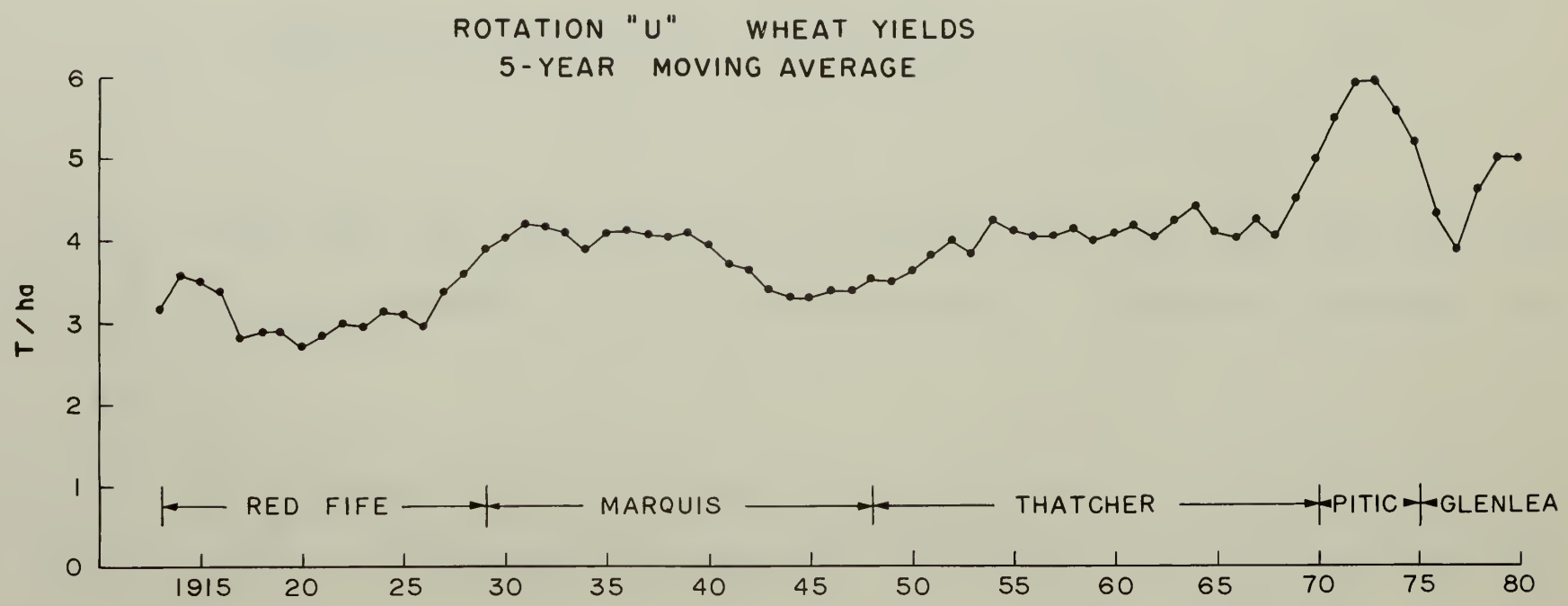

Fig. 3. Long-term yield trends of wheat grown on Rotation U. All points are 5-yr moving averages. The cultivars and periods during which they were grown are also shown.

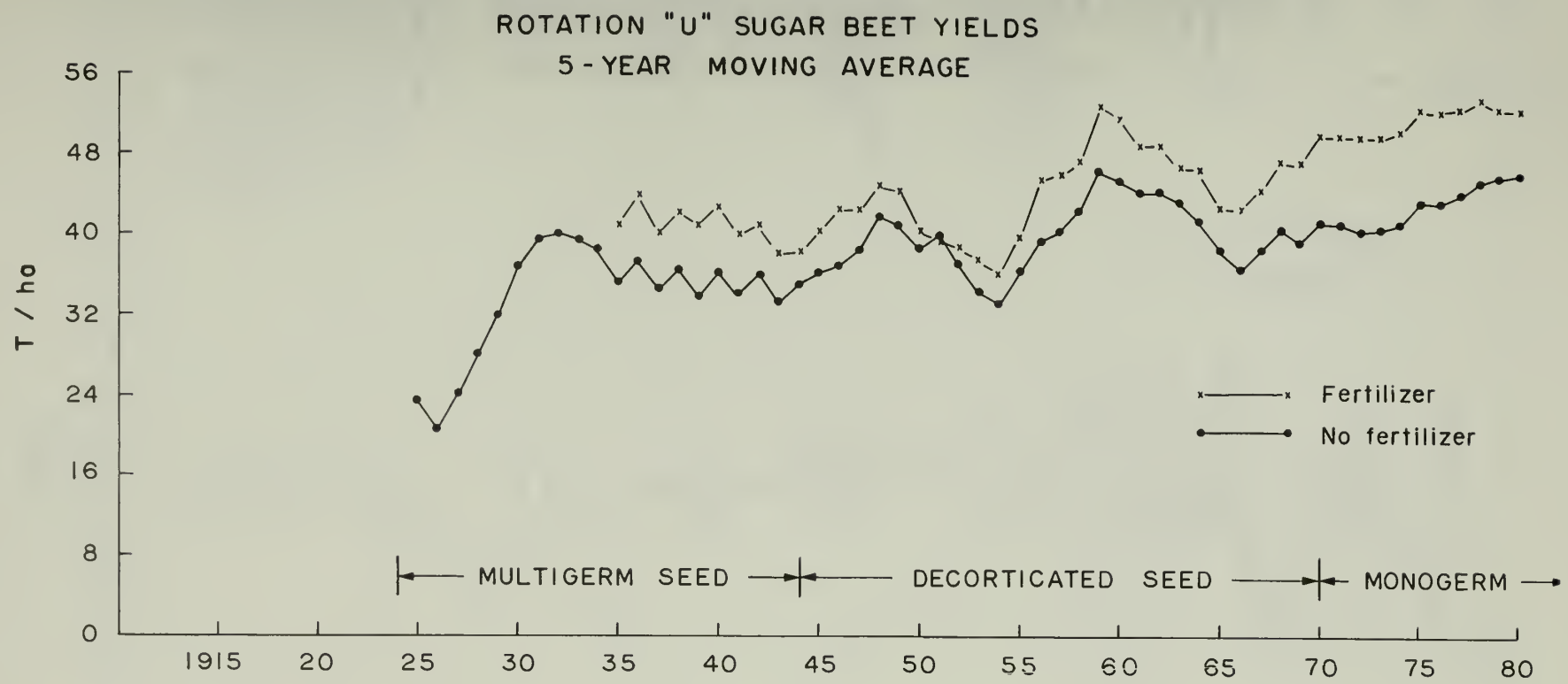

Fig. 4. Long-term yield trends of sugar beets grown on Rotation U; x—x fertilized and ●—● no fertilizer added. All points are 5-yr moving averages. The type of seed and the periods during which they were grown are also shown.

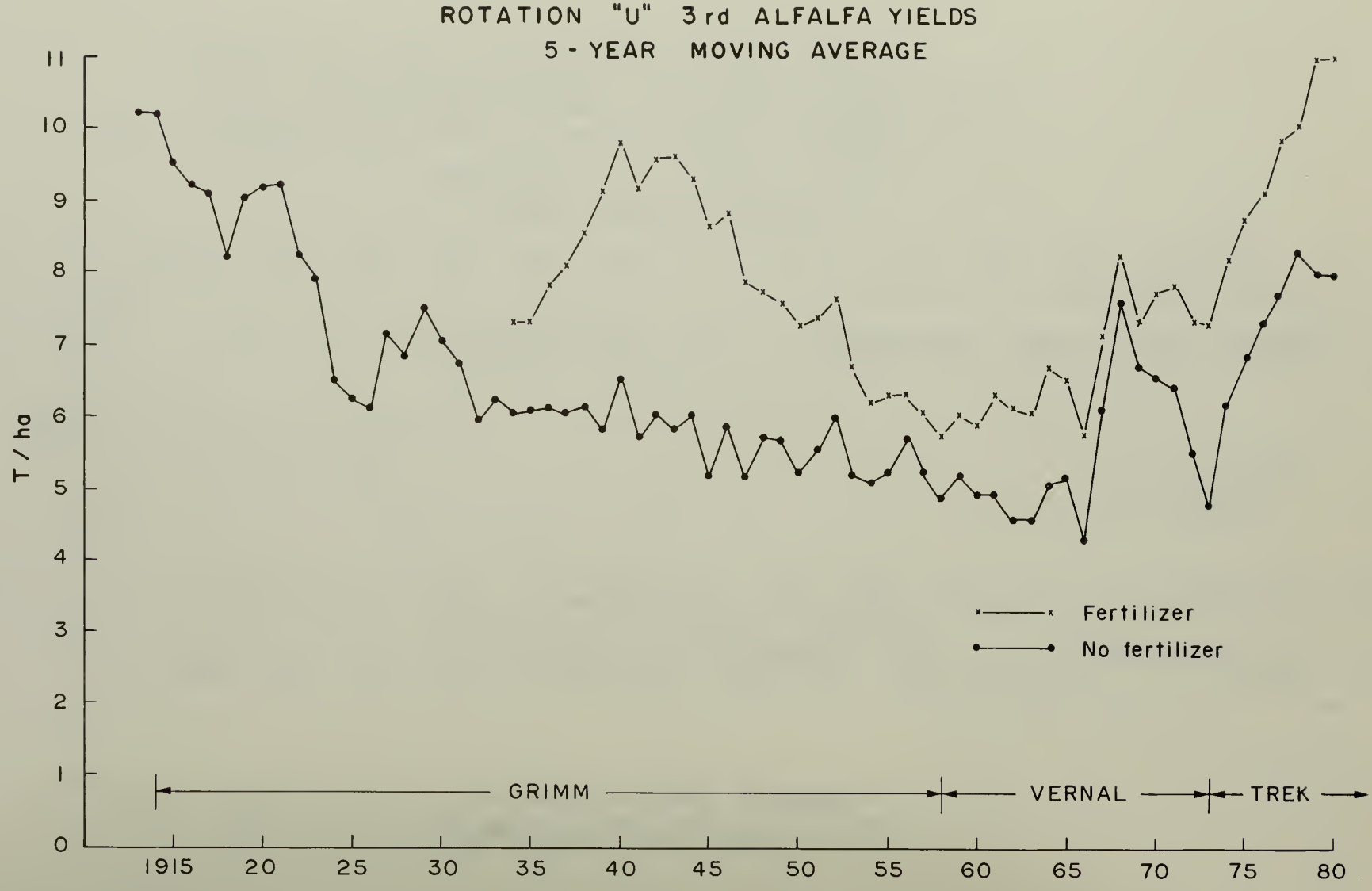

Fig. 5. Long-term yield trends of third-year alfalfa grown on Rotation U; x—x fertilized and ●—● no fertilizer added. All points are 5-yr moving averages. The cultivars and the periods during which they were grown are also shown.

CONVERSION FACTORS

Metric units	Approximate conversion factors	Results in:
LINEAR		
millimetre (mm)	× 0.04	inch
centimetre (cm)	× 0.39	inch
metre (m)	× 3.28	feet
kilometre (km)	× 0.62	mile
AREA		
square centimetre (cm^2)	× 0.15	square inch
square metre (m^2)	× 1.2	square yards
square kilometre (km^2)	× 0.39	square mile
hectare (ha)	× 2.5	acres
VOLUME		
cubic centimetre (cm^3)	× 0.06	cubic inch
cubic metre (m^3)	× 35.31	cubic feet
cubic metre (m^3)	× 1.31	cubic yards
CAPACITY		
litre (L)	× 0.035	cubic foot
hectolitre (hL)	× 22	gallons
hectolitre (hL)	× 2.5	bushels
WEIGHT		
gram (g)	× 0.04	oz avdp
kilogram (kg)	× 2.2	lb avdp
tonne (t)	× 1.1	short tons
AGRICULTURAL		
litres per hectare (L/ha)	× 0.089	gallons per acre
litres per hectare (L/ha)	× 0.357	quarts per acre
litres per hectare (L/ha)	× 0.71	pints per acre
millilitres per hectare (mL/ha)	× 0.014	fl. oz per acre
tonnes per hectare (t/ha)	× 0.45	tons per acre
kilograms per hectare (kg/ha)	× 0.89	lb per acre
grams per hectare (g/ha)	× 0.014	oz avdp per acre
plants per hectare (plants/ha)	× 0.405	plants per acre