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DOMINION OF CANADA—DEPARTMENT OF AGRICULTURE

CROP ROTATIONS

in the

PRAIRIE PROVINCES

by

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EXPERIMENTAL FARMS
SERVICE

y authority of the Hon. JAMES G. GARDINER, Minister of Agriculture,
Ottawa, Canada

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The Dominion Experimental Farms have conducted experiments with various types of crop rotations since 1911. Valuable information has been obtained on the yields which may be expected in different regions from various systems of cropping.

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ACKNOWLEDGMENT

The authors desire to thank the staffs of the Dominion Experimental Farms and Chemistry Division, Science Service, of the Dominion Department of Agriculture and the Department of Soils of the University of Alberta for their assistance in providing information for this bulletin.

Crop Rotations in the Prairie Provinces

Introduction

This bulletin contains information on the results of crop rotation experiments conducted on the Dominion Experimental Farms in Manitoba, Saskatchewan and Alberta. As many of these experiments were commenced about 1911, and have been continued substantially unchanged, they provide over 30 years of records from different systems of cropping. These records furnish a reliable guide as to the yields which may be expected in different regions from various crop rotations. Farming is a permanent business and it is important to know in advance what yields may be expected from different rotations, not merely during the immediate future, but over a long period of years.

Crop rotation is the growing of different crops upon the same land in a definite order and in recurring succession. The simplest form of rotation is the two-year wheat and summerfallow rotation, in which one-half of the land is in wheat and the other half is in summerfallow, the positions being reversed each year. This is really a rotation of wheat with summerfallow and not with other crops, although, to distinguish it from continuous cropping, it is usually considered as a crop rotation. Other crop rotations extend for three or more years and, besides grain, may include such crops as grass and legumes, or intertilled crops as corn, sunflowers or roots. One of the important objectives in the rotation experiments on the Dominion Experimental Farms is the comparison between rotations having grain crops only with the so-called mixed-farming rotations which include hay or intertilled crops in addition to grain.

The results of the various rotation experiments are reported in this bulletin in separate sections for each of the Dominion Experimental Farms. Additional information is included showing the yields of wheat per acre on the Dominion Illustration Stations and Substations, as well as in the various provincial crop districts throughout the Prairie Provinces. Information on the effect of commercial fertilizers, farm manure and green manure is presented in separate chapters under these headings. Some facts are given on the influence of cropping over a long period of years on the chemical constituents of the soil. As the soil and climatic conditions vary widely throughout the Prairie, and as they profoundly affect the results from crop rotations, a brief statement is given in regard to them.

Meteorological Records

On the Dominion Experimental Farms in the Prairie Provinces

Wide variations in climatic conditions are experienced throughout the Prairie Provinces. Although the area, as a whole, might be described as having a continental, semi-arid to sub-humid climate, such differences exist as to profoundly affect the growth of crops in various districts. To the very great variations in soil zones and soil types, as discussed in another chapter of this bulletin, there must be considered, also, the variable effect of climate. These factors should be studied in any consideration of agronomic results.

The following tables give information on certain meteorological conditions on the Dominion Experimental Farms in the Prairie Provinces.

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TABLE 1.—MEAN MONTHLY TEMPERATURES
DOMINION EXPERIMENTAL FARMS IN THE PRAIRIE PROVINCES
(Degrees, Fahrenheit)

Station	Period Years	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Morden, Man.	24	3·5	7·5	20·2	38·1	53·1	62·2	69·0	66·5	56·3	42·8	24·3	9·9	37·8
Brandon, Man.	44	−1·5	2·3	18·3	37·8	51·1	60·1	65·5	62·7	52·7	40·3	21·5	6·6	34·8
Indian Head, Sask.	36	·3	5·3	18·9	37·1	50·3	59·6	65·2	62·2	52·1	39·3	22·3	8·1	35·1
Regina, Sask.	50	− ·3	2·6	16·5	37·7	50·7	59·7	64·7	62·1	51·9	39·3	21·6	8·3	34·6
Melfort, Sask.	32	−2·7	3·0	15·9	36·1	49·7	58·1	63·1	59·6	49·6	37·3	19·5	4·7	32·8
Rosthern, Sask.	29	−3·4	2·5	15·7	37·3	51·5	59·7	64·6	61·5	50·9	38·3	20·5	5·1	33·7
Scott, Sask.	31	− ·3	3·7	16·5	35·8	50·1	57·5	61·1	60·9	50·4	38·3	21·5	7·1	33·5
Swift Current, Sask.	21	9·2	12·9	25·0	39·9	52·2	59·3	66·2	62·9	52·7	41·2	25·9	14·5	38·5
Manyberries, Alta.	14	12·7	12·8	26·9	41·7	53·3	60·4	69·0	65·9	54·9	43·1	27·3	18·1	40·5
Lethbridge, Alta.	41	17·3	18·5	28·9	42·1	51·0	58·6	64·5	62·3	53·3	44·5	31·5	21·9	41·2
Lacombe, Alta.	35	8·5	12·3	23·3	39·1	49·3	56·1	61·1	58·5	49·7	39·9	24·7	12·9	36·3
Beaverlodge, Alta.	27	8·7	13·1	22·3	37·5	49·1	55·5	60·0	57·8	49·3	39·1	23·0	11·7	35·6
Fort Vermilion, Alta.	34	−11·1	−4·2	9·5	31·3	47·9	55·9	60·8	57·5	46·2	32·9	10·5	−5·5	27·6

TABLE 2.—AVERAGE PRECIPITATION
DOMINION EXPERIMENTAL FARMS IN THE PRAIRIE PROVINCES
(Inches)

Station	Period Years	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Morden, Man.	24	·85	·90	1·10	1·29	2·14	3·12	2·77	1·89	2·10	1·26	1·15	·89	19·47
Brandon, Man.	47	·89	·67	·96	1·17	1·95	3·13	2·81	2·50	1·92	1·03	·86	·79	18·68
Indian Head, Sask.	46	·77	·69	1·06	·89	1·91	3·47	2·32	1·98	1·74	1·20	·90	·76	17·69
Regina, Sask.	50	·52	·35	·66	·81	1·70	3·06	2·17	1·71	1·30	·82	·58	·42	14·10
Melfort, Sask.	31	·53	·32	·71	·71	1·63	2·48	2·74	1·99	1·90	·93	·74	·49	15·17
Rosthern, Sask.	29	·60	·47	·82	·86	1·36	2·54	2·53	1·71	1·52	·91	·68	·69	14·69
Scott, Sask.	31	·68	·59	·66	·90	1·44	2·33	2·18	1·56	1·32	·73	·62	·69	13·69
Swift Current, Sask.	57	·67	·58	·71	·80	1·79	2·97	2·17	1·78	1·21	·75	·50	·60	14·53
Manyberries, Alta.	14	·56	·48	·73	1·01	1·33	2·71	1·33	·73	·99	·67	·59	·59	11·71
Lethbridge, Alta.	41	·63	·67	·87	1·14	2·35	2·77	1·74	1·55	1·72	·90	·75	·67	15·76
Lacombe, Alta.	35	·62	·63	·75	1·15	1·96	3·38	2·78	2·37	1·56	·82	·70	·63	17·35
Beaverlodge, Alta.	27	1·32	·89	1·21	·82	1·50	2·05	2·32	1·85	1·79	1·21	1·35	1·25	17·55
Fort Vermilion, Alta.	34	·66	·39	·60	·52	1·27	1·75	1·88	1·66	1·25	·71	·58	·62	11·90

TABLE 3.—EVAPORATION FROM A FREE WATER SURFACE

DOMINION EXPERIMENTAL FARMS IN THE PRAIRIE PROVINCES

(Inches)

Station	Years	May	June	July	Aug.	Sept.	Total
Morden, Man.	14	4·44	6·02	5·99	5·13	3·88	25·46
Brandon, Man.	15	....	4·10	4·13	4·15	2·89	....
Indian Head, Sask.	15	3·47	3·61	4·69	4·88	2·86	19·51
Rosthern, Sask.	16	3·94	4·77	5·70	5·71	4·26	24·38
Scott, Sask.	20	4·68	4·00	4·99	4·11	2·74	20·52
Swift Current, Sask.	21	5·79	5·99	7·40	6·44	4·18	29·80
Manyberries, Alta.	15	5·25	7·11	8·50	7·31	5·00	33·17
Lethbridge, Alta.	21	4·90	4·99	6·14	5·10	3·47	24·60
Lacombe, Alta.	20	3·26	3·13	3·85	3·22	1·93	15·39
Beaverlodge, Alta.	21	3·52	3·70	4·31	3·52	1·88	16·93

TABLE 4.—AVERAGE DATES OF SEEDING AND HARVESTING

DOMINION EXPERIMENTAL FARMS IN THE PRAIRIE PROVINCES

Station	Elevation	Average Date of First Seeding of Spring Wheat		Average Date of First Harvesting Spring Wheat	
		Period (Years)	Date	Period (Years)	Date
Morden, Man.	992	21	April 20	20	July 29
Brandon, Man.	1200	19	April 24	19	Aug. 3
Indian Head, Sask.	1924	14	April 19	10	Aug. 8
Rosthern, Sask.	1672	13	May 3	13	Aug. 23
Scott, Sask.	2164	34	April 29	31	Aug. 14
Swift Current, Sask.	2440	22	April 25	22	Aug. 11
Lethbridge, Alta.	2961	31	April 21	31	Aug. 8
Lacombe, Alta.	2783	15	April 28	21	Aug. 26
Beaverlodge, Alta.	2484	15	April 28	26	Aug. 25
Fort Vermilion, Alta.	950	16	May 1	16	Aug. 21

The warmest annual temperature among the Dominion Experimental Farms in the Prairie Provinces is to be found in southern Alberta at Lethbridge with 41·2 degrees, and at Manyberries with 40·5 degrees Fahrenheit. These Stations have the mildest winters, being moderated by the warm chinook winds. The highest summer temperature is to be found at Morden in southern Manitoba, although Manyberries is almost as warm.

The coldest annual temperature is to be found at Fort Vermilion located near the northern boundary of Alberta with 27·6 degrees Fahrenheit. The summer temperature of this Station is approximately the same as at Beaverlodge and Lacombe. The winter temperature, however, is very much colder with a mean January temperature of 11·1 degrees below zero. The lowest temperature ever experienced at this Station has been 78 degrees Fahrenheit below zero on January 11, 1911, but in the summer it has reached a maximum of 101 degrees above, on July 18, 1941.

The heaviest annual precipitation is to be found at Morden, Manitoba, with a total of 19·47 inches. Brandon comes next with 18·68 inches. The lowest precipitation is at Manyberries in southern Alberta, with 11·71 inches, although at Fort Vermilion in northern Alberta it is almost the same with 11·90 inches. Lacombe and Beaverlodge have almost the same total annual precipitation with 17·35 and 17·55 inches, respectively, but Lacombe receives more during the summer months. Indian Head, Saskatchewan, receives 3·59 inches more precipitation than Regina, although these places are only 32 miles apart; they are, however, in different soil zones. The month of June receives the heaviest rainfall at most Stations, with July coming next. Precipitation is usually light during the winter, but at Beaverlodge it is relatively heavier than at other Prairie Stations. The above data, it should be remembered, are average figures over a long period of years, but in many years the precipitation is much below the average giving rise to drought conditions.

When evaluating the comparative moisture conditions of various districts, consideration must be given not only to precipitation but to the amount of evaporation. Unfortunately there is no entirely satisfactory method of measuring evaporation which will relate to soil conditions. However, some comparison may be obtained by the amount of evaporation from a tank of water, four feet in diameter and two feet deep, set in the ground with the rim of the tank just a few inches above the surface. It will be seen from the data in Table 3, obtained from such evaporation tanks, that the average evaporation during the five-month period from May to September, inclusive, at Manyberries in southern Alberta of 33·17 inches, is somewhat over twice that at Lacombe, with only 15·39 inches. It is obvious that, where there is less evaporation, the efficiency of the rainfall is greater.

Many factors affect the dates of seeding and harvesting in different regions. Temperature, precipitation, evaporation, elevation, topography and soil type all influence these dates, with the last three mentioned factors exerting a variable effect even within a single region. However, Table 4 shows the approximate dates of first seeding of spring grain and first harvesting of Banner oats on the Dominion Experimental Farms in the Prairie Provinces. Lethbridge seeds first but Morden harvests first. Lacombe harvests much later than any other Station—even than at Fort Vermilion which is over 400 miles to the north. Accordingly, while Lacombe suffers greater danger from frost than the other Prairie Stations, it is probably less affected by drought.

Other meteorological factors are also important in crop production. The frequency and severity of hail damage varies considerably in different regions throughout the Prairie. Hot or strong winds may affect some areas more than others. Chinook winds may moderate the severity of winter temperatures and periodically remove the snow cover in some districts. The humidity of the atmosphere is very different in the various regions. Frosts are more prevalent and severe in some areas than in others. All these factors have a direct effect on crop growth.

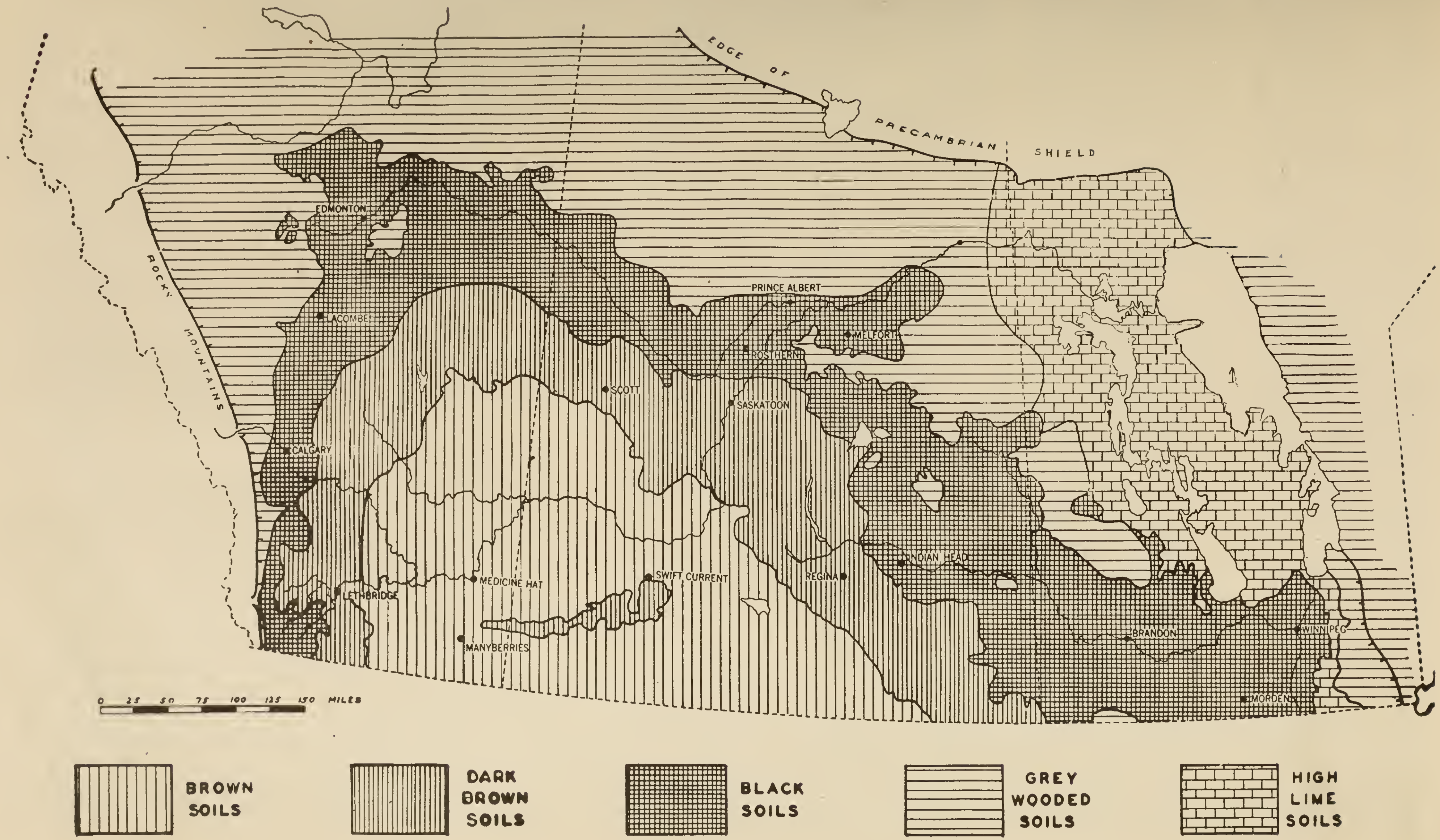
Soil Zones

Many different types of soil, each with its own significance in crop production and soil management, occur in the Prairie Provinces. While it is not possible to discuss in this bulletin the characteristics of each soil type, nevertheless they may be grouped into five major zones on the basis of certain common characteristics. Since these zones coincide closely with broad climatic and vegetative zones the kinds of crops that can be successfully grown, and hence the types of agriculture that can be practised, are closely related to them. For this reason a brief description of these zones and their effect on agriculture is included in this bulletin. Their location is shown on the sketch map on page 9.

The Brown Soil Zone

This zone is found on the open treeless prairie of Saskatchewan and Alberta where it covers some 34 million acres. It coincides with the drier part of the prairie and its climate may be classed as semi-arid. The relatively low moisture efficiency has limited the cover of native vegetation to a short stand of grass with the result that the total amount of organic matter in the soil is relatively low, a fact that largely accounts for the prevailing light or drab brown colour of

GENERALIZED SOIL MAP OF THE PRAIRIE PROVINCES



the surface soils. The soils have undergone little or no leaching as is shown by the shallow depth to which lime carbonate has been leached.

The agriculture practised in the Brown Soil Zone is normally largely confined to wheat farming and cattle ranching. While some 87 per cent of the zone is occupied, only about 44 per cent is improved, the remainder being left in native pasture. The margin of safety even for wheat farming is narrow as is shown by the fact that the rainfall is often at or below the minimum necessary for successful crop production.

The Dark Brown Zone

This zone, comprising some 30 million acres, lies in a broad belt surrounding the Brown Soil Zone on the east, north and west, on the open prairies of Saskatchewan and Alberta. While located in a region of limited rainfall the moisture efficiency is somewhat greater than in the Brown Soil Zone. Because of this fact there is a heavier cover of grass which is reflected in the darker colour of the surface soil with a higher organic-matter content. The lime carbonate has been leached to a somewhat greater depth.

While the type of agriculture is similar to that followed in the Brown Zone the climatic conditions are somewhat less hazardous, thus permitting a greater development and a somewhat more diversified agriculture. Ninety-six per cent of the total area is occupied and 62 per cent is improved. Wheat is the most important crop, but is not quite so dominant as in the Brown Zone.

The problems of farming in both these soil zones of the open prairie are quite similar. The climatic conditions in both areas have limited the type of farming largely to straight grain growing with the frequent use of the summerfallow, that is, a summerfallow every two or three years. This system is usually considered hard on the nitrogen and organic-matter contents of the soil, and while as yet crop yields have not been greatly affected by such losses, a lowering of the initially high fertility of the soils would seem inevitable. Soil drifting has been a serious menace in both areas. Although it is a problem that farmers will always have to face, recent experimental work has shown that it can be controlled by the adoption of suitable cultural and cropping practices.

The Black Soil Zone

Between the soils of the open prairie and the forest lies a zone of black soils covering an area of about 42 million acres. This zone corresponds closely to the Park region, so-called because of the prevalence of clumps of poplar and willow trees. The average annual precipitation in this zone of 15 to 19 inches, according to location, is only a few inches greater than in the Brown Soil Zones, but the evaporation is considerably lower. This results in a sub-humid climate which under natural conditions supports a luxuriant growth of grasses and shrubs. The surface soil is black and is usually rich in organic matter. The greater depth at which the carbonate layer is found, 18 to 40 inches, also indicates that these soils have been formed under moister conditions than those of the Brown and Dark Brown Zones of the open short grass prairie.

The agriculture practised in this zone is of a more varied nature than in the other grassland zones. While many farmers practise straight grain production, this is the great mixed-farming area of the Prairie Provinces. Wheat is an important crop, but other grains, clovers and grasses are relatively of much greater importance than in the two brown soil zones.

The soil problems encountered in this zone are somewhat different from those in the brown soil zones. While dry years do occur, the drought problem is not so acute. Soil drifting is a problem in some areas but it can be controlled by proper methods of farming. However, water erosion is a more serious problem than on the open prairies and damage from this type of erosion is probably greater than from wind erosion. Soil fertility is a problem in many parts of this zone but as the sub-humid climate will permit the incorporation of legumes in the rotation and the economic use of fertilizers and manure, the maintenance of soil fertility should not be difficult.

In addition to the main area of the Black Soil Zone, there are several additional important areas of black soils in the forest zone. The most important of such areas are in the Peace River district where they are extensively farmed. The agriculture practised there and the soil problems encountered are generally similar to those in the main zone.

The Grey Wooded or Northern Podsol Zone

This zone covers the major part of Saskatchewan and Alberta and includes a considerable area in Manitoba. Altogether it covers an area of well over 100 million acres. While it is covered with a forest of poplar, willow, spruce and pine, the climate is only sub-humid. The total average annual precipitation is not high, ranging from 16 to 22 inches over most of the area, with a low figure towards the northern part of only 11·9 inches at Fort Vermilion. However, the moisture efficiency of the rainfall is comparatively high as the evaporation is low.

The soils of this zone are characterized by a light grey, ash-like mineral layer lying just below a thin layer of organic matter on the surface. The thickness of this grey layer or horizon varies from a few inches to as much as 10 or 12 inches. Below this leached layer the subsoil may be fairly compact but seldom approaches the condition of a hardpan.

Where lime carbonate has been present in the parent material it occurs in the soil profile, but at a greater depth than in black soils which have been formed on similar parent material. These soils are always acidic in the upper horizons but not highly so, the pH usually being around 6.

Only a limited amount of agricultural development has taken place as yet in this soil zone. The type of farming practised can be described as mixed farming with oats, barley and hay being as important as wheat. At the present time the most serious soil problem in this zone is the fertility of the soils, but fortunately experimental work indicates that this problem, at least in many areas, can be overcome. Another problem making an appearance in this zone is water erosion. Erosion from wind is not important as yet, but as more development takes place and larger fields are cultivated, this type of erosion is likely to occur.

The High-Lime Zone

This zone occurs principally in Manitoba, extending over the area between Lake Manitoba and Lake Winnipeg, and along the western side of the former lake. It is a zone where the nature of the parent material rather than climate and vegetation has been the dominating factor in determining the nature of the soils. Except for small areas of grassland in the southern portion, the soils have developed under a forest cover. The climatic conditions and the vegetation are such that these soils would have developed as grey wooded soils if it had not been for the very high lime content of the parent material which prevented the typical development of such soils.

The well-drained soils vary in their nature, depending on whether they have developed under grass or under forest. Under grass there is a shallow black surface horizon lying directly on a high-lime layer while under woods there is a thin light grey leached horizon just below the leaf mat, succeeded by a greyish brown to greyish black nutty layer below which lies the high-lime parent material.

This zone has only a small percentage of cultivated land, devoted to mixed farming. Much of the area is not suitable for agriculture owing to the occurrence of large areas with poor drainage, the occurrence of coarse textured soils or the presence of rock close to the surface.

Location of Experimental Stations in Reference to Soil Zones

The results reported in this bulletin, obtained from the various crop rotations on the Dominion Experimental Farms, apply to the brown, dark brown and black soil zones. Swift Current is located in the brown soil zone, Scott, Regina and Lethbridge in the dark brown soil zone, while Morden, Brandon, Indian Head, Rosthern, Melfort and Lacombe lie in the black soil zone. However, in another section of the bulletin the results of some experimental work conducted in the grey wooded soils are briefly discussed. Little experimental work has been done on crop rotations in the High-Lime Zone, and nothing has been reported in this bulletin.

The grouping of soils into zones is of value in that it gives a broad generalized picture of soil, climatic and vegetative conditions, but there is a danger that it tends to over simplify the actual soil conditions that exist within each zone. Soil surveys have shown that within each zone many different types of soil exist ranging from non-arable to good agricultural types. As pointed out in the introduction to this section, each of these many types has its own significance in crop production and cultural practices. For example, the type of soil determines its water-holding capacity, its susceptibility to drifting or water erosion, its natural fertility, and its adaptability to produce crops. Again, some types of soil can be modified easily by man while others are resistant to change. For these reasons it is important to know as far as possible the characteristics of the type or types of soil on which crops are raised. This is not an easy task, for soils are complex bodies, but it can be accomplished by careful observation and by the use of soil survey reports and soil maps where these are available. With this knowledge it is possible to use experimental information and the experience gained on other farms on the same or similar types of soil with the view of utilizing the land to the best advantage.

Crop Rotation Experiments at Morden, Manitoba

A comparison is available at this Station for a period of approximately 20 years between a four-year grain rotation and a six-year mixed-farming rotation. The grain rotation consists of summerfallow, wheat, wheat and oats and represents a common cropping practice used rather extensively in Manitoba, particularly in former years. The mixed-farming rotation now consists of corn, wheat, hay, hay, wheat and oats, but previous to 1934 the sequence of crops was somewhat different, the arrangement being corn, wheat, wheat, oats, hay and hay. It has been found that much better stands of hay have been obtained when seeding down with wheat the first year after corn. While the yields of hay do not show any increase in the following table this has been due to failures other than those related to obtaining a stand. These experiments are conducted on Morden heavy clay loam to clay.

The following table shows the average yields per acre which have been obtained from these two rotations. These figures afford a reliable guide as to the yields which may be expected over a long period of years:—

TABLE 5.—YIELD PER ACRE ON ROTATION EXPERIMENTS AT MORDEN, MANITOBA

Four-Year Grain Rotation "E"	Entire Period		Last 10-year Period, 1933–1942
	Number of Years 1923–1942	Average Yield	
1st year—Summerfallow	....	....	....
2nd year—Wheat	20 years	27·5 bu.	28·3 bu.
3rd year—Wheat	20 "	23·7 "	24·4 "
4th year—Oats	20 "	50·9 "	45·2 "

Six-Year Mixed Farming Rotation "G"	Number of Years 1923–1933	Average Yield
1st year—Corn	11 years	7·67 tons
2nd year—Wheat	11 "	26·5 bu.
3rd year—Wheat	11 "	22·8 "
4th year—Oats	11 "	58·8 "
5th year—Hay	11 "	1·96 tons
6th year—Hay	11 "	1·93 "

Present Crop Sequence	Number of Years 1934–1942	Average Yield
1st year—Corn	8 years	7·95 tons
2nd year—Wheat	9 "	30·8 bu.
3rd year—Hay	9 "	1·80 tons
4th year—Hay	9 "	1·77 "
5th year—Wheat	9 "	25·9 bu.
6th year—Oats	8 "	59·6 "

The practice of summerfallowing has not proved so valuable at Morden as it has in drier regions. In the four-year grain rotation an average increase of only 3·8 bushels of wheat per acre was obtained over the 20-year period from wheat immediately following summerfallow as compared with wheat after wheat in the third year of the rotation. Even the oat crop in the fourth year of the rotation produced as many pounds per acre of grain as were produced by the wheat crop in the first year of the rotation. Obviously, in this district, the summerfallow is not required to conserve moisture and, if used at all, would be employed to control weeds in the event this could not be accomplished by some other type of crop rotation.

Corn may be used as a substitute for summerfallow as may be seen from the yield of wheat after corn in the mixed-farming rotation. This yield, over a period of 20 years, is slightly larger than the 20-year average yield of wheat after summerfallow in the grain rotation. Making allowances for variations in yields it would seem to be quite safe to assume that grain yields after corn in this district are fully equal to those after summerfallow.

Yields of wheat after hay are good but not quite so high as those after summerfallow or corn. In the mixed-farming rotation, wheat yielded 25·9 bushels after hay over a period of nine years as compared with 30·8 bushels after corn. This is a very satisfactory yield, however, and proves that hay may be used in a rotation without impairing the yield of subsequent crops. In the last year of the hay crop in the rotation the first cutting only should be harvested, making it possible to plough the land early and work as a partial summerfallow for the remainder of the season.

The value of including alfalfa in the hay mixture at Morden is very outstanding. A mixture of alfalfa and western rye or crested wheat grass gave an average yield, over a period of nine years, of 1·80 tons per acre as compared with 1·06 tons for grass alone. While the hay mixture was left for two years only in the mixed-farming rotation shown in the above table, it is probable that better results would be obtained if the alfalfa mixture were left in hay for a longer period, possibly for three to five years. This would require a different rotation in order to obtain the desired proportion of the various crops, but it would reduce the cost of seeding and the risk of failure to obtain a good stand.

Another advantage of alfalfa at Morden has been its beneficial effect upon the yields of subsequent crops as compared with grass hay. In some years this effect is very outstanding, increased growth being observed not only in the crop immediately following alfalfa but even in crops four years afterwards.

Wheat immediately after alfalfa gave an increased yield, over a period of two years, of 10·2 bushels per acre as compared with following crested wheat grass while four years afterwards the increase was 6·1 bushels and was quite evident to the eye. In other years, however, little, if any, difference is observed. Sweet clover has also proved beneficial for subsequent crops and perhaps is even superior to alfalfa especially during dry years. These two crops are valuable at Morden for their effect upon the yields of subsequent crops and are particularly useful on the lighter types of soil where productivity is difficult to maintain.

The application of manure has not given any significant increase in yield of corn. It would seem advisable to reserve the manure for use on less fertile parts of the farm or for high knolls susceptible to soil drifting.

A comparison has been made in the four-year grain rotation between common and durum wheats. Durum wheat gave an increased yield, over the period of 20 years, of 3·7 bushels on summer-fallow land and 2·2 bushels on stubble. As the common wheats in the earlier years of the experiment included varieties susceptible to rust it is probable that in future years less difference will be apparent.

Additional experiments with other rotations have been conducted at Morden. A three-year rotation of wheat, wheat and sweet clover has given good results. Satisfactory yields have been obtained and weeds controlled without the use of a summerfallow. Another successful rotation consists of five years devoted to corn, wheat, sweet clover, wheat and oats, with an additional area, equal in size to the area of one of the preceding crops, seeded to an alfalfa hay mixture which is left for hay for a period of five years. It is then ploughed and used for the other crops in the rotation while another area is seeded to alfalfa for a period of five years. Care is taken to avoid ploughing up the old stand of alfalfa until a new stand has been successfully established. Another four-year rotation which consisted of summerfallow, fall rye, wheat and fall rye, was conducted to learn the comparative yield of fall rye after fallow and after wheat. Over a period of ten years the fall rye after fallow yielded 34·2 bushels per acre, while after wheat it produced 23·5 bushels. This rotation was not very successful on account of the low value of the rye crop and the volunteering of the rye in the succeeding wheat crop. It showed, however, that a fair crop of fall rye could be obtained at Morden when seeded in the stubble of a wheat crop, a practice which is not successful in drier regions.

The mixed-farming rotations including hay and corn were more satisfactory than the grain rotations in controlling weeds. This is an important advantage wherever weeds are a serious factor, especially as the control is accomplished without special work on the weeds. The fall rye rotation, however, was a type of grain rotation which did control weeds, fall rye being particularly valuable for this purpose.

Crop Rotation Experiments at Brandon, Manitoba

Crop rotation experiments have been conducted on the Dominion Experimental Farm at Brandon since 1911. However, as certain changes have been made in the crop sequence or location of some of these rotations, a continuous record is available for one rotation only, the four-year grain rotation "E", of summerfallow, wheat, wheat and oats. The five-year mixed-farming rotation "F" has been conducted for the same period of time but a change was made from the practice of seeding down with barley after corn to seeding down with wheat which gives better results because of less lodging of the nurse crop. Accordingly, only the yields are reported for the crop sequence as it stands at the present time although these yields are very similar to those for the entire period.

A comparison is available of two six-year mixed-farming rotations "G" and "H". Records from these rotations are available for about 16 years, but as all the crops did not commence in the same year the yields are reported in the following table for the ten-year period from 1933 to 1942.

The above rotations are located partly on fertile Assiniboine clay loam to clay soil and partly on lighter hillside soil in the valley of the Assiniboine river. Another four-year mixed-farming rotation is located on much less fertile, Souris sandy loam, just north of the Assiniboine valley. This latter rotation was commenced in 1932, much more recently than the other rotations.

The following table shows the average yields per acre which have obtained from these rotations:—

TABLE 6.—YIELDS PER ACRE IN ROTATION EXPERIMENTS AT BRANDON, MANITOBA

Four-Year Grain Rotation "E"	Entire Period		Last 10-year period 1933–1942
	Number of Years 1911–1942	Average Yield	
1st year—Summerfallow	32 years	....	....
2nd year—Wheat	32 "	24·5 bu.	25·0 bu.
3rd year—Wheat	32 "	15·6 "	14·8 "
4th year—Oats	32 "	31·4 "	31·7 "

Five-Year Mixed-Farming Rotation "F"	Number of Years 1934–1942	Average Yield
1st year—Corn—manure 12 tons	9 years	7·41 tons
2nd year—Wheat	9 "	26·57 bu.
3rd year—Sweet clover	9 "	2·04 tons
4th year—Wheat	9 "	25·12 bu.
5th year—Barley	9 "	29·60 bu.

Six-Year Mixed-Farming Rotation "G"	Number of Years 1933–1942	Average Yield
1st year—Corn—Manure 12 tons	10 years	6·05 tons
2nd year—Wheat	10 "	21·3 bu.
3rd year—Alfalfa, sweet clover and western rye hay	10 "	1·49 tons
4th year—Alfalfa, sweet clover and western rye hay	10 "	1·15 tons
5th year—Wheat	10 "	18·8 bu.
6th year—Oats	10 "	37·1 bu.

Six-Year Mixed-Farming Rotation "H"	Number of Years 1933–1942	Average Yield
1st year—Summerfallow	10 years	....
2nd year—Wheat	10 "	25·7 bu.
3rd year—Alfalfa, sweet clover and western rye hay	10 "	1·53 tons
4th year—Alfalfa, sweet clover and western rye hay	10 "	0·94 tons
5th year—Wheat—manure 12 tons	10 "	21·1 bu.
6th year—Oats	10 "	36·7 bu.

Four-Year Mixed-Farming Rotation (On light infertile soil)	Number of Years 1933–1942	Average Yield
1st year—Summerfallow	10 years	....
2nd year—Wheat	10 "	15·0 bu.
3rd year—Sweet clover and brome grass hay	10 "	1·18 tons
4th year—Oats	10 "	30·4 bu.

Wheat after summerfallow in the four-year grain rotation "E" has averaged 24·5 bushels per acre as compared with 15·6 bushels after stubble. This shows a very considerable value for the summerfallow in this region. Although this experiment has been in progress for 32 years the yields during recent years are fully as high as those obtained when the experiment was commenced, as will be observed from the yields obtained during the last ten years, indicating very little, if any decline in the productivity of this soil.

In fact, in a comparable adjoining four-year rotation, where 12 tons of farm manure were applied, at first to the oat crop and then later to the wheat crop in the third year of the rotation, the yields have been increased only to a very limited extent. During the last ten years, from 1933 to 1942, the wheat in the second year of the rotation was increased 3·7 bushels per acre, the next wheat crop in the rotation 1·8 bushels while the oats were increased only ·4 bushel. This makes a total increase of 5·5 bushels of wheat and ·4 bushel of oats for the 12 tons of manure. It is evident, therefore, that manure need not be used for grain crops on soil which is as fertile as this Assiniboine valley soil.

The most outstanding feature, perhaps, of this four-year grain rotation has been its very heavy infestation with wild oats. Although there is a well-worked summerfallow once every four years, and varying methods have been tried, including surface cultivation rather than ploughing, no success has been obtained in getting the wild oats under control, especially in the third and fourth years of the rotation. Whether deferred seeding of the grain crops may accomplish this object has not yet been learned. Wild oats grow well on this soil and are controlled best and most economically by mixed-farming rotations having the land in hay crop for two years in succession as in rotations "G" and "H". Where the hay crop remains for one year only, as in rotation "F", the wild oats, although less prevalent than in the four-year grain rotation, are present in considerable numbers.

The yield of wheat after corn is quite good in the five-year rotation "F" but is much smaller in the six-year rotation "G". The reason for this difference is that the soil is a more fertile clay loam in rotation "F" while in rotation "G" it is a less fertile sandy loam, partly located on a hillside. Rotation "F" has been in progress, also, for a much longer period of years. Wheat after sweet clover hay seems to have given somewhat better yields than after the alfalfa and grass hay mixture. However, having two consecutive years in hay, as in rotations "G" and "H", is preferable for weed control.

On the infertile, Souris sandy loam, the average yield of wheat after summerfallow was only 15·0 bushels per acre or about 60 per cent of the yield obtained on the fertile clay loam valley soil. The yield in pounds per acre of oats after sweet clover has been fully equivalent to the yield of wheat after summerfallow, indicating that a partial summerfallow on this sandy soil is about equal to a summerfallow for the entire season.

A very successful eight-year rotation, used on the Illustration Stations in Manitoba, consists of summerfallow, grain, grain, hay, pasture, break and summerfallow, grain and grain. This eight-year rotation may be located on four fields, the first and fifth years of the rotation being in one field, the second and sixth years in another field and similarly for the other years of the rotation. This arrangement reduces the cost of fencing and enables the livestock to graze one field all year without injuring any of the other crops not desired for pasture. The only weakness of this rotation is that the grass and legume mixture is seeded down with a grain crop two years removed from a summerfallow when it would would be preferable to seed down with wheat on summerfallow land. However, by observing precautions in reducing the rate of seeding the nurse crop and by planting on a firm seed-bed, good catches are usually secured. This rotation provides a satisfactory proportion of the various crops for a livestock farmer.

Crop Rotation Experiments at Indian Head, Saskatchewan

A comparison is available for a period of over 30 years on the Dominion Experimental Farm at Indian Head, between a three-year grain rotation and a nine-year mixed-farming rotation. The grain rotation "C" consists of summer-fallow, wheat, wheat, while the mixed farming rotation "R" includes summer-fallow, wheat, oats, hay, hay, hay and break, corn, wheat, oats. Both rotations are located on black Indian Head clay soil but unfortunately rotation "C" is on somewhat lighter soil and the topography, in part, is more undulating, which does not provide quite as good soil conditions as are enjoyed by rotation "R".

The following table gives the average yields per acre which have been obtained from these experiments:—

TABLE 7.—YIELDS PER ACRE ON ROTATION EXPERIMENTS AT INDIAN HEAD, SASK.

Three-Year Grain Rotation "C"	Entire Period		Last 10-year period 1933–1942
	Number of Years 1912–1942	Average Yield	
1st year—Summerfallow	31 years	....	....
2nd year—Wheat	31 "	25·9 bu.	24·5 bu.
3rd year—Wheat	31 "	15·0 "	13·1 "

Nine-Year Mixed Farming Rotation "R"	Entire Period		Last 10-year period 1933–1942
	Number of Years 1911–1942	Average Yield	
1st year—Summerfallow	32 years	....	....
2nd year—Wheat	32 "	33·8 bu.	31·4 bu.
3rd year—Oats	32 "	42·7 "	38·1 "
4th year—Hay—Alfalfa and western rye grass	32 "	0·99 tons	0·54 tons
5th year—Hay	23 "	1·28 "	1·02 "
6th year—Hay and partial fallow	24 "	0·98 "	0·66 "
7th year—Corn—12 tons manure	30 "	7·99 "	5·94 "
8th year—Wheat	32 "	27·6 bu.	22·0 bu.
9th year—Oats	32 "	47·1 "	38·8 "

While the average yield of 33·8 bushels of wheat per acre after summer-fallow in the mixed-farming rotation "R" is much higher than the yield of 25·9 bushels in rotation "C", it would not be safe to assume that this higher yield is due entirely to the effect of the rotation. Apparently the yields were always higher on rotation "R", even when the experiment started. During the ten-year period from 1912 to 1921, the yield of wheat on summerfallow on rotation "R" was 36·0 bushels per acre, while that on rotation "C" was 28·5 bushels or 7·5 bushels per acre more. During the last ten years, from 1933 to 1942, the yield of wheat on summerfallow on rotation "R" has been 6·9 bushels greater. Evidently the comparative inherent productivity of the soil is being maintained at about the same level irrespective of the effects of the two rotations.

The most serious disadvantage of the three-year grain rotation "C" is its pollution with wild oats, especially in the wheat crop grown on stubble. In some years this crop has been so badly infested with wild oats that it was necessary to mow and use it for hay. The only effective control over this weed in this rotation is to defer seeding about three weeks in the spring in order to destroy the first growth of wild oats and enable the wheat to get ahead of the weeds. This method is very effective although it may result in a lower yield of wheat than is possible with earlier seeding on clean land and, in certain districts, may expose the crop to greater danger from frost. Surface cultivation, although helpful in controlling wild oats, has not been found completely effective and must be supplemented by deferred seeding.

In the mixed-farming rotation "R" there is no trouble from wild oats, the three consecutive years in hay completely eliminating this weed. Deferred seeding in the spring is unnecessary, therefore, in this rotation. Owing largely to this freedom from wild oats, the second crop after summerfallow gives a much larger yield per acre than the second crop in the grain rotation. It is true, the second crop is oats in the mixed-farming rotation and wheat in the grain rotation and, hence, it is not possible to compare the yields in bushels per acre. Nevertheless, if the comparison is made in pounds it will be seen that 1,451 pounds of oats per acre have been obtained as compared with only 900 pounds of wheat.

The yield of wheat after corn has not been as good as after summerfallow. During the entire period of 32 years the difference has been 6·2 bushels per acre more on summerfallow but if the comparison is made during a relatively dry ten-year period, from 1933 to 1942, there is a very much larger difference of 9·4 bushels greater yield. It is evident that corn is not a very satisfactory summerfallow substitute crop in this district.

Hay crops have not yielded very well at Indian Head. There is some difficulty in securing a good stand in a dry year and the first year in hay always contains a much larger percentage of weeds than occurs in older stands. It might be preferable in this region to keep an area in hay for a longer period of years, then plough and include it in a grain rotation, seeding hay again on a new area. Oat sheaf hay will yield more per acre than perennial hay crops but, of course, it has not the same effect on the organic-matter content of the soil.

A rotation of this kind has been in progress at Indian Head since 1935 but the weather has been so dry in several years during this period that frequent failures have occurred with the hay crops. This cropping arrangement consists of a four-year rotation of summer-fallow, wheat, sweet clover and oats, with a block of land equal in size to that devoted to one of the above crops seeded to alfalfa. The grain crops have yielded fairly well during this period but the hay crops, both sweet clover and alfalfa, have been practically a failure.

Crop Rotation Experiments at Rosthern, Saskatchewan

Crop rotation experiments were conducted on the Dominion Experimental Station at Rosthern commencing in 1912 and continuing until the Station was closed in 1939. Records are available throughout the entire period for two mixed-farming rotations but on account of the land on which the grain rotation was originally located being required for other purposes, the records for this rotation do not cover as many years. These experiments were located on black, Blaine Lake loam and light loam.

The following table gives the average yields per acre which have been obtained from these experiments:—

TABLE 8.—YIELDS PER ACRE ON ROTATION EXPERIMENTS AT ROSTHERN, SASK

Three-Year Grain Rotation "C"	Number of Years 1923–1938	Average Yield
1st year—Summerfallow		
2nd year—Wheat	16 years	23·0 bu.
3rd year—Wheat	16 "	17·4 "

Six-Year Mixed Farming Rotation "J"	Number of Years 1912–1939	Average Yield
1st year—Summerfallow	....	....
2nd year—Wheat	27 years	22·9 bu.
3rd year—Wheat	27 "	17·2 "
4th year—Oats	27 "	35·0 "
5th year—Hay—western rye	27 "	0·62 tons
6th year—Hay	27 "	0·63 "

Eight-Year Mixed Farming Rotation "P"	Number of Years 1912–1939	Average Yield
1st year—Summerfallow	....	....
2nd year—Wheat	26 years	25·6 bu.
3rd year—Wheat	26 "	18·1 "
4th year—Summerfallow—manured 12 tons	26 "	....
5th year—Roots 1912–1931	18 "	18·74 tons
Corn 1926–1939	12 "	5·5 "
6th year—Barley	26 "	36·4 bu.
7th year—Hay—western rye	26 "	0·75 tons
8th year—Hay	26 "	1·02 "

Wheat grown on summerfallow in the grain rotation gave an average yield of 23·0 bushels per acre as compared with 17·4 bushels when grown as the second crop after summerfallow. The summerfallow has had the effect, therefore, of increasing the average yield 5·6 bushels per acre or 32 per cent.

Barley after corn or roots in the mixed-farming rotation "P" has given the excellent yield of 36·4 bushels or 1,747 pounds per acre. This is a greater yield in pounds per acre than that secured from wheat on summerfallow which itself, at 25·6 bushels or 1,536 pounds per acre, was very satisfactory. While corn and roots have proved excellent summerfallow substitute crops at this Station, insofar as their effect on the following yield of barley has been concerned, the yield of the corn crop itself was very low while the root crop entailed considerable labour to produce.

Hay has not yielded very well at Rosthern in comparison with the much more satisfactory yields of grain. In the six-year rotation "J", where the grass was seeded down with an oat crop three years removed from summerfallow, the yield was about two-thirds of a ton per acre, while in the eight-year rotation "P" the yield ranged from three-quarters to one ton per acre. It is probable that when a good stand of hay has been secured in this district it should be left for a longer period of years before ploughing and including the land in a grain rotation. The addition of alfalfa along with the grass would also, no doubt, increase the yield.

Crop Rotation Experiments at Scott, Saskatchewan

Crop rotation experiments have been conducted on the Dominion Experimental Station at Scott since 1912. A comparison is available between a three-year grain rotation "C" and a six-year mixed-farming rotation "J" of summerfallow, wheat, wheat, oats, hay and hay. Other rotations have also been included but have not been conducted for such a long period of years. These experiments are located on dark brown, Weyburn loam.

The following table shows the average yields per acre which have been obtained:—

TABLE 9.—YIELDS PER ACRE ON ROTATION EXPERIMENTS AT SCOTT, SASK.

Three-Year Grain Rotation "C"	Entire Period		Last 10-year Period 1933–1942
	Number of Years 1912–1942	Average Yield	
1st year—Summerfallow	....	....	....
2nd year—Wheat	31 years	16·4 bu.	10·6 bu.
3rd year—Wheat	31 "	14·5 "	8·6 "

Six-Year Mixed Farming Rotation "J"	Entire Period		Last 10-year Period 1933–1942
	Number of Years 1912–1942	Average Yield	
1st year—Summerfallow	....	....	....
2nd year—Wheat	31 years	19·1 bu.	10·1 bu.
3rd year—Wheat (*)	25 "	14·9 "	8·7 "
4th year—Oats	30 "	39·0 "	19·4 "
5th year—Hay	27 "	0·74 tons	0·53 tons
6th year—Hay	19 "	0·67 "	0·65 "

* Oats replaced wheat 1919–1924.

Wheat yields have declined seriously at this Station during the last ten years. While wheat on summerfallow in the three-year grain rotation "C" has averaged 16·4 bushels per acre over the entire period of 31 years, it has dropped from 21·1 bushels per acre during the first ten years of the experiment to only 10·6 bushels during the last ten years. This tremendous drop in yield cannot be attributed to the fact that the wheat is grown in a grain rotation because in the six-year mixed-farming rotation "J", where grass has been included for two years in each cycle of the rotation, the yield of wheat after summerfallow has declined from 25·4 bushels per acre, as the average for the first ten years of the experiment, to only 10·1 bushels during the last ten years from 1933 to 1942. Evidently climatic conditions have been particularly unfavourable during the last ten years. Furthermore, no particularly good years have been enjoyed since 1915 and 1916 when 40·0 and 40·3 bushels per acre, respectively, were obtained on rotation "C" on summerfallow.

Strange as it might seem in this dry region, the average yield of wheat after summerfallow in the three-year grain rotation "C" is only 1·9 bushels more than the yield of wheat after wheat. This is due largely to the greater infestation of weeds, especially lambs' quarters and wild buckwheat, in the crop seeded on summerfallow than in the second crop wheat. Fortunately, the application of ammonium phosphate fertilizer gives a very effective control of these weeds and has increased the average yield of wheat on summerfallow 4·5 bushels per acre. In the mixed-farming rotation "J", where there are fewer weeds than on rotation "C", there has been a much greater difference of 4·2 bushels per acre between the yield of wheat after summerfallow as compared with wheat after wheat.

Hay yields have been light at Scott. At first western rye grass was used but in later years a mixture including sweet clover, crested wheat grass and western rye grass has been used. This has given somewhat improved yields. In another rotation where sweet clover has been used without any grass, the average yield, over a period of 17 years, has been ·53 of a ton per acre. It would seem that in this district if hay is grown it might be preferable to leave it for a few years before ploughing. In this way, less trouble would be experienced with weedy hay, which frequently occurs the first year after seeding, and there would be less danger of failing to get a good stand. Oat sheaves give a much larger yield per acre than can be secured from any of the biennial or perennial hay crops. Corn has not proved a satisfactory crop at this Station. Sunflowers have given much better yields, particularly as they are not affected so much by frost.

Crop Rotation Experiments at Swift Current, Saskatchewan

Crop rotation experiments have been conducted on the Dominion Experimental Station at Swift Current, commencing in 1923. Unfortunately, the land on which these experiments were originally located had to be used for other purposes which necessitated a change in location and interfered with any cumulative effect which the various rotations might have had on the soil. Since this Experimental Station was established in 1921 the farm has been cut by a new highway, a railroad and a large irrigation ditch. However, while the yields from these experiments do not indicate the effect of different cropping systems over a long period of years, they do show what average yields may be expected from various crops in this district. The experiments have been conducted on Haverhill loam soil.

The following table shows the average yields per acre which have been obtained:—

TABLE 10.—YIELDS PER ACRE ON ROTATION EXPERIMENTS AT SWIFT CURRENT, SASK.

Two-Year Grain Rotation "B"	Entire Period		Last 10-Year Period 1933–1942
	Number of Years 1924–1942	Average Yield	
1st year—Summerfallow	....	....	....
2nd year—Wheat	19 years	16·0 bu.	10·0 bu.

Three-Year Grain Rotation "C"	Entire Period		Last 10-Year Period 1933–1942
	Number of Years 1924–1942	Average Yield	
1st year—Summerfallow	....	....	....
2nd year—Wheat	19 years	16·8 bu.	13·5 bu.
3rd year—Wheat	19 "	9·2 "	6·3 "

Seven-Year Mixed-Farming Rotation	Number of Years 1925–1936	Average Yield
1st year—Summerfallow	12 years	....
2nd year—Fall rye	12 "	13·8 bu.
3rd year—Corn	12 "	1·86 tons
4th year—Wheat	12 "	13·6 bu.
5th year—Hay	12 "	0·49 tons
6th year—Hay and partial fallow	12 "	0·25 "
7th year—Wheat	12 "	10·6 bu.

The practice of summerfallowing has a very pronounced beneficial effect at Swift Current. In the three-year grain rotation "C", the average yield of wheat over a period of 19 years after summerfallow has been 16·8 bushels as compared with only 9·2 bushels after wheat or 81 per cent more. During the last ten years the yield has been more than twice as much on summerfallow. When the yield is twice as much on summerfallow, a two-year rotation of summerfallow and wheat will produce exactly as much grain as a three-year rotation of summerfallow and two years of wheat and with decidedly less cost of production. While the yield of wheat on summerfallow in the two-year rotation at Swift Current did not happen to produce quite as much as in the three-year rotation, the small difference may be attributed to the variability in the soil. The two-year grain rotation at Swift Current would seem to be preferable to the three-year rotation. Crop yields are very variable from year to year in this district, depending upon the amount of the precipitation. Wheat on summerfallow is much more likely to produce some crop in dry years than wheat grown after wheat.

The mixed-farming rotation at Swift Current has been a failure. Fall rye and especially corn and hay have given very poor yields. Wheat yields after hay have been depressed. The hay crop itself has included a large amount of weeds so that its quality has been poor. Oat sheaves at this Station give a much larger yield than biennial or perennial hay crops, a result which is found in all dry regions. If hay is grown it should be left for several years on the land before ploughing and including in a grain rotation.

Crop Rotation Experiments at Lacombe, Alberta

Crop rotation experiments were commenced on the Dominion Experimental Station at Lacombe in 1911. A comparison is available between a three-year grain rotation and two mixed-farming rotations. These experiments are located on black loam soil.

The following table shows the average yields per acre which have been obtained.

TABLE 11.—YIELDS PER ACRE ON ROTATION EXPERIMENTS AT LACOMBE, ALBERTA

Three-Year Grain Rotation "C"	Entire Period		Last 10-Year Period 1933–1942
	Number of Years 1913–1942	Average Yield	
1st year—Summerfallow	....	....	....
2nd year—Wheat	29 years	25·7 bu.	19·7 bu.
3rd year—Wheat	29 "	16·0 "	11·0 "

Seven-Year Mixed-Farming Rotation "O"	Entire Period		Last 10-Year Period 1933–1942
	Number of Years 1912–1942	Average Yield	
1st year—Summerfallow	....	....	....
2nd year—Wheat	20 years	31 bu.	33·2 bu.
3rd year—Hay	29 "	1·72 tons	1·72 tons
4th year—Hay	19 "	1·44 "	1·45 "
5th year—Potatoes—Manure 15 tons	22 "	213·4 bu.	247·7 bu.
6th year—Wheat	32 "	34·0 "	33·6 "
7th year—Oats	32 "	60·8 "	68·8 "

Six-Year Mixed-Farming Rotation "K"	Entire Period		Last 10-year Period 1933–1942
	Number of years 1912–1942	Average Yield	
1st year—Corn—Manure 15 tons	22 years	9·55 tons	11·2 tons
2nd year—Wheat	23 "	32·0 bu.	37·2 bu.
3rd year—Barley	32 "	37·9 "	51·0 "
4th year—Hay	31 "	1·32 tons	1·28 tons
5th year—Hay	19 "	2·19 "	2·32 "
6th year—Hay	19 "	1·49 "	1·75 "

The mixed-farming rotations at Lacombe have shown an outstanding advantage over the grain rotation, especially during the last ten years. The three-year grain rotation "C" has become polluted with wild oats which has very seriously reduced the yields while in both the mixed-farming rotations the land is practically free of this weed. The application of farm manure, the inclusion of mixed alfalfa and western rye grass hay together with hoed crops in the mixed-farming rotations have resulted in very much larger yields than have been obtained from the grain rotation. The mixed-farming rotations, it is true, have enjoyed the benefit of one application of manure throughout each cycle of the rotation while the grain rotation did not receive any manure and this, in itself, would increase the yields to some extent. Mixed-farming rotations, however, would naturally necessitate livestock farming and hence manure would be produced with this type of farming but would not likely be available if a grain rotation were used.

An attempt has been made to control wild oats in the three-year grain rotation "C" by the use of surface tillage rather than ploughing and, in recent years, by the practice of deferred seeding in the spring. These methods, especially the deferred seeding, have helped to some extent but in the black, park belt soils, wild oats seem to find almost ideal conditions for growth and it is doubtful if they will provide complete control. Deferred seeding in this region, moreover, exposes the crop to greater danger from frost damage in the fall with consequent reduction both in yield and quality of the grain. Barley, it is true, could be used instead of wheat in order to control the wild oats more effectively, but this three-year grain rotation has been designed to learn what results would be obtained when wheat is used. This experiment proves that this type of rotation is unsatisfactory for this region. It may succeed for a few years but ultimately the wild oats will pollute the land and reduce the yields. Even a two-year rotation of summerfallow and wheat has great difficulty in controlling wild oats in this district.

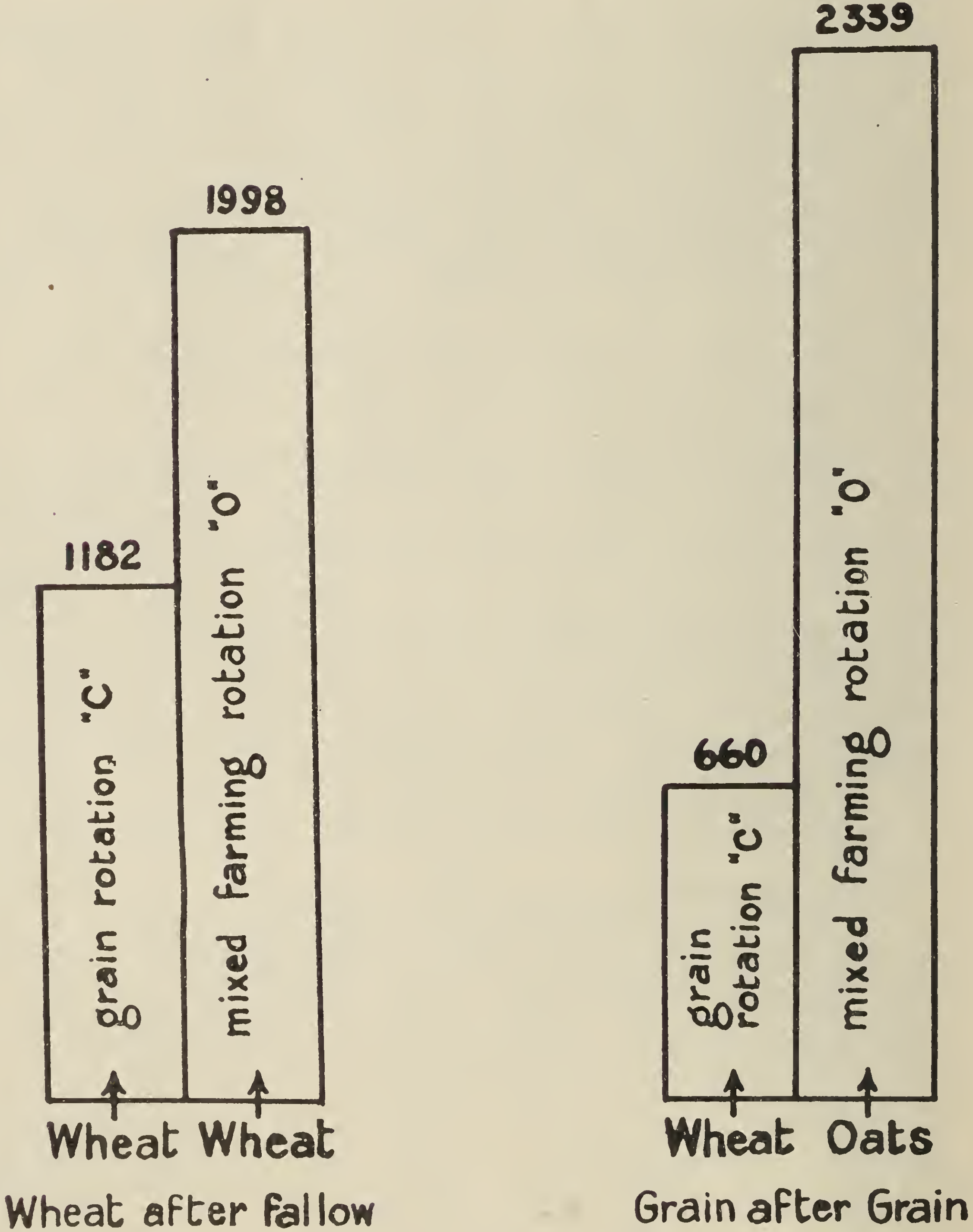
The use of ammonium phosphate fertilizer, seeded with a combination grain and fertilizer drill, has increased the yield considerably on rotation "C" and has provided some control over the wild oats. Where 50 pounds of ammonium phosphate have been applied to the wheat on summerfallow the yield, over a nine-year period, has been increased to 27·0 bushels per acre as compared with 18·8 bushels where no fertilizer was used. The residual effect of this fertilizer gave a yield on the second crop wheat of 13·2 bushels per acre as compared with 10·0 bushels on the untreated check. This gives a total increase, in the two wheat crops in the rotation, of 11·4 bushels of wheat for 50 pounds of ammonium phosphate. It shows the great value of this fertilizer in this district under conditions where the land has become polluted with wild oats and somewhat reduced in fertility.

The mixed-farming rotations offer a remarkable contrast in comparison with the grain rotation. One of these rotations, rotation "O", is located immediately adjoining the grain rotation "C" and if there is any difference in the soil it would seem to be in favour of rotation "C". The yields of wheat on summerfallow during the last ten years have averaged 33·2 bushels per acre

CROP.YIELDS

In Grain Versus Mixed Farming Rotations

DOM. EXP. STATION, LACOMBE, ALTA.



10 YEAR AVERAGE YIELDS 1933-1942
POUNDS PER ACRE

on the mixed-farming rotation "O" as compared with only 19·7 bushels in the grain rotation. The yields of wheat after potatoes or corn have been fully equal to those after summerfallow. No comparison is available between the yields of second crop wheat after summerfallow but it is interesting to compare, in pounds per acre, the average yield, during the last ten years, of oats, after wheat in rotation "O", at 68·8 bushels or 2,339 pounds, as compared with wheat after wheat in rotation "C" at only 11 bushels or 660 pounds per acre. This is over three times the yield and, moreover, has produced a much better quality of grain. Barley in rotation "K" has done even better with the remarkable average yield of 51·0 bushels or 2,448 pounds per acre.

Hay yields have been fairly good at Lacombe but not proportionately as good as the grain yields in the mixed-farming rotations. While both potatoes and corn have given fairly good yields at Lacombe it is improbable that either crop could be used extensively in mixed-farming rotations in this district.

Cover crops have given promising results at Lacombe and may be used on an extensive scale. A light seeding of one-half bushel of wheat on August 1 on summerfallow land provides considerable fall pasture and does not reduce the yield of grain the following year. Moreover, it controls soil drifting very effectively.

An eight-year mixed-farming rotation might be used omitting intertilled crops and utilizing cover crops. This rotation might consist of summerfallow, seeded to a cover crop on August 1, wheat, barley seeded down, hay, pasture, early pasture—break in June and summerfallow or seed to a cover crop, wheat and oats. This eight-year rotation might be located in four fields by pairing the first and fifth years of the rotation, second and sixth years, third and seventh years, and fourth and eighth years.

In other rotations which were conducted at Lacombe for shorter periods of years, it was learned that when sweet clover was grown for hay and the land ploughed immediately after the crop was removed and worked as a partial summerfallow, the yields of grain the following year were very satisfactory. They were not quite so large as after summerfallow but greater than following a mixed alfalfa and grass sod. However, if land is left in hay for one year only it will not control wild oats satisfactorily.

Crop Rotation Experiments at Lethbridge, Alberta

Crop rotation experiments have been conducted on the Dominion Experimental Station at Lethbridge since 1912. These experiments include more rotations and have been continued with fewer changes than on any other Experimental Station in Canada. Moreover, rotations have been located on both dry and irrigated land. Very reliable information is available, therefore, over a long period of years on the results which may be expected under these soil and climatic conditions from different systems of cropping. These rotation experiments are conducted on dark brown loam.

The following table shows the average yields per acre which have been obtained from the various rotations. Rotation "U" at the end of the table is irrigated while all the other rotations are located on dry land.

TABLE 12.—YIELDS PER ACRE ON ROTATION EXPERIMENTS AT LETHBRIDGE, ALBERTA

Continuous Wheat "A"	Entire Period		Last 10-Year Period 1933–1942
	Number of Years 1912–1942	Average Yield	
Wheat (spring)	31 years	12·3 bu.	10·0 bu.

Two-Year Grain Rotation "B"	Entire Period		Last 10-Year Period 1933–1942
	Number of Years 1912–1942	Average Yield	
1st year—Summerfallow..................	....	....	....
2nd year—Wheat (spring)................	31 years	27·4 bu.	27·7 bu.

Three-Year Grain Rotation "C"	Entire Period		Last 10-Year Period 1933–1942
	Number of Years 1912–1942	Average Yield	
1st year—Summerfallow..................	....	....	....
2nd year—Wheat (spring)................	31 years	25·5 bu.	23·9 bu.
3rd year—Wheat (spring) (*)............	19 "	16·2 "	13·6 "

* Wheat replaced oats in 1924.

Six-Year Mixed-Farming Rotation "J"	Entire Period		Last 10-Year Period 1933–1942
	Number of Years 1912–1942	Average Yield	
1st year—Summerfallow (*).............	21 years	....	....
2nd year—Wheat (spring)................	21 "	21·8 bu.	17·8 bu.
3rd year—Wheat (spring)................	21 "	17·3 "	13·8 "
4th year—Oats..........................	21 "	21·3 "	14·0 "
5th year—Hay (alfalfa and western rye)..	21 "	·64 tons	·50 tons
6th year—Hay or pasture................	21 "	·90 "	·62 "

* Manured—12 tons per acre.

Six-Year Mixed-Farming Rotation "M"	Entire Period		Last 10-Year Period 1933–1942
	Number of Years 1912–1942	Average Yield	
1st year—Summerfallow..................	31 years	....	....
2nd year—Wheat (winter)................	31 "	29·5 bu.	32·0 bu.
3rd year—Oats..........................	31 "	38·4 "	29·7 "
4th year—Summerfallow (*).............	31 "	....	....
5th year—Pea and oat hay...............	31 "	2·15 tons	2·08 tons
6th year—Oats..........................	31 "	43·5 bu.	31·5 bu.

* Manured—12 tons per acre.

Five-Year Mixed-Farming Rotation "Z"	Entire Period		Last 10-Year Period 1933–1942
	Number of Years 1922–1942	Average Yield	
1st year—Summerfallow (*).............	....	....	....
2nd year—Wheat (spring)................	21 years	22·8 bu.	17·5 bu.
3rd year—Wheat (spring) (†)...........	17 "	15·5 "	10·8 "
4th year—Sweet clover seeded...........	17 "	·09 tons	·13 tons
5th year—Sweet clover hay..............	17 "	·92 "	·72 "

(*) Manure—12 tons per acre.
(†) Wheat replaced oats in 1926.

Nine-Year Mixed-Farming Rotation "S"	Entire Period		Last 10-Year Period 1933–1942
	Number of Years 1912–1942	Average Yield	
1st year—Summerfallow (*)	....	....	....
2nd year—Corn	31 years	6·27 tons	4·26 tons
3rd year—Winter rye	18 "	28·3 bu.	29·2 bu.
4th year—Summerfallow	....	....	....
5th year—Wheat (winter)	31 years	26·8 bu.	26·9 bu.
6th year—Wheat (spring)	6 "	18·2 "	....
7th year—Summerfallow	....	....	....
8th year—Pea and oat hay	31 years	2·09 tons	2·13 tons
9th year—Wheat (spring)	6 "	16·8 bu.	....

(*) Manure—12 tons per acre.

Ten-Year Rotation "T", Alfalfa for Seed	Entire Period		Last 10-Year Period 1933–1942
	Number of Years 1912–1942	Average Yield	
1st year—Summerfallow (*)	....	....	....
2nd year—Wheat (winter)	31 years	26·8 bu.	25·1 bu.
3rd year—Oats	31 "	36·8 "	23·5 "
4th year—Summerfallow	....	....	....
5th year—Alfalfa seed	31 "	0·43 "	0·14 "
6th year—Alfalfa seed	31 "	0·36 "	0·19 "
7th year—Alfalfa seed	31 "	0·24 "	0·19 "
8th year—Summerfallow	....	....	....
9th year—Corn	27 "	3·80 tons	2·78 tons
10th year—Wheat (spring)	31 "	20·5 bu.	15·8 bu.

* Manure—12 tons per acre.

IRRIGATED ROTATION

Irrigated Ten-Year Rotation "U"	Average Yield 31 Years 1912–1942	Yield during Last 10 Years 1933–1942	
		No Fertilizer	Fertilizer (†)
1st year—Wheat	53·5 bu.	60·0 bu.	62·1 bu.
2nd year—Sugar beets (20 years)	14·79 tons	16·0 tons	18 89 tons
3rd year—Oats	96·4 bu.	105·4 bu.	108·7 bu.
4th year—Barley	61·8 bu.	70·3 bu.	70·8 bu.
5th year—Alfalfa hay	2·19 tons	2·20 tons	2·64 tons
6th year—Alfalfa hay	3·25 "	2·78 "	4·21 "
7th year—Alfalfa hay	3·40 "	2·84 "	3·83 "
8th year—Alfalfa hay	3·29 "	2·44 "	3·91 "
9th year—Alfalfa hay (*)	3·23 "	2·02 "	3·35 "
10th year—Alfalfa hay	3·39 "	2·15 "	2·67 "

* Manure—12 tons per acre in autumn.
† Fertilized—100 lb. per acre triple superphosphate on 2nd, 5th, and 8th crops in the rotation, commencing in 1933.

Continuous wheat at Lethbridge has averaged 12·3 bushels per acre over a period of 31 years while during the last ten years the yield has been 10·0 bushels per acre. This method of cropping has not proved satisfactory as the yields have been substantially lower than in either the two-year and three-year rotations where summerfallow has been included. Wild oats, strange to say, have been controlled in this continuous wheat by the practice of deferred seeding in the spring although prior to the adoption of this method this weed had become so prevalent that in some years the crop had to be cut for hay. However, if perennial weeds should happen to gain access to this area, it would be impossible to control them without the use of a summerfallow.

Both the two-year rotation "B" and the three-year rotation "C" have given excellent results. Actually the yields of wheat on summerfallow have been somewhat higher in the two-year rotation but it is not known for certain whether this is due to the rotation itself or to the location of the land on which this rotation is conducted. The two-year rotation is located immediately adjoining a highway while the three-year rotation is next to the two-year rotation. In dry years the two-year rotation has proved more satisfactory than the three-year rotation as the latter has experienced some failures of the second crop after summerfallow.

Unlike in the black soil area, as at Lacombe, the results with mixed-farming rotations on dry land at Lethbridge have not been satisfactory. Weeds may be controlled in grain rotations at Lethbridge quite as effectively as in mixed-farming rotations. Yields from biennial or perennial hay crops are very small and in the first year after seeding usually contain a large proportion of weeds. Much larger yields, possibly ranging from two to three times as much, may be obtained from pea and oat hay or probably from oat sheaves alone. Corn yields have been too low to make this crop profitable for silage production, considering its high cost of production. Wheat yields after corn, moreover, are reduced substantially as may be seen in rotation "T". Alfalfa for seed was a failure, the average yield ranging from only about one-quarter to less than one-half bushel per acre.

Winter wheat ranged in yield, over a period of 31 years, from 26·8 bushels per acre in rotation "T" to 29·5 bushels in rotation "M". It is difficult to compare the yields of winter wheat with spring wheat on adjoining land but it would seem that the winter wheat has given a slightly larger yield. Winter rye has given a somewhat larger yield per acre than spring wheat but as its average price per bushel is less, the crop is not so valuable.

The use of farm manure and legume hay crops on dry land have not yet given any significant increase in yield as compared with yields in grain rotations without these practices. Wheat yields on summerfallow have been exceptionally good at this Station in the grain rotations without any indication to date of any tendency to decline.

Irrigated Rotation Experiments

On the irrigated land in rotation "U", at Lethbridge, the largest yields of crops have been obtained of any yields in any of the rotation experiments conducted by the Dominion Experimental Farms throughout Canada. These crops, however, are grown under irrigation.

The sequence of crops in the irrigated rotation "U" has been changed somewhat since it was commenced. At first potatoes were grown instead of sugar beets for the first 11 years during which period the yield averaged 499·1 bushels per acre. These intertilled crops at first followed immediately after alfalfa but the strong roots of this crop volunteered the next year in the intertilled crop and were difficult to kill, requiring considerable labour to hoe and cultivate. Accordingly wheat was inserted between the alfalfa and the intertilled crop with considerable improvement insofar as this difficulty was concerned. Another trouble has been to get a satisfactory new seeding of alfalfa when seeding down with a nurse crop of barley yielding about 70 bushels per acre. In an effort to overcome this, seeding has been made after the barley crop has been harvested but it is now proposed to change the crop sequence and seed down with wheat, growing the barley in the first year of the rotation. Notwithstanding these difficulties, marvellous crop yields have been secured and with the use of an extremely small application of manure.

However, after this rotation had been in progress for about 12 years, producing each year exceptionally heavy yields per acre, the alfalfa crop started to decline in yield and to become infested with dandelions. The soil had become too deficient in phosphorus for the requirements of the alfalfa crop, although for the grain crops in the rotation there had been no sign of any decrease in yield. Accordingly, three applications of 100 pounds each per acre of triple superphosphate have been made during the course of the ten years of the rotation. The result has been an immediate and substantial increase in the yield of alfalfa and a fair increase in the yield of sugar beets. Wheat, oats and barley, however, have not shown any increase from the application of the fertilizer.

On irrigated land at Lethbridge, Alta., in rotation "U" which has been in progress for 31 years, the average yields for the last 10 years from 1933-1942 have been as follows: wheat 62·1 bu. per acre, sugar beets 18·89 tons, oats 108·7 bu. and barley 70·8 bu. while alfalfa has averaged 3·45 tons per acre.

These results have shown that the six years of alfalfa in this rotation have adequately maintained, and in fact have even increased the supply of nitrogen in the soil, as will be seen by referring to the special chapter on "The Effect of Cultivation and Cropping on the Nitrogen Content of Prairie Soils", but the exceptionally large yields of crops have reduced the supply of phosphorus to such an extent it is no longer sufficient to support large yields of alfalfa. While good crop rotations can supply ample organic matter and nitrogen for excellent yields, they cannot add minerals to the soil. If these become deficient they must be added as commercial fertilizers.

There seem to be some indications that the amount of phosphorus now being applied in the three applications of 100 pounds each per acre of triple superphosphate fertilizer is not sufficient. With such heavy yields per acre, much more phosphorus is removed by the crops than is applied in the commercial fertilizer and unless a substantially larger application of farm manure is returned to the land, or a larger application made of commercial fertilizer, yields of alfalfa may not be maintained. Possibly applications of fertilizer every other year might be necessary for alfalfa.

The amount of farm manure applied to the soil has been comparatively small, only 12 tons per acre once during each cycle of the ten years of this rotation. Considering the exceptionally large yields which have been secured, much heavier rates of application could be employed if the hay, coarse grains, straw and sugar beet tops were fed to livestock and the manure returned to the land. Accordingly an increase in the rate of applying manure has recently been made and it will be interesting to learn if even larger yields may be obtained in future years.

Other irrigated rotations have been conducted at Lethbridge designed particularly to obtain additional information in regard to the production of sugar beets. For the production of satisfactory yields of this crop the application of manure or commercial fertilizers has been found to be essential.

On irrigated land at Lethbridge, Alta., in rotation "U" which has been in progress for 31 years, the average yields for the last 10 years from 1933-1942 have been as follows: Wheat 62·1 bu. per acre, sugar beets 18·89 tons, oats 108·7 bu. and barley 70·8 bu. while alfalfa has averaged 3·45 tons per acre.

Alfalfa should remain in an irrigated rotation for a minimum of four years. It requires about two years to develop and produce its maximum yield per acre. If a shorter rotation is desired, sweet clover may be substituted for alfalfa. The growing of two intertilled crops in succession provides an excellent opportunity to eradicate weeds and is more effective for this purpose than where hoed crops are divided by grain crops.

Crop Rotation Experiments in England and the United States

Rothamsted, England

The oldest experimental work with crop rotations in the world is located on the Rothamsted Experiment Station at Harpenden, England. On this Station field experiments with wheat and turnips were commenced in 1843, and rotation experiments in 1848. While this Experimental Station is located in a region where the average annual precipitation is 28·6 inches, as compared with approximately 15 to 20 inches on the Prairie Provinces, it is obvious that such long-time records are of inestimable value in studying the influence of rotations on soil productivity.

The following table gives the average yields of wheat at Rothamsted for 22 years, every fourth year from 1855 to 1939, where wheat was grown continuously, where it was alternated with summerfallow and when it was grown in a four-year rotation of turnips, barley, summerfallow and wheat. The object of taking yields every fourth year is to have a comparison during the same years among all three treatments, the wheat in the four-year rotation being grown only every fourth year. During this long period of 85 years no manure or commercial fertilizers of any kind have been applied.

TABLE 13.—COMPARISON OF WHEAT GROWN CONTINUOUSLY AND IN ROTATION, ROTHAMSTED, ENGLAND

Cropping System	Wheat per Acre (bu.)
Wheat continuously	10·7
Wheat after fallow, 2-year rotation—summerfallow, wheat	14·5
Wheat after fallow, 4-year rotation—summerfallow, wheat, turnips, and barley	22·7

Wheat grown continuously has given an average yield of 10·7 bushels per acre. When grown after summerfallow in the two-year and four-year rotations, the yields have been substantially larger at 14·5 and 22·7 bushels per acre, respectively. However, in the case of the two-year rotation as compared with wheat continuously a considerably smaller total production of wheat was obtained per acre as the crop was grown only every other year. It should be mentioned, however, that in recent years it has become impossible to grow wheat continuously at Rothamsted on account of weeds, making it necessary to include a summerfallow every five years, but the yield now assumed for the continuous wheat is at least two years after the summerfallow. While the yield of wheat per acre after summerfallow in the four-year rotation was double that where it was grown continuously, nevertheless the turnip crop in this rotation was practically a failure, as turnips require manurial treatment and no manure was applied in these rotations. As the barley crop has a more shallow root system than wheat, the fertility of the soil may have been more effectively utilized than where wheat alone was grown.

The wheat crop in the Rothamsted experiments was better able to withstand soil deterioration than swedes, barley, clover or beans. This is shown by the results from two, four-year rotations consisting of swedes, barley, clover or beans, and wheat, which have been in progress since 1852. These rotations are identical, except one receives manure while the other is left unmanured. Taking the yields of each crop during the fifteenth and sixteenth cycles of the rotations in the manured rotation as 100, the comparative yields of the unmanured crops have been as follows: Swedes, 4·7 per cent, barley 49·7 per cent, beans or clover 24·9, and wheat 68·6 per cent. The swedes were a failure without manure, even though grown in a rotation. Wheat, on the other hand, has given the largest yield of any of the crops when grown without manure as compared with manure. However, the wheat yield on the unmanured rotation has declined from 81·8 per cent of the manured yield in the 2nd to 5th cycles of the rotation to 68·6 per cent in the 15th and 16th cycles of the rotation.

TABLE 14.—EFFECT OF CLOVER AS COMPARED WITH SUMMERFALLOW, ROTHAMSTED, ENGLAND

Treatment	Effect of Summerfallow		Effect of Clover	
	Summer-fallow	Wheat after summerfallow grain and straw (pounds) per ac.	Clover (cwt.) per ac.	Wheat after clover grain and straw (pounds) per ac.
Unmanured	....	4028	14·0	3696
Mineral fertilizer	....	5147	47·0	6053
Complete fertilizer	....	5493	50·1	6093

The value of legumes was determined at Rothamsted in a comparison of two four-year rotations, in which, in one rotation, summerfallow was used, while in the other clover or beans was grown. These rotations were, respectively, summerfallow, wheat, swedes and barley, as compared to clover or beans, wheat, swedes and barley. The following table gives the average yields during a period in which seven clover crops have been grown.

On the unmanured land, the yield of clover has been very small with the result that the following wheat crop has been less than where wheat followed a summerfallow. Possibly the amount of nitrogen which this small crop of clover was able to fix in the soil was insufficient to compensate for the better tilth provided by the fallow. Where fertilizers were applied, however, the yield of clover was more than tripled and the yield of wheat increased substantially above that secured after fallow. Undoubtedly where fertilizer was used the clover has had a very beneficial residual effect on the wheat crop as well as producing a heavy growth of clover hay.

Urbana, Illinois

The crop rotation experiments on the Agricultural Experiment Station at Urbana, Illinois, are the oldest rotation experiments in America, having been in progress since 1876. The results are of particular interest inasmuch as the soil is naturally fertile and somewhat comparable with the soil in some parts of the Canadian Prairie. The precipitation, however, is very much more favourable, averaging approximately 35 inches annually, which is about twice that received in most parts of the Canadian Prairie. The evaporation in Illinois is much greater, on the other hand, and the ground is not frozen for as many months of the year.

TABLE 15.—COMPARISON OF DIFFERENT CROP ROTATIONS AT URBANA, ILLINOIS

AVERAGE YIELDS PER ACRE FOR A PERIOD OF 55 YEARS FROM 1888 TO 1942

Cropping System	Corn (bu.)	Oats (bu.)	Red Clover (tons)
Continuous corn	29·2	....	....
Corn, oats	36·2	36·9	....
Corn, oats, clover	48·0	49·6	1·44

Three systems of cropping have been compared at Illinois: continuous corn; corn and oats grown alternately in a two-year rotation; and corn, oats and red clover grown in a three-year rotation. Since 1904, manure, lime and phosphorus have been applied on one part of the land, leaving the remainder as a check

TABLE 16.—EFFECT OF MANURE, LIME AND PHOSPHATE IN CROP ROTATIONS AT URBANA, ILLINOIS

AVERAGE YIELDS PER ACRE FOR A PERIOD OF 12 YEARS FROM 1931 TO 1942

Cropping System	Corn (bu.)		Oats (bu.)		Clover (tons)	
	Check	Manure lime and phosphate	Check	Manure lime and phosphate	Check	Manure lime and phosphate
Continuous corn	26·0	50·3	....	....	....	....
Corn, oats	33·5	61·8	36·4	61·3	....	....
Corn, oats, clover	43·2	63·6	59·1	77·4	1·26	2·55

without any treatment. Table 15 gives the average yields of crops without treatment for a period of 55 years, from 1888 to 1942, under the different cropping systems, while Table 16 gives average yields for the 12-year period from 1931 to 1942, both on the untreated check and where manure, lime and phosphate have been applied.

The results from the rotation experiments in Illinois have shown that the three-year rotation including clover has given much better yields than the two-year rotation, which in turn gave larger yields of corn than where this crop was grown continuously. The yield of the unmanured continuous corn decreased rapidly during the first few years of cropping, after which the decrease was very much retarded. With the two-year rotation of corn and oats, the decreases have been slower and smaller in amount, while, with the three-year rotation of corn, oats and clover the decreases have been still less. It seems from these experiments that good crop rotations, while not preventing absolutely any decrease in crop yields, render the decreases very small and postpone for many years the time of serious soil impoverishment. Continuous cropping to corn and the two-year rotation of corn and oats without treatment have completely failed to produce satisfactory yields.

Where manure, lime and phosphorus have been applied the yields have been considerably increased in all the cropping systems over those secured on the untreated checks. The increases from this treatment are somewhat less in the three-year rotation but this is due no doubt to the fairly large yields in this rotation on the untreated land. The application of manure, lime and phosphate in the three-year rotation has enabled the production during the last twelve-year period of very heavy yields of 63·6 bushels per acre of corn, 77·4 bushels of oats, and 2·55 tons of clover hay. Under Illinois conditions this method of cropping has not only maintained but may even have increased crop yields.

Huntley, Montana

Under irrigation conditions at Huntley, Montana, the effect of crop rotations has been shown in a very striking manner. Experiments have been conducted for many years with a large number of cropping systems. The following table gives the average yields from a few treatments with oats, potatoes, sugar beets and corn for a period of nine years, from 1927 to 1935, in experinments which were commenced in 1912.

TABLE 17.—EFFECT ON YIELD OF CROP ROTATION UNDER IRRIGATION AT HUNTLEY, MONTANA

Method of Cropping	Oats bu. per acre	Potatoes bu. per acre	Sugar beets tons per acre	Corn bu. per acre
Grown continuously	31·4	92·4	7·9	17·5
Grown continuously—manured	56·2	221·3	11·0	50·1
Alternating with wheat	44·5	....	....	....
Alternating with oats	....	117·7	4·7	33·0
Alternating with oats—manured	....	273·2	16·6	....
Following alfalfa	99·9	282·2	5·0	59·0
Following alfalfa—manured	....	....	17·3*	....

* Following oats but alfalfa in the rotation.

Under irrigation, the effect of crop rotations which include alfalfa is much more outstanding than under dry land conditions. The yields of oats, potatoes and corn are over three times as large after alfalfa as in continuous cropping. Alternating these crops with another cereal crop, such as wheat or oats, has only a very small beneficial effect. Applying farm manure is very helpful, particularly with potatoes grown continuously. Corn is greatly helped by manure or by simply growing the corn after alfalfa. Even growing corn after oats gives almost double the yield as compared with growing it continuously.

Sugar beets differ very much from potatoes, oats and corn, in that there is very little if any beneficial effect following alfalfa. Apparently, additional fertility in the form of farm manure, or as commercial fertilizers, is indispensable for a heavy crop of sugar beets.

When alfalfa itself is grown for several years in succession the yield the first year is very much less than in the second or subsequent years. Apparently, two years are required to obtain sufficient root development to support a maximum yield. Farm manure had only a small effect on the yield. While these experiments at Huntley, Montana, did not appear to show a deficiency of phosphorus for satisfactory alfalfa production over a period of years, at Lethbridge, Alberta, the addition of phosphate fertilizer was indispensible. At Lethbridge, alfalfa showed a much greater need for phosphorus than was required by other crops except sugar beets.

Crop Rotations and Weed Control

Weeds, like economic crops, thrive best under certain soil and climatic conditions. Owing to the widely varying conditions throughout the Prairie Provinces, some areas are infested with certain weeds, while other areas have different weeds. Thus, on the heavier soils of the eastern part of the prairie, where there is more precipitation, perennial sow thistles thrive, while, in the drier regions of the southwest, tumbling mustard and Russian thistles are prevalent. Sow thistles will not grow to any appreciable extent in a dry soil, or Russian thistles in a moist soil. Between these two extremes there is a wide variety of soil and climatic conditions in which numerous weeds flourish. In addition to the weeds previously mentioned, the following are perhaps among the most common and destructive: wild oats, couch grass, sweet grass, stinkweed, mustards, Canada thistle, lamb's quarters, and wild buckwheat. In addition, there are a few extremely persistent weeds which are in a class by themselves insofar as difficulty of eradication is concerned. This latter list includes leafy spurge, hoary cress, field bindweed, poverty weed and Russian knapweed.

In considering the most effective and economical methods of controlling weeds, it is necessary first to consider the characteristics of the weed itself, and the soil and climatic conditions under which it is growing. As the Dominion Experimental Farms are located in different agricultural regions where the soil and climate are very different, the rotation experiments on these Stations have afforded an excellent opportunity of observing the effects of various systems of cropping over a long period of years on the control of weeds. The results in this regard from certain types of rotations have been very striking at some Stations, being fully if not more important than the effect of these rotations on soil productivity.

The most outstanding result has been the remarkable superiority of mixed-farming rotations over straight wheat rotations in the control of wild oats in the black soil zone area of the Prairie Provinces. Wild oats thrive in the black soil zone, but where mixed-farming rotations, including two years of hay, are practised this weed is almost completely eradicated. However, where a three-year rotation of summerfallow, wheat and wheat, or other similar rotation, is followed, it has become almost, and at some Stations quite impossible to produce satisfactory wheat crops. Some practices assist materially, such as surface tillage and deferring seeding about three weeks in the spring to enable one crop of wild oats to be grown and destroyed before seeding; but even these methods in regions where wild oats thrive best have been only partially successful. A two-year rotation of summerfallow and wheat gives better control of wild oats than a three-year rotation of summerfallow, wheat and wheat or a longer grain rotation, but it does not give complete success, especially after dry years during which time many wild oat seeds fail to germinate on the summerfallow. The use of barley, and especially an early variety of barley, is much superior to wheat in controlling wild oats. However, in any locality in the black soil zone where wild oats or other similar weeds are giving trouble, mixed-farming rotations will be found a very effective and economical method of control, and at the same time will produce larger yields of grain. On the Dominion Experimental Stations at Lacombe, Indian Head and Brandon, wild oats have given considerable trouble on the grain rotations, but have been effectively controlled on the mixed-farming rotations.

In the drier brown and dark brown soil zones, mixed-farming rotations have not given as good results as grain rotations. Hay crops have not yielded well, and grain after hay has been no better, if as good as after another grain crop. Moreover, weed growth has been just as prevalent on the mixed farming as in grain rotations. Unlike the situation in the black soil zone, therefore, mixed-farming rotations cannot be recommended for the drier brown soil zones, either from the crop yield point of view or for their effect on the control of weeds.

Strange as it might seem, wheat grown continuously on the same land for over 30 years on the Dominion Experimental Station at Lethbridge is just as clean as in the adjoining three-year rotation of summerfallow and two years of grain. However, this result may be attributed partly to good methods and partly to good luck. If certain persistent weeds had happened to gain access to this area, undoubtedly it would have been impossible to control them successfully in continuous wheat. However, the land has the usual allotment of the common weeds of this region, especially Russian thistles and formerly wild oats. The wild oats were effectively eradicated a few years ago by the practice of surface cultivation rather than ploughing, and especially by deferring seeding about three weeks in the spring so as to enable one crop of wild oats to be killed before the wheat is seeded. It is hoped to obtain better control of the Russian thistles by the use of the blade cultivator immediately after harvest, at which time this weed starts to make considerable growth. The success of these weed control methods at Lethbridge indicates the possibilities of utilizing proper tillage and cropping methods requiring very little extra labour if the proper methods can be found. Usually continuous wheat or long grain rotations produce very weedy land.

Other methods of weed control have also proved helpful under various conditions. Each weed, or type of weed, may need to be handled differently or the soil or climatic conditions may require different methods of control. It is advisable to secure as much reliable information as possible, therefore, in regard to weed control in order to reduce the cost of controlling weeds and to enable the production of the largest possible yields.

The use of commercial fertilizers with a combination fertilizer and grain drill has frequently assisted materially in the control of certain weeds. Obviously this method is effective only where the fertilizer stimulates the growth of the grain crop, and thereby assists in smothering the weeds. Sometimes a heavier rate of seeding gives better control of certain weeds. This method can be used, however, only in the more humid areas where there is sufficient soil moisture to support the heavier growth. A combination of heavier rates of seeding and the use of commercial fertilizer has given splendid results on the Dominion Experimental Station at Melfort, Saskatchewan. Over a period of six years the average yield of wheat on summerfallow has been 20·5 bushels per acre from a rate of seeding of 1 bushel per acre and 23·3 bushels from 2½ bushels. However, when 40 pounds of ammonium phosphate per acre were applied, the yields were increased to 26·5 bushels and 32·5 bushels per acre, respectively. It is clear that the combination of heavier rates of seeding and the use of commercial fertilizers has proved very successful in increasing the yields at this Station. It has helped also to control mustard, stinkweed, and wild oats much more effectively.

Some crops give better control of weeds than other crops. Barley is better than wheat or oats. Barley tends to smother weeds and its earlier maturity enables it to be cut before some weeds have ripened their seeds. Early varieties of barley, therefore, are particularly helpful in this respect. Oats cut early for green feed have a similar effect. Intertilled crops afford an opportunity to cultivate the land and perhaps to hoe some patches of weeds, but the opportunity is not always taken and sometimes if neglected, these crops are more weedy than grain crops. Nevertheless, intertilled crops, if well handled, are much more effective in controlling weeds than are grain crops.

Tillage methods should be designed for the best possible weed control. Usually surface cultivation is better than ploughing which buries the seed too deeply to permit germination. Summerfallows should be worked intelligently, but not so intensively as to create conditions conducive to soil drifting. Sometimes mustard and stinkweed can be reduced in a grain crop by the use of a drag harrow or light mulcher when the weeds have just started to emerge above the ground. Rod weeders have been used about four days after seeding in an attempt to destroy young weed seedlings before the grain appears. The success of these methods depends primarily on the timeliness of the operations and on the amount of moisture in the soil. In some years they are very successful, while in others they may give very poor results. If the soil is wet, they should not be attempted.

The use of chemical sprays and dusts is applicable, as yet, only to small areas. The expense of these treatments, the difficulty of obtaining a sufficient supply of water conveniently available, and the effect of unfavourable weather conditions limits their use. Clean seed should always be used. Sometimes new weeds are introduced on a farm through the purchase of new seed containing only a few seeds of some new weed. Farm manure should be rotted before it is applied if there is danger of spreading weeds. The burning of stubble should be avoided, not only as being a poor practice in itself in its destruction of organic matter, but on account of the danger of exposing the land to soil drifting and the spreading of weed seeds. The seeds of some weeds live many years in the ground so that every effort should be made to avoid polluting the soil.

With regard to the extremely persistent weeds such as leafy spurge, hoary cress, field bindweed, poverty weed and Russian knapweed their presence should be regarded as a serious calamity and every effort made to eradicate them completely before they can spread. It is possible that, if left without any special treatment, some of these weeds may so reduce the yields of crops as to render the land of no economic value whatever. Practically all of these weeds require about three consecutive years of very well worked summerfallow to completely eradicate them. The use of chemical sprays is very effective and will probably eradicate the weeds in two years, but this treatment is expensive except when applied on small areas. With some of these weeds the practice of a two-year rotation of well-worked summerfallow and wheat, while not eradicating the weed, may enable satisfactory wheat crops to be grown. Unfortunately, however, this practice may allow the gradual spread of the weed. A cropping plan of two consecutive years of summerfallow and then wheat followed by a two-year rotation of summerfallow and wheat supplemented by the judicious use of chemical sprays and hoeing on persistent patches should ultimately destroy these weeds completely. Nothing short of complete destruction of these weeds should satisfy anyone. If they get beyond control they may constitute a serious menace not only to other fields on the farm but to other farms in the district.

Commercial Fertilizers

Experiments with commercial fertilizers have been conducted for many years on the Dominion Experimental Farms in the Prairie Provinces. In the early years of this work the fertilizers were applied broadcast, a method which failed to give any appreciable increase in yield. By the use of the combination grain and fertilizer drill, however, in which the fertilizer was placed beside the seed in the drill row, much better results have been obtained. The following table shows the average yields of wheat on summerfallow from certain experiments in which ammonium phosphate, 11-48-0, has been used, as compared with the yield on untreated checks.

TABLE 18.—EFFECT OF FERTILIZER ON THE YIELD OF WHEAT ON SUMMERFALLOW

Station	Pounds of ammonium phosphate per acre	Number of years record	Ave. yield per acre with fertilizer bu.	Ave. yield per acre without fertilizer bu.	Increased yield per acre bu.
Morden, Man.	40	10	32·6	30·2	2·4
Brandon, "	50	9	22·9	20·7	2·2
Indian Head, Sask.	50	8	27·2	22·6	4·6
Regina, "	35	11	24·0	19·3	4·7
Melfort, "	42	5	27·5	21·4	6·1
Scott, "	35	14	17·3	13·2	4·1
Swift Current, "	25	6	17·8	17·4	0·4
Lethbridge, Alta.	30	12	21·9	22·2	−0·3
Lacombe, "	50	9	27·0	18·8	8·2
Beaverlodge, "	35	7	26·5	23·5	3·0

The value of commercial fertilizer, as reported in the above experiments, has ranged from nothing at all in the drier regions, as at Lethbridge and Swift Current, up to 6·1 bushels of wheat increase per acre at Melfort and 8·2 bushels at Lacombe. It is obvious that under dry conditions commercial fertilizers fail to increase the yield. Frequently, the fertilized wheat looks better early in the spring, but when the crop is harvested there may be too much growth to enable the grain to fill properly. In some years, when the precipitation is above average, an improvement in the yield may be obtained, but over a period of years no benefit has been secured.

Results from the use of commercial fertilizers have varied considerably at several Experimental Stations, depending upon the type of the soil and the condition of the particular field on which the fertilizer has been applied. At some Stations, the response to fertilizers varies depending upon whether the land has been cropped to grain for many years or is infested with weeds. An outstanding instance of the effect of these conditions is to be found at Lacombe, Alberta, where the average increase in the yield of wheat on summerfallow, over a period of nine years, as reported in the above table, has been 8·2 bushels per acre. This experiment is located on a three-year rotation of summerfallow, wheat, and wheat, rotation "C", which has been cropped in this manner for 30 years and is now infested with wild oats. The effect of the fertilizer has been remarkable under these conditions not only on the wheat crop grown on summerfallow but also on the second crop wheat, where the residual influence of the fertilizer has given an increase of 3·2 bushels per acre. This makes a total increase, therefore, of 11·4 bushels of wheat from 50 pounds of ammonium phosphate. However, in another area at the Lacombe Station where the soil is more fertile and has not been cropped to grain for so many years, there has been no significant increase from fertilizers. It is clear from these experiments, therefore, that, even in regions where fertilizers do give profitable returns, care should be taken to try the fertilizer first on the less fertile soil. Nevertheless, on another field of very

At Scott, Saskatchewan, an application of ammonium phosphate to wheat on summerfallow has given an average increase, over a period of thirteen years, of 4·4 bushels per acre. Very effective control of lambs quarters and wild buckwheat has been obtained where the fertilizer was applied.

At Lacombe, Alberta, an application of ammonium phosphate to wheat on summerfallow has given an average increase, over a period of nine years, of 8·2 bushels per acre. In addition the residual effect on the second crop of wheat amounted to an increase of 3·2 bushels per acre.

productive land at Lacombe, in the seven-year, mixed-farming rotation "O", ammonium phosphate applied to wheat after summerfallow has given an average increase over a period of two years of 13·4 bushels per acre. Strange as it might seem, during these two years the effect of fertilizer has been greater on this rotation than on the less productive land of the adjoining rotation "C", where, during this same period, an average increase of 8·8 bushels has been obtained. The period of years is too short, however, to draw definite conclusions.

At most stations where fertilizers give an increase in yield when applied to grain on summerfallow there is no residual influence on the second crop. If the fertilizer is applied direct to the second crop, there is much less response than if it is applied to the crop on summerfallow. While the rates of application mentioned in the foregoing table are higher than those used by many farmers, they are given in order to show the response which may be expected from reasonably heavy applications. Frequently, more economical results may be obtained from lighter applications, especially in the somewhat drier areas, and experiments should be conducted over a period of years on every farm where fertilizers are used in order to learn the most profitable rate of application.

Some differences in the response to fertilizer by different varieties of wheat have been observed on the Dominion Experimental Station at Scott, Saskatchewan. The Thatcher variety has given the largest increase among the varieties compared, with Marquis next, and early varieties showing the least response. Phosphate fertilizer has hastened the maturity of wheat about five days, as compared with wheat grown on unfertilized land. No significant increases from fertilizer have been obtained on hay crops on dry land.

On irrigated land, commercial fertilizers have given a considerable increase in yield, especially on alfalfa and sugar beets, as will be observed by referring to Table 12, giving the average yields on the irrigated rotation "U" at Lethbridge, Alberta. It will be seen from the records of that rotation that three applications of 100 pounds each of triple superphosphate in the ten-year rotation have given a total increase of 6·1 tons of alfalfa hay and 2·9 tons of sugar beets, with relatively small increases in yields of grain. While the above rates of applying the triple superphosphate have given very good results, there are indications that heavier rates would be even more satisfactory. Evidentally the effect of the alfalfa and sugar beets in the rotation, along with a very small application of farm manure, has enabled the grain crops to produce satisfactory yields without the use of commercial fertilizers.

Sugar beets seem to require the addition of commercial fertilizer or farm manure much more than any of the other farm crops grown in these experiments. Without manure or fertilizer it is impossible to produce satisfactory yields. As an average of eight years results at Lethbridge, in a four-year rotation of wheat, sweet clover, and two years of sugar beets, the yield of the first year sugar beets yielded only 8·03 tons per acre, without manure or fertilizer, and with the yields steadily declining. Where 200 pounds per acre of triple superphosphate was used the yield was raised to 16·98 tons per acre, while with 30 tons of manure per acre it was 21·27 tons. Adding the triple superphosphate to the manure did not increase the yield in the first year sugar beet crop, but did so in the second crop of beets. Ploughing under the sweet clover as green manure did not have very much effect in increasing the yield.

In the grey wooded soil zone the effect of commercial fertilizer, especially sulphur, has been outstanding, particularly when legumes were included in the crop rotation. The results of experiments conducted on these soils are reported in this bulletin in a special chapter on these soils.

Farm Manure

One of the outstanding differences between the agriculture of humid and semi-arid regions is the much smaller response obtained in the drier regions from the use of farm manure. Experiments have been conducted on the Dominion Experimental Farms in order to determine what increases in yield may be obtained from the use of farm manure. Table 19 gives the yields of various crops to which manure has been applied as compared with untreated checks. At some Stations the residual effect of the manure on other crops in the rotation, in addition to the crop to which the manure is applied, is also shown.

TABLE 19.—EFFECT OF FARM MANURE ON THE YIELDS OF CROPS

Station	Crop	Tons of manure per acre	Number of years records	Average yield per acre with manure	Average yield per acre without manure	Increased yield per acre
Morden, Man.	Corn	12	8 yrs.	7·95 T.	7·34 T.	0·61 T.
Brandon, Man.	Wheat	12	17 "	30·6 bu.	27·4 bu.	3·2 bu.
	Wheat		17 "	17·0 "	16·7 "	0·3 "
	Oats		17 "	36·6 "	33·3 "	3·3 "
Indian Head, Sask.	Wheat	8	18 "	28·5 "	25·9 "	2·6 "
	Wheat	8	18 "	16·1 "	15·1 "	1·0 "
	Corn	8	18 "	7·6 T.	7·2 T.	0·4 T.
	Wheat		17 "	23·3 bu.	23·1 bu.	0·2 bu.
	Oats		17 "	38·1 "	38·5 "	−0·4 "
Melfort, Sask.	Wheat	9	3 "	31·1 "	27·6 "	3·5 "
	Wheat		3 "	20·7 "	20·5 "	0·5 "
Scott, Sask.	Wheat	12	11 "	17·2 "	14·4 "	2·8 "
	Wheat		9 "	9·2 "	9·5 "	−0·3 "
Swift Current, Sask.	Wheat	10	4 "	11·6 "	12·6 "	−1·0 "
Lethbridge, Alta.	Wheat	12	10 "	18·7 "	18·2 "	0·5 "
	Wheat		10 "	12·4 "	12·0 "	0·4 "
Lacombe, Alta.	Wheat	10	13 "	46·5 "	41·3 "	5·2 "
	Wheat		13 "	32·5 "	27·3 "	5·2 "
Beaverlodge, Alta.	Wheat		7 "	29·3 "	23·5 "	5·8 "
	Wheat		7 "	20·4 "	18·0 "	2·4 "

It may be surprising to observe the very small increases in yields which have been obtained from the use of farm manure. Usually smaller increases have been obtained from manure than from fertilizers and there is much more labour involved in applying the manure. At Beaverlodge, however, manure has given substantially better results than fertilizers. The response to manure has usually been greater in the more moist areas, while in the drier regions no increase whatever has been obtained. This result is similar to that obtained with commercial fertilizer. Corn has shown very little response to applications of manure.

The effect of manure on any farm may vary from field to field, depending upon the soil type, topography and previous treatment of the land. The best results will be obtained where the manure is applied to the less fertile soil and to areas susceptible to drifting. Potatoes and root crops have greater need for manure than grain, hay, or corn crops.

The residual, cumulative effect of farm manure may improve the productivity of the soil in some regions over a long period of years. When experiments are commenced with farm manure the land may be fairly productive and several years of cropping may elapse before the productivity becomes impaired. For this reason the results from the above experiments may become more favourable to the use of farm manure in future years. This would seem to apply more particularly to the Black and Grey Soil regions, and least to the Brown Soils in the drier regions. Where soils are deficient in some element, such as phosphorus, or sulphur, commercial fertilizers should be applied along with manure to supply this deficient element.

Green Manure

The practice of ploughing under a growing crop to enrich the soil is sometimes called green manuring. The Dominion Experimental Farms have conducted a number of experiments in order to determine whether this practice has any value under conditions in the Prairie Provinces. The following table gives the average yields of wheat per acre at four Stations after various treatments.

TABLE 20.—EFFECT OF GREEN MANURE ON THE YIELD OF WHEAT (BU. PER AC.)

Treatment of fallow year	*Brandon* 15 years	*Indian Head* 9 years	*Scott* 13 years	*Lacombe* 9 years
Summerfallow	35·0	36·1	21·9	37·6
Peas, ploughed under in early fall	33·8	33·5	21·6	36·3
Peas, ploughed under in blossom	32·5	32·6	21·2	36·5
Summerfallow, 12 tons manure	36·4	40·2	26·4	40·9

These experiments show that there has been no increase in yield by ploughing under a crop of peas as green manure. Similar results were obtained when tares were used. As these treatments entail considerable expense, it is obvious that they are not economical under these conditions. Where farm manure was applied there was a small increase in yield.

Experiments have been conducted at Lethbridge, comparing the effect of ploughing under sweet clover for green manure with harvesting it as a hay crop upon the yield of wheat the following year. The average yield of wheat, over a period of 15 years, has been 16·3 bushels per acre where the sweet clover was ploughed under as green manure, 14·1 bushels where the sweet clover was cut for hay and the land ploughed, in comparison with 18·2 bushels on a standard ploughed summerfallow. In another experiment at Lethbridge it was found that, when the sweet clover was ploughed under early, better results were obtained than where the crop was allowed to make more growth. When the sweet clover was ploughed under on May 15, the average yield of wheat over a period of four years was somewhat greater than after a standard summerfallow, although the reason may have been due to earlier tillage of the land. This result would seem to indicate that perhaps this method of handling the sweet clover as green manure might give increased yields over standard summerfallow, but additional records over a longer period of years would be required to confirm these results.

At Regina sweet clover was used as a green manure crop in two different methods. In one case the sweet clover was sown with the second crop of wheat and turned under next summer in the first summerfallow tillage operation. As an average of 12 years' results, the yield of wheat the following year was 20·1 bushels per acre, as compared with 22·0 bushels after a summerfallow handled in the regular manner without any crop of green manure. In another method the sweet clover was sown during the summerfallow year, in late June or early July, and in the following spring the seeding of wheat was deferred until there was some growth of sweet clover to turn under. As an average of 12 years' results the yield of wheat has been 11·7 bushels per acre, as compared with 18·9 bushels after a standard summerfallow. Obviously both of these methods have been worse than useless at Regina. At Brandon, as an average of five years' results, wheat after sweet clover ploughed under as green manure yielded 43·4 bushels, as compared with 41·9 bushels after standard summerfallow. At Beaverlodge, Alberta, as an average of seven years' results, the yield of wheat after sweet clover ploughed under was 30·3 bushels per acre as compared with 30·1 bushels where the crop was harvested as hay and the land ploughed. At Scott, Saskatchewan, as an average of eleven years' results, sweet clover ploughed under for green manure gave an average yield of 13·4 bushels of wheat per acre, as compared with 14·4 on standard summerfallow. Where twelve tons of manure were applied the yield was 17·2 bushels, and where both manure and fertilizer were used, 19·7 bushels per acre.

The most important conclusion to be drawn from these experiments is that ploughing under a crop for green manure is not advisable in the Prairie Provinces. In most cases the yield of wheat the following year is less than is obtained after a standard summerfallow. In regions where there is sufficient moisture, it is preferable to harvest the crop for hay rather than to plough it under for green manure. The land should then be ploughed as soon as possible to promote the conservation of soil moisture as much as possible. Whether there are any special conditions in which green manure might give profitable results, it is impossible to predict, but the results of these experiments will serve to indicate the need of proceeding slowly on a small scale with this method before adopting it extensively on a large acreage.

Cropping and Fertilizer Experiments in the Grey Wooded Soil Zone

While the grey wooded soils in the Prairie Provinces are only sparsely settled at the present time, future settlement on virgin lands must largely be confined to this zone. The better types of these wooded soils are comparatively fertile, but such soils constitute only a small proportion of the total area. The poorer types are relatively low in fertility, but if this condition could be corrected there are extensive areas which could be satisfactorily farmed.

At the present time a considerable number of field experiments are being conducted by the Experimental Stations at Lacombe, Beaverlodge, Scott and Melfort on Illustration Stations in the Grey Wooded Soil Zone. Most of these experiments have been started in recent years and hence it is too early to report the results obtained from various crop rotations and fertilizer experiments. However, some experiments have been conducted on the Illustration Station at Cheddarville, Alberta, since 1931. In that year the value of sulphur as a fertilizer for clover was clearly demonstrated, 50 pounds of sulphur applied to a sweet clover hay field giving a yield of 2·5 tons of hay per acre, while the untreated area gave only 0·5 ton per acre. Later experiments showed the value of incorporating clover in a rotation for the benefit of subsequent grain crops. The yield of barley in 1941 following a clover crop averaged 24·5 bushels more than that after summerfallow.

The longest successive record of the effect of clover in a rotation and the effect of various fertilizers both on clover and on grain in the Grey Wooded Soil Zone is to be found in a publication "Wooded Soils and Their Management", by F. A. Wyatt, J. D. Newton and V. Ignatieff, University of Alberta, Bulletin No. 21, Third Edition, 1941. This publication reports results of cropping and fertilizer experiments conducted by the University of Alberta on a typical grey wooded soil at Breton, Alberta. These experiments have been conducted without interruption since 1931.

Two principal cropping systems have been followed at Breton. One rotation consists of wheat, oats, barley seeded down to clovers, and hay consisting of a mixture of sweet and Altaswede clovers. For the first eight years the clover occupied the land for only one year, but after the first two rotation cycles the land was left in clover hay for two years. The other cropping system consists of land on which wheat is the only crop grown, the land being summerfallowed occasionally in order to control weeds. Various fertilizers were applied to every crop in both systems every year.

The only crop in these experiments where the comparative value of clover in the rotation can be studied is wheat. In the grain system the average yield of wheat on the unfertilized plots over a period of ten years, has been 12·3 bushels per acre, while after clover it has been 14·7 bushels. On the fertilized plots the effect of clover on the subsequent wheat crop was much more marked, the increases from the five best fertilizer treatments ranging from 10·8 to 20·1 bushels of wheat per acre after clover, as compared with increases of only 3·1 to 5·2 bushels per acre on the continuous wheat. It will be seen from these data that the same fertilizers gave increases for the wheat crop from three to five times as great when they were applied to wheat following clovers as when they were applied to wheat grown continuously.

The yield of oats following wheat after clover on the same five fertilizer treatments ranged from 51·0 to 62·1 bushels per acre, as compared with the check, unfertilized plots, averaging 33·2 bushels per acre. Barley, third crop after clovers, for these fertilizer treatments yielded 21·2 to 24·7 bushels per acre, with the check plots averaging 14·2 bushels per acre. Thus it is evident that the effect of the fertilizers became less marked the farther the grain crop was removed from the clover.

Rather spectacular increases were obtained during the ten-year period, from 1931 to 1940, from the use of fertilizers on the sweet and Altaswede clover mixture used in the rotation. The average yield from the check plots was only 1,157 pounds per acre of cured hay, while the highest yielding fertilized plot averaged over two and a half tons per acre. This shows that, by the proper use of fertilizers on the Breton field, clover yields have been increased three to five times above those obtained on the unfertilized plots. The yields reported above for the clover mixture represent only one cutting per year in early July as the land was ploughed shortly after the first cutting to prepare for the succeeding wheat crop.

The results from the best fertilizers for both grain and clover at the Breton field are shown in the following table.

TABLE 21.—INCREASES IN YIELD PER ACRE OF WHEAT, OATS, BARLEY AND CLOVER FROM VARIOUS FERTILIZERS AT BRETON, ALBERTA

(TEN-YEAR PERIOD, 1931–1940)

Fertilizer Treatment	Wheat Cont. (bu.)	Mixed Farming Rotation			
		Wheat 1st crop after clover	Oats 2nd crop after clover	Barley 3rd crop after clover	Clover
Manure	3·7	10·8	17·8	7·0	1499 lbs.
Manure and phosphate	5·2	15·8	22·1	10·5	3071 lbs.
Ammonia sulphate	4·9	14·6	28·9	10·3	3565 lbs.
Ammonium phosphate 16–20	3·1	14·9	23·2	8·5	3426 lbs.
Ammonium phosphate 16–20 plus potassium sulphate	4·8	20·1	27·4	9·2	4000 lbs.

The experiments on the Breton field showed that the greatest increases in the yields of grain crops were obtained from fertilizers carrying a high content of nitrogen. This fact indicates, also, why clover has a decided beneficial effect on the yield of subsequent grain crops. Manure alone gave fair increases but for best results it apparently should be supplemented with an application of phosphatic fertilizer.

The fertilizers giving the greatest increases for the clover were ammonium phosphate (16-20) and ammonium sulphate or combinations of these with other materials such as potash and manure. These two fertilizers were likewise the most effective for the grain crops. However, while their effectiveness for grain crops appears to lie principally in their high nitrogen content, from other experiments conducted on grey wooded soils by the Alberta Department of Soils, their effectiveness for clover appears to lie in their sulphur content.

The experiments at Breton and Cheddarville point to the same conclusions regarding the best treatments for the grey wooded soils, namely the use of a rotation containing clover, the application of high nitrogen fertilizers for grain crops, and the use of fertilizers containing sulphur for leguminous crops. The two best fertilizers at the present time containing appreciable quantities of both these elements are ammonium sulphate and ammonium phosphate (16-20). Generally these fertilizers should be applied at the rate of 50 to 60 pounds per acre, although a slightly lower rate may be sufficient for clovers.

The results obtained at Breton and Cheddarville may not hold true throughout the entire grey wooded zone. However, from recent work it would appear that similar results may be obtained over wide areas, particularly in the moister parts of the zone.

The Effect of Season on Crop Yields

The season has a far greater effect on the yield of crops in most parts of the Prairie Provinces than any other factor. In all parts, even in the most favoured, the effect is very important. While the character of the season is uncontrollable, it is very desirable to study the records of the past so that they may afford a guide as to what may be expected in the future. No trustworthy predictions can be offered for any future year, but it is reasonable to assume that, if sufficiently comprehensive records are available from the past, they may be useful in estimating what may be expected in the future.

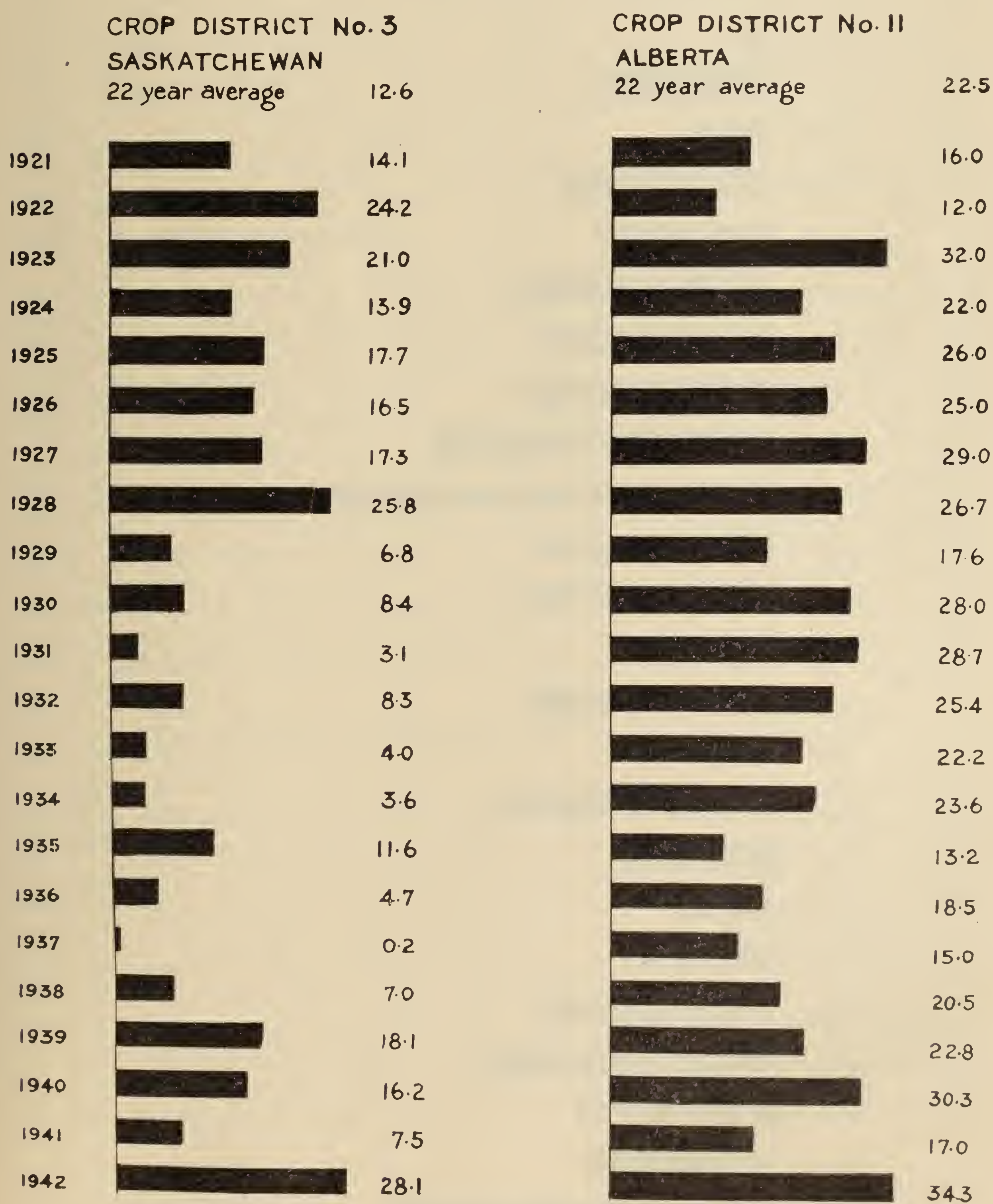
It should be remembered that adverse or favourable seasons may continue for several years in succession. Not only must one be on guard against attempting to estimate the value of a district from the success or failure of one year's crop, but even several years may be insufficient to properly judge its real productive capacity. The problem is to learn how long a period should be taken. Fortunately a study of past records in various regions provides some information on the extent and duration of cycles of good and poor years.

An outstanding instance of extreme variations in yields is to be found in the average yields of wheat in crop district No. 3, in southwestern Saskatchewan. Over a period of 22 years, from 1921 to 1942, the average yield of wheat, as may be calculated from Table 25, has been 12·6 bushels per acre. For a seven-year period, from 1922 to 1928, excellent yields were obtained averaging 19·5 bushels per acre. However, these good years were followed by ten poor years, from 1929 to 1938, during which the average yield for the crop district was only 5·8 bushels per acre, or less than one-third of the yields obtained in the preceding period. The extreme variations for individual years over the entire crop district have ranged from 25·8 bushels per acre in 1928 to 0·2 bushels in 1937. It is obvious that anyone farming in this district in the cycle of good years was in a very favourable position to make a success of his business, while those operating during the following ten years were very liable to fail. The situation was greatly aggravated by the fact that during the cycle of dry years the prices of wheat were only about one-half as much as during the good years.

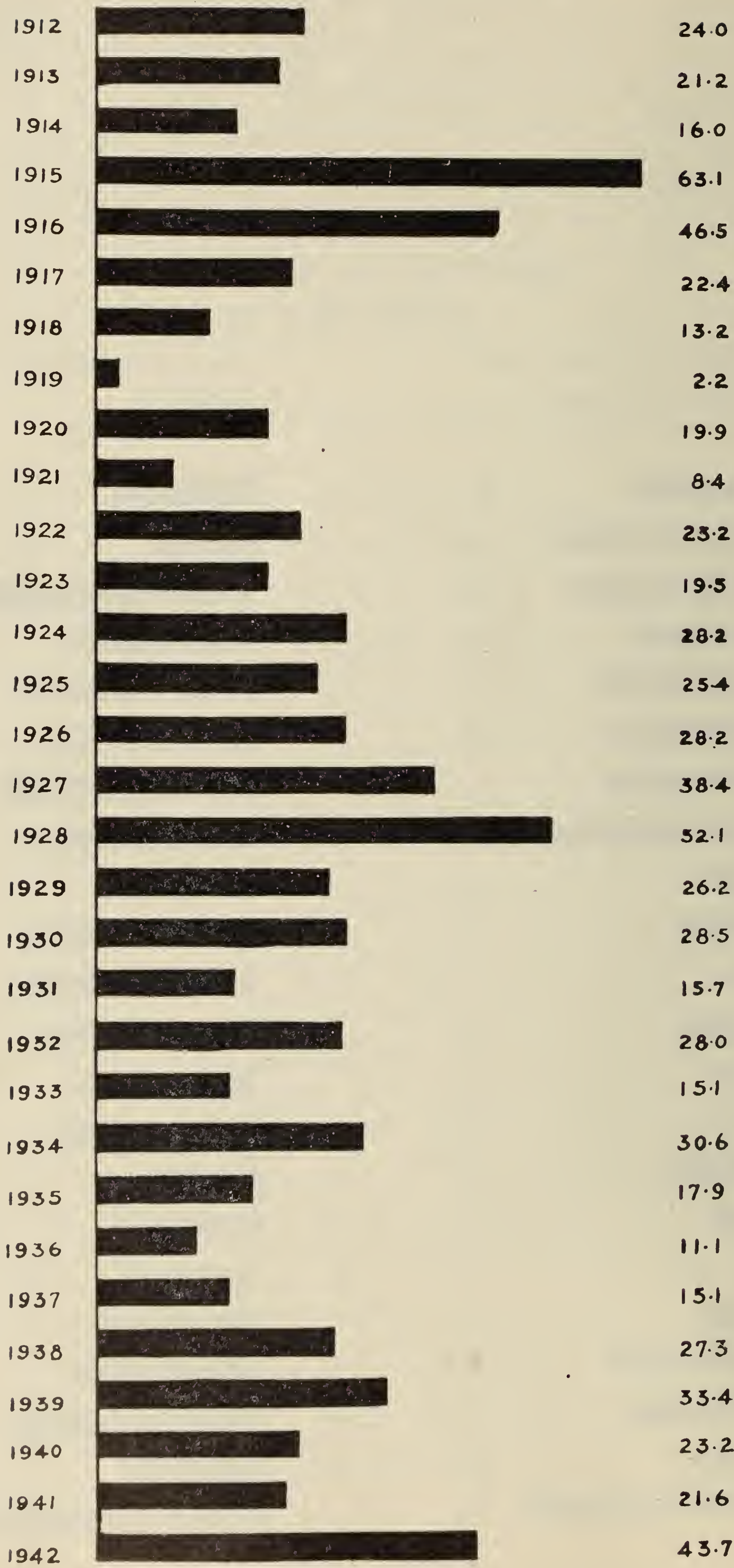
Larger yields and smaller variations in yields occur in northern crop districts. In crop district 11, around Edmonton, Alberta, the average yield of wheat over a period of 22 years, from 1921 to 1942, as shown in Table 26, has been 22·5 bushels per acre. For the seven-year period from 1922 to 1928 the average yield was only slightly higher at 24·7 bushels, while for the ten-year period from 1929 to 1938 it was only slightly lower at 21·2 bushels. In this crop district there are apparently no very long periods of particularly good or poor yields. The extreme variation in individual years has ranged, during the 22-year period, from 12·0 bushels in 1922 to 34·3 bushels in 1942. Two years seems to be about the limit of the duration of poor yields when in 1921 and 1922 average yields throughout the crop district of only 16·0 bushels and 12·0 bushels per acre, respectively, were obtained.

When yields on individual farms are studied, the variations are much greater than throughout entire crop districts. Variations in the yield of wheat sown on stubble land are much greater than those on summerfallow. Greater difficulties are experienced, however, in interpreting the effect of season on

VARIATIONS IN WHEAT YIELDS
(Bushels per acre)



YIELDS OF WHEAT ON SUMMERFALLOW
DOM. EXP. STATION, LETHBRIDGE, ALBERTA
31 Year Average—25·5 Bus. Per Acre



yields on individuals farms, owing to the variable infestation of weeds and to injury by frost, hail, or soil erosion. In spite of the best possible methods of production, wide variations in yields occur from year to year. The weather, without doubt, has the greatest effect, but good methods, except in years of extreme drought, produce much better yields. Whether good methods have more effect in a normal as compared with an exceptionally good season seems to depend upon the soil and region. Possibly the better the soil and the region, the greater will be the difference between good and poor methods of production in a favourable year.

On the Dominion Experimental Station at Lethbridge, Alberta, the average yield of wheat on summerfallow over a period of 31 years, from 1912 to 1942, on the three-year grain rotation "C", has been 25·5 bushels per acre. Individual yields have ranged from 63·1 bushels per acre in 1915 to 2·2 bushels in 1919. The best period of four consecutive years occurred from 1914 to 1917 when an average field of 42·0 bushels per acre was obtained; this high yield, however, was secured on account of exceptionally heavy crops in 1915 and 1916. From 1926 to 1929 a more uniform high average yield of 36·2 bushels per acre was secured. The poorest period of four consecutive years occurred from 1918 to 1921, with an average yield of only 10·9 bushels of wheat per acre on summerfallow.

At Lacombe, Alberta, wheat after potatoes in a six-year mixed-farming rotation, over a period of 32 years from 1911 to 1942, has averaged 34·0 bushels per acre. The largest yield was 63·9 bushels per acre in 1942, while in 1916 the crop was frozen. Large yields of oats and barley, however, were obtained in 1916. Two consecutive poor yields were experienced in 1936 and 1937 when only 11·4 bushels of wheat were obtained each year.

Occasionally in years when grain yields are poor on account of drought some other crops like hay or corn may give relatively better yields. This is an important advantage of mixed-farming rotations over grain rotations in regions where such rotations are suitable. However, adequate moisture is even more necessary for the hay crop than for grain, but in some years when the rain comes early in the season it may benefit the hay more than the grain. Corn can withstand short periods of drought better than hay or grain, but it must have a reasonable supply of moisture, together with fairly warm weather.

Wheat Yields on Illustration Stations and Substations

The Dominion Experimental Farms have supervision over a large number of Illustration Stations and Substations in various parts of Canada. Considerable experimental work is conducted on these Stations including a number of crop rotations. The Chief Supervisor of Illustration Stations has supplied information in regard to the yields on these rotations. Table 22 gives the average yields of wheat after summerfallow which have been obtained on 68 Stations in the three Prairie Provinces over the period during which the work has been in progress. Table 23 gives the yield of wheat after summerfallow as compared with the yield after stubble on a number of these Stations.

This information is useful in providing a reliable guide to the yields which may be expected in these districts, especially where the records cover a sufficient number of years.

TABLE 22.—YIELDS OF WHEAT AFTER SUMMERFALLOW

Station	Soil	Period	Number of Years	Ave. Yield per acre (bu.)
Manitoba—				
Arborg	Arborg C. L. & C. (High Lime)	1926–1942	17	24·9
Boissevain	Waskada H. L. & C. L. (Dk. Brown-Black)	1938–1942	5	23·7
Crystal City	Carroll F. S. L. & F. S. C. L. (Black)	1937–1942	6	18·5
Dugald	McTavish, C. (Black)	1925–1941	17	24·0
Gilbert Plains	Gilbert, S. L. & F. S. L. (Black & Grey Black)	1926–1942	17	23·2
Goodlands	Waskada C. L. (Dk. Brown-Black)	1936–1942	7	19·1
Gunton	Fort Garry C. (Black & Grey Black)	1924–1942	18	23·3
Hargrave	Oxbow H. L. (Black)	1940–1942	3	25·0
Katrime	Newton, F. S. C. L. (Black)	1929–1942	14	22·7
Lenswood	.... S. L. (Grey-Black)	1940–1942	3	29·9
Lyleton	Souris L. (Black)	1936–1942	7	17·2
Petersfield	Red River C. (Black)	1926–1939	12	32·2
Pipestone	Bede L. C. S. & S. L. (Dk. Brown-Black)	1927–1942	16	10·5
Plumas	Almasippi L. C. S. & S. L. (Black)	1925–1939	15	14·3
Roblin	Newdale, C. L. Wooded phase (Grey-Black)	1928–1939	12	18·5
St. Rose	.... S. L.	1926–1938	13	14·7
Swan River	.... (Grey-Black)	1930–1942	13	26·6
Silberton	Newdale C. L. (Black)	1938–1942	5	26·6
Saskatchewan—				
Alameda	Oxbow and Estevan L. (Black & Dk. Brown)	1935–1942	8	16·1
Arcola	Asquith L. L. & F. S. L. (Dk. Brown)	1938–1942	5	17·3
Aylesbury	Weyburn L. (Dk. Brown)	1938–1942	5	15·8
Birch Hills	Melfort Si. C. L. (Black)	1936–1942	7	29·0
Canuck	Haverhill & Echo C. L. (Brown)	1936–1942	7	17·6
Calder	Yorkton L. (Black)	1939–1942	4	28·2
Carmichael	Cypress C. L. (Dk. Brown)	1936–1942	7	19·2
Davidson	Elstow L. (Dk. Brown)	1938–1942	5	18·9
Fox Valley	Fox. Valley Si. C. L. & L. (Brown)	1928–1942	15	13·5
Glaslyn	Waitville L. (Grey)	1934–1942	9	15·3
Glenbush	Whitewood & Oxbow L. (Grey)	1930–1942	13	28·7
Gravelbourg	Sceptre C. (Brown)	1936–1942	7	23·9
Guernsey	Asquith L. L. & F. S. L. (Dk. Brown)	1924–1942	19	18·5
Hafford	Cudworth & Blaine Lake L. (Black)	1932–1942	11	17·5
Juniata	Asquith F. S. L. & L. L. (Dk. Brown)	1936–1942	7	16·1
Kincaid	Fox Valley Si. C. L. (Brown)	1936–1942	7	23·7
Kindersley	Sceptre H. C. (Brown)	1923–1942	22	24·1
Lens	Etomami & Tisdale C. (Grey-Black)	1923–1942	11	32·5
Limerick	Haverhill C. L. (Brown)	1936–1942	7	16·4
Loverna	Fox Valley Si. C. L. (Brown)	1927–1942	16	16·2
Meadow Lake	lacustrine Si. C. L. (Grey-Black)	1929–1942	14	33·6
Meota	Blaine Lake & Shellbrook L.L. (Black)	1919–1942	23	28·5
Paddockwood	.... L. (Grey-Black)	1932–1942	11	22·7
Parkside	Shellbrook F. S. L. (Grey-Black)	1935–1942	8	19·9
Pelly	Canora L. L. (Black)	1929–1942	14	24·8
Radville	Trossachs C. L. (Dk. Brown)	1917–1942	26	21·3
Riverhurst	Fox Valley Si. L. (Brown)	1922 1942	21	14·5
Shaunavon	Haverhill & Cypress C. L. (Brown)	1915–1942	28	18·8
Strasbourg	Weyburn L. & L. L. (Dk. Brown)	1935–1942	8	18·7
Tompkins	Fox Valley L. & Si. C. L. (Brown)	1936 1942	7	15·6
Tugaske	Weyburn L. & L. L. (Dk. Brown)	1919–1942	24	18·5
Valjean	Hatton F. S. L. (Brown)	1935–1942	8	11·5
Wawota	Ryerson & Oxbow L. (Black)	1924–1942	19	17·7
White Fox	.... V. F. S. L. (Grey Black)	1936–1942	7	31·6
Yorkton	Canora Si. C. L. (Black)	1935–1942	8	22·0
Alberta—				
Acadia Valley	lacustrine C. & C. L. (Brown)	1938–1942	5	25·3
Bindloss	eolian Si. L. (Brown)	1925–1942	18	15·4
Castor	solonetzic Si L. (Dk. Brown)	1934–1942	9	16·3
Cessford	solonetzic L. (Brown)	1927–1942	16	11·6
Chauvin	alluvial & eolian L. (Dk. Brown)	1933–1942	11	18·0
Claresholm	alluvial & lacustrine F. S. L. & S. L. (Dk. Brown)	1937–1942	6	22·0
Consort	solonetzic L. (Dk. Brown)	1932–1942	11	16·5
Craigmyle	alluvial & glacial L.L. (Dk. Brown)	1938–1942	5	24·1
Drumheller	lacustrine C. L. & C. (Dk. Brown)	1937–1942	6	22·1
Foremost	lacustrine & glacial Si. L. & C. L. (Brown)	1915–1942	28	18·4
Lomond	glacial C. L. (Brown)	1935–1942	8	15·4
Metiskow	alluvial S. & L. S. (Dk. Brown)	1938–1942	5	9·3
Nobleford	lacustrine Si. L. (Dk. Brown)	1938–1942	5	36·2
Pincher Creek	lacustrine C. & L. (Black)	1917–1942	26	23·6
Whitla	glacial L. (Brown)	1916–1942	27	14·3

In the above table it is only possible to indicate the dominate soil at each station. The soil zone in which each station lies is indicated by the name in brackets. The following abbreviations with respect to soil texture were used: S.-sand, L.S.-loamy sand, C.S.-coarse sand, L.C.S.-loamy coarse sand, S.L.-sandy loam, F.S.L.-fine sandy loam, V.F.S.L.-very fine sandy loam, L.L.-light loam, L.-loam, H.L.-heavy loam, Si.L.-silt loam. Si.C.L.-silty clay loam, C.L.-clay loam, C.-clay, H.C.-heavy clay, F.S.C.L.-fine sandy clay loam.

TABLE 23.—YIELD OF WHEAT AFTER FALLOW COMPARED WITH WHEAT AFTER STUBBLE

Station	Period	Number of Years	Average Yield per Acre	
			After Fallow	After Stubble
			bu.	bu.
Manitoba—				
Arborg	1938–1942	5	28·9	21·7
Boissevain	1938–1942	5	23·7	20·3
Crystal City	1937–1942	6	18·5	13·0
Goodlands	19 6–1942	7	19·1	14·5
Katrime	1938–1942	5	32·9	25·5
Lyleton	1936–1942	6	18·9	13·4
Lyleton	1938–1942	5	20·8	15·3
Pipestone	1938–1942	5	8·8	6·5
Saskatchewan—				
Aylesbury	1938–1942	5	15·8	13·0
Fox Valley	19 8–1942	9	13·7	8·0
Kincaid	1938–1942	5	32·8	21·3
Radville	1930–1942	13	18·0	10·4
Tugaske	1933–1942	10	16·8	12·4
White Fox	1938–1942	5	36·4	29·8
Yorkton	1936–1942	7	23·3	18·6
Alberta—				
Acadia Valley	1938–1942	5	25·3	19·1
Bindloss	1933–1942	10	12·8	8·2
Cessford	1933–1942	10	8·3	6·0
Claresholm	1938–1942	5	26·4	19·8
Craigmyle	1938–1942	5	24·1	16·8
Foremost	1933–1942	10	16·4	9·5
Lomond	1938–1942	5	19·7	8·8
Nobleford	1938–1942	5	36·2	21·4
Pincher Creek	1934–1942	9	29·7	21·6
Whitla	1933–1942	10	12·7	9·6

TABLE 24.—WHEAT YIELDS BY CROP DISTRICTS IN MANITOBA

Bushels per Acre

Year	Crop Districts														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Prov. Average
1921	5·7	9·3	11·9	16·9	16·7	9·4	10·9	10·8	12·7	15·6	12·6	11·2	20·3	11·0	11·1
1922	17·7	17·8	19·0	19·8	20·6	20·6	20·3	16·2	16·0	26·5	20·0	22·4	26·0	18·4	19·2
1923	9·8	9·6	9·6	12·9	12·8	11·7	13·5	9·5	10·3	16·7	11·9	12·4	17·9	13·6	12·3
1924	16·4	16·3	19·9	20·0	17·9	15·9	17·1	17·5	14·9	12·9	15·4	9·9	14·5	14·7	16·9
1925	18·5	18·7	18·3	17·8	18·9	13·7	17·1	19·6	15·0	18·3	12·9	14·3	20·0	14·6	17·8
1926	23·1	24·7	22·6	22·6	23·7	16·5	22·5	23·4	18·5	22·5	18·6	13·9	23·6	17·0	22·6
1927	16·7	15·6	10·7	10·8	11·0	11·0	16·5	11·1	10·8	18·5	11·5	11·4	14·0	10·6	14·0
1928	20·7	21·7	16·1	21·8	21·5	16·3	21·0	20·8	20·5	21·6	19·2	19·9	20·4	17·8	19·7
1929	13·2	12·1	14·4	16·5	15·5	14·3	14·1	12·5	12·4	15·2	14·2	14·2	20·2	13·4	13·7
1930	14·2	20·6	19·3	17·6	18·8	17·0	18·3	17·9	16·8	18·8	17·1	17·5	19·2	16·7	18·3
1931	1·7	6·5	13·6	15·7	18·3	14·9	7·5	9·9	11·5	14·6	19·2	15·9	22·0	22·2	11·1
1932	10·8	16·5	15·0	16·4	14·9	13·9	16·1	16·3	16·8	22·3	18·6	19·0	22·7	19·9	16·6
1933	3·5	11·8	13·9	14·5	14·8	14·2	12·2	13·2	14·7	18·7	19·6	15·4	24·4	22·0	12·8
1934	0·6	9·0	19·7	23·3	25·3	17·4	11·3	14·9	18·0	17·7	21·0	19·1	23·7	17·3	14·6
1935	9·2	7·8	11·0	12·1	11·2	9·6	7·1	6·0	5·8	6·5	10·5	8·6	15·0	9·4	8·7
1936	5·0	7·3	13·4	14·0	16·2	11·0	9·0	11·9	13·9	15·9	15·6	14·3	20·5	14·4	10·9
1937	12·4	16·1	21·2	22·0	23·2	18·4	11·9	15·2	18·8	11·7	15·8	19·0	14·6	14·7	16·7
1938	9·8	14·5	16·2	16·2	19·0	16·9	16·4	17·6	17·4	20·7	18·9	17·6	18·4	14·2	16·0
1939	14·6	15·3	20·4	20·4	21·5	18·3	16·4	21·7	23·3	23·4	27·6	26·0	33·5	24·2	19·7
1940	19·9	18·5	20·6	24·2	26·2	21·2	14·0	17·8	22·1	14·9	17·8	13·9	20·7	15·1	18·8
1941	17·6	20·5	20·2	21·2	22·3	20·6	20·0	19·5	22·4	21·5	19·5	19·5	19·5	18·5	20·2
1942	20·6	26·6	28·8	30·8	31·9	25·7	25·9	25·6	27·3	30·5	26·9	28·8	30·0	24·4	26·9
Ave. 22 Yrs. (1921–1942)	12·8	15·3	17·1	18·5	19·2	15·9	15·5	15·9	16·3	18·4	17·5	16·6	20·9	16·5	16·3

Wheat Yields in Provincial Crop Districts—22 years average (1921-1942)

TABLE 25.—WHEAT YIELDS BY CROP DISTRICTS IN SASKATCHEWAN

Bushels per Acre

Year	1	2	3	4	5	6	7	8	9	Prov. Average
1916	8·2	11·7	14·3	18·1	15·4	15·7	18·0	16·9	17·5	16·3
1917	14·9	13·2	12·5	12·2	19·2	14·4	13·2	17·3	13·5	14·2
1918	10·3	12·1	8·1	4·7	16·0	11·8	5·2	21·3	6·8	10·0
1919	9·9	10·6	5·8	3·5	20·3	9·4	6·8	13·0	6·0	8·5
1920	9·3	10·2	11·0	9·9	15·0	8·5	13·8	15·6	17·3	11·2
1921	9·8	11·9	14·1	8·6	16·8	14·5	13·2	22·3	20·2	13·7
1922	23·2	23·2	24·2	18·7	21·2	16·0	12·2	24·2	16·0	20·2
1923	15·1	17·5	21·0	18·0	19·4	22·6	28·0	23·7	27·1	21·3
1924	14·8	12·8	13·9	6·7	10·1	6·3	5·6	8·9	9·1	10·2
1925	17·2	19·3	17·7	9·8	19·9	17·7	21·3	25·3	20·8	18·5
1926	24·0	21·9	16·5	8·8	19·6	12·9	12·5	18·7	16·3	16·2
1927	18·0	17·8	17·3	26·9	20·5	18·9	20·5	19·8	21·1	19·5
1928	20·2	21·8	25·8	27·1	21·9	22·3	24·0	20·9	20·5	23·3
1929	16·1	7·9	6·8	13·2	14·3	10·6	12·1	19·6	13·9	10·7
1930	13·9	11·2	8·4	13·7	16·0	10·9	19·9	24·1	29·3	13·7
1931	4·8	1·8	3·1	5·7	10·6	8·4	13·0	22·0	23·4	8·9
1932	11·9	11·0	8·3	15·7	17·2	11·6	16·9	22·0	20·7	13·6
1933	8·5	12·4	4·0	4·3	23·4	5·6	4·1	16·6	14·4	8·4
1934	4·8	4·8	3·6	4·3	18·1	8·2	8·6	16·7	18·1	8·6
1935	4·3	7·4	11·6	7·1	9·7	13·8	10·6	16·3	14·3	10·8
1936	6·0	9·9	4·7	1·3	17·7	10·6	5·3	14·4	8·1	8·0
1937	3·9	1·5	·2	·1	7·5	1·2	1·4	10·2	5·5	2·6
1938	8·2	10·1	7·0	9·9	15·2	9·3	11·7	13·8	9·0	10·0
1939	8·5	11·5	18·1	17·9	23·3	20·8	20·7	29·4	21·5	19·1
1940	15·9	13·2	16·2	19·4	16·0	15·0	21·8	23·2	17·2	17·1
1941	21·1	16·8	7·5	10·0	14·9	7·4	9·5	15·8	11·5	11·1
1942	23·5	25·9	28·1	23·4	27·3	27·8	27·8	28·3	28·8	27·1
Ave. 27 Yrs. (1916–1942)	12·8	12·9	12·2	12·1	17·2	12·9	14·0	19·2	16·6	13·8
Ave. 22 Yrs. (1921–1942)	13·4	13·3	12·6	12·3	17·3	13·3	14·6	19·8	17·6	14·2

TABLE 26.—WHEAT YIELDS BY CROP DISTRICTS IN ALBERTA

BUSHELS PER ACRE

Year	Crop Districts																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Prov. Average
1921	9·0	15·0	9·0	15·0	7·0	14·0	9·5	14·0	12·0	12·0	16·0	13·0	18·0	16·0	9·5	11·0	12·0	10·3
1922	8·0	16·0	8·0	16·0	7·0	12·0	10·0	14·0	13·5	9·5	12·0	14·0	12·0	13·5	12·0	11·0	12·0	11·2
1923	18·0	25·0	18·0	30·0	28·0	35·0	28·0	32·0	28·0	25·0	32·0	25·0	26·0	30·0	31·0	26·0	28·0	28·0
1924	4·0	12·0	6·0	14·0	7·0	12·0	6·0	14·5	12·0	16·0	22·0	17·0	16·0	20·6	16·0	14·0	15·0	11·0
1925	10·0	18·0	12·0	20·0	17·0	18·0	19·0	21·0	17·0	19·0	26·0	23·0	17·0	23·0	22·0	16·0	18·0	18·0
1926	7·5	18·0	11·0	25·0	16·0	19·0	19·0	23·0	18·0	16·0	25·0	22·0	12·0	18·0	29·0	20·0	25·0	18·5
1927	30·0	28·5	31·2	30·2	27·7	26·0	25·3	25·0	20·0	26·8	29·0	22·4	25·7	27·8	34·0	33·2	35·0	27·4
1928	27·0	24·5	24·5	24·7	20·8	26·5	20·5	22·2	19·3	22·0	26·7	20·0	19·5	23·0	19·5	19·8	12·7	25·5
1929	13·8	22·3	11·0	15·8	6·2	9·6	4·9	10·8	13·1	10·5	17·6	15·8	14·0	19·3	23·3	20·4	17·4	12·0
1930	10·1	23·7	11·2	24·4	10·9	16·6	20·2	18·9	26·0	28·9	28·0	29·1	30·9	31·4	30·3	30·5	32·2	18·6
1931	7·8	14·1	10·0	15·9	7·6	17·3	16·1	23·7	26·8	23·8	28·7	23·9	24·3	27·1	26·6	21·7	23·3	17·7
1932	15·5	18·9	16·0	22·2	16·8	25·2	18·5	21·3	26·8	21·9	25·4	24·4	25·1	26·6	23·9	18·5	15·7	20·4
1933	12·1	9·7	7·3	9·4	3·1	13·2	11·1	16·6	21·6	18·7	22·2	18·8	22·1	19·9	21·2	19·8	19·0	12·0
1934	14·5	20·6	9·2	15·4	4·6	13·9	10·3	14·0	16·2	21·6	23·6	21·9	23·6	21·3	26·6	25·8	26·8	15·0
1935	13·1	14·0	11·4	13·4	9·9	19·0	8·8	19·1	19·8	12·3	13·2	5·5	12·4	10·6	16·1	17·3	23·6	13·6
1936	4·2	6·8	8·2	5·9	2·9	7·2	4·9	13·1	17·3	12·0	18·5	18·5	16·0	16·9	21·5	26·4	23·4	9·1
1937	3·0	18·0	7·0	8·0	4·0	7·0	3·0	10·0	18·0	13·0	15·0	15·0	19·0	15·0	16·0	14·0	15·9	9·4
1938	13·9	23·8	14·6	18·9	15·1	17·4	16·6	22·0	20·5	18·8	20·5	21·2	15·0	15·5	14·1	10·8	12·8	17·9
1939	13·0	17·3	15·0	17·8	14·6	19·5	12·8	19·3	21·6	16·7	22·8	16·9	22·3	22·7	18·3	20·5	23·3	17·9
1940	15·1	21·9	22·1	24·5	23·4	25·8	21·5	25·1	25·2	24·0	30·3	25·0	22·2	26·2	23·5	28·8	29·3	21·6
1941	16·3	21·9	12·9	15·9	6·8	13·6	5·7	12·4	19·8	12·7	17·0	18·4	16·1	18·1	24·8	21·8	22·0	15·0
1942	24·8	30·6	25·1	31·7	27·8	31·0	24·8	31·8	31·1	30·8	34·3	28·0	31·1	30·9	25·4	24·5	26·9	29·0
Ave. 22 Yrs. (1921–42)	13·2	19·1	13·7	18·8	12·9	18·1	14·4	19·3	20·2	18·7	22·5	19·9	20·0	21·5	22·0	20·5	21·3	17·2

List of Crop Rotations

In the preceding chapters of this bulletin, detailed information has been presented on the results obtained over a long period of years with various crop rotations on the Dominion Experimental Farms in the Prairie Provinces. The following list gives some examples of different types of rotations which might be useful for different conditions. Before selecting any of these rotations, however, for any farm in any region, it would be advisable to refer to the results of the rotation experiments on the nearest Experimental Farm or the Station where the soil and climatic conditions may be most comparable. In fact it might be desirable to consult with the staff at the Station in order to secure as much information as possible. All the following rotations have not been tried at each Station, but perhaps there may have been a sufficient number to provide useful information which may serve as a guide in selecting the most suitable cropping system.

Grain Rotations

Two-year grain rotation—

1st year—summerfallow
2nd year—wheat.

This rotation is adapted to the driest regions of the Prairie Provinces.

Three-year grain rotation—

1st year—summerfallow
2nd year—wheat.
3rd year—wheat.

This rotation might be used in dry areas where the second crop of wheat yields nearly as much as the first crop after summerfallow.

Four-year grain rotation—

1st year—summerfallow
2nd year—wheat.
3rd year—wheat.
4th year—oats or barley.

This rotation provides a large percentage of the land in grain but it is very subject to severe weed infestation.

Grain rotations or cropping methods for special conditions—

On light soils where summerfallow is liable to drift when left unseeded, a two-year rotation of summerfallow and fall rye may be attempted. Sometimes fall rye and spring wheat are alternated. Occasionally weeds are allowed to grow for two years without any cultivation, and then the land is spring ploughed for wheat. However, if conditions are so unfavourable that such methods must be used, it is very doubtful if the land should be under cultivation. Except in periods of high prices, this land is really submarginal.

Mixed-Farming Rotations

Three-year mixed-farming rotation—

1st year—summerfallow or intertilled crops, manure.
2nd year—wheat.
3rd year—sweet clover.

This rotation might be used on sandy soils where sweet clover will give better results than mixed alfalfa and grass hay. It will provide considerable feed for livestock.

Four-year mixed-farming rotation—

1st year—summerfallow or intertilled crops, manure.
2nd year—wheat.
3rd year—sweet clover hay—then plough immediately.
4th year—oats or barley.

This rotation might be used where sweet clover can be grown successfully, and the land can be ploughed immediately to provide good conditions for the following grain crop. Permanent pasture must be available elsewhere. However, one year in hay is not very effective in controlling wild oats or in providing organic matter for the soil.

Five-year mixed-farming rotation—

1st year—summerfallow or intertilled crops, manure.
2nd year—wheat.
3rd year—sweet clover hay. Then plough immediately.
4th year—wheat.
5th year oats or barley.

This rotation might be used where corn may replace a summerfallow and where permanent pasture is available elsewhere. However, one year in hay is not very effective in controlling wild oats or in providing organic matter.

Six-year mixed-farming rotation—

1st year—summerfallow or intertilled crops, manure.
2nd year—wheat.
3rd year—hay.
4th year—hay or pasture—plough in July.
5th year—wheat.
6th year—oats or barley.

This rotation might be used where mixed alfalfa and grass hay gives good results and where it is desired to seed down with a nurse crop immediately after corn or summerfallow.

Seven-year mixed-farming rotation—

1st year—summerfallow.
2nd year—wheat.
3rd year—hay.
4th year—hay or pasture—plough in July.
5th year—summerfallow or intertilled crops—manure.
6th year—wheat.
7th year—oats or barley.

This rotation might be used under conditions not quite so favourable as in the case of the preceding six-year rotation. It contains a larger percentage of the land in intertilled crop or summerfallow.

Eight-year mixed-farming rotation—

(May be arranged in four fields)
1st year—summerfallow—manure.
2nd year—wheat.
3rd year—barley.
4th year—hay.
5th year—pasture.

6th year—pasture in May, break in June and summerfallow.
7th year—wheat.
8th year—oats.

This eight-year rotation may be located on four fields by grouping the 1st and 5th years of the rotation in one field, 2nd and 6th years, 3rd and 7th years and 4th and 8th in three other fields. Considerable fencing may be eliminated by this arrangement. The only serious drawback is that the grass and legume hay crop is seeded with the second crop of wheat after summerfallow when it would be preferable to seed down with the first crop. However, by following the best methods of seeding down, satisfactory results may usually be obtained. This rotation provides a very good proportion of the various types of crops for livestock, as well as having 25 per cent of the acreage in wheat.

Eight-year mixed-farming rotation with cover crop—

(May be arranged in four fields)
1st year—summerfallow and cover crop pasture, manure.
2nd year—wheat.
3rd year—barley.
4th year—hay.
5th year—pasture.
6th year—pasture in May, summerfallow and cover crop pasture.
7th year—wheat.
8th year—oats.

This eight-year rotation may be located on four fields by grouping the 1st and 5th years of the rotation in one field, 2nd and 6th years, 3rd and 7th years, and 4th and 8th years in three other fields. Cover crop seeded during the first part of August at the rate of ½ bushel of wheat per acre will be ready to pasture about the middle of September. This rotation will provide considerable coarse grain and hay, as well as a large acreage of pasture for livestock, in addition to having 25 per cent of the land in wheat. It is adapted only where cover crops are successful.

This rotation could be modified if desired as follows: summerfallow and cover crop, wheat, hay, hay, pasture, intertilled crop or summerfallow and cover crop, wheat, oats. This would provide a more favourable location in the rotation to seed down the alfalfa and grass mixture and would give a larger acreage in pasture. However, it would reduce the acreage in grain.

Nine-year mixed-farming rotation—

1st year—summerfallow.
2nd year—wheat.
3rd year—oats.
4th year—hay.
5th year—hay or pasture.
6th year—early pasture, break in June and summerfallow.
7th year—corn—manure.
8th year—wheat.
9th year—oats.

This nine-year rotation is really a combination of three, three-year rotations. It would require considerable fencing if livestock were pastured, but this could be reduced by the use of electric fencing.

Combination Rotation—

1st year—summerfallow or intertilled crops, manure.
2nd year—wheat.

3rd year—sweet clover hay, then plough immediately.
4th year—wheat.
5th year—oats.
6th area—hay left for five years.

In this rotation a new area is seeded at the end of every five years to alfalfa or a mixture of alfalfa and grass for hay. This type of rotation might be modified to meet different requirements. If desired, the fields rotated every year could be arranged in a straight grain rotation, such as a three-year grain rotation, with an additional one-fourth of the area left in hay for a number of years, and then included in the grain rotation. This modified type of combination rotation might be used in dry areas where it is desired to have an area left in hay for a number of years. The combination rotation shown above may be used in more humid regions, especially where corn and alfalfa grow well.

Hay and Pasture Mixtures—

Except where otherwise specified, about five pounds per acre of alfalfa should be included in hay and pasture mixtures, along with those grasses which grow best in the various regions. Small grass and legume hay seed should be seeded on a firm seed-bed, but should not be seeded too deeply. If seeded with a nurse crop, the rate of seeding of the nurse crop should be reduced.

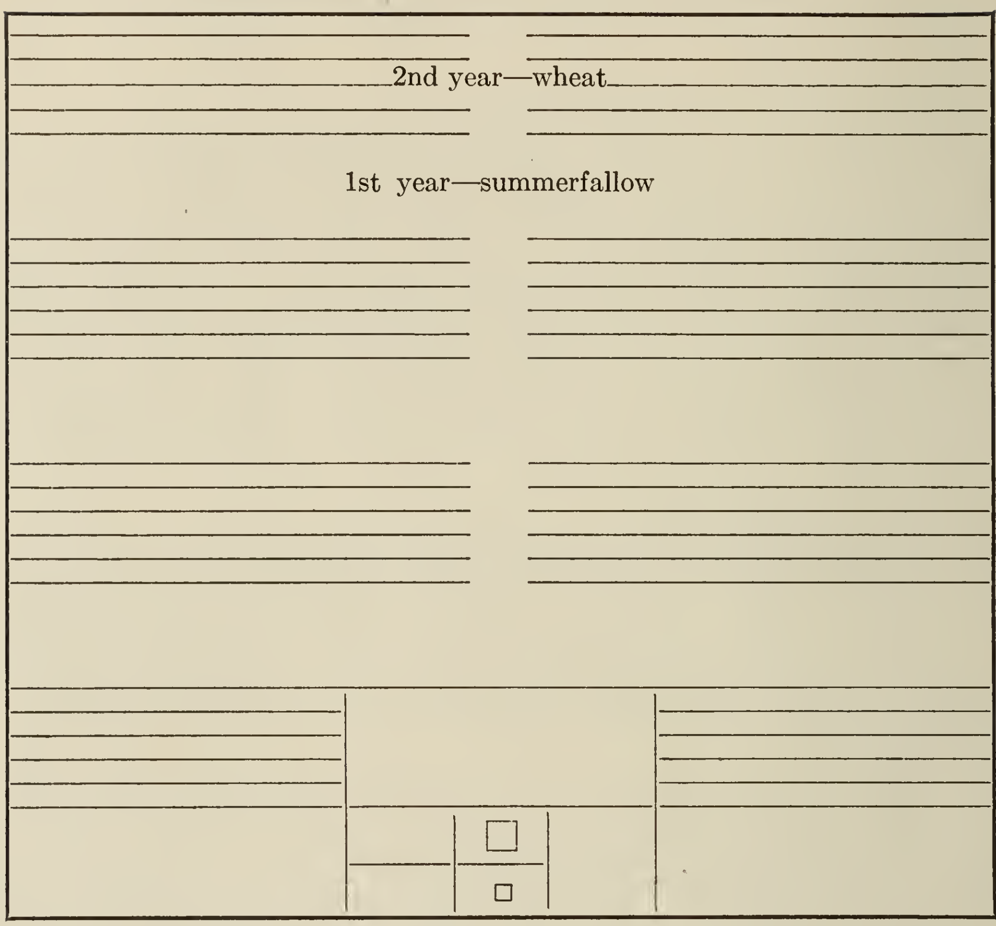
Intertilled Crops—

While corn is probably the most generally grown intertilled crop, other intertilled crops such as sunflowers, potatoes, roots or soybeans could be used. In so far as a summerfallow substitute crop is concerned, potatoes are probably the most efficient, but unfortunately on account of market limitations cannot be used extensively. However, under dry conditions a summerfallow usually conserves more moisture than any intertilled crop and also enables a better control of weeds.

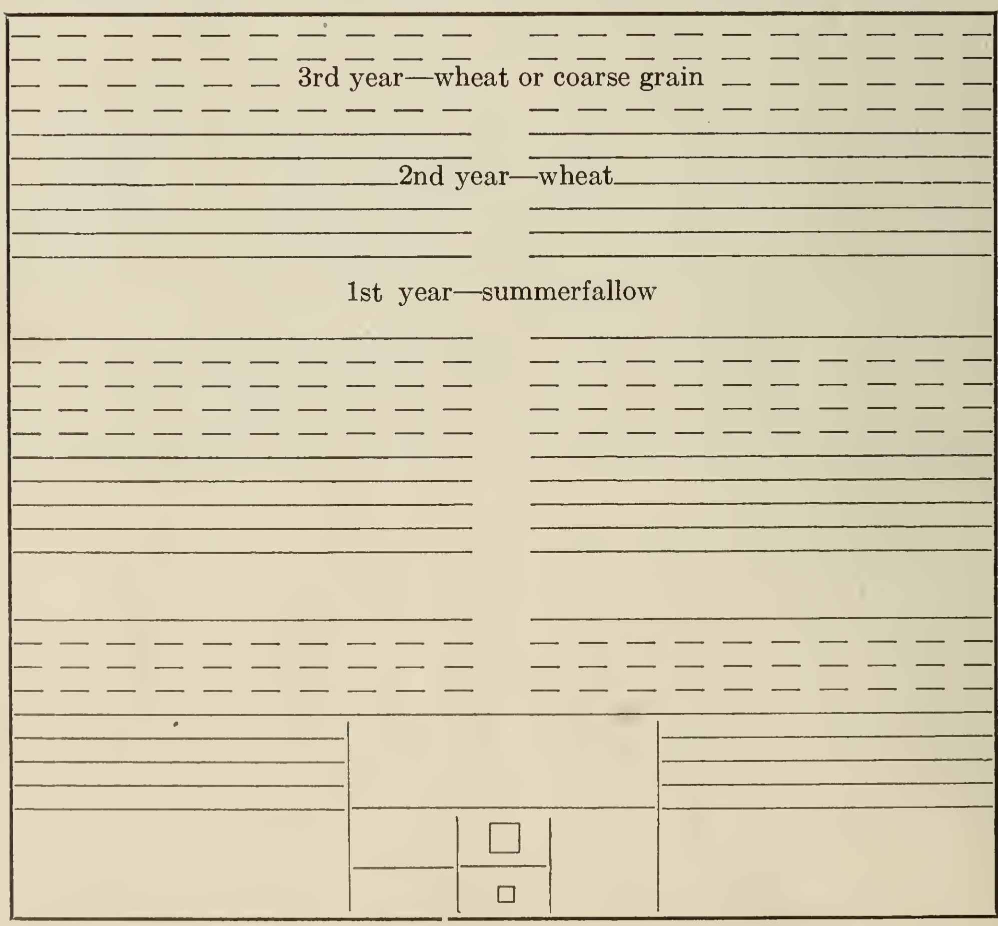
Soil Erosion Control—

Every effort should be made to control soil erosion caused either by wind or water. Strip farming has been found very helpful in checking both soil drifting and erosion caused by water. Surface tillage is preferable to ploughing in most regions. Sod land, of course, affords perfect control, and if some parts of the farm can be seeded to hay or pasture, it is an excellent means of preventing soil erosion. Frequently the serious character of losses caused by soil erosion is not fully realized, in that the loss is permanent and the productivity of the soil impaired for many years if indeed it can ever be fully restored. For this reason, crop rotations should be planned not only with the object of growing the desired acreages of the various crops in the most suitable sequence, but also to reduce and if possible prevent losses caused by soil erosion.

TWO-YEAR GRAIN ROTATION STRIP FARMING PLAN



THREE-YEAR GRAIN ROTATION STRIP FARMING PLAN



SIX-YEAR MIXED FARMING ROTATION

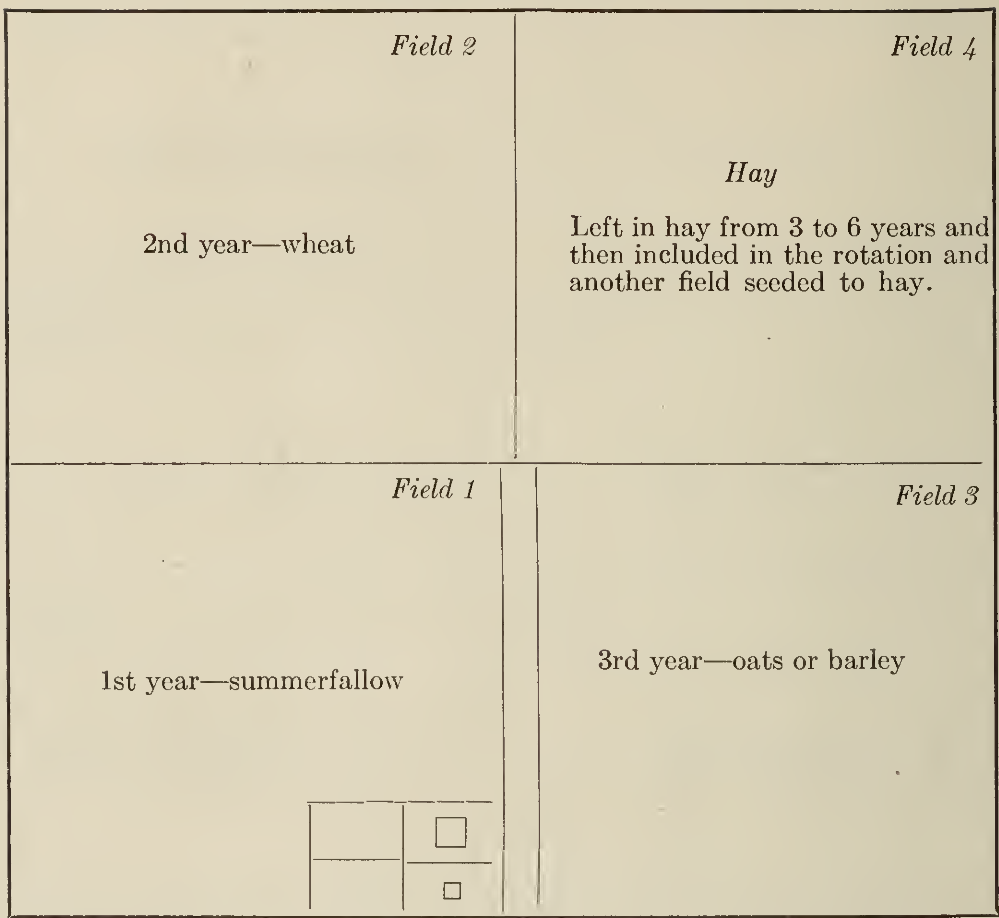
Field 3 3rd year—hay	*Field 6* 6th year—oats or barley
Field 2 2nd year—wheat	*Field 5* 5th year—wheat
Field 1 1st year—summerfallow or corn	*Field 4* 4th year—hay or pasture, plough in July

EIGHT-YEAR MIXED FARMING ROTATION

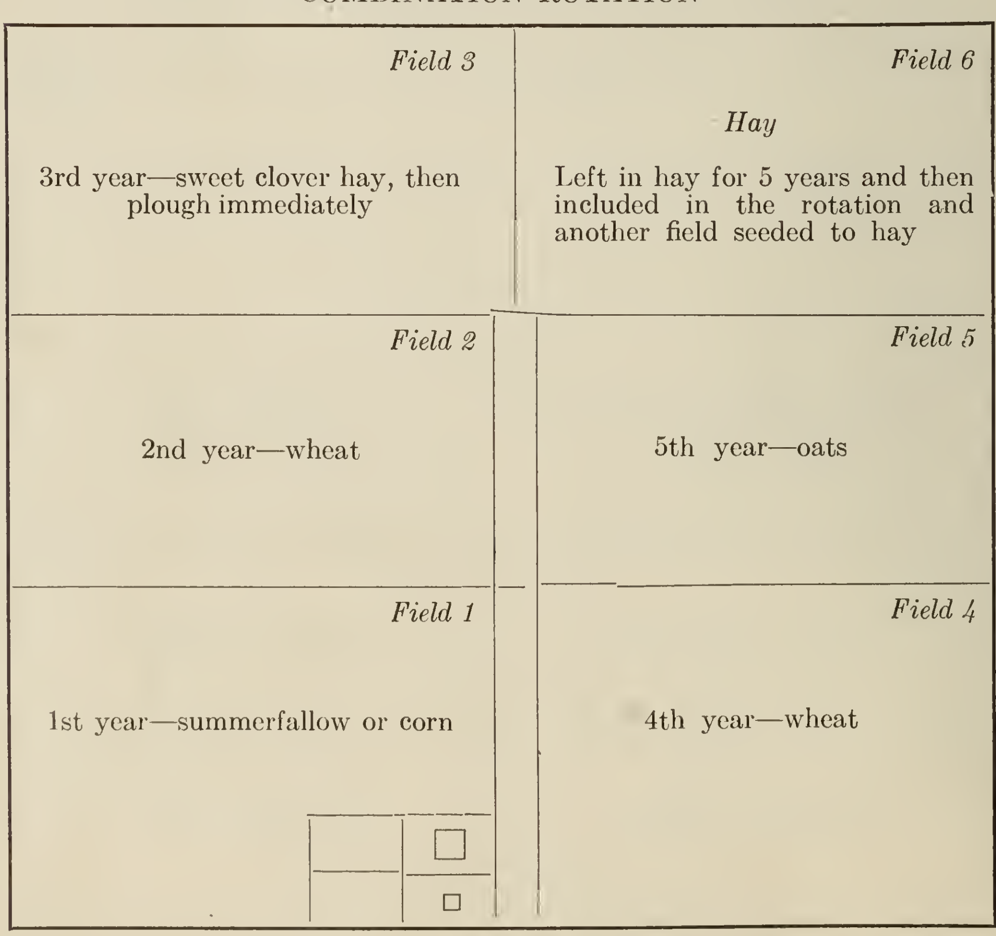
(Arranged in four fields)

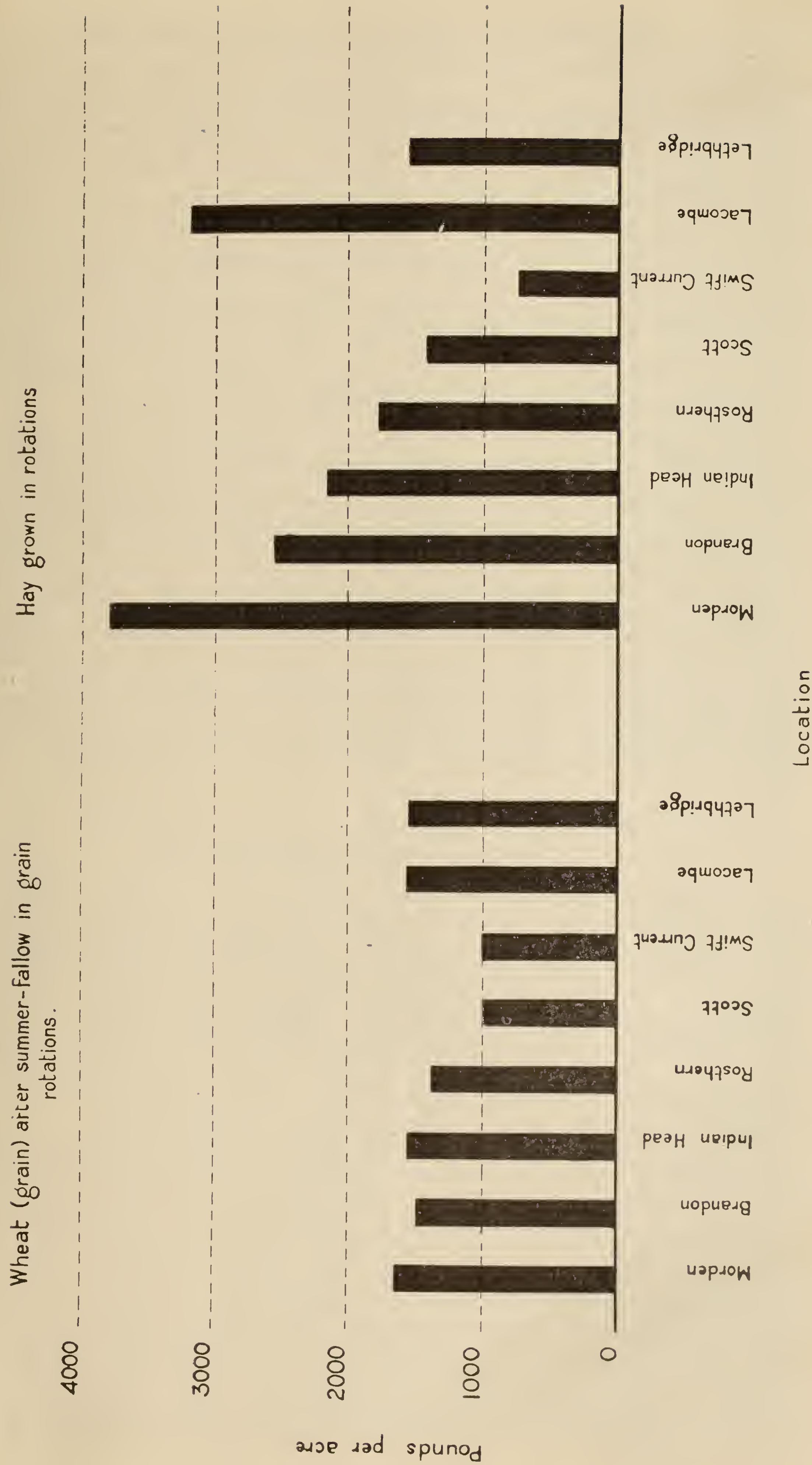
Field 2 2nd year—wheat 6th year—Break in June and summerfallow	*Field 4* 4th year—hay 8th year—oats
Field 1 1st year—summerfallow 5th year—pasture	*Field 3* 3rd year—barley 7th year—wheat

COMBINATION ROTATION



COMBINATION ROTATION





Average Yields of Wheat and Hay at Dominion Experimental Stations in the Prairie Provinces

The Value of an Annual Crop Plan of the Farm

In order to keep a record of the crops grown each year on all the fields or parts of the farm, it is very desirable to enter this information each year on a small plan of the farm. On this plan may be written the crops which have been grown on each field and the yields per acre which have been obtained. Other useful information may be recorded such as dates of seeding and harvesting, presence of weeds in various fields, and where soil drifting has occurred or manure applied. When this plan is made each year, it facilitates following a rotation accurately and growing the desired acreage of the various crops in the proper fields. With this information, it may be possible to improve the rotation along the line of adapting certain crops to soils to which they are suited. Above all, such a plan provides a definite record of the results of each year's work on the farm and, over a period of years, becomes increasingly valuable in planning the farm operations. Farming is a long-time business and records are necessary if much improvement is to be made.

This annual crop plan may be drawn in a book so that many years' records will be kept readily available for reference. It is possible to use a few pages in the book to make a record of all cash receipts and expenditures, and to record once a year an inventory of the value of all the equipment, livestock and crops on the farm. These records, together with the cropping plan of the farm, give accurate information of each year's program on the farm, and are the best means of studying how to improve the farm business. No commercial enterprise would consider conducting its business without yearly records and neither should any farm enterprise. This method of keeping farm records is perhaps the most simple of any system, but it gives, undoubtedly, the most fundamental information, and it has the great advantage of being extremely simple and requiring little time to accomplish. If a more complete system of accounting is desired, a suitable Farm Account Book may be obtained from the Dominion Department of Agriculture at a cost of ten cents.

The Effect of Cultivation and Cropping on the Nitrogen Content of Prairie Soils

Cropping practices over wide areas in the Prairie Provinces consist largely of summerfallow and grain. Such methods of farming are considered to be wasteful of soil fertility, at least in so far as the nitrogen and organic-matter contents of the soil are concerned. The most important factor in this loss of soil fertility is probably erosion caused either by wind or water, but the work of these destructive agencies is readily apparent and remedial measures can be taken to combat it. Not so apparent and hence in some ways more dangerous are the losses that occur through the removal of plant food elements from the soil by crop growth and cultivation. The following discussion deals with information on the effects of cropping and cultivation on the nitrogen content of prairie soils.

In 1905 Dr. F. T. Shutt, Dominion Chemist, analysed cultivated soils and corresponding virgin soils collected at Portage la Prairie and Indian Head. At Portage la Prairie after 25 years of cultivation the surface 8 inches of soil had lost nearly 25 per cent of its original nitrogen content. At Indian Head the loss of nitrogen, after 22 years of cultivation, amounted to 30 per cent, of which approximately 10 per cent was due to the removal by grain crops and 20 per cent to loss by fallowing and other cultural operations. Further investigations 16 years later at Indian Head showed that the total loss during the period of 38 years amounted to approximately 40 per cent, of which roughly 17 per cent was removed by crops and 23 per cent by cultivation. These results indicated that the loss due to cultivation alone materially decreased with time, amounting to 20 per cent during the first 22 years but to only 3 per cent during the second period of 16 years.

Recent studies conducted under the P.F.R.A. at the University of Alberta largely substantiate Dr. Shutt's earlier work, although they indicate more moderate losses. In these studies samples of soil were collected from many locations in the different soil zones, care being taken to sample only fields that apparently had suffered no loss from erosion. The results showed that the average loss in nitrogen in the surface 6 inches by crop removal and cultivation amounted to 17 per cent in the brown soil zone, 18 per cent in the dark brown zone and 18 per cent in the black soil zone. The results reported in this investigation also showed that the rate of loss of nitrogen is more rapid during the first few years following the initial breaking of the sod.

While in most areas there is little evidence that the productivity of the prairie soils has been materially affected as yet by the loss of nitrogen through crop removal or cultural operations, the productivity of these soils will be seriously affected if such losses continue to occur at the same rate in future years. While it is generally accepted that rotations including leguminous crops with or even without regular applications of manure will maintain or even increase the nitrogen supply of the soil, unfortunately such rotations are not well adapted to the drier parts of the prairies. However, it is thought by some that even under straight grain rotation the nitrogen content of the soil will reach a state of equilibrium before the productivity of the soil is seriously affected by the loss of this element. This theory assumes that the accumulation in the soil of nitrogen by non-symbiotic nitrogen-fixing organisms and from rainfall will equal the losses from cultivation and crop removal.

Some information on the effect of different crop rotations in the Prairie Provinces on the nitrogen content of the soil is being provided by certain studies in progress at the Division of Chemistry, Science Service, Department of Agriculture, Ottawa. This Division collected soil samples to a depth of 12 inches from rotation fields on the Dominion Experimental Station at Lethbridge in 1922, and in 1925 from rotation fields at Brandon, Scott and Lacombe. All these fields were again sampled to the same depth in 1940. The changes in the nitrogen content of the soils to a depth of one foot under different types of rotations could be determined for an 18-year period at Lethbridge, and for a 15-year period at Brandon, Scott and Lethbridge. The results obtained from this investigation are briefly discussed below.

At Brandon, Manitoba, no change in the nitrogen content of the soil occurred under the four-year grain rotation "E" of summerfallow wheat, wheat, oats, while the soil under the similar rotation "D" which received 12 tons of farm manure every four years showed a gain in nitrogen that was practically equivalent to the amount of this element in the manure applied. On the other hand the two six-year mixed-farming rotations "G" and "H" which have two years of hay in each six year cycle and also receive 12 tons of manure per acre during that period, showed a loss of between 5 and 6 per cent during the 15-year period. These results are just the opposite of what might be expected to happen under these four rotations. The explanation may lie in the fact that while the grain rotations are located on a clay to clay loam with a moderate slope, the mixed-farming rotations for the most part are on more rolling fine, sandy loam.

At Scott, Saskatchewan, the rotations under study include the two-year grain rotation "B", the three-year grain rotation "C", the four-year mixed-farming rotation "D", and the six-year mixed-farming rotation "J". Rotation "B" showed a slight loss in nitrogen of about 2½ per cent; rotation "C" showed no loss or gain; rotation "D" lost almost 10 per cent of its nitrogen content, while "J" showed a gain of 11 per cent. These results indicate that the grain rotations have almost reached a state of balance between the loss of nitrogen owing to removal by crops and by cultural practices, and the gain of nitrogen by natural agencies. The results from the mixed-farming rotations would appear to be contradictory. However, when the nitrogen content of these fields in 1925 is compared with the nitrogen content in 1940 it appears that possibly under such rotations the nitrogen level of the soil approaches a condition of equilibrium at about the same level as in the grain rotations, namely approximately 0·2 per cent. Thus rotation "D", which in 1925 had a nitrogen content of ·225 per cent, fell to ·201 per cent in 1940, while rotation "J" showed a gain from ·179 per cent in 1925 to ·199 per cent in 1940. None of the above rotations received any manure.

At Lacombe, Alberta, three rotations were studied—the three-year grain rotation "C", the six-year mixed-farming rotation "K" with three years of mixed alfalfa hay, and the seven-year mixed-farming rotation "O" with two years in mixed alfalfa hay. Striking losses of nitrogen occurred in "C", the content of this element dropping from ·520 to ·434 per cent, while the other two rotations showed striking gains, "O" increasing from ·308 to ·418 per cent and "K" from ·312 to ·392 per cent. These results certainly indicate that, under the conditions prevailing at this Station, mixed-farming rotations containing two or three years of alfalfa and receiving applications of manure build up the nitrogen supply of the soil, while straight grain rotations deplete the supply of this element. These changes in the nitrogen content of the soil may explain, at least in part, the superior yields in the mixed-farming rotations as compared with the grain rotation, as may be seen by referring to Table 11 where the Lacombe yields are reported. While the supply of nitrogen in the soil is still very high in the grain rotation, it may not be in as active a condition as in the mixed-farming rotation. However, while the above analyses demonstrate the trend under different rotations, it will require another period of years before the results can be wholly accepted. Since even in 1940 the total nitrogen was still higher in the grain rotation than in the mixed-farming rotations, it is possible that after the soils approach nearly the same nitrogen level, losses and gains from the different rotations may be much smaller than was the case during the 1925-40 period. These rotations, however, have been in progress since 1911 and the comparative results have been outstanding.

At Lethbridge, Alberta, soils were included from continuous wheat "A", three grain rotations; rotation "B", summerfallow, wheat; rotation "C", summerfallow, wheat, wheat; mixed farming rotation "T", which included four years of alfalfa for seed; and from the ten-year irrigated rotation "U" with six years of alfalfa.

The three grain rotations lost from 10 to 17 per cent of their nitrogen during the 18-year period from 1922 to 1940, the mixed rotation "T", also on dry land, showed a gain of almost 10 per cent, while the irrigated rotation "U" showed a gain of 18·0 per cent. Taking rotation "B" as an example of a grain rotation, it was found that the nitrogen content dropped from ·162 to ·140 per cent; rotation "T", on the other hand, showed a gain of from ·155 to ·170 per cent, while the irrigated rotation "U" gained from ·167 to ·197 per cent. The figures clearly show the effect of different kinds of rotations on soils that in 1922 contained approximately the same amount of nitrogen.

These effects on the nitrogen content of the soil and the very beneficial effect from the use of alfalfa is perhaps more clearly shown in the following table.

Rotation "B"—dry land, two-year rotation—summerfallow, wheat.

Rotation "T"—dry land, ten-year rotation—summerfallow, wheat, oats, summerfallow, alfalfa (for seed) three years, summerfallow, corn, wheat.

Rotation "U"—irrigated ten-year rotation—wheat, sugar beets, oats, barley, alfalfa (hay) six years.

TABLE 27.—NITROGEN BALANCE IN ROTATION EXPERIMENTS ON THE DOMINION EXPERIMENTAL STATION, LETHBRIDGE, ALBERTA FOR AN 18-YEAR PERIOD, 1922 TO 1940

(POUNDS PER ACRE IN SURFACE FOOT)

Rotation	Total Period of 18 Years				Nitrogen balance of rotation per year	Nitrogen fixed by alfalfa per year
	Change in nitrogen content of soil	Nitrogen removed by crops	Nitrogen added by manure	Nitrogen balance of rotation		
"B"	− 880	600	None	− 280	− 16	....
"T"	+ 600	288*	216	672	37	124
"U"	+1200	2230	216	3214	179	298

* In calculating the nitrogen balance for rotation "T" no loss was included for the removal of the alfalfa crops for seed as it was assumed that this loss would be compensated by the gain from the leaves dropping on the ground.

In all the rotations mentioned in the above table the land had been under cultivation from 10 to 15 years before the fields were sampled in 1922. Hence, the greatest loss due to cultural operations alone had probably occurred by 1922. Nevertheless, rotation "B" continued to lose a considerable amount of nitrogen from this cause, this loss amounting to 280 pounds or about one-half of the total removed by the crops.

The beneficial effect of alfalfa in a rotation on dry land is shown in the figures obtained for rotation "T" and even more strikingly in rotation "U" on irrigated land. Alfalfa was the only crop in these rotations which fixed the atmospheric nitrogen. Although some nitrogen is added to the soil by natural agencies, such as from rainfall or the action of non-symbiotic nitrogen-fixing bacteria, it is assumed that these additions are approximately equivalent to the losses of nitrogen caused by cultivation. In rotation "T" the gain in nitrogen of 37 pounds per year or 370 pounds for the ten-year rotation cycle can be directly attributed to the three years in the rotation when the land was under alfalfa. Thus the gain in nitrogen for each year of alfalfa was 124 pounds per acre. This is a surprising figure since the alfalfa crops, although harvested for seed, were rather poor. In the irrigated rotation "U", where the land was under alfalfa for six years out of the ten years of the rotation, the gain for each year in the rotation was 179 pounds per acre and therefore for each year the land was in alfalfa amounted to 298 pounds per acre per year. The amount of nitrogen fixed by alfalfa at Lethbridge has been spectacular and it would appear even larger if any allowance were made for gains below the one-foot depth.

The results on the nitrogen content of the soil show clearly that location and soil type may greatly influence the effect of different rotations. Further investigations on this important problem are required as there is vital need for more knowledge if the productivity of prairie soils is to be maintained. While many soils still have good reserves of nitrogen, as judged by recent crop yields and by their ability to accumulate large amounts of nitrates, the removal of grain crops without returning anything to the soil may ultimately seriously affect their productivity.

Summary of Crop Rotation Experiments

The Dominion Experimental Farms in the Prairie Provinces have conducted experiments with various types of crop rotations since 1911. Valuable information has been obtained on the yields which may be expected in different regions from various systems of cropping continued unchanged over

In the black and grey wooded soil zones, mixed farming rotations have been preferable to grain rotations in that they have controlled weeds much more effectively and in some regions have given much better yields. On the other hand, in the drier brown and dark brown soil zones grain rotations have given better results.

a long period of years. Farming is a permanent business and it should be conducted so as to maintain or preferably increase the productivity of the soil rather than, as is too often the case, impoverish it. Detailed information on the results obtained from the various rotations may be found in this bulletin in the chapters dealing with each particular Station, while the results from experiments on commercial fertilizer, farm manure, green manure, and other subjects, will be found in the chapters relating to these subjects. Anyone interested in designing a suitable crop rotation for any particular farm might find it useful to study the results of the rotation experiments conducted on the nearest Experimental Farm, or located in a region with similar soil and climatic conditions. It might then be helpful to review the chapter entitled "List of Crop Rotations" in order to see if any other similar type of rotation might be more suitable for his requirements.

It is important to remember that wide variations exist throughout the Prairie Provinces in soil zones and soil types as well as in climatic conditions. Although the area as a whole may be described as having a continental, semi-arid to sub-humid climate, such differences exist as to profoundly affect the growth of different crops in various districts. Temperature, precipitation, and evaporation vary considerably from one region to another, thereby affecting the growth of crops to a considerable extent. The average date of harvesting, for example, is about four weeks later in central Alberta than in southern Manitoba.

The beneficial effect of mixed-farming rotations over straight grain rotations is outstanding in the black and grey wooded soil zones. In the drier brown and dark brown soil zones, on the other hand, these rotations seem to possess no advantage over grain rotations. On the Dominion Experimental Farm at Lacombe, Alberta, located in the black soil zone, the yield of wheat after summerfallow during the ten-year period from 1933 to 1942, has been 19·7 bushels per acre in a three-year grain rotation, as compared with 33·2 bushels in an adjoining mixed-farming rotation. The second crop of wheat in the grain rotation averaged only 11·0 bushels per acre, as compared with an average yield of 68·8 bushels of oats after wheat in the mixed farming rotation. There is no question but that the mixed-farming rotation at this Station has been very much better than the grain rotation. The advantage is due to the inclusion of a legume hay crop, the application of farm manure and the very much better control of wild oats in the mixed-farming rotation than in the straight grain rotation. At Morden, in southern Manitoba, the value of a legume hay crop, alfalfa, as compared with a grass hay, has been outstanding on the yields of subsequent crops. At this Station an intertilled crop, such as corn, has proved an effective summerfallow substitute, the yields of subsequent crops of grain after corn being as good as after summerfallow. In dry regions however, these crops have not proved so valuable in crop rotations.

On all the Experimental Stations in the black soil zone, weed control has been immeasurably better in the mixed-farming rotations than in the straight grain rotations. It seems impossible to have effective control of weeds in grain rotations unless special practices are followed such as surface cultivation, deferred seeding in the spring, the use of barley or green feed crops, or the practice of alternate wheat and summerfallow. Even these practices are only partially successful in districts where wild oats thrive. Mixed farming rotations, which include two years of hay or pasture, however, are quite effective in controlling this weed and without any extra cultivation or expense. Some weeds, on the other hand, cannot be controlled by crop rotations and require special methods to eradicate them.

In the drier areas mixed-farming rotations have no advantage in controlling weeds. Moreover, as they have no beneficial effect in producing better yields, and as perennial hay crops are very unsatisfactory, mixed-farming rotations cannot be recommended for these regions. If grass or legume crops are desired, they should be left on the land for a number of years and the area then included in the grain rotation rather than to follow the practice of seeding the grass seed regularly every year in a crop rotation. In fact, this method of producing hay crops may be used in any dry region where it is difficult to get good stands of hay and the first year of hay is liable to be weedy. The decision as to whether or not a two-year grain rotation of summerfallow and wheat is preferable to a three-year or longer grain rotation will depend upon a number of conditions, especially upon the relative yield of wheat after summerfallow and after wheat. Where yields are nearly twice as much after summerfallow as after another crop of grain, the two-year grain rotation is preferable. Usually long grain rotations become very weedy.

Considerable variation in the response to commercial fertilizers has been observed throughout the Prairie Provinces. In the drier areas, as at Lethbridge and Swift Current, no increase in yield has been obtained. On the other hand, at Melfort and Lacombe, in the black soil zone, increases of 6·1 and 8·2 bushels per acre, respectively, have been secured from the application of ammonium phosphate to wheat on summerfallow. Several Stations have had average increases ranging from two to five bushels per acre. Even on the same farm considerable differences may be obtained in the response to commercial fertilizers. Usually the greatest increases will be secured on the least fertile fields, but this is not always the case.

In the grey wooded soil zone, especially in western, central Alberta, the application of sulphur has given amazing results on leguminous hay crops. Nowhere in Canada, perhaps, are the results from any commercial fertilizers so outstanding. Without sulphur, leguminous crops are not satisfactory, while the use of this element produces yields about equal to those obtained in the black soil zone. The sulphur may be applied as an ingredient of other fertilizers, such as ammonium sulphate, single superphosphate, or the 16-20 formula of ammonium phosphate. For grain crops a high nitrogen fertilizer gives best results. The combination of nitrogen, sulphur and phosphorus, in mixed-farming rotations, including legume hay crops, enables the production of very heavy yields, two to five times as much as those obtained without these practices. Further information is necessary, however, to learn in what other other areas of the grey wooded soil zone the use of such treatments will produce these favourable results.

The application of farm manure has given a smaller increase in yield than that obtained from commercial fertilizers. Those Stations which fail to give any response to fertilizers have failed also to give any increased yield from manure. Stations which give the largest response to fertilizer have usually given the greatest response to manure, but not as much as from fertilizer. The results at Beaverlodge, however, have been an exception, manure giving better results than fertilizer. It would seem advisable to apply farm manure to the lightest and poorest land on the farm and to those areas most susceptible to soil drifting. The rate of application should not be excessive, possibly not over ten tons per acre, and in the drier areas should be applied during the summerfallow year.

The ploughing under of a growing crop as green manure in an effort to enrich the soil has not, in these rotation experiments, given beneficial results. Although this practice is frequently advocated in agricultural text books, it is not applicable in the Canadian Prairies. It has arisen and has been found useful under entirely different conditions where higher temperatures, greater precipitation and shorter winters prevail.

Under irrigation conditions, farm manure has produced outstanding increases in crop yields, particularly of sugar beets but also of other crops as well. Commercial fertilizers and legume green manure crops have been quite valuable. At Lethbridge, where phosphate fertilizer failed to give any increase in yield of wheat under dry land conditions, it proved to be absolutely essential under irrigation for the production of satisfactory yields of alfalfa. Alfalfa and sugar beets showed a great requirement for phosphorus while grain crops, in the irrigated rotation at this Station, have not yet indicated any need for this element, producing over the last ten-year period the marvellous yield of 60·0 bushels of wheat, 70·3 bushels of barley, and 105·4 bushels of oats per acre, without any fertilizer and with only 12 tons of manure once during the ten-year rotation. Alfalfa, however, declined in yield, became infested with dandelions, and no longer would produce a satisfactory crop without fairly substantial applications of phosphatic fertilizer.

Crop yields vary widely from one region to another and, as is well known, from one year to another. Even a period of ten years is insufficient in some regions to give a reliable average yield. Other regions have much less variation from year to year. Anyone desiring to commence farming in any region should study the records of crop yields over as long a period of years as possible, and should compare these yields with those obtained elsewhere. In some areas the average yields may be two or even three times as much as those obtained in other areas and probably with less variation and fewer crop failures as well. It is wise to avoid selecting submarginal or very low producing land. Frequently the market price fails to correspond with the real producing and earning power of the land. Other factors, it is true, require consideration in evaluating land, such as quality of grain produced, cost of operation, proximity to market and other conditions, but yield per acre is usually by far the most important.

In regions where crop rotations produce increased yields they will be found to possess other advantages as well. Weed control, as has been mentioned previously, is more effectively and economically obtained in certain types of rotations. Losses from certain insects and fungous diseases may be reduced. Where legume crops are included in the rotation, the supply of nitrogen in the soil may be maintained or even substantially increased. Rotations do not, however, maintain the supply of mineral elements, such as phosphorus. There is less danger of total loss from drought, hail and frost when several crops are produced, as compared with one crop only. When properly arranged, crop rotations afford some protection against wind and water erosion of the soil. Labour is distributed throughout the seasons better when several crops are grown, as compared with a single crop system. It must be remembered, however, that in the drier brown and dark brown soil zone regions, mixed-farming rotations have not been successful, and that rotations with grain and summerfallow have given better financial results.

The effect of cultivation and cropping on the loss of nitrogen, organic matter and mineral constituents of the soil is a very important factor in any consideration of permanent agriculture. These losses can be determined only by chemical analyses and can be measured only over a relatively long period of years. It has been already mentioned that where legumes are included in the rotation the supply of nitrogen in the soil can be maintained or even increased, but that the mineral elements cannot be restored by any type of rotation. However, where crops are fed to livestock and the manure applied to the land, most of the minerals will be returned. Commercial fertilizers may be used where the supply of any mineral becomes reduced to such an extent as to limit crop yields.

In the brown soil zones the problem of decreasing soil fertility is not at present, and perhaps for many years is not liable to become a serious factor. The supply of minerals in the soil seems to be sufficient for the production of good yields for many years, while the amount of nitrogen, even in rotations without legume crops, appears to be sufficient. Soil impairment from wind and water erosion are the greatest immediate evils to be feared in these regions. Ultimately, however, it would seem that the single crop system of straight grain production without the use of legume crops or the return of manure or straw to the land might reduce the productivity of the soil. When this will occur it is impossible to predict but experiments should be continued so that it may be possible to determine when this point is reached, in order that changes in farming practices might be instituted immediately.

In the black soil zone, on the other hand, serious soil deterioration, both from cropping and erosion, has already occurred in some regions and will most certainly occur elsewhere unless well planned rotations and other soil conservation practices are adopted. In fact, during the period in which the rotation experiments have been in progress on some of the Dominion Experimental Farms, a marked deterioration has already occurred and where originally the grain rotations gave greater returns, now the mixed-farming rotations are much superior. In the grey wooded soil zone, where the level of fertility is very low, it is necessary to commence farming on virgin soil with the best practices, in order to build up the fertility so as to enable the production of satisfactory yields. In both the black and grey wooded soil zones, improved methods must be adopted and continued permanently if the most profitable returns are to be secured in these regions.