CROP ROTATIONS AND SOIL MANAGEMENT FOR THE PRAIRIE PROVINCES

By
E. S. HOPKINS AND S. BARNES

DOMINION OF CANADA
DEPARTMENT OF AGRICULTURE

BULLETIN No. 98—NEW SERIES

DIVISION OF FIELD HUSBANDRY
DOMINION EXPERIMENTAL FARMS

Printed by direction of the Hon. W. R. Motherwell, Minister of Agriculture,
Ottawa, Ont.

DOMINION EXPERIMENTAL FARMS BRANCH

PERSONNEL

Director, E. S. Archibald, B.A., B.S.A.

Dominion Field Husbandman........ E. S. Hopkins, B.S.A., M.S.
Dominion Chemist........ Frank T. Shutt, M.A., D.Sc.
Dominion Horticulturist........ W. T. Macoun.
Dominion Cerealist........ L. H. Newman, B.S.A.
Dominion Botanist........ H. T. Güssow.
Dominion Animal Husbandman........ G. B. Rothwell, B.S.A.
Dominion Forage Crop Specialist........ G. P. McRostie, B.S.A., Ph.D
Dominion Poultry Husbandman........ F. C. Elford.
Chief, Tobacco Division........
Dominion Bacteriologist........ Grant Lochhead, Ph.D.
Dominion Apiarist........ C. B. Gooderham, B.S.A.
Chief Officer, Extension and Publicity........ F. C. Nunnick, B.S.A.
Chief Supervisor of Illustration Stations........
Economic Fibre Specialist........ R. J. Hutchinson.

ALBERTA

Superintendent, Experimental Station, Lacombe, Alta., F. H. Reed, B.S.A.
Superintendent, Experimental Station, Lethbridge, Alta., W. H. Fairfield, M.Sc.
Superintendent, Experimental Sub-station, Beaverlodge, Alta., W. D. Albright.
Superintendent, Experimental Sub-station, Fort Vermilion, Alta., Robt. Jones.

BRITISH COLUMBIA

Superintendent, Experimental Farm, Agassiz, B.C., W. H. Hicks, B.S.A.
Superintendent, Experimental Station, Summerland, B.C., W. T. Hunter, B.S.A.
Superintendent, Experimental Station, Invermere, B.C., R. G. Newton. B.S.A.
Superintendent, Experimental Station, Sidney, B.C., E. M. Straight, B.S.A.

MANITOBA

Superintendent, Experimental Farm, Brandon, Man., M. J. Tinline, B.S.A.
Superintendent, Experimental Station, Morden, Man., W. R. Leslie, B.S.A.

SASKATCHEWAN

Superintendent, Experimental Farm, Indian Head, Sask., W. H. Gibson, B.S.A.
Superintendent, Experimental Station, Rosthern, Sask., W. A. Munro, B.A., B.S.A.
Superintendent, Experimental Station, Scott, Sask., Victor Matthews, B.S.A.
Superintendent, Experimental Station, Swift Current, Sask., J. G. Taggart, B.S.A.

NEW BRUNSWICK

Superintendent, Experimental Station, Fredericton, N.B., C. F. Bailey, B.S.A.

NOVA SCOTIA

Superintendent, Experimental Farm, Nappan. N.S., W. W. Baird, B.S.A.
Superintendent, Experimental Station, Kentville, N.S., W. S. Blair.

PRINCE EDWARD ISLAND

Superintendent, Experimental Station, Charlottetown, P.E.I., J. A. Clark, M.S.A.
Superintendent, Experimental Fox Ranch, Summerside, P.E.I., G. Ennis Smith.

ONTARIO

Central Experimental Farm, Ottawa, Ont.
Superintendent, Experimental Station, Kapuskasing, Ont., S. Ballantyne.
Superintendent, Experimental Station, Harrow, Ont., H. A. Freeman, B.S.A., M.Sc.

QUEBEC

Superintendent, Experimental Station, Cap Rouge, Que., G. A. Langelier, D.Sc.A.
Superintendent, Experimental Station, Lennoxville, Que., J. A. McClary.
Superintendent, Experimental Station, Ste. Anne de la Pocatière, Que., J. A. Ste. Marie, B.S.A
Superintendent, Experimental Station. La Ferme, Que., P. Fortier, Agr.
Superintendent, Experimental Station. Farnham, Que., J. E. Montreuil, B.S.A.

TABLE OF CONTENTS

DOMINION OF CANADA

DEPARTMENT OF AGRICULTURE

BULLETIN No. 98—NEW SERIES

Good crop rotations and proper cultural methods promote the production of profitable crops.

CROP ROTATIONS AND SOIL MANAGEMENT FOR THE PRAIRIE PROVINCES

By E. S. Hopkins and S. Barnes

THE ADVANTAGES OF CROP ROTATION

Crop rotation is the growing of different crops upon the same land in a definite order and in recurring succession. The simplest form of crop rotation is the two-year wheat and summer-fallow rotation, in which one-half of the land is in wheat and the other half in summer-fallow, the positions being reversed each year. 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.

The chief advantages of crop rotation consist in maintaining the productivity of the land at a higher level, in distributing the farm labour more uniformly throughout the season, and in controlling more effectively weeds, insects, and fungous diseases. These advantages, fortunately, may be secured without any additional expenditure beyond that required where no rotation is followed. The Dominion Experimental Farm system established in 1911 a comprehensive experiment to test the value of different types of crop rotations on its various farms in different parts of the prairie provinces. This bulletin gives a detailed statement of the yields and profits secured from these rotations and some information regarding their suitability for different conditions. As this information has been secured over a long period of years, it affords a fairly reliable guide to farmers living in districts served by these farms.

COST OF PRODUCTION FACTORS AND RETURN VALUES USED IN CALCULATING PROFITS ON ROTATIONS

In order to make a comparison of the net returns from the various types of rotations, accurate records have been kept of the cost of production and the returns from each crop. As most of the rotations were commenced in 1911, they have been in operation for a brief pre-war period when prices were low, as well as during the war period when prices were high, and again for a period after the war when some prices have dropped. However, to simplify the calculations and, at the same time, to make them more useful in estimating possible future returns, average prices have been used to cover the entire period during which the rotations have been in progress. That is to say, although the cost of manual labour has ranged in this period from 15.3 cents an hour in 1911 to 39.3 cents an hour in 1920 an average cost has been used of 24 cents an hour or $2.40 per ten-hour day which includes the cost of manual labour together with the cost of board and room. In the same way, although the price of wheat in Saskatchewan has ranged from 56 cents a bushel in 1912 to $2.32 a bushel in 1919, an average price of $1.18 has been used. The figures presented furnish a reliable index to the average costs and profits of the different rotations during the period they have been in operation. To get some idea of possible future profits, one may substitute any figure desired.

The following factors, based on past records of actual experience, have been used in connection with the estimation of the cost of producing crops on all the rotations. Manual labour has been figured at 24 cents an hour, horse labour at 8.5 cents an hour, machinery $1.06 per acre, twine 45 cents an acre. Threshing has been charged at 10 cents a bushel for wheat, 7 cents a bushel for barley and 6 cents a bushel for oats. The cost of the summer-fallow has been distributed on the basis of two-thirds of the cost being charged to the first crop after the summer-fallow and one-third to the second crop. Seed grain was charged at 50 per cent above the price of market grain. A value of $2 a ton was given for oat and barley straw but no value was given for wheat straw. Wherever manure was applied to the land it was charged at $1 a ton. The value of corn silage was estimated on the basis of 3 pounds of corn silage being equal to 1 pound of mixed hay, roots were valued on the basis of 6 pounds of roots being equal to 1 pound of mixed hay.

The following factors, which have been used in calculating the return values on the rotations vary somewhat among the various farms. The return prices for grain and hay have been taken from figures reported for the various provinces by the Dominion Bureau of Statistics. As has been already mentioned, they constitute the average price over the entire period covered by the rotations, that is, from 1911 to 1926.

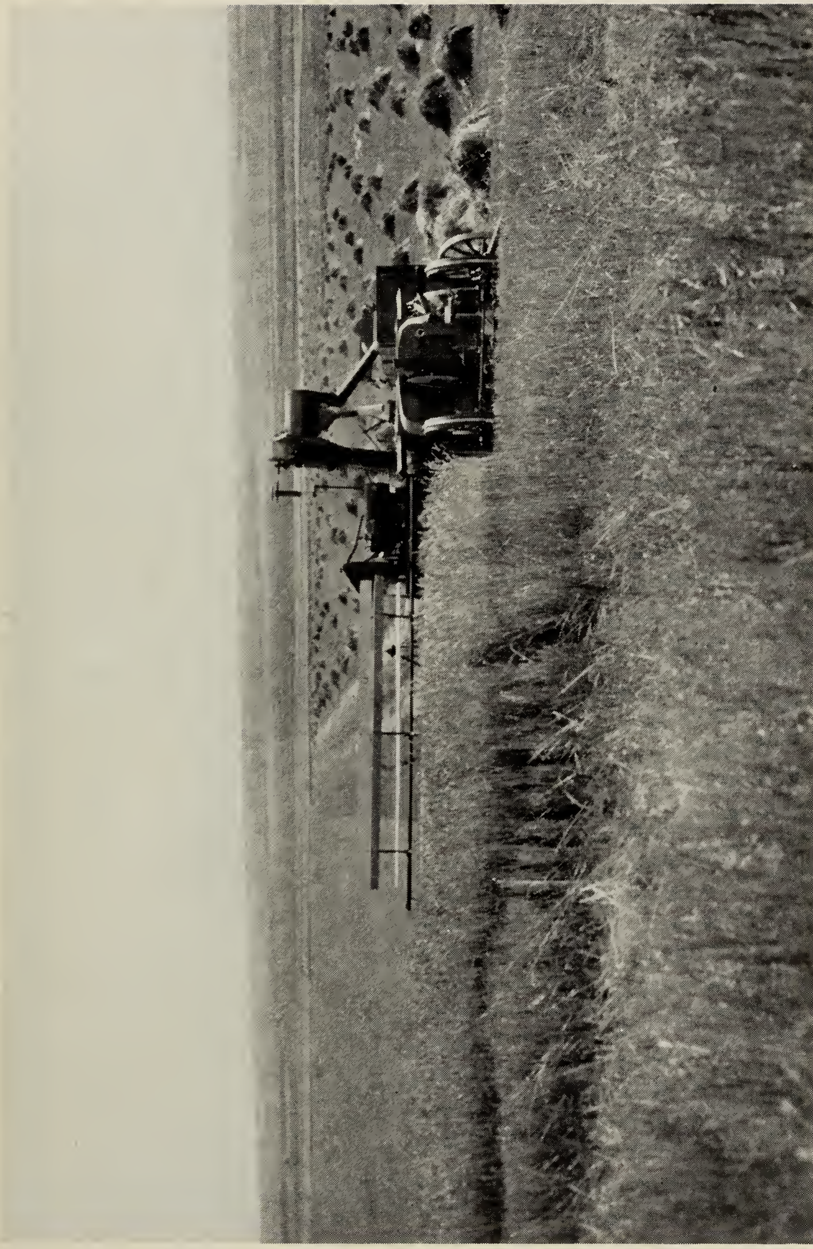
CROP VALUES USED ON VARIOUS FARMS

Station	Rent per acre	Wheat per bushel	Oats per bushel	Barley per bushel	Mixed Hay per ton
	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.
Brandon, Man.	3 25	1 21	0 44	0 62	10 92
Indian Head, Sask.	3 00	1 18	0 40	0 56	9 09
Rosthern, Sask.	2 50	1 18	0 40	0 56	9 09
Scott, Sask.	2 50	1 18	0 40	0 56	9 09
Lacombe, Alta.	3 25	1 11	0 39	0 55	11 64
Lethbridge, Alta.—					
Dry land	2 25	1 11	0 39	0 55	11 64
					Alfalfa
Irrigated land	6 00	1 11	0 39	0 55	11 64

CONTINUOUS WHEAT

In order to have some comparison between crops grown in rotations and a crop grown continuously, wheat has been grown on two Experimental Farms continuously, year after year, without the application of any manure or fertilizers, on the same land for fifteen years. While fair yields have been secured in favourable seasons by this system of cropping, dry seasons have resulted in failures. A very serious objection to continuous wheat growing is that weeds ultimately become so abundant that finally it becomes impossible to produce a profitable crop of wheat. Without a summer-fallow or an intertilled crop to provide an opportunity for thorough cultivation, or without a hay crop in the rotation, the weeds steadily increase and choke out the grain. Furthermore, such a system makes no provision for distributing labour throughout the season, the rush coming all in the spring and fall months.

The production of wheat continuously on the same land year after year without any rotation is very poor practice. On the Experimental Farm at Scott, Sask., during the last fifteen years, the plot of land in continuous wheat has averaged 14.8 bushels per acre while at Lethbridge, Alta., during the same period, it has averaged 13.1 bushels per acre. At Scott, the continuous wheat plot



In districts to which it is adapted, the combined reaper-thresher will save approximately ten cents a bushel in harvesting wheat.

was located close to a row of trees which caught some snow and has increased somewhat the yield of wheat per acre above that secured on land not influenced by the trees. At both farms, the land on which the continuous wheat has been grown has become exceedingly weedy.

TWO-YEAR ROTATION

First year: Summer-fallow
Second year: Wheat

First year: Summer-fallow	1928—Summer-fallow 1929—Wheat
Second year: Wheat	1928—Wheat 1929—Summer-fallow

This rotation divides the land into two parts, one-half being in summer-fallow and the other in wheat. It is adapted only to extremely dry regions where, in order to produce a profitable crop, it is necessary to conserve in the summer-fallow land as much moisture as possible. However, as one-half of the land is not producing a crop, this rotation is not as economical as a longer grain rotation in districts where more moisture is available. In the majority of dry regions a three-year rotation of summer-fallow, wheat, wheat, is most commonly used and in the next chapter, in which this rotation is described, a statement is presented showing under what circumstances the two-year or the three-year rotation is the more profitable.

The following table gives the average yields, cost of production, value and profit per acre, over a period of 15 years from 1912 to 1926, on the two-year rotation, on the dry land of the Dominion Experimental Station, Lethbridge, Alta. This land, which was broken in 1907, has never received any farmyard manure or commercial fertilizers.

TWO-YEAR ROTATION AT LETHBRIDGE

Rotation	Average yield per acre	Average cost per acre	Profit per acre on crop	Profit per acre on rotation
	bushels			
Summer-fallow: Wheat..............................	25·9	$17·19	$11·56	$5·78

It will be seen that the average yield of wheat from 1912 to 1926 inclusive has been 25·9 bushels per acre which is a very satisfactory yield. However, during this period of 15 years, the yield has varied all the way from 1·7 bushels per acre in 1919 to 60·2 bushels per acre in 1915. The yields during the latter years of the period seem to be quite as large as those secured when the rotation was commenced.

With wheat valued at $1.11 per bushel there has been a fairly substantial profit of $5.78 per acre. The cost of production was $17.19 per acre which included the cost of $7.10 per acre for summer-fallowing the land the previous year. As it required 11·06 hours of manual labour to handle one acre of summerfallow and to produce one acre of wheat, and as there was a profit of $11.56 on the rotation, one might reckon the return on the manual labour of $1.04 per hour, over and above the wages of 24 cents an hour which has already been included. That is to say, the profit which has been made on the rotation may, if it is desired, be credited to the labour. In other words, the total return for the labour has been $1.28 per hour.

On the Dominion Experimental Farm at Lacombe, Alberta, wheat after summer-fallow in the three-year grain rotation has averaged, over a period of thirteen years, 31.4 bushels per acre while wheat after wheat has averaged 19.0 bushels.

THREE-YEAR ROTATION

First year: Summer-fallow
Second year: Wheat
Third year: Oats.

First year: Summer-fallow	1928—Summer-fallow 1929—Wheat 1930—Wheat
Second year: Wheat	1928—Wheat 1929—Wheat 1930—Summer-fallow
Third year: Wheat	1928—Wheat 1929—Summer-fallow 1930—Wheat

In this rotation the land is divided into three equal areas, one-third being in summer-fallow, one-third in wheat seeded on summer-fallow land, and one-third in wheat seeded after wheat. This rotation is followed more extensively perhaps than any other throughout the greater part of the grain growing sections of the three Prairie Provinces. It has the advantages of providing a large area of wheat which in many districts is the most profitable crop and, by having a fair acreage of summer-fallow, it provides for the control of weeds and enables the farm labour to be distributed moderately well throughout the summer months although in this regard it is not so suitable as some of the mixed-farming rotations. The disadvantages of this rotation are that it makes no provision for the return of fertility to the soil, it predisposes in some districts towards soil drifting and, unless the land is well cultivated, there is danger of the weeds getting so numerous that wheat production may eventually become unprofitable.

In the drier parts of the Prairie Provinces, there is occasionally some discussion as to whether it would be wise to change the common three-year rotation of summer-fallow, wheat, wheat, to a two-year rotation of summer-fallow and wheat. The answer to this question depends upon a number of circumstances but under average conditions the three-year rotation is more profitable.

The most important point in deciding which of these two rotations is preferable, is the relative yield per acre on summer-fallow and on ploughed stubble land. It is obvious that if the yield on stubble land is only 50 per cent of that on fallow land, the two-year rotation would be preferable because there would be produced exactly the same number of bushels of grain on both rotations but, owing to the fewer acres seeded, the two-year rotation would entail less expense. However, it is uncommon for average yields, over a period of years, to show such differences between fallow and stubble land. On the various Dominion Experimental Farms, where accurate records have been kept for many years, the yields on ploughed stubble land have ranged from approximately 60 per cent to 85 per cent of the yields on summer-fallow. In individual years these percentages have varied widely and, of course, certain farms have consistently given different results from farms in other districts. On the whole, however, the yields on stubble land have been sufficiently high to make the three-year rotation more profitable than the two-year rotation.

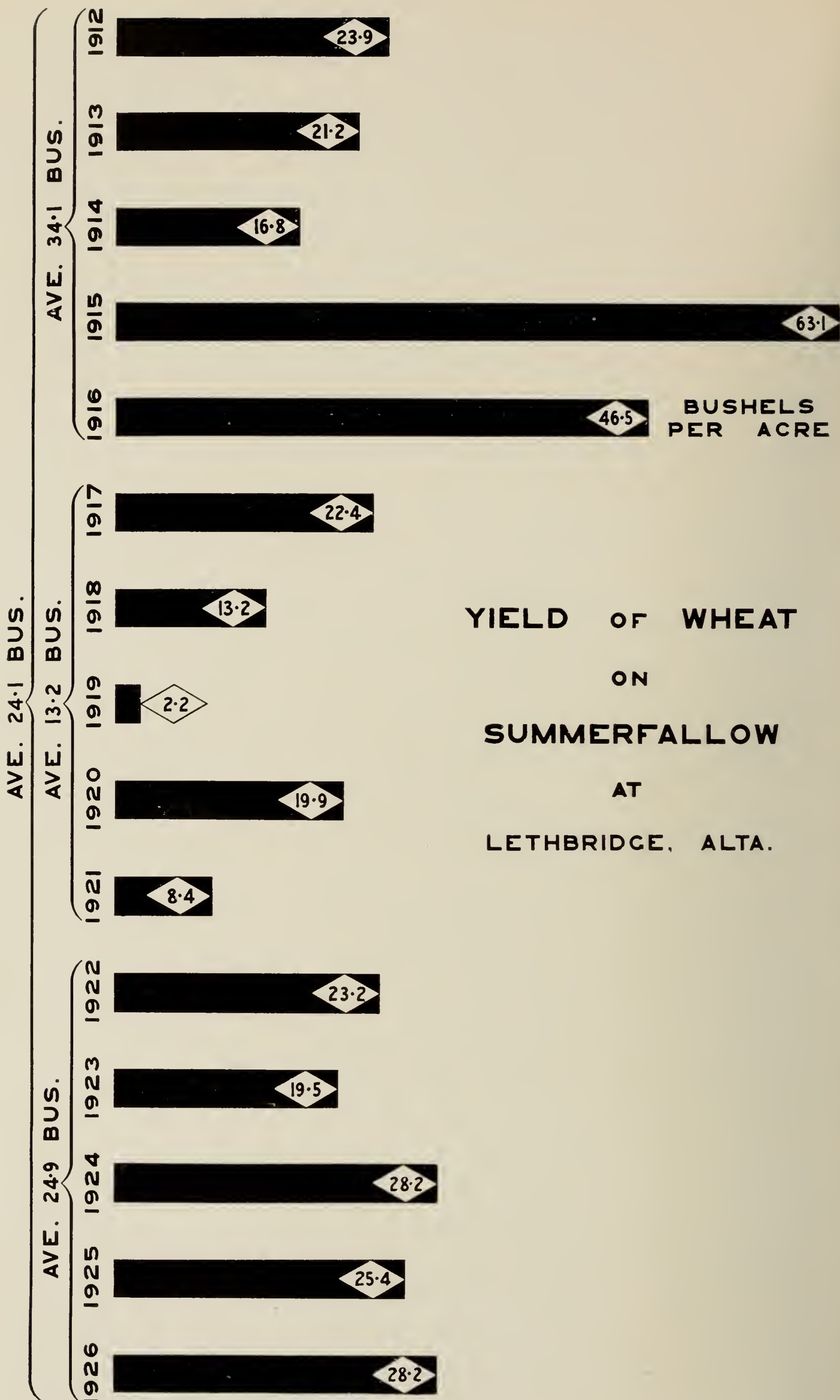
The next factor to consider in deciding between the two-year and the three-year grain rotations is the price of wheat. If the price is high the longer rotation will be more profitable because there will be a greater total production of wheat while, if the price is very low, the two-year rotation would be preferable. Another important point is the amount of labour available. If there is sufficient help and equipment to handle the three-year rotation, the larger acreage will supply a greater total gross revenue which will mean a larger farm income. However, if much spring ploughing has to be done, the seeding may be delayed incurring, in some districts, greater risk from rust and frost. The destruction of soil fibre is not so rapid with a summer-fallow every third year as with one every second year. There is also less danger of soil drifting on the three-year rotation. All things considered, the present custom of using a three-year grain rotation seems preferable in the great majority of districts to changing to a two-year rotation.

The following table gives the average yields, value, cost of production, and profit per acre on the three-year rotation conducted over a period of fifteen years on the Dominion Experimental Farms at Indian Head, Scott, Lacombe, and Lethbridge. No manure or fertilizers have been applied to this rotation.

RESULTS OF THREE-YEAR ROTATION

Station	Rotation Year	Average yield per acre	Average cost per acre	Profit on crop per acre	Profit on rotation per acre
		bushels	$ cts.	$ cts.	$ cts.
Indian Head, Sask.	Summer-fallow.				
	Wheat	28·0	19 53	13 51	
	Wheat	18·1	16 61	4 74	6 08
Scott, Sask.	Summer-fallow.				
	Wheat	19·2	14 32	8 33	
	Wheat	16·9	14 02	5 92	4 75
Lacombe, Alta.	Summer-fallow.				
	Wheat (13 years)	31·4	19 14	15 71	
	Wheat (13 years)	19·0	16 24	4 85	6 85
Lethbridge, Alta.	Summer-fallow.				
	Wheat	24·1	14 19	12 56	
	Oats (12 years)	38·7	12 68	4 41	5 66

Throughout the period of 15 years during which these rotations were conducted very satisfactory yields have been obtained on most of the farms. Moreover, with wheat valued at $1.18 per bushel on the Saskatchewan farms and at $1.11 on the Alberta farms very fair profits were secured. It will be understood, of course, that there have been some years when losses have been suffered but throughout the entire period, good profits were secured. It is easily possible to calculate at what price the wheat would have to sell to just break even. For example, at Indian Head the wheat on summer-fallow cost 70 cents per bushel to produce and on stubble land 92 cents per bushel.


1912
23·9
1913
21·2
1914
16·8
1915
63·1
1916
46·5
BUSHELS PER ACRE
1917
22·4
1918
13·2
1919
2·2
1920
19·9
1921
8·4
1922
23·2
1923
19·5
1924
28·2
1925
25·4
1926
28·2
AVE. 34·1 BUS.
AVE. 13·2 BUS.
AVE. 24·9 BUS.
AVE. 24·1 BUS.
YIELD OF WHEAT
ON
SUMMERFALLOW
AT
LETHBRIDGE, ALTA.

FOUR-YEAR ROTATION

First year: Summer-fallow.
Second year: Wheat.
Third year: Wheat.
Fourth year: Oats.

First year: Summer-fallow	1928—Summer-fallow 1929—Wheat 1930—Wheat 1931—Oats
Second year: Wheat	1928—Wheat 1929—Wheat 1930—Oats 1931—Summer-fallow
Third year: Wheat	1928—Wheat 1929—Oats 1930—Summer-fallow 1931—Wheat
Fourth year: Oats	1928—Oats 1929—Summer-fallow 1930—Wheat 1931—Wheat

In this rotation the land is divided into four equal areas, one-quarter being in summer-fallow, one-half in wheat, and one-quarter in oats. This rotation is employed in the moister areas of the prairie where grain farming is followed. As the land is summer-fallowed only once in four years, there is not as much opportunity as in the two preceding rotations, to control weeds and conserve moisture. However, in districts where there is more precipitation there is not the same necessity of conserving moisture.

The following table gives the average yields, value, cost of production and profit per acre, over a period of 14 years on this four-year rotation at the Dominion Experimental Farm, Brandon, Man. No manure or fertilizers have been applied to this rotation.

FOUR-YEAR ROTATION AT BRANDON

Rotation	Average yield per acre	Average cost per acre	Profit on crop per acre	Profit on rotation per acre
	bushels			
Summer-fall w Wheat	25·9	$18·17	$13·17	
Wheat (13 years)	18·0	16·37	5·41	$6·45
Oats (11 years)	43·4	13·87	7·23	

OTHER GRAIN ROTATIONS

The grain rotations which have previously been described have all been in operation for many years on one or more of the Dominion Experimental Farms. There has recently been commenced a few new rotations which may perhaps have some special advantage for certain particular conditions but which have not yet been in operation for sufficient time to warrant the expression of any definite opinion regarding them.

In extremely dry regions or, on particularly light, sandy soil, fall rye has been found to produce somewhat larger yields than wheat. Under such conditions a three-year rotation of summer-fallow, fall rye and fall rye has been used fairly satisfactorily. The main disadvantage of this rotation arises, unfortunately, from the relatively low price of fall rye compared with wheat which often more than offsets the advantage of the larger yields secured from the fall rye. In the more humid regions, the common three or four-year grain rotations, which have been previously described, have been slightly modified. After the summer-fallow, wheat is seeded for one or two years, as the case may be, and then fall rye is seeded in the fall on the wheat stubble rather than the usual practice of seeding oats the following year. This practice saves considerable labour, but it is not successful under dry conditions, the fall rye failing to make a good stand.

In the milder areas of southern Alberta, where fall wheat will give yields equal to those secured from spring wheat, as may be seen by referring to the nine-year rotation at Lethbridge described on page 21 fall wheat might be included in a grain rotation. A three-year rotation of summer-fallow, fall wheat, and spring wheat, might prove more profitable under these conditions than the usual three-year rotation which includes only the spring wheat. It must be remembered, however, that the southern Alberta area is the only area in Western Canada where fall wheat has, up to the present time, given profitable results.

MIXED FARMING ROTATIONS

All the rotations previously mentioned have been grain rotations in which no other type of crop has been included. However, the Dominion Experimental Farm system has experimented for many years not only with grain rotations but with what may be called mixed farming rotations. That is to say, these rotations have included such other crops as corn, sunflowers, roots, hay or pasture in addition to grain crops. The object has been to learn what yields of these crops could be obtained and how profitable they would be in comparison with straight grain rotations. Moreover, these mixed farming rotations afford a comparison as to the effects of these diverse cropping systems upon the productivity of the soil, its liability to drifting and the effectiveness of the different systems in the control of weeds. After the detailed statement has been given of the various mixed farming rotations which have been in progress for many years on some of the Dominion Experimental Farms an attempt will be made to discuss the relative advantages of mixed farming and grain rotations in the three prairie provinces.

FIVE-YEAR ROTATION

First year: Corn or summer-fallow.
Second year: Barley or oats.
Third year: Hay.
Fourth year: Wheat.
Fifth year: Wheat.

First year: Corn or fallow	1928—Corn or fallow 1929—Barley or oats 1930—Hay 1931—Wheat 1932—Wheat
Second year: Barley or oats	1928—Barley or oats 1929—Hay 1930—Wheat 1931—Wheat 1932—Corn or fallow
Third year: Hay	1928—Hay 1929—Wheat 1930—Wheat 1931—Corn or fallow 1932—Barley or oats
Fourth year: Wheat	1928—Wheat 1929—Wheat 1930—Corn or fallow 1931—barley or oats 1932—Hay
Fifth year: Wheat	1928—Wheat 1929—Corn or fallow 1930—Barley or oats 1931—Hay 1932—Wheat

In this mixed farming rotation, there are two-fifths of the land in wheat, one-fifth in hay, one-fifth in coarse grain, and one-fifth in corn. As this rotation has no provision for pasture, other pasture land would be required. A portion of the area in the first year of this rotation would ordinarily be handled as summer-fallow as there would be too much corn silage produced if one-fifth of the farm were in corn. Assuming a production of seven tons of corn per acre it is easily possible to figure the acreage of corn required. If 40 pounds of silage were fed per day to mature cattle 4 tons of silage would be necessary in a period of 200 feeding days for each animal. In other words, for 35 mature cattle 140 tons of silage would be required which would be grown on 20 acres of land if the corn yielded 7 tons per acre. While 7.03 tons of corn silage per acre has been the average yield on this rotation at Brandon over a period of 14 years, it would be wise to make provision for a smaller than average yield and use a somewhat larger acreage of corn. The land not seeded to corn could be summer-fallowed.

The manure which is produced on the farm should be applied for the corn crop; at Brandon an application of 12 tons per acre has been ploughed under for the corn crop. It should be applied on the wheat stubble and ploughed under for the corn crop. If bad weeds are present on the farm, it is preferable to rot the manure so as to kill the weed seeds. The hay crop which has been used in this rotation at Brandon has consisted of a mixture of alfalfa and western rye grass. Only one cutting of hay is taken each year after which the sod land is ploughed and kept cultivated for the remainder of the season in preparation for the wheat crop the following year. As the hay remains only one year in the rotation, it would be possible and somewhat cheaper, to seed the biennial sweet clover along with western rye grass.

Where corn has been grown the previous year, discing the corn stubble has given as large a yield of grain as ploughing and at less cost.

The following table gives the average yields, values, cost of production and profit per acre over a period of 14 years on this five-year mixed farming rotation at the Dominion Experimental Farm, Brandon, Man.

FIVE-YEAR ROTATION AT BRANDON

Rotation	Average yield per acre	Average cost per acre	Profit on crop per acre	Profit on rotation per acre
		$ cts.	$ cts.	$ cts.
1. Corn	7·03 tons	24 17	1 42	
2. Barley	39·4 bush.	13 23	13 20	
3. Hay (12 years)	1·23 tons	11 22	2 21	8 17
4. Wheat (13 years)	26·6 bush.	16 21	15 97	
5. Wheat (12 years)	18·8 bush.	14 68	8 06	

The average profit on this mixed farming rotation at Brandon was $8.17 per acre. This is considerably larger than the profit of $6.45 secured at Brandon on the four-year grain rotation of summer-fallow, wheat, wheat and oats. The reasons for the better results from the mixed farming rotation at Brandon consist in the elimination of the summer-fallow, the substitution of corn, and the periodical dressings of farm manure. As corn does fairly well at Brandon a small profit was made from the corn land. The barley was also a fairly profitable crop being uninjured by rust.

SIX-YEAR ROTATION

First year: Summer-fallow
Second year: Wheat
Third year: Wheat
Fourth year: Oats
Fifth year: Hay
Sixth year: Pasture

In this mixed farming rotation, there is one-third of the land in wheat, one-sixth in coarse grain, one-sixth in hay, one-sixth in pasture, and one-sixth in summer-fallow.

There is one disadvantage with this rotation in that the grass is seeded with the third grain crop after summer-fallow which is liable to be weedy and the soil on which it is growing has no reserve of soil moisture. It is usually preferable to seed grass with the first grain crop after summer-fallow or corn. It must be said that at Scott where this rotation has been under test for 16 years no trouble has been experienced in getting a stand of grass. At Rosthern, however, considerable difficulty has been encountered; in a period of eleven years, there were three years when the hay was a complete failure and three additional years when it was possible to replace the hay with oats. A small modification of this rotation might be made by seeding a portion of the summer-fallow land to corn or sunflowers. This arrangement would provide additional feed and give more net returns from the land.

The following table gives the average yields, values, cost of production and profit per acre on this six-year rotation at the Dominion Experimental Station, Rosthern, Sask., over a period of 14 years, and at Scott, Sask., over a period of 16 years. In these rotations no application of manure has been made.

SIX-YEAR ROTATION AT ROSTHERN AND SCOTT

Station	Rotation year	Average yield per acre	Average cost per acre	Profit on crop per acre	Profit on rotation per acre
			$ cts.	$ cts.	$ cts.
Rosthern, Sask.	1. Summer-fallow				
	2. Wheat	25·4 bush.	15 85	14 12	
	3. Wheat	18·3 bush.	13 60	7 99	4 93
	4. Oats (13 years)	40·6 bush.	9 98	8 26	
	5. Hay (10 years)	0·6 tons	5 98	−0 53	
	6. Hay (11 years)	0·73 tons	6 86	−0 23	
Scott, Sask.	1. Summer-fallow.				
	2. Wheat	23·9 bush.	15 56	12 64	
	3. Wheat (10 years)	20·2 bush.	14 61	9 22	
	4. Oats	43·1 bush.	10 93	8 31	5 60
	5. Hay (9 years)	0·94 tons	6 89	1 65	
	6. Pasture	....	4 71	1 79	

Minus signs (—) indicate losses.

A study of the above table will show the average yields of the various crops which have been obtained at Rosthern over a period of 14 years and at Scott over a period of 16 years. These yields will afford a fairly reliable guide as to what average yields may be expected over a long period of years. It will be understood, of course, that wide variations frequently occur in individual years from these average yields. The table also shows what crops have given the most profit.

SIX-YEAR ROTATION

First year: Corn and Summer-fallow
Second year: Wheat
Third year: Barley
Fourth year: Hay
Fifth year: Hay
Sixth year: Hay or pasture

This rotation devotes one-half of the area to hay or pasture, one-sixth to wheat, one-sixth to barley and one-sixth to corn or summer-fallow. There could be seeded whatever acreage of corn would be required and the remaining acreage in the first year of the rotation could be handled as summer-fallow. The manure which is produced on the farm should be applied for the corn crop; at Lacombe an application of 15 tons per acre has been given. There is possibly a larger acreage in hay in this rotation than would be required on most farms. If this were the case, the sixth year in the rotation could be seeded to a cereal crop, the land being ploughed the preceding summer after one cut of hay had been removed, and cultivated during the remainder of the season.

The following table gives the average yields, values, cost of production and profit per acre, over a period of 15 years on this six-year rotation at the Dominion Experimental Station, Lacombe, Alta.

SIX-YEAR ROTATION AT LACOMBE

Rotation	Average yield per acre	Average cost per acre	Profit on crop per acre	Profit on rotation per acre
		$ cts.	$ cts.	$ cts.
1. Corn (5 years)	7·27 tons	36 92	−8 72	
2. Wheat (15 years)	29·1 bush.	15 71	16 59	
3. Barley (16 years)	30·6 bush.	14 71	4 12	3 10
4. Hay (14 years)	1·35 tons	11 49	4 21	
5. Hay (3 years)	1·09 tons	10 78	1 89	
6. Hay (3 years)	0·98 tons	10 87	0 53	

The results of this rotation show what average yields of corn, wheat, barley and hay may be expected over a long period of years at Lacombe. The profit from this rotation at Lacombe has not been as large as from the three-year grain rotation.

SIX-YEAR ROTATION

First year: Corn and summer-fallow
Second year: Wheat
Third year: Hay
Fourth year: Pasture
Fifth year: Wheat
Sixth year: Oats

In this rotation there is one-third of the acreage in wheat, one-sixth in oats, one-sixth in hay, one-sixth in pasture and one-sixth in corn or summer-fallow. This mixed farming rotation gives a very satisfactory acreage of the various crops. It makes provision for the seeding of hay with wheat on corn or fallow ground which is the best place in the rotation to ensure a stand of grass. The pasture land is ploughed and worked as soon as the hay crop in the third year of the rotation has been harvested; thereby giving a partial summer-fallow for this land. However, in very dry areas such a partial summer-fallow after a hay crop does not conserve sufficient moisture for a good crop of wheat the following year but in many districts it gives very good results.

SIX-YEAR ROTATION

First year: Summer-fallow.
Second year: Wheat.
Third year: Oats.
Fourth year: Summer-fallow.
Fifth year: Peas and oat hay.
Sixth year: Oats.

This is a mixed farming rotation which has been tried in a dry district where the usual perennial hay crops, such as Western rye, brome grass and alfalfa, do not give satisfactory results on unirrigated land. A mixture of peas and oats is used, therefore, as a substitute for the usual perennial hay crops. In the very dry regions, perennial hay crops do not give satisfactory results either failing in many years to give a stand or becoming dried up by drought. There is only one wheat crop in this rotation which is not a good arrangement for the better wheat producing areas but, near the foot hills, where the frost free period is shorter, this rotation may be of some value. The high cost of seed peas is also a drawback in this rotation but it could be overcome by producing sufficient seed peas on the farm.

The following table gives the average yields, values, cost of production and profit per acre on this six-year rotation over a period of fifteen years, from 1912 to 1926, at the Dominion Experimental Station, Lethbridge, Alta. Twelve tons of manure per acre have been applied to the summer-fallow in the fourth year of the rotation. To produce this quantity of manure would necessitate the feeding of crops which have been grown on other land.

SIX-YEAR ROTATION AT LETHBRIDGE

Rotation	Average yield per acre	Average cost per acre	Profit on crop per acre	Profit on rotation per acre
		$ cts.	$ cts.	$ cts.
1. Summer-fallow.				
2. Winter wheat	24·2 bush.	18 42	8 44	
3. Oats (14 years)	38·7 bush.	16 61	0 48	
4. Summer-fallow	......	......	......	2 53
5. Peas and oat hay	2·22 tons	21 32	4 50	
6. Oats	43·7 bush.	17 26	1 78	

The returns show that wheat has been the most profitable crop of any used in this rotation. A mixture of peas and oats has been used for hay owing to the very low yields which are secured at Lethbridge from such perennial hay crops as brome and western rye grass.

SIX-YEAR ROTATION

First year: Corn and summer-fallow.
Second year: Oats.
Third year: Oats.
Fourth year: Barley.
Fifth year: Hay.
Sixth year: Pasture.

This mixed farming rotation has been tried in a district where rust has seriously affected profitable wheat production. In this rotation wheat has been omitted entirely and coarse grains substituted. Whatever acreage in the first year of the rotation is not required in corn is handled as summer-fallow. The hay and pasture consist of a mixture of western rye grass and alfalfa. The rotation has not been in operation a sufficient length of time to know how it will compare with other rotations which include wheat.

SEVEN-YEAR ROTATION

First year: Intertilled crop.
Second year: Wheat.
Third year: Oats.
Fourth year: Summer-fallow.
Fifth year: Barley.
Sixth year: Hay.
Seventh year: Pasture.

This mixed farming rotation devotes one-seventh of the land to wheat, two-sevenths to coarse grains, and one-seventh to each of hay, pasture, summer-fallow and intertilled crop. A mixture of western rye grass and alfalfa is employed as the hay crop in this rotation. If one-seventh of the area were too large for the intertilled crop a part of the acreage could be handled as summer-fallow. During the last four years at Lacombe, the barley crop in the fifth year in the rotation has been replaced by wheat, which at the prices used in this bulletin gives more profit than barley. However, as the barley was used for a period of 12 years the figures for it are being used in this bulletin.

The following table gives the average yields, values, cost of production and profit per acre on this seven-year rotation from 1911 to 1926 at the Dominion Experimental Station, Lacombe, Alta. An application of 15 tons of manure per acre has been applied to the sod and fall ploughed for the benefit of the potato crop.

SEVEN-YEAR ROTATION AT LACOMBE

Rotation	Average yield per acre	Average cost per acre	Profit on crop per acre	Profit on rotation per acre
		$ cts.	$ cts.	$ cts.
1. Potatoes (7 years)	232·1 bush.	60 59	83 31	16 16
2. Wheat (15 years)	34·1 bush.	15 68	22 17	
3. Oats (16 years)	55·5 bush.	16 10	7 54	
4. Summer-fallow	....	....	....	
5. Barley (12 years)	38·6 bush.	21 66	1 57	
6. Hay (13 years)	1·41 tons	15 52	0 88	
7. Pasture	....	9 81	−2 31	

In calculating the returns from this rotation, potatoes have been figured at 62 cents per bushel which accounts for the very high returns secured. This price represents the average price stated by the Dominion Bureau of Statistics for the province of Alberta from 1912 to 1926. It would not be wise in planning a rotation to expect such a price for potatoes in the future or to assume that the market would always absorb all the potatoes produced.

EIGHT-YEAR ROTATION

First year: Summer-fallow.
Second year: Wheat.
Third year: Wheat.
Fourth year: Summer-fallow.
Fifth year: Intertilled crop.
Sixth year: Barley or oats.
Seventh year: Hay.
Eighth year: Pasture.

This mixed farming rotation divides the land into eight fields. There is one-quarter of the acreage in each of wheat and summer-fallow and one-eighth in each of intertilled crop, coarse grain, hay and pasture. This rotation has such an arrangement of the crops that it is very similar to a combination of two rotations, the first three years of the rotation being similar to the usual three-year grain rotation while the last five years are similar to a five-year mixed farming rotation.

The following table gives the average yields, values, cost of production and profit per acre, over a period of 13 years on this eight-year rotation at the Dominion Experimental Station, Rosthern, Sask. An application of 15 tons of manure per acre has been made before ploughing the summer-fallow for the benefit of the turnips.

EIGHT-YEAR ROTATION AT ROSTHERN

Rotation	Average yield per acre	Average cost per acre	Profit on crop per acre	Profit on rotation per acre
		$ cts.	$ cts.	$ cts.
1. Summer-fallow	....	....	....	2 25
2. Wheat	27·3 bush.	18 53	13 68	
3. Wheat	18·7 bush.	16 00	6 06	
4. Summer-fallow	....	....	....	
5. Turnips	14·12 tons	29 63	−8 31	
6. Barley	35·1 bush.	15 20	6 45	
7. Hay (11 years)	0·75 tons	7 95	−1 14	
8. Hay (11 years)	1·08 tons	8 50	1 31	

The results from this rotation indicate that, at the values used in this bulletin, wheat has given the largest profit of any of the crops, followed in order, by barley and hay. The turnips were produced at a loss which was due in part to the extra expense of being seeded on the summer-fallow land without securing a proportionately increased yield. It is usually not profitable to seed an intertilled crop on summer-fallow land. In the hay crop, in the seventh year of the rotation, there have been five complete failures and two additional failures where the hay was replaced by grain. In the hay crop in the eighth year of the rotation there were three complete failures and two additional hay failures when it was possible to replace the hay with grain. These results indicate the difficulties in hay production in some localities.

NINE-YEAR ROTATION

First year: Summer-fallow
Second year: Corn or sunflowers
Third year: Wheat
Fourth year: Oats
Fifth year: Summer-fallow
Sixth year: Wheat
Seventh year: Oats
Eighth year: Hay
Ninth year: Hay

In this rotation there are two-ninths of the area in wheat, two-ninths in hay or pasture, two-ninths in oats, two-ninths in summer-fallow, and one-ninth in corn or summer-fallow. A slight modification in this rotation was made at Indian Head in which, instead of having a summer-fallow in the first year of the rotation, a crop of hay was cut off this land after which it was ploughed and cultivated during the remainder of the season. This modification will usually increase the returns from the rotation.

The following table gives the average yields, values, cost of production and profit per acre on this rotation over a period of 16 years on the Dominion Experimental Farm at Indian Head, Saskatchewan. Manure has been applied to the corn crop at the rate of 12 tons per acre.

NINE-YEAR ROTATION AT INDIAN HEAD

Station	Rotation year	Average yield per acre	Average cost per acre	Profit on crop per acre	Profit on rotation per acre
			$ cts.	$ cts.	$ cts.
Indian Head, Sask.	1. Hay (8 years)	1·44 tons	9 25	3 83	
	2. Corn (14 years)	10·43 tons	38 07	−6 47	
	3. Wheat	33·4 bush.	17 91	21 50	
	4. Oats	52·2 bush.	15 83	7 05	
	5. Summer-fallow	....	....	....	6 35
	6. Wheat	37·1 bush.	23 06	20 71	
	7. Oats	46·0 bush.	18 54	1 86	
	8. Hay	1 27 tons	9 19	2 35	
	9. Hay (7 years)	1·73 tons	9 38	6 34	

An examination of the yields secured in this rotation affords a useful reference as to what yields may be expected in the future. The table shows also what crops have given the largest profits over this period of years.

NINE-YEAR ROTATION

First year: Summer-fallow
Second year: Corn
Third year: Spring wheat
Fourth year: Summer-fallow
Fifth year: Fall wheat
Sixth year: Oats
Seventh year: Summer-fallow
Eighth year: Peas and oat hay
Ninth year: Rye pasture

This mixed farming rotation has been arranged for a dry area where perennial hay crops, such as western rye, brome grass and alfalfa, do not give satisfactory results. A mixture of peas and oats has been used for hay, and fall rye has been used for pasture. It will be observed that fall wheat has given as large a yield as spring wheat in this rotation over a period of sixteen years. However, the fall wheat was seeded on summer-fallow land while the spring wheat was seeded after corn which would give the fall wheat a somewhat better chance. In another rotation at Lethbridge which has been in progress for 16 years fall wheat seeded on summer-fallow has averaged 27.0 bushels per acre while spring wheat seeded on corn land has yielded only 20.9 bushels per acre. In the two and three-year grain rotations, spring wheat has averaged on summer-fallow land, over a period of fifteen years, 25.9 and 24.1 bushels per acre respectively. It would seem that on the dry land around Lethbridge as large a yield of fall wheat could be expected as of spring wheat. As fall wheat is very useful in checking soil drifting a certain area of this crop might prove very profitable in districts where fall wheat will grow satisfactorily. As there are three summer-fallows in this nine-year rotation a good opportunity is afforded to control weeds.

The following table gives the average yields, values, cost of production and profit per acre on this rotation over a period of 15 years at the Dominion Experimental Station, Lethbridge, Alta. An application of 12 tons of manure per acre has been applied to the summer-fallow preceding the corn crop.

NINE-YEAR ROTATION AT LETHBRIDGE

Rotation	Average yield per acre	Average cost per acre	Profit on crop per acre	Profit on rotation per acre
		$ cts.	$ cts.	$ cts.
1. Summer-fallow	......	......	......	2 36
2. Corn	7·79 tons	29 69	0 53	
3. Spring wheat (13 years)	25·1 bush.	15 46	12 40	
4. Summer-fallow	......	......	......	
5. Fall wheat	25·5 bush.	18 34	9 96	
6. Oats	38·0 bush.	15 73	1 09	
7. Summer-fallow	......	......	......	
8. Peas and oat hay	2·0 tons	20 81	2 45	
9. Fall rye pasture (13 years)	......	12·62	−5 12	

By comparing the returns of this rotation at Lethbridge with those of the three-year grain rotation given on page 9, it will be seen that the three-year grain rotation has been considerably more profitable. However, in the case of the fall rye pasture in this rotation it is almost impossible to set a correct estimate of its value; perhaps if some harvested crop had been grown instead of the rye pasture, a larger profit would have been secured.

ROTATIONS FOR IRRIGATED LAND

CONTINUOUS ALFALFA (Irrigated)

For a period of thirteen years, a stand of alfalfa was grown on the same piece of land without ploughing or re-seeding. The average yield of alfalfa over this period of thirteen years was 3.93 tons per acre. Valuing the alfalfa at $11.64 per ton there was a total return of $45.74 per acre. The total cost of production averaged $12.97 per acre leaving a profit of $32.77 per acre. However, the returns from this continuous stand of alfalfa have not been as large as those secured from the ten-year rotation, in which six years were in alfalfa, three in grain and one in intertilled crop.

Irrigated land. on the Dominion Experimental Farm at Lethbridge, Alberta, has averaged, over a period of sixteen years, 46.0 bushels of wheat per acre, 89.0 bushels of oats, 52.1 bushels of barley, and 495.0 bushels of potatoes. Alfalfa has averaged 3.66 tons per acre.

TEN-YEAR ROTATION (Irrigated)

First year: Potatoes or sugar beets
Second year: Wheat
Third year: Oats
Fourth year: Barley
Fifth year: Alfalfa
Sixth year: Alfalfa
Seventh year: Alfalfa
Eighth year: Alfalfa
Ninth year: Alfalfa
Tenth year: Alfalfa

This irrigated rotation has six-tenths of the area in alfalfa, three-tenths in grain and one-tenth in potatoes or sugar beets. The potatoes were grown for a period of twelve years and the sugar beets for a period of four years. This rotation has given very satisfactory results. An application of 12 tons of manure to the acre has been given to the alfalfa, the year preceding the inter-tilled crop. The other crops were grown for the entire period of sixteen years.

The following table gives the average yields, values, cost of production and profit per acre on this ten-year irrigated rotation over a period of 16 years at the Dominion Experimental Station, Lethbridge, Alta.

TEN-YEAR ROTATION (IRRIGATED) AT LETHBRIDGE

Rotation	Average yield per acre	Average cost per acre	Profit on crop per acre	Profit on rotation per acre
	bushels	$ cts.	$ cts.	$ cts.
1. Potatoes (12 years)	495·5	84 30	222 91	
2. Wheat	46·0	20 17	30 89	
3. Oats	89·0	20 94	15 77	
4. Barley	52·1	18 92	11 73	
	tons			
5. Alfalfa (15 years)	1·89	13 75	8 25	44 54
6. Alfalfa	3·54	15 28	25 92	
7. Alfalfa	3·82	15 06	29 40	
8. Alfalfa	4·07	15 51	31 86	
9. Alfalfa	4·24	15 68	33 67	
10. Alfalfa	4·40	16 26	34 96	

It will be observed that the average yield of potatoes on irrigated land over a period of 12 years, was 495.5 bushels per acre. At the price of 62 cents per bushel, which was the average price over that period, there was a very large profit secured on the potatoes. However, it would be unsafe to expect this price in making calculations for the future. For a period of four years sugar beets were grown instead of potatoes. During this period the sugar beets gave an average yield of 10.93 tons per acre with an average value of $80.33 per acre. As the cost of producing the sugar beets was $52.68 per acre there was a net profit of $27.65 per acre. The high average yields of all the crops in this irrigation rotation are worthy of special notice.

FIFTEEN-YEAR ROTATION (Irrigated)

First year: Barley
Second year: Corn—12 tons of manure
Third year: Wheat
Fourth year: Oats
Fifth year: Peas
Sixth year: Alfalfa
Seventh year: Alfalfa
Eighth year: Alfalfa
Ninth year: Alfalfa
Tenth year: Alfalfa
Eleventh year: Alfalfa
Twelfth year: Alfalfa
Thirteenth year: Alfalfa
Fourteenth year: Alfalfa
Fifteenth year: Alfalfa

This fifteen-year irrigated rotation has two-thirds of its area in alfalfa and the other third divided into five equal parts to produce barley, corn, wheat, oats and peas. This rotation is really a rotation within a rotation. Instead of breaking up one field of alfalfa each year and seeding down one field each year, the breaking and seeding are done once in five years at which time five fields are handled at a time. Under this arrangement the land is in alfalfa for ten years before it is broken. After it has been broken, a rotation of barley, corn, wheat, oats and peas is followed for five years when the land is seeded back to alfalfa and another five fields of alfalfa are broken and so rotated. Manure has been applied to the corn crop at the rate of 12 tons per acre.

The following table gives the average yields, values, cost of production and profit per acre on this fifteen-year rotation at the Dominion Experimental Station, Lethbridge, Alberta.

FIFTEEN-YEAR ROTATION (IRRIGATED) AT LETHBRIDGE

Rotation	Average yield per acre	Average cost per acre	Profit on crop per acre	Profit on ro ations per acre
		$ cts.	$ cts.	$ cts.
1. Barley (13 years)	40·9 bush.	18 24	6 25	
2. Corn	7·69 tons	29 11	0 73	
3. Wheat	33·9 bush.	19 24	18 39	
4. Oats	60·8 bush.	18 71	7 00	
5. Peas	18·7 bush.	22 90	9 82	
6. Alfalfa (10 years)				
7. Alfalfa				
8. Alfalfa	3·02 tons	12 58	22 57	18 25
9. Alfalfa				
10. Alfalfa				
11. Alfalfa (12 years)				
12. Alfalfa				
13. Alfalfa	3·10 tons	12 34	23 74	
14. Alfalfa				
15. Alfalfa				

The yields on this fifteen-year rotation have not equalled those of the preceding ten-year rotation largely on account of the fact that there has not been as much irrigation water available for it. Furthermore, the potato crop in the ten-year rotation gave a very much higher profit than the corn in the fifteen-year rotation. It must be remembered, moreover, in connection with both of these rotations, that the alfalfa has been figured at $11.64 per ton but in some years there is no market for alfalfa, at this price. In order to be safe persons devoting such a large acreage of their land to alfalfa should make provision for feeding a considerable portion on their own farm.

THE VALUE OF AN ANNUAL CROP PLAN OF THE FARM

In order to keep a record of what crops have been grown each year on all the fields or various parts of the farm, it is desirable to draw each year a small plan of the farm. On this plan may be written the crops which have been grown on each field or part of the farm and the yields per acre which have been obtained. If desired, such additional information may be recorded as dates of ploughing, seeding and harvesting. When this plan is made every year, it facilitates the following without error of any rotation which may be desired. It enables one to learn what fields produce the largest yields of certain crops, providing information to enable the improvement of the rotation along the line of adapting certain crops to soils to which they are suited. Observations may be recorded regarding the presence of weeds in various parts of the farm, where soil drifting has occurred, where manure has been applied and any other points of interest. Above all, such a plan provides a definite record of the results of each year's work on the land and over a period of years is very instructive. Farming is a long-time business and records are necessary if much improvement is likely to be made.

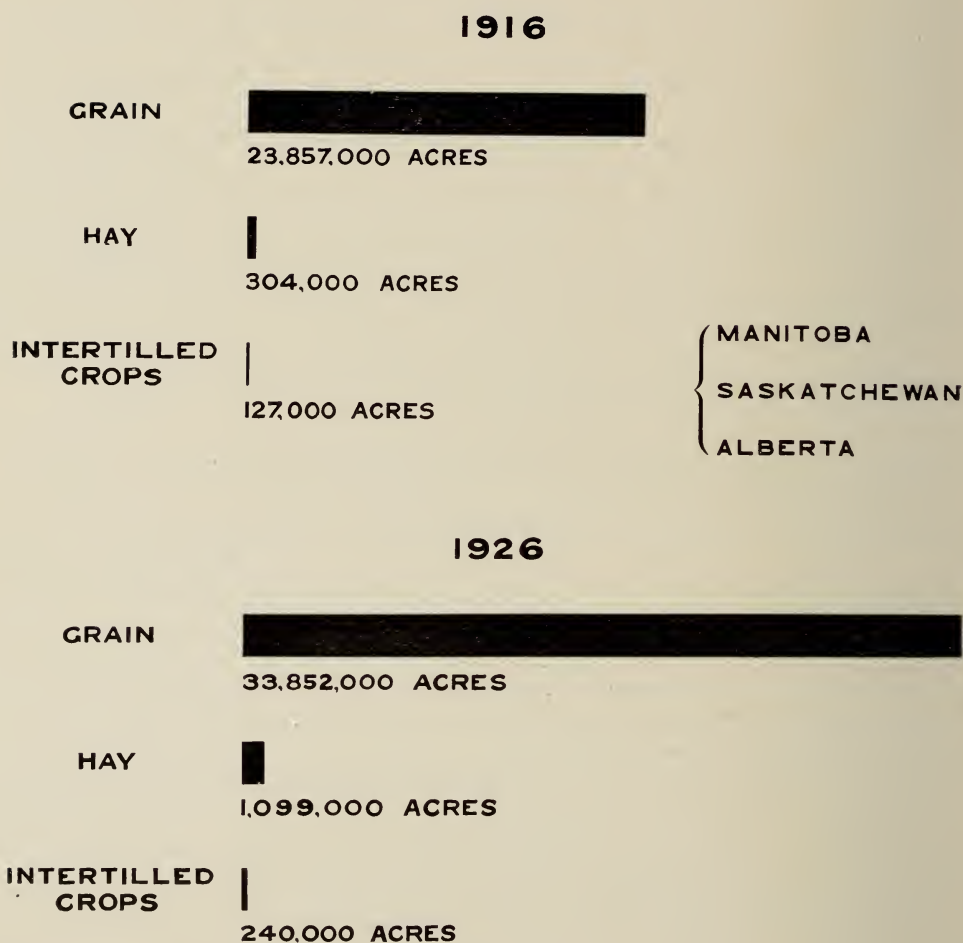
Such a plan may be drawn in a book so that many years' records will be kept easily available. It is possible to use a few pages in the book to make a record of all cash receipts and expenditures and to record once a year an inventory of the value of all the equipment, livestock and crops on the farm. These records, together with the cropping plan of the farm, give accurate information of each year's progress on the farm and are the best means of studying how to improve the farm business. No commercial enterprise would consider the conduct of 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 easy to do. If a more elaborate system of accounting is desired, it may be adopted later.

ADVANTAGES OF MIXED FARMING AND GRAIN ROTATIONS

Before discussing the relative merits of mixed farming and grain rotations it may not be out of place to define what is meant by these two types of rotations. A grain rotation is understood to be any rotation from which the farm derives a large percentage of its revenue from grain. While it is difficult to fix any definite percentage, it is usually assumed that 50 per cent or more of the income should be derived from one source to designate the particular type of farming. A mixed farming rotation, sometimes called diversified rotation, is one in which several types of crops are grown and where the farm does not derive 50 per cent of its revenue from one source. It is obvious that these two systems gradually grade into each other and the figure of 50 per cent is purely arbitrary. The object, however, of defining what is meant by the term mixed farming is to avoid the confusion arising from including as mixed farming any farm where a small percentage of the income, such as, say, 10 to 20 per cent, is secured from sources other than grain. It is clear that such percentages are relatively insignificant compared with the source from which the main part of the revenue is derived.

While it is impossible to make an absolutely definite comparison between mixed farming and grain rotations, it is useful to make as close a comparison as is possible under the circumstances. These two types of rotations have been grown side by side on several Experimental Farms for a period of fifteen years and afford a fair idea of what yields of the various crops may be expected and

COMPARATIVE ACREAGES OF VARIOUS KINDS OF CROPS



what profits may be obtained from them. Accurate records have been kept of the cost of producing these crops and information is available regarding the market price of hay and grain. With such crops as corn for silage and roots, which have no market price, their value has been based on the value of hay, three pounds of silage or six pounds of roots being regarded as equal in value to one pound of hay.

Undoubtedly some criticisms may be offered against cost of production figures on crops in rotations. Some crops are handled at a season of the year when other work is not pressing and, therefore, even though these crops do not pay very much per hour for the labour spent upon them, nevertheless, it is claimed by some to be better to work for a small wage per hour than to have no work at all available at this particular season of the year. However, it is well to know definitely just how much one is securing for his work with various crops so that, with the aid of this information, it might be possible to increase the acreage of the more profitable crops. There is also the factor of additional expense required as equipment for mixed farming rotations but this item has not been included in these calculations.

The following table gives a comparison between the profit per acre on grain and on mixed farming rotations at Brandon, Indian Head, Scott, Lacombe, and Lethbridge. The figures have been taken from the more detailed statements regarding these rotations which have already been given in this bulletin.

PROFITS FROM GRAIN AND MIXED FARMING ROTATIONS

Farm	Rotation	Profit per acre on rotation
		$ cts.
Brandon	4-year—Summer-fallow, wheat, wheat, oats	6 45
	5-year—Corn, barley, hay, wheat, wheat	8 17
Indian Head	3-year—Summer-fallow, wheat, wheat	6 08
	9-year—Hay, corn, wheat, oats, summer-fallow, wheat, oats, hay, hay	6 35
Scott	3-year—Summer-fallow, wheat, wheat	4 75
	6-year—Summer-fallow, wheat, wheat, oats, hay, pasture	5 60
Lacombe	3-year—Summer-fallow, wheat, wheat	6 85
	6-year—Corn, wheat, barley, hay, hay, hay	3 10
Lethbridge	3-year—Summer-fallow, wheat, oats	5 66
	6-year—Summer-fallow, wheat, oats, summer-fallow, peas and oat hay, oats	2 53

The above table shows that at Brandon, Indian Head and Scott, a small advantage has been obtained from the mixed farming rotations while at Lacombe and Lethbridge substantially larger profits have been secured from the grain rotations. It might seem that in the more easterly portion of the prairie mixed farming rotations were superior while further west grain rotations were preferable. There are some reasons for this. The easterly portion of the prairie is very much more subject to rust which injures both the yield and quality of wheat while not affecting other types of crops grown in the mixed farming rotations. Corn and hay crops have given better results in the more easterly portions of the prairie. Some localities seem better adapted to one type of farming than to the other and, generally speaking, it is not wise to attempt to grow too large an acreage of any crop that has not yet proved its suitablity to a district.

At Brandon, the five-year mixed farming rotation has given good results. It has eliminated the expense of the summer-fallow, and the corn, barley and hay have given very fair returns. At Indian Head, in the nine-year mixed farming rotation, the average yield of wheat on summer-fallow, over a period of fifteen years, was 36.4 bushels per acre while in the three-year grain rotation the yield of wheat on fallow was 28.0 bushels per acre. However, during the first five years of the rotation experiments, the nine-year rotation gave a yield of wheat on fallow of 39.2 bushels per acre while, for the same period, the yield of wheat on fallow, in the three-year rotation was only 28.8 bushels per acre. Possibly the soil on which the three-year rotation is located is not as fertile. At Scott the six-year mixed farming rotation has given somewhat larger returns than the three-year grain rotation. The yields of wheat have been greater and there has been a smaller percentage of summer-fallow. In an eight-year mixed farming rotation at Scott which adjoins the three-year grain rotation the yields of wheat are very nearly equal but the profit from it is only 83 cents per acre as compared with $4.75 per acre in the grain rotation and $5.60 per acre in the six-year mixed farming rotation. The eight-year mixed farming rotation consists of summer-fallow, wheat, wheat, summer-fallow, sunflowers, barley, hay, hay. The reason for the smaller profit on this rotation compared with that secured from the six-year rotation is due to smaller yields of wheat, to the fact that the sunflower crop was not profitable being grown on summer-fallow land, and to a charge for manure while on the six-year rotation no manure was applied. It would appear as though the land on which the six-year rotation was grown was naturally more productive.

At Lethbridge, the grain rotations on the dry farm have given substantially larger profits than the mixed farming rotations. In fact, at Lethbridge it is difficult to establish mixed farming rotations owing to the almost impossibility of growing profitable hay crops. Indeed a mixture of peas and oat hay rather than the usual perennial hay crops is used in the mixed farming rotations at Lethbridge.

At Lacombe the three-year grain rotation has given very much larger returns than the six-year mixed farming rotations. The poor results with this six-year rotation may be due to there being too large a proportion of the acreage in hay, one-half of the land being in hay, and hay not giving very profitable returns. Corn, also, has not given very good results at Lacombe. It is probable that some better mixed farming rotation, having a smaller acreage in hay, would give larger profits. A seven-year rotation at Lacombe described on page 18 of this bulletin, which included potatoes instead of corn and had only two years in hay, was the most profitable of any rotation but the profits came chiefly from the potatoes and as this crop has not an unlimited market in the West, it would be unsafe to figure similar profits on future operations.

Undoubtedly the decision between grain rotations and mixed farming rotations must rest upon which type will give the largest returns to the farmer. The tables which have been presented show the profit which has been obtained per acre of land but in reality the real basis should be which system gives the greatest net profit per farmer. There is plenty of land. Unfortunately, the present experiments do not embrace this phase of the question and each must figure for himself what system will produce the largest returns. It may not be out of place, however, to draw attention to some points which have a bearing upon this question. Any type of farming which permits the use of large machinery by means of which one man can do the work formerly done by several men, naturally, in the very nature of things, is entitled to and usually does secure a larger income. The price of most of the chief agricultural products is influenced by the supply, demand and cost of production throughout the world. If one country, by means of employing better methods and large labour-saving equipment can produce cheaper than other countries, this means that farmers engaged in the production of such products will obtain a relatively larger return.

That is to say, a man who uses a large eight-horse team or a tractor with large machinery can do very much more work per day and will usually secure more returns than where a man works by his own strength alone or with only a two-horse team. A horse generates, perhaps, the motive force of seven men and, therefore, when driving eight horses one man employs the motive force of fifty-six men. It is obvious that the returns of this man should be large especially if the product which he is producing is handled in other parts of the world by primitive methods. However, if a man is engaged in the production of a commodity which requires considerable hand labour and this is also produced by other countries where manual labour is cheap, it is scarcely probable that the returns will be very large unless considerably better methods are employed. It should be made clear that the returns from a man's work are measured not by how arduously he works but by how much he produces by his work.

In so far as the control of weeds is concerned there is no question but that the mixed farming rotations are superior. The use of hay and intertilled crops make possible the keeping of certain weeds in check that are very difficult to handle with grain crops and summer-fallow alone. Furthermore, soil drifting is checked more effectively when the farm is arranged into a mixed farming rotation but, unfortunately, the districts where drifting is a serious menace are the very places which are too dry to grow hay crops profitably. A mixed farming rotation, by producing crops which are harvested in different months of the year, enables a better distribution of labour than is possible with a grain rotation. However, where there is a fairly large acreage of summer-fallow in the grain rotation, there is provided considerable useful work during the summer months.

Mixed farming rotations provide a more uniform revenue from year to year than straight grain growing. In the latter system, the revenue is large when the crop is good but small when the crop is poor. In mixed farming rotations there is a chance that some other type of crop may be good if the wheat is poor but sometimes in years of extreme drought, all the crops are poor. In grain farming a crop failure means a loss in revenue for that year. This makes the task of financing the farm business more difficult than almost any other type of work or business. It necessitates the most rigid economy until a sufficient reserve is created to meet one or two crop failures. This is an absolutely fundamental point in grain farming. Mixed farming distributes the income more uniformly throughout the year and is not subject to such large fluctuations from year to year.

THE EFFECT OF CROP SEQUENCE

The experiments with crop rotations have given information not only in regard to yield and profit from the various crops but also in regard to the effect of one crop upon the yield of the crop following. Very complete information is available on the yield of wheat after summer-fallow and also after the first crop of wheat after summer-fallow. The following table shows this information on five Experimental Farms. As the periods of years during which these rotations have been in progress are not exactly the same on all the farms, it is not possible to compare the yields among the different farms but only the two wheat yields on the same farm. At Lethbridge, oats were grown after the wheat on summer-fallow but a fairly accurate guide as to what wheat yield might have been secured may be obtained by assuming one-half of the oat yield.

YIELDS PER ACRE IN BUSHELS

Experimental Farm	Period	Wheat after fallow	Wheat after wheat
Brandon	12 years	27·2	19·5
Indian Head	15 years	28·0	18·1
Scott	15 years	19·2	16·9
Lacombe	13 years	31·4	19·0
Lethbridge	12 years	23·3	(Oats) 38·7

The above figures show what yields of wheat may be expected on summer-fallow land and on second crop land at these farms. These yields were all obtained from the same rotation at all the farms.

The yield of wheat after corn is usually very fair being somewhere below the yield after summer-fallow and considerably above the yield after wheat itself. At Indian Head, in a rotation which has been in operation for sixteen years, wheat after summer-fallow has averaged 37.1 bushels per acre while after corn it has averaged 33.4 bushels per acre. The yields of wheat after sunflowers are not nearly as large as after corn and approximate very closely the yield of wheat on ploughed wheat stubble. Wheat after potatoes is usually somewhat better than after corn but the acreage of potatoes grown on most farms is so small that it is impossible to derive much advantage from this fact.

The effect of a sod crop is very good in moist regions or in wet years in a dry region. If the weather is dry the yield of wheat after sod is liable to be small. At Brandon over a period of twelve years the yield of wheat after a hay crop consisting of a mixture of alfalfa and western rye was 27.0 bushels per acre while after wheat in the same rotation was 18.8. In another nearby rotation during the same period the yield after summer-fallow was 27.3 bushels per acre. At Scott in certain cultural plot experiments over a period of eight years the yield of wheat after rye grass sod was 15.9 bushels per acre while after wheat was 14.4 bushels and after summer-fallow 21.7 bushels per acre. At Indian Head in plot experiments over a period of seven years, the yield of wheat after sod was 30.4 bushels per acre, after wheat was 22.6 bushels, after corn 29.3 bushels and after summer-fallow 38.7 bushels per acre.

It is sometimes thought that the ploughing under of a leguminous crop, frequently called green manuring, will increase the productivity of the soil. Experiments have been conducted on this point at four Experimental Farms but no beneficial influence has yet been observed. The experiment has been conducted in a three-year rotation of summer-fallow, wheat and oats, the summer-fallow year being used in some plots to plough under a green leguminous crop. In other plots the land is simply summer-fallowed without any other treatment while in one plot manure is applied at the rate of 12 tons per acre. The following tables present the yields which have been obtained, the first table giving the yield of wheat in the second year of the rotation and the second table giving the yield of oats following the wheat.

YIELDS OF WHEAT (AFTER FALLOW) IN BUSHELS PER ACRE

Treatment of Fallow Year	Brandon 15 years	Indian Head 9 years	Scott 13 years	Lacombe 9 years
Summer-fallow	34·7	34·2	21·2	38·9
Peas, ploughed under early July	33·8	33·5	21·6	36·3
Peas, ploughed under in blossom	32·5	32·6	21·2	36·5
Tares ploughed under late July	32·3	35·5	20·1	37·7
Summer-fallow, manure 12 tons	36·4	40·2	26·4	40·9
Summer-fallow	36·3	37·9	22·6	36·3

YIELD OF OATS (AFTER WHEAT) IN BUSHELS PER ACRE

Treatment of Fallow Year	Brandon 13 years	Indian Head 9 years	Scott 11 years	Lacombe 9 years
Summer-fallow	72·1	55·6	49·8	68·4
Peas ploughed under early July	72·0	56·0	48·4	63·6
Peas ploughed under in blossom	67·6	54·6	45·2	68·5
Tares ploughed under in late July	68·3	55·0	45·3	65·9
Summer-fallow, manure 12 tons	73·7	61·7	49·6	73·3
Summer-fallow	71·5	54·7	46·2	58·3

These experiments show that there has been no increase in yield by ploughing under such leguminous crops as peas or tares. Whether increases would take place in the event the experiments were conducted for a longer period of years no one knows but for the periods mentioned, which are of fair duration, no increases have occurred. As these treatments entail considerable expense it is obvious that their practice is unjustifiable.

Small increases have followed the application of farm manure. As this experiment was designed primarily to learn the value of ploughing under a leguminous crop in the summer-fallow year, the application of manure was made on the summer-fallow also. However, in another experiment designed specifically to learn the value of farmyard manure and where it should be applied, it was observed that the application of the manure to the stubble of the first crop and the ploughing of it under to benefit the second crop after the summer-fallow gave better results than applying the manure on the summer-fallow land. An exception to this result might arise in extremely dry regions where the application of the manure to the summer-fallow might avoid excessive drying out of the soil. The greatest value from manure will be obtained by applying it to the least fertile parts of the farm and the areas most liable to drift.

Unfortunately, the experiments with crop rotations on the prairie do not afford a comparison over a long period of years between the effect of a legume and a non-legume hay crop upon the yields of the following crop. For the last two years on the Dominion Experimental Farm at Morden, Man., a comparison is available between the effect of a mixture of sweet clover and western rye grass, and western rye grass alone while, for a period of three years, a comparison is available between the effect of a mixture of alfalfa and western rye grass, and western rye grass alone. These periods of time are not sufficiently long to afford absolutely reliable proof as to the value of legumes but they perhaps indicate what results may be secured under these particular conditions of soil and climate. The experiment is being continued so that in time definite conclusions may be drawn.

The effect of sweet clover was determined in a four-year rotation of corn, wheat, hay, and a mixture of peas and oats harvested for grain. The hay crop was divided so that one-half was seeded to a mixture of sweet clover and western rye grass and the other half to western rye alone. The average yield of grain, over a period of three years, was 10·62 bushels per acre higher after the sweet clover mixture. The effect of the alfalfa was determined in a six-year rotation of corn, wheat, wheat, oats, hay and hay. The hay crop was divided so that one-half was seeded to a mixture of alfalfa and western rye grass and the other half to western rye grass alone. In 1926, the yield of wheat on corn land, which had been preceded by the alfalfa mixture, was 4·78 bushels higher than after the grass alone while, in 1927, the yield was 8·15 bushels higher. Furthermore, the yield of wheat after wheat, that is, the third crop after the legume, was 9·34 bushels higher than after the western rye grass alone. It is possible that the very favourable results in 1927 were due to a more abundant moisture supply, the beneficial influence of legumes being more evident in humid than in very dry regions.

In the three prairie provinces of Canada in 1927 there were seeded 20,440,000 acres of wheat. Suitable crop rotations will do much to maintain high yields on this extensive area.

THE EFFECT OF ROTATIONS ON SOIL PRODUCTIVITY

The period of years during which these rotations have been in progress is not sufficient to be certain whether crop yields are increasing or decreasing during later years. Where crop records covering a long period of time are available there is ample evidence to show that grain yields are higher when these crops are grown in rotation with other crops than when grain is grown alone.

The oldest experimental work with crop rotations in the world has been done at Rothamstead, England. While this Experimental Station is located in a region where the average precipitation of 28·34 inches is almost twice that received on the Prairie Provinces, it is of considerable value to study the very useful data which have been obtained. On this Station wheat has been grown under various rotation treatments since 1848 and records with wheat are available since 1855. It is obvious that such long time records are of inestimable value in studying the influence of rotations upon soil productivity.

The following table gives the average yield of wheat at Rothamstead for a period of 15 years, every fourth year from 1855 to 1911 inclusive, where wheat was grown continuously, where it was alternated with summer-fallow, and where it was grown in a four-year rotation of turnips, barley, summer-fallow and wheat. The object of taking yields every fourth year is to have a comparison among all three treatments, the wheat in the four-year rotation being grown every fourth year. During this long period no manure or commercial fertilizers of any kind have been applied.

YIELD OF WHEAT PER ACRE (BUSHELS) AT ROTHAMSTEAD, ENGLAND

Wheat continuously	11·8
Wheat after fallow 2-year rotation	17·2
Wheat after fallow 4-year rotation	26·9

Wheat grown continuously has yielded approximately two-thirds as much as where alternated with fallow and less than one-half as much as where grown after fallow in the four-year rotation. As the wheat after fallow in the two-year rotation occupies the land only every other year while the continuous wheat is produced every year, the total amount of wheat produced on the continuous plot is greater than that in the two-year rotation. It will be observed that the yield of wheat after fallow in the four-year rotation has been very much higher than where it simply alternated with fallow in the two-year rotation. It is stated that the yield of turnips is very small in the four-year rotation, as this crop requires heavy manurial treatment and none is given in this rotation. It is believed that as the barley crop has a much shallower root system than the wheat, the fertility of the soil may be more effectively utilized than where wheat alone has been grown.

Unfortunately, the climatic and soil conditions at Rothamstead, England, are not very similar to those prevailing on the Canadian prairie thus making it difficult to apply the results of these experiments to prairie conditions. Fall wheat has been grown at Rothamstead while on the prairie, spring wheat is chiefly used and, moreover, the yields of grain at Rothamstead are heavier in those years when the precipitation is below the average.

It was found in the Rothamstead experiments that the wheat crop 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 that one receives manure while the other is left unmanured. Taking the yields during the fifteenth and sixteenth cycles of the rotations of each crop 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, beans or clover 24·9, and wheat 68·6 per cent. The swedes were an absolute 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 66·0 per cent in the 10th to 14th cycles and 68·6 per cent in the 15th and 16th cycles of the rotation.

The influence of a leguminous crop in the rotation reduces to a certain extent the loss of nitrogen from the soil. It has been estimated that approximately two-thirds of the nitrogen content of a legume plant is derived from the air and one-third from the soil and that two-thirds of the total is stored in the leaves and stems of the plant and one-third in the roots. If this be the case, when the legume crop is removed from the field, it will take with it only the amount of nitrogen derived from the air. In other words, there will be no loss of nitrogen from the soil, the amount remaining practically the same as before the crop was grown. This result may be expected in soils containing an average amount of nitrogen. However, when the soil is very rich in nitrogen, there is a tendency for the legume to derive a greater amount of its nitrogen from the soil and perhaps actually leave the soil slightly poorer in nitrogen while, when the soil is poor in nitrogen, there may be an increase in this element even when the legume crop is removed from the land. If the leguminous crop is ploughed under instead of being removed from the land it will obviously increase the amount of nitrogen in the soil. To what exact extent this increase will take place is not known, because the richer the soil is in nitrogen, the smaller is the percentage of nitrogen derived by legumes from the air. Most prairie soils are now fairly well supplied with nitrogen although in time this quantity will be reduced. It will be seen, however, by reference to page 30 of this bulletin, that where legumes were ploughed under the yields of the subsequent crops were not increased. This practice, on the other hand, introduces the factor of adversely affecting the moisture supply of the soil nullifying to some extent the beneficial influence of the increased nitrogen supply. Where non-leguminous crops are harvested, however, there would be a constant drain upon the nitrogen supply of the soil.

The value of legumes was ascertained at Rothamstead, England, in a comparison made in a four-year rotation, in which, in one instance clover or beans were grown before wheat and, in the other, the land was left in summer-fallow. Where the land was not manured or fertilized, the yield of wheat following clover was slightly less than after fallow as were also the yields of swedes and clover in the suceeding years of the rotation. However, where manure or fertilizers were applied the yields of all the crops in the rotation were substantially larger after the clover than after fallow. There was produced from the land, moreover, the legume crop itself instead of having it in bare fallow.

The results with crop rotations at the Illinois Agricultural Experiment Station are of interest because the soil is naturally richer than at Rothamstead, being in this regard, more comparable to the soil of the Canadian prairie. Crop rotations at the Illinois Station have been in progress since 1876. Three systems of cropping were compared; continuous corn; corn and oats grown alternately in a two-year rotation; and corn, oats and red clover grown in a three-year rotation. The following table gives the average yields of these rotations during the last twelve years of the experiment, that is, from 1915 to 1926. No manure or commercial fertilizers of any kind have been applied since the experiment started.

COMPARISON OF YIELDS IN DIFFERENT ROTATIONS, ILLINOIS

Cropping System	Corn (bushels)	Oats (bushels)	Red Clover (tons)
Continuous corn	24		
Corn, oats	34	33	
Corn, oats, clover	43	55	1·9

It will be seen that the three-year rotation which included the legume has given very much larger yields than the two-year rotation where it was not used. Likewise, the two-year rotation has given a larger yield of corn than where corn was grown continuously. There can be no question from these results that crop rotation, especially when including clover, maintained crop yields much higher than where continuous cropping was practised.

In another part of these Illinois experiments, manure, lime and phosphorus have been applied since 1904 and, in the two-year rotation, sweet clover has been used as a green manure, being seeded with the oats and ploughed under for the corn. During the last twelve years the continuous corn gave an average yield of 42 bushels per acre; the two-year rotation yielded 64 bushels of corn and 63 bushels of oats; the three-year rotation yielded 59 bushels of corn, 77 bushels of oats and 1.9 tons of clover hay per acre. It will be seen, by referring to the yields in the table where no manure was applied, that the added fertility has very considerably increased the yields of all the crops. The value of rotations over continuous cropping is evident both where manure was applied and where is was withheld.

In the unmanured continuous corn experiments in Illinois, there was a very rapid decrease in yield 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. Under Illinois conditions it seems that the use of good crop rotations, combined with the return to the land of manure or crop residues and the application of lime and phosphorus, maintains and even increases crop yields.

It must be remembered in studying the results of the Illinois experiments that the average annual precipitation is 34 inches which is twice as much as that received in most parts of the Canadian prairie and, moreover, the period during which the ground is frozen is materially less. At Rothamstead, England, also, the precipitation is much greater and the winter much milder than on the Canadian prairie. On the Canadian prairie, the enormous influence of variable seasons is such as to render short time average results very unreliable.

If a five-year period is taken at the commencement of these experiments and the yields compared with those of the last five-year period, the occurrence of one or more years of exceptionally good crops, of droughts or of rust of varying degrees of intensity, makes it almost impossible to estimate definitely the change in the productivity of the soil. If the reader will turn to page 10 of this bulletin which presents a chart giving each year's yield of wheat on summer-fallow land over a period of fifteen years at Lethbridge, Alberta, it will readily be seen how the occurrence of phenomenally large crops or of almost complete failures makes five-year average figures of little value in some places for comparison. This chart shows that the yield has varied from 63.1 bushels per acre in 1915 to 2.2 bushels in 1919. The two good years of 1915 and 1916, when the moisture conditions were excellent, gave a combined yield of 109.6 bushels which is somewhat more than the combined yield of 108.8 bushels received during the following seven years. It is obvious that on this farm the moisture factor is exerting a predominant influence and that the fertility factor is very largely masked by the presence or absence of sufficient soil moisture.

At Indian Head, Sask., where the smallest variations have occurred, the yields of wheat on summer-fallow varied, in the three-year grain rotation, from 37.1 bushels per acre in 1913 to 23.0 bushels in 1923. If the fifteen-year period from 1912 to 1926 be divided into three equal periods of five years each, at the commencement, middle and later years of the experiment, average yields of 28.8 bushels, 28.2 bushels, and 27.4 bushels per acre have been obtained respectively. In a similar way, if the yields of wheat after wheat be divided into the same periods, average yields of 18.0 bushels, 17.3 bushels, and 18.9 bushels per acre were secured. From the Lethbridge experiments, it would appear that the five-year period was altogether too short to base an average yield while, at Indian Head, the yields during these three periods of five years each have been remarkably similar. Turning to the nine-year mixed farming rotation at Indian Head, which includes two hay crops in the rotation and has 12 tons of manure applied to the corn crop, the average yield of wheat after summer-fallow in the first five-year period was 39.2 bushels per acre, in the second five-year period 32.8 bushels per acre, and in the third five-year period 38.2 bushels per acre. These yields, although considerably higher than in the three-year grain rotation have been maintained during the last five-year period about the same as in the first five-year period. It is impossible to say whether this higher yield is due to the different type of rotation or to a naturally more fertile soil on which the nine-year rotation is located. The fact that the first five-year period averaged 39.2 bushels per acre while the same period in the three-year rotation averaged only 28.8 bushels per acre might indicate that the land was originally more productive. These experiments on crop rotation will have to be continued unchanged for many years so as to learn definitely what systems of cropping are permanently the most productive.

Wherever crops are removed from the land there is always some loss of soil fertility, the chief losses being the elements nitrogen, phosphorus and potash. When legumes are grown, however, as will be seen by reference to page 34 of this bulletin, there is practically no loss of nitrogen because legumes derive their nitrogen in part from the air as well as from the soil. Where crops are sold from the farm, the greatest loss of fertility occurs, but when fed to live stock and the manure returned to the land, the loss is greatly reduced. There is still some loss, however, owing to the use by the animals of a small fraction of these elements and to the losses in the handling of the manure before it is applied to the land, but the losses in fertility are very much less than where grain is sold from the farm and the straw burnt.

METHODS USED IN PRODUCING CROPS IN ROTATIONS

GRAIN CROPS

Before grain is seeded, the land should be put in good condition. If planted on summer-fallow or stubble land, the soil should be handled in accordance with some of the better methods described in the chapters in this bulletin dealing with the summer-fallow and stubble treatments. If the grain crop is seeded on tame hay sod land it is very advisable to plough the sod as early as possible, preferably immediately after the hay crop has been removed. It should then be disced and thoroughly worked throughout the remainder of the season to keep the weeds under control. The object of the early ploughing is to get the sod decomposed and to conserve the soil moisture as much as possible. If weeds with underground rootstalks are present it might be advisable to give the land a second ploughing late in the fall. In the case of brome grass sod it is very doubtful, however, whether this method even will give satisfactory results except in dry years. Brome grass is difficult to eradicate and requires usually an entire season of summer-fallow if a thorough job is to be done. The land should then be ploughed early, thoroughly worked throughout the season and reploughed in the fall.

Where grain crops are seeded on "breaking" it is absolutely necessary to "break" the virgin sod the year previous to that in which the grain is seeded. The sod should be ploughed as early as possible, preferably before the middle of July and thoroughly worked throughout the remainder of the season. In this way the tough virgin sod becomes decomposed and the soil moisture conditions satisfactory. If grain crops are seeded the same year as the virgin sod is broken, their yield is very small and the land is also in very poor condition for the crop the following year.

Where grain crops follow corn or sunflower crops, it is usually unnecessary to plough the land in preparation for seeding. Discing or cultivating are quite sufficient. In fact this treatment is superior to ploughing in cases where annual or winter annual weeds are present as these weeds have been largely eradicated by the cultivation for the silage crops. If many underground weeds are present, however, ploughing will be necessary.

While it is impossible to give definite information regarding the best rate of seeding the various grain crops which will apply to all parts of the prairie provinces, it may be of some value to present certain average amounts which will serve as a guide. It may be mentioned that the rate of seeding on summer-fallow is usually slightly heavier than on stubble land. The same principle also applies on rich soils and more humid climates as compared with poorer soils and drier regions. Where weeds are prevalent, a slightly heavier rate of seeding seems to give a better stand. Any variety of grain which has smaller kernels than the common varieties, requires slightly less seed per acre.

Under average conditions, Marquis wheat will give the most satisfactory results when seeded on summer-fallow land at the rate of $1\frac{1}{2}$ to $1\frac{3}{4}$ bushels per acre. On stubble land, the seeding might be reduced to $1\frac{1}{4}$ to $1\frac{1}{2}$ bushels per acre. In dry regions it is customary to seed somewhat less than these amounts but is is doubtful whether such a practice is justifiable. Certainly where many weeds are present a lighter seeding does not seem to give as large a yield. The average rate of seeding barley is $1\frac{1}{2}$ bushels per acre, oats $2\frac{1}{2}$ bushels and fall rye $1\frac{1}{4}$ bushels per acre.

Good varieties of grain suitable to the district should be grown. The seed should be of good quality and should be free from weeds. It should be treated for smut. Early seeding is desirable to reduce the risk of injury by frost and rust and to increase yields. Under most conditions, the grain should be seeded from two to three inches in depth. Where the soil is very fine and dry, the deeper depth is preferable while in heavy moist soil the shallower depth may give better results.

HAY AND PASTURE CROPS

The most useful hay crops for the prairie are Western rye grass, brome grass, alfalfa, and sweet clover. In some localities a few other crops are used to some extent, such as meadow fescue, timothy and red clover, but, in the main, the first four mentioned are the heaviest yielding and have the widest adaptability. Brome grass is not suited to a short rotation where the land is too frequently broken and seeded to grain or to cultivated crops. Its underground rootstalks are very difficult to eradicate, especially during wet weather; under such conditions, the crop which is seeded on the land the following year, is injured.

The most economical method of seeding down these crops is with grain as a nurse crop on summer-fallowed land. It is true they may be seeded down on land that has been in a grain crop for one or more years after summer-fallow but the possibility of failure on such land is somewhat greater. The reason for this lies in the fact that such land is more weedy and has no reserve of soil moisture. While wheat has usually been found to be the best nurse crop, barley and oats may also be used if these crops are desired for the particular piece of land which is to be seeded to hay. It is wise, however, to seed them

In many districts a mixture of alfalfa and Western rye grass has proved a very productive hay crop. Where alfalfa does not grow well, sweet clover is often satisfactory.

at a slightly smaller rate of seeding than when they are seeded alone without any grass or clover seed because it is particularly important to avoid having the grain crop fall down, as lodged grain frequently kills completely the young stand of grass or clover plants. It is not profitable, as a usual practice, to seed down grass or clover seed alone without a nurse crop. Such a method is too expensive as it loses the value of the grain crop which is used as a nurse crop and rarely gives a very much larger yield of hay than when it is seeded with a nurse crop. Moreover, in very dry years, the grass and clover seed may fail to catch even when seeded without a nurse crop in which case the land and the work have both been a total loss while if a nurse crop had been used some grain would be secured.

When sown separately, Western rye grass, brome grass, alfalfa or sweet clover may be seeded at 10 pounds per acre. It is possible that even less than this quantity would be enough but this quantity would be more certain to secure a good stand all over the field. A mixture of western rye and alfalfa has given excellent success in many places; this mixture may be seeded at the rate of 5 pounds of each of these crops or ten pounds in all per acre. In seeding alfalfa or sweet clover it is important to avoid seeding too deeply. Preferably, these crops should be seeded with a grass seed attachment on the grain drill or should be broadcasted with a broadcast seeder and harrowed. If these are not available, it is possible to seed these crops from the grain box of the seed drill by mixing the seed with cracked wheat and seeding shallow. Alfalfa and sweet clover should be inoculated previous to seeding on land where these crops have not previously been grown.

Cereal crops are also extensively used as hay crops. They are particularly valuable in districts where the ordinary hay crops fail to grow satisfactorily or as emergency hay crops when the ordinary hay crops have winter killed or failed to germinate. Oats make a very satisfactory annual hay crop. They should be seeded at the rate of three bushels per acre and cut when the oat kernels are in the milk stage. A mixture of peas and oats, consisting of one bushel of peas and two bushels of oats makes a somewhat better hay crop especially in regard to its feeding value. The cost of the seed peas, however, unless produced on the farm, is a drawback to this mixture. Fall rye is also extensively used for hay or for both hay and pasture.

For pasture purposes the principal crops are brome grass, sweet clover and fall rye. Brome grass is a perennial while the other two crops produce some growth the first year, pass through one winter and produce their main crop and mature the second year. They then die. For land which is intended to be left in pasture for several years brome grass is perhaps the most satisfactory pasture crop. However, as it is difficult to eradicate owing to its underground root-stalks, it is usually unwise to include brome grass in a short rotation of crops. When left for several years, brome grass tends to become sod bound which reduces its productivity. In such circumstances, it is best to plough it shallow, harrow it to make the surface level and in another year normal growth will be resumed. To avoid any decreased yield for even one year, the land after it has been worked may be seeded to oats with perhaps a small additional seeding of brome grass seed. The oats will not produce a large crop as they will be crowded by the brome grass but they will produce some green feed.

Sweet clover produces excellent pasture for one season. It should not be pastured too closely, however, during the first fall of its growth as it is liable to be weakened and killed during the following winter. Fall rye makes very good fall pasture if seeded early enough in the season but it should not be eaten off too closely as it is then liable to winter kill. If desired for fall pasture during the first year of its growth, the fall rye should be seeded early in July while if desired for grain it should not be seeded until around September 1. If not pastured too closely fall pasturing does not injure the rye so much as spring pasturing. Fall rye is usually seeded at the rate of 1¼ bushels per acre.

In cooler districts, sunflowers will outyield corn but in warmer areas the corn crop is the more satisfactory. Lower photograph shows combined corn harvester and silage cutter.

SILAGE CROPS

The selection of what silage crop to use to secure the best returns depends upon the district, the type of soil, and the equipment available. In the warmer and moister regions corn gives very fair results. Sunflowers will grow in districts where the temperature is cooler than is desirable for corn. It should be remembered in this connection that sunflowers are decidedly harder on the land than is corn and that the yield of grain the next year will not be as large as after corn. Oats, or a mixture of peas and oats make good silage. This crop is more adapted to the cooler than the warmer districts. If desired, it may be used as green feed. Sweet clover also makes good silage and may be used in districts where it grows satisfactorily.

Corn or sunflowers are usually seeded in rows 36 inches or 42 inches apart. This is done by blocking up certain openings in the seed drill so as to seed at the desired distance. The rates of seeding should be about 15 to 20 pounds of corn and about 10 pounds of sunflowers per acre. Northwestern Dent or Minnesota No. 13 varieties are very suitable for most parts of the prairie while the Mammoth Russian variety of sunflowers has given the best results. Sunflowers may be seeded somewhat earlier than corn as this crop will grow in a cooler temperature. Sunflowers can be seeded early in May but there is no advantage in seeding corn much before May 24. As it is desirable to get as much growth as possible during the warm part of the summer, it is not wise to seed after the first week in June. It is more economical to eradicate as many weeds as possible before seeding these crops than attempt to remove them afterwards by hoeing or cultivation. As a rule these crops should be produced on land which would otherwise be summer-fallowed. The land should be ploughed as early as possible so as to allow sufficient time for several cultivations before the crop is planted. After the corn is through the ground sufficient cultivation should be given to keep the land reasonably free from weeds but excessive or too deep cultivations are undesirable.

When oats are grown for silage they are usually seeded somewhat heavier than when seeded for grain. A rate of 3 bushels per acre is very satisfactory. The crop should be cut for silage when the oats are in the dough stage. When sweet clover is used for silage it should be cut just before the crop reaches the full bloom stage.

THE SUMMER-FALLOW

The main advantages of the summer-fallow are to control weeds, to conserve moisture and to facilitate earlier seeding in the spring. The disadvantages of the summer-fallow consist in that there is no revenue from the land for one entire year and, in districts liable to soil drifting, the summer-fallow soil is more liable to blow.

The chief points in handling a summer-fallow are to plough the land early and to keep it thoroughly cultivated throughout the season to prevent the growth of weeds. The land to be summer-fallowed should be ploughed as early after spring seeding is finished as possible and preferably should be completed before the end of June. The longer the land stands without ploughing the more soil moisture is used by the weeds and the less moisture there will be available the following year for the grain crop. Moreover, unploughed soil has a hard surface which facilitates a larger proportion of "run-off" after heavy rains than takes place on ploughed land. It is usually unnecessary to plough the summer-fallow more than once but if certain kinds of weeds are present, such as couch grass, a second ploughing in the late summer or fall will often prove very advisable. Under such conditions two ploughings are very much more effective in eradicating these weeds; in fact, if the cultivation of the land has been unduly delayed for any reason, two ploughings are indispensible. However, under ordinary circumstances, one ploughing will produce as large yields the following year as two ploughings.

The ploughing should be done at a depth of from five to six inches. Experiments have proved that there is no advantage to be gained by ploughing deeper than this and experience has shown that if the ploughing is done much shallower, the work is often done poorly. Experiments have been conducted over a long period of years at several Experimental Farms in which the depth of the ploughing was varied from three inches to eight inches. There was practically no difference in the yield of grain the following year from any of the treatments. Furthermore, where subsoiling was undertaken it produced no increased yields. It must not be inferred from these experiments that any kind of ploughing will be good enough. Not at all. Thorough ploughing is very necessary in order to have all the land turned and to cut and cover all weeds. If the plough is set at too shallow a depth, it will jump out of the ground and leave spots unploughed. This permits weeds to remain in these spots and when these set seed the next crop, and the soil as well, become polluted. Moreover, when the plough is allowed to jump out of the ground the surface is left very uneven and not in a proper condition to absorb rain or to permit a full stand of grain. A depth of from five inches to six inches will usually prove most satisfactory.

In recent years a new method of handling the summer-fallow has been tried which consists in simply cultivating the land as much as is required without ploughing it. This method has not yet been tried long enough to enable a definite opinion to be made regarding it. It would be entirely unsuited to land infested with couch grass as the cultivator would not be able to pull out the roots without ploughing. Even on land not having weeds with underground rootstalks, there is often trouble if the cultivation is unduly delayed by wet weather or other cause. In such cases the plough is the only implement that can do a good job. The advantages which this method possesses are that it makes possible a more rapid working of all the land earlier in the season and also, by leaving the stubble on the surface, soil drifting is checked to some extent. However, all things considered, this method does not appear to be as satisfactory as the standard method of ploughing the land to be summer-fallowed as early as possible and thoroughly cultivating it throughout the season. Some trials have also been made in handling the summer-fallow by ploughing the stubble land in the fall previous to the actual summer-fallow year. Throughout the summer-fallow year the land is cultivated as frequently as is required but it is not ploughed again. It is claimed that this method and the method of handling the summer-fallow without any ploughing are somewhat more effective in controlling wild oats than the standard method of summer-fallowing, but it is impossible to say definitely whether or not this is the case.

It is very necessary to cultivate the land throughout the season sufficiently to keep the weeds in check. If the weeds are allowed to grow they defeat the purposes for which the summer-fallow is used. However, additional cultivation beyond that necessary to keep the weeds in check is unnecessary and inadvisable. It was formerly believed by many persons that a soil mulch would conserve soil moisture but experiments have shown that this is not the case on prairie soils. Weeds constitute the chief agency through which soil moisture is lost and, when these are kept down further cultivation is unnecessary. In fact, too fine pulverizing of the soil tends to make it blow, incurring serious injury. Readers interested in the subject of soil drifting should turn to the chapter in this bulletin relating to soil drifting which is found on page 49 so as to study what methods have been found to be most effective in overcoming this trouble.

Land to be summerfallowed should be ploughed early and cultivated sufficiently throughout the season to control weeds.

STUBBLE TREATMENT

As the great majority of the acreage of cereal crops in the Prairie Provinces is seeded on the land which has already grown one or more cereal crops, it is important to study what is the best treatment to give such land. In the three Prairie Provinces, in 1926, there were approximately 23,600,000 acres seeded on stubble land as compared with approximately 9,350,000 acres on summer-fallow land. It is obvious that information concerning the best methods of cultivating stubble land has an important influence upon the yield of cereal crops.

In the drier areas of the prairie, the ploughing of the land in the spring, harrowing and seeding immediately, gives the best results. However, in the more humid areas of the prairie, fall ploughing gives as good yields the following year as spring ploughing, and, as fall ploughing makes possible earlier seeding the following spring, in such districts fall ploughing is more preferable. In districts where rust is prevalent, early seeding is extremely valuable in that the crop matures earlier and often escapes a considerable amount of rust which seriously injures later crops. In other districts where fall frosts are serious, fall ploughing, by making possible earlier seeding in the spring, is very useful. Although no experimental data are available on the subject, it is generally believed that if the soil is extremely dry, it is unwise to plough it in the fall. Ploughing under such conditions appears to dry out the subsoil and make poor conditions for the crop the following year. Where fall ploughing is done, better results are obtained when it is done early in the fall. Where fall ploughing is done late in the fall early discing or cultivation is sometimes useful.

The worst method of seeding the stubble land is simply to seed the land without any cultivation at all. This method is sometimes followed when the work gets delayed and farmers are anxious to get the seeding done before it is too late. However, in most instances, and especially if there are many weeds on the land, this method is an absolute failure.

Under such circumstances when the work is delayed in the spring and there is not time to plough the land, good results have been obtained by burning the stubble, discing or cultivating the land and then seeding. Unfortunately, the stubble is often too short to get a good burn in which case the crop is often very weedy. In recent years, where headers or combines have been used and the straw cut quite high, it is very easy to get a good burn. The high straw stubble also holds more snow than the short stubble as cut with a binder, making the moisture conditions somewhat better.

METHODS OF CONTROLLING WEEDS

Owing to different soil and climatic conditions, certain areas of the prairie are infested with certain weeds which are particularly adapted to these conditions. Thus in the heavier soils in the eastern part of the prairie where there is somewhat more precipitation, perennial sow thistle is extremely prevalent while in the lighter and drier regions of the southwestern part of the prairie tumbling mustard and Russian thistle are very bad. Sow thistle does not grow to any appreciable extent in dry soil or Russian thistles in moist soil. Between these two extremes there are a wide variety of soils and climatic conditions in which numerous weeds flourish. In addition to the weeds already named, the following perhaps are among the most destructive: wild oats, couch grass, sweet grass, stink weed, mustards and Canada thistle. There are many others, to be sure, but these are probably the most injurious over a larger area of country.

Where a farmer is conducting a strictly grain farm with wheat, the chief crop, it is certainly more difficult to control weeds than where mixed farming is followed. The frequent growing of the same crop especially a grain crop makes it difficult to employ certain methods which are fairly effective in eradicating weeds. Where weeds are seriously affecting the yields of grain, and where mixed farming rotations are profitable, it may prove the best plan to change the type of farming somewhat, and to adapt on at least a part of the farm a mixed farming rotation. In those parts of the prairie where hay crops, corn and coarse grains do well the introduction of one or more of these crops will be found to be very useful in combatting weeds. This bulletin has described several mixed farming rotations which might serve as a guide to persons desiring to adopt this type of farming. In districts where mixed farming rotations are not successful it is very desirable to adapt a type of grain rotation which will provide for frequent summer-fallowing of the land.

Of all the separate methods used to eradicate weeds, the summer-fallow is perhaps the most effective. As the methods of handling the summer-fallow have already been described on page 41, persons interested may refer to this material and also to the information on stubble treatment on page 44 of this bulletin. It may not be out of place, however, to point out that the summer-fallow must be thoroughly worked if the weeds are to be successfully controlled. With some weeds like perennial sow thistle and couch grass the failure to give one cultivation when it is required may allow the weeds a new start in life and render useless all the previous cultivation given to the field. For this reason it is wise to not handle more land than one can properly work if a thorough job is to be expected. On grain rotations it is absolutely necessary that a very thorough job be done in handling the summer-fallow and stubble land.

Sometimes a partial summer-fallow gives very good results. After a hay crop is removed or a pasture field pastured until the middle of the summer, the land may be ploughed and worked during the remainder of the season. Until the sod rots, a disc will have to be used but afterwards a cultivator may be employed if desired. This method is very economical as a crop of hay may be obtained or the land may be pastured for a time, thereby not losing the revenue from the land for an entire year. However, the treatment is not as effective in controlling weeds as the summer-fallow and the crop the following year does not yield as heavily. Where green feed is grown, a certain opportunity is provided to eradicate weeds. If the land is ploughed and cultivated thoroughly before the green feed is seeded considerable weed growth will be removed. As the crop is cut green, the weeds which grow are removed before they have had an apportunity of ripening their seeds.

Fall rye is a fairly effective smothering crop. On account of making quite a growth the previous fall and by getting a very early start in the spring, some weeds are choked out. Stinkweed and wild oats are checked very much by fall rye. Sweet clover is also an effective crop in crowding out certain weeds. Most hay crops, if a good stand can be secured, will hold many weeds in check. As alfalfa is cut twice during the summer, it prevents many weeds from maturing their seed. Fortunately a mixture of western rye grass and alfalfa makes a very productive hay crop in many districts. Occasionally the harrowing of the growing grain crop, when not seeded down, either before it has emerged from the ground or shortly afterwards has proved of some slight value but the practice is not a uniform success.

It may be of some interest to know how long weed seeds will live in the ground. The Michigan Agricultural College is now conducting an experiment to learn definitely just how many years the common weeds will lie dormant in the soil and then resume growth when suitable conditions are created. They planned an experiment in which weed seeds were mixed with sand and placed in uncorked pint bottles, buried 20 inches below the surface, and slanted with the mouth downwards to prevent the accumulation of water in the bottles about the seed. One of these bottles is removed every five years and there are sufficient bottles to continue the experiment for 100 years. The experiment has already run 40 years and it has been found that many weed seeds still germinate quite satisfactorily. After forty years in the soil, the following weeds germinated: black mustard, pepper grass, pigweed, ragweed, wild primrose, common plantain, purslane and curled dock. It is interesting to know that some of these weed seeds failed to germinate when removed in the earlier years of the experiment but did so in later years. Ragweed, in fact, failed to germinate in every trial except the last, that is, after forty years in the soil. With such remarkable results as this, who knows how long weed seeds will last? It is certain that no one should assume that he can ever let up in his war against weeds, especially if his land has once become infested. It is clear that preventing weeds getting a start on the land is pre-eminently the most important method of weed control. The neglect of weeds for one year only, may plague a man with this trouble all his life.

SOIL MOISTURE

Soil moisture is of such vital importance in the production of crops on the prairies that a short discussion on the relationship of moisture to crops and moisture conservation may not be out of place in this bulletin.

The water used by crops comes from that originally absorbed by the soil from rain falling on its surface. In humid regions the rainfall is often greater in amount than the capacity of the soil and drainage is necessary before crops can be grown successfully. On the prairies, however, the rainfall is much less and drainage unnecessary. As a rule the total annual precipitation is scarcely sufficient to moisten the ground more than a few feet below the surface. The soil on the prairies may be likened to a huge sponge which absorbs water received as rain and loses it again by evaporation or to a growing crop. Some soils, such as clay, are able to absorb and hold comparatively large quantities of water and these soils are usually the most valuable for agricultural purposes. Sandy soils, on the other hand, are unable to hold much water; rain is readily absorbed but it is either quickly lost again by evaporation or it passes down beyond reach of plant roots.

MOISTURE SUPPLY AND CROP GROWTH

Plants growing in the soil have the power of extracting water held by the soil through their roots. This water which also contains dissolved material from the soil, enables the plan to function normally; the water is afterwards passed off through the leaves of the plant. If additional supplies in the form of rain do not arrive the reserve of moisture in the soil is soon exhausted and the crop is injured.

A growing crop of grain begins to make a perceptible use of water when it is about 4 to 6 inches in height. If an ample supply be available the rate of use of water increases with the growth until the grain begins to head out. The rate is then maintained at the maximum until ripening of the grain begins when the amount of water used falls off rapidly. If for any cause the supply of water runs short the crop is forced to adjust itself to the deficiency and the yield is lessened. Under very favourable conditions a crop of wheat can use as much as half an inch of water daily when at its maximum requirement, and experiments have shown that such a crop can easily dispose of as much as 20 inches during its growth. When it is remembered that 20 inches of precipitation is considered a good total annual amount for the prairies, many districts receiving considerably less than this, and further, that under ordinary conditions a large part of the annual rainfall is lost to crops by evaporation and run off, it is remarkable that satisfactory yields can be secured under such comparatively low rainfall. Fortunately the distribution of the rainfall on the prairies, as a rule, fits in admirably with the needs of spring seeded grain crops, the greatest amounts being received at the time of greatest need.

The statement is frequently made that diversification of crops will enable the farmer to harvest something when dry weather causes the grain to fail. This must not be taken to mean that crops other than grain are unaffected by drought. In times of drought all crops suffer, no economic plants can exist without water. The usual conception of drought, however, is the lack of rain during the summer months; the total rainfall may not have been below normal but grain crops were injured because of its abnormal distribution. At the same time such a condition while injuring grain crops may have been favourable to other crops whose maximum water requirements come at a different period to that of grain.

THE RELATION OF SNOW TO SOIL MOISTURE

It is generally believed that the soil benefits considerably by the water from melting snow, but investigations made recently in Russia showed that, under certain conditions, the amount of water entering in this manner was insignificant. If the soil were moist and entered the winter in a frozen condition none of the water from melting snow was absorbed. A dry soil on the other hand benefitted considerably.

THE CONSERVATION OF SOIL MOISTURE

The relation of crop yields on the prairies to the moisture supply is well known. Abundant moisture during the growing season usually means high yields. The average season, however, is not one of abundant moisture, in fact the average can be more correctly termed deficient in moisture. If the maximum possible yields are to be secured, therefore, moisture conservation is essential.

Moisture in the soil originates from the natural precipitation over which there is no control. Something can be done, however, to have the soil in good condition to absorb rain readily, but more particularly to avoid the loss of moisture which has been absorbed. The most efficient and widespread means yet devised for storing and conserving moisture in the soil is the summer-fallow by which a portion of the rainfall of one year is stored for the use of a crop the following year. The amount stored by well prepared summer-fallow varies considerably depending on the amount and distribution of the rainfall; under average conditions from 25 per cent to 30 per cent of the total annual precipitation may be conserved by this means. The marked difference frequently observed between crops seeded on summer-fallow and those on ploughed stubble land leaves no room for doubt as to the value of the summer-fallow.

The necessity for summer-fallowing is apparent after an examination of the soil from which a crop has been removed. Under the deficient rainfall conditions in the West, grain crops will exhaust all the available moisture during their growth. A crop the following year, therefore, is dependant on the moisture retained from the fall and spring rains, which are normally very light, and that obtained during the growing season. By permitting the land to lie fallow for one season an apportunity is given for the soil to absorb moisture to be used by a crop the following year.

In the preparation of summer-fallow land, the objective is the storage and retaining of as much of the season's precipitation as possible. Because of the many different types of soil throughout the West no hard and fast rules can be given on the treatment necessary when summer-fallowing, but uniformly satisfactory results have been secured when the ploughing or cultivating was done early. Cultivation of the summer-fallow except to keep down weeds and maintain the soil in good tilth is neither advisable nor necessary, in fact on some soils it is a detriment. Where soil drifting is a menace the soil requires only the minimum of cultivation necessary to hold the weeds in check.

Unless proper methods of handling the land are followed, soil drifting will cause in many districts serious economic loss.

SOIL DRIFTING

Soil drifting occurs to such a varying degree and frequency in various sections of the three Prairie Provinces that it is not possible to give any one method to overcome this evil which will be applicable to all cases and under all conditions.

The movement of soil by the wind is a natural phenomenon. Throughout the world large areas of rich soil owe their origin to the deposition of fine material carried by the wind. When this action takes place on cultivated land, however, to such an extent that crops are severely injured or ruined, the prevention of soil drifting becomes a problem of great importance.

The drifting of soil is undoubtedly favoured by certain factors the chief of which are, an exposed surface, dry weather and high wind velocity. Contributing factors are the alternate freezing and thawing of the soil, by which the surface particles are rendered very fine, and continued cultivation which eventually produces the same result. The kind of soil also appears to have some influence as a sandy soil blows more readily than any other, but no type of soil escapes when the peculiar combination of conditions favourable to drifting arise.

In order to secure information on the extent of soil drifting and what is being done to combat it, a questionnaire was prepared and sent to a number of farmers in the three Prairie Provinces. The information contained in the replies furnishes a valuable summary of practical experience with the problem. It is evident that each farmer must adopt the method of control which fits best into his particular conditions. It is also significant that of all the methods put forward not one has been uniformly effective in all cases.

The drifting of soil during high winds occurs in all three Prairie Provinces and on almost every type of soil. It occurs but rarely, or not at all, in sections where bluffs or other forms of natural protection exist. Even in the open country the occurrence is by no means an annual one although some sections suffer to a greater or less degree each year. The drifting occurs chiefly in the spring, but in many cases both in winter and spring. The summer-fallow and fall ploughing appear to be the worst affected, possibly on account of the disintegrating action of late fall rains and the frost, but in a few cases spring ploughed land has also drifted.

The most obvious remedy to overcome soil drifting is to provide some form of protection for the soil. This protection may consist of a lumpy surface to resist the action of the wind on the fine particles or some soil binding material such as the roots of grasses. Newly broken land as a rule does not drift and may resist the action of the wind for several seasons depending on the occurrence and severity of the storms. Where it has been possible to compare, during a windstorm, newly broken land which was not drifting with drifting land immediately adjoining, the most noticeable difference between the soils was that the first still contained the roots of the original sod.

The seeding down of grass, as in a crop rotation, affords a means for providing the soil with binding material necessary to resist the action of high winds, but in the adoption of this method several practical difficulties are involved. Grass crops appear to be more successful in areas where soil drifting is not a menace to crop production and moisture is not the all important factor. Where the opposite to these conditions exists, it is difficult to secure a stand of grass and the crop is unprofitable. Furthermore in the drier sections, the yield of wheat following a grass crop is invariably depressed below that from land previously summer-fallowed. However, where grass crops could be grown successfully farmers, as a rule, agreed on the value of grass residues to prevent soil drifting.

Land which has produced a crop of sweet clover does not drift readily, according to the majority of farmers who have grown this crop. Others, however, are very emphatic in stating that sweet clover land drifted sooner than any other. Some distinction must apparently be made between a green crop ploughed under and the residue left in the soil after removing a crop of hay, the former apparently being the more effective.

The general opinion regarding the value of corn stubble to combat soil drifting was similar to that given above for sweet clover. A disadvantage in the case of corn, however, is that the area on which this crop may be grown to advantage is necessarily small in proportion to that devoted to grain.

There appears to be very little doubt regarding the beneficial effect of trees. Where a natural growth of trees exists soil drifting is a rare occurrence. The drifting occurs chiefly on the open plains, but the planting and care of trees on these areas, except to furnish shelter for the home and farm buildings is, for the present at least, economically out of the question.

Winter rye has proved a useful crop in areas subject to soil drifting. This crop is grown in preference to wheat on some of the sandy soils. The rye plants protect the soil during the winter and spring when soil drifting is most likely to occur. A disadvantage with this crop is that its effectiveness only lasts during the cropping season. If it is desired to raise a crop of wheat after the rye, summer-fallowing of the land is first necessary. Some other precautions must then be taken to keep the soil from moving away during high winds.

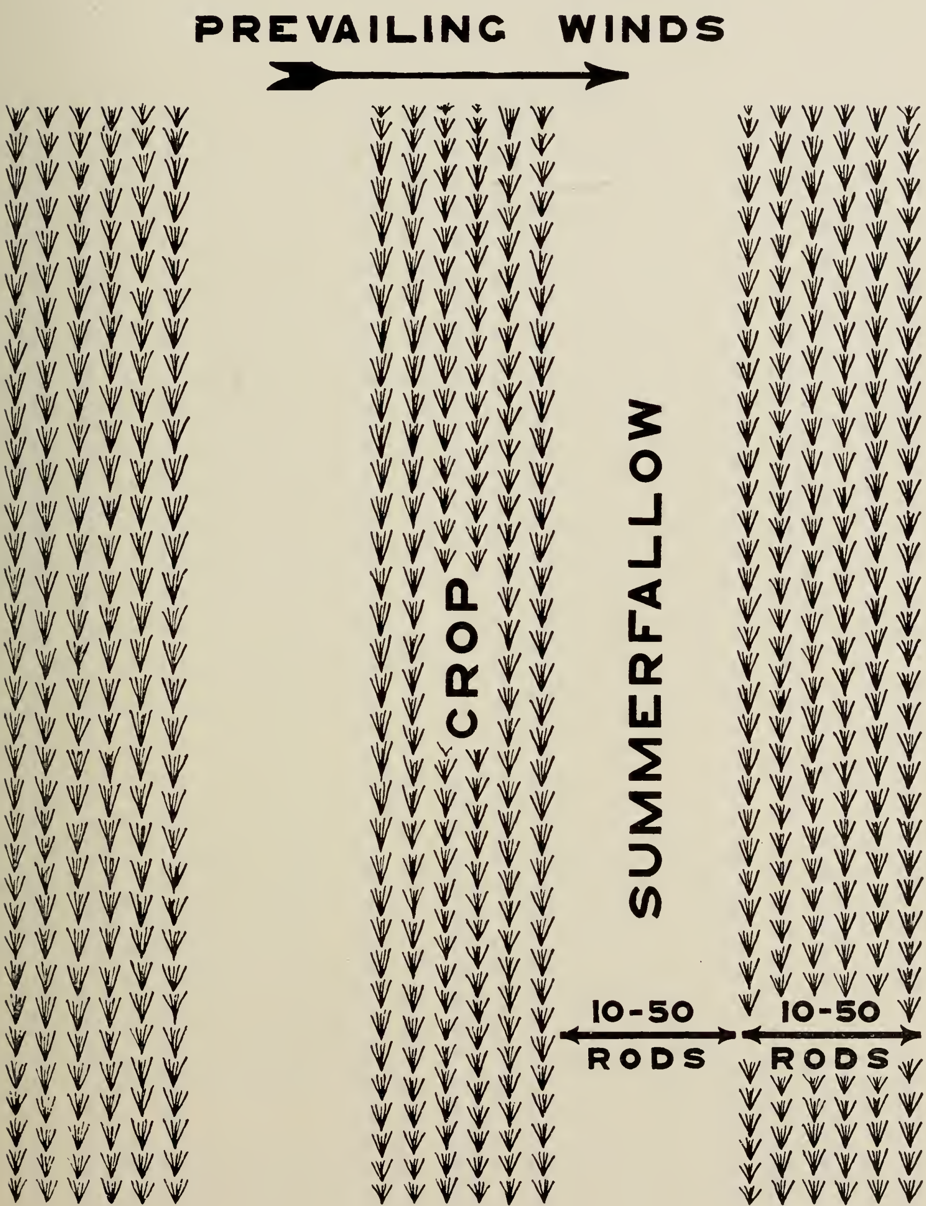
A few farmers in southern Alberta have found fall wheat valuable where the land is liable to drift. The chief objection against fall wheat is its liability to winter killing, but as soon as hardy strains can be developed this crop will no doubt be grown more extensively. On the Dominion Experimental Farm at Lethbridge fall wheat has given as large yields as spring wheat but this has been the only region where fall wheat has yet proved to be a profitable crop.

In certain areas where soil drifting is severe, a system known as strip farming is being practised successfully by a number of farmers. The land is divided into parallel strips, varying in width from ten rods or less to fifty rods, arranged at right angles to the prevailing winds. The diagram shows the disposition of the various strips. Each alternate strip is cropped while the others are summer-fallowed. The rotation thus adopted fits in with the climatic conditions which necessitate frequent summer-fallows to conserve the meager moisture supply.

To protect summer-fallowed land, a light crop of oats or barley is sometimes seeded late in July or early in August. The growth from this crop, which does not reach maturity, may be allowed to pass through the winter or can be used for pasturing stock. In the first case the snow caught during the winter may provide a certain amount of moisture to the soil and in the second the tramping of the stock tends to pack the land. In the following spring the land is either disked or cultivated and seeded to wheat. The objection to this method is that, owing to the uncertain climatic conditions, it is difficult to gauge the proper date on which to seed the protection crop. If this is able to make much headway all the available soil moisture stored in the summer-fallow will be removed to the detriment of the wheat crop the following year.

Where conditions favouring soil drifting occur at infrequent intervals, farmers have conducted their cultural operations so that the soil is always left in the best condition to resist drifting, that is, the surface is left cloddy. To accomplish this the cultivator, both spring tooth and stiff tooth type, has been used extensively, in fact, some farmers, in order to avoid working their land more than is absolutely necessary, use the cultivator in preference to the plough when preparing for the second crop after summer-fallowing. The cultivator is frequently used just before freeze-up and also before seeding in the spring. Some farmers find it profitable to pack the land, particularly if it be slightly moist, and then to use the cultivator. Others have used the disk with every other blade removed. In all cases the object sought is the same, to produce and preserve a cloddy surface to the soil.

DIAGRAM SHOWING ARRANGEMENT OF FIELD IN STRIP FARMING



It sometimes happens that a farmer is compelled to deal with a condition in which soil drifting is threatening or is actually in progress. Two methods of control are suggested, both of which have proved successful in most cases. A thin layer of straw may be spread over the ground or furrows may be made at intervals of from 1 to 2 rods across the affected areas in a direction at right angles to the wind. In making the furrows either the plough or the duckfoot cultivator may be used, the object being to place obstructions and stop the movement of soil particles across the surface of the field. The actual distance apart of the furrows will be determined by the severity of the storm. Several farmers reported success with the use of straw, one man having followed this practice for the past twenty years. His method has been to drive down the field with the wind and toss the straw into the air spreading very thinly, but making sure that all the surface is covered. In such cases as these prompt action and good judgment are essential.

Notwithstanding all that may be done to combat soil drifting success will depend largely on community effort. One man's effort may be wasted if fine material from a neighbour's land drifts over to his. This fine material quickly disintegrates other soils and the drifting area rapidly expands.

*ALKALI LANDS

Throughout the West are to be found patches of land which, on account of their peculiar nature and effect on vegetation, are known as alkali lands. These patches vary in size from a few square feet to several acres and are usually characterized by a whitish appearance due to the presence of certain salts. They occur chiefly in low places where water accumulates and later evaporates, and on the soils containing a considerable proportion of clay. When grain is seeded on these spots the yield is either very poor or the crop is an absolute failure.

In the reclamation of alkali lands only the removal of the harmful salts is involved, such lands are very fertile as a rule and, when freed of excessive alkali and provided with moisture, will yield abundantly. The removal of the salts can be accomplished by washing or leaching out the injurious compounds, which are readily soluble in water, and carrying them away by drainage. On the dry land farm the reclamation of any considerable area of alkali land is out of the question but for small depressions the natural drainage of the soil can be improved by heavy and frequent applications of farm manure. Certain crops are more tolerant of alkali than others. Of the more common farm crops, brome grass and sweet clover are the best and could be used to precede grain crops.

BURN-OUT LANDS

In certain sections of the Prairie Provinces and more particularly in south-western Saskatchewan and southern Alberta the prairie surface contains many irregular but roughly circular depressions varying from 3 to 6 inches in depth and from a few feet to twenty feet or more across. These depressions are known under various names such as " burn-outs ", " blow-outs " or " slick spots." The depressions are usually bare or support a scanty growth of vegetation while the surrounding prairie is well covered with grass. The burn-outs appear to be spots which from some cause or other have lost the original surface soil. The soil in a burn-out is very fine in texture and so impervious that after water has been standing in the depressions for several days the soil below the first few inches is quite hard and dry.

* For a complete discussion on alkali lands the reader is referred to Bulletin No. 21 New Series, "Alkali Soils" by Dr. F. T. Shutt, Dominion Department of Agriculture, Ottawa.

Where the burn-out spots are not extensive the land, when placed under cultivation, will produce very fair crops in favourable seasons. Breaking by the usual method has been a difficult process as the plough tends to slide out on striking a burn-out spot. If the work is not well done crops are very uneven for the first few years after breaking, those on the burn-outs being thin and stunted. This fact suggests the necessity of having the normal prairie soil well mixed with that from the burn-outs. It has also been observed by residents in burn-out areas that the burn-out spots get smaller in the course of time. This is undoubtedly due to the encroachment of the prairie sod favoured by the drifting of soil into the depressions from adjoining cultivated fields. A more satisfactory preparation for this type of land has been secured by the use of powerful machinery. The breaking is done early and preferably with the ground moist. The soil is later well worked down and mixed by means of a heavy float or scrubber.

GUMBO LANDS

Throughout the West are areas of clay lands which, on account of certain peculiarities, require special treatment during cultivation. Two extensive areas in Saskatchewan are found in the plains centering on Regina and what is known as the Goose Lake country. The soil is distinctly grey when air dry, but appears a dark brown when wet. It is very heavy and plastic when wet, but under proper treatment granulates readily to an excellent tilth. Although this type of soil is generally known among farmers as "gumbo" the term is more properly applied to the hard intractable clay, which is darker in colour and bakes badly, which is usually found along creek and river bottoms.

In the cultivation of these clay lands it is not possible to operate with the usual type of farm implements. Implements which have a shearing action when passing through the soil do not scour and quickly become clogged particularly if the soil be moist. Disk ploughs are preferred to the usual type of mouldboard plough as these can be cleaned readily.

The soil is very fertile and absorbs and retains water readily. It is particularly adapted to wheat production, although all crops adapted to the climate can be grown successfully.

Date Due

DEC 30 2011			
MAY 02 2012			

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1928