Dry Farming in Western Canada

John Bracken

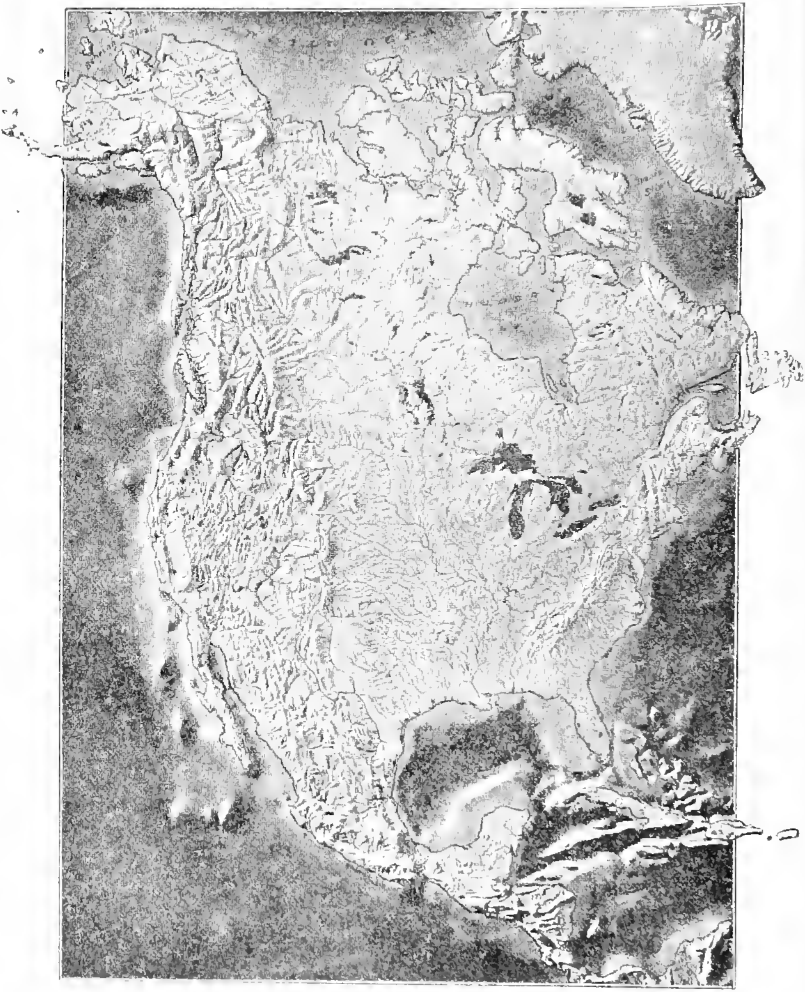

Fig. 1.—Physical Features of North America.—(After Tarr).
The Prairie Provinces lie between the Rocky Mountains on the West and the Hudson's Bay and Great Lakes on the East.

DRY FARMING

IN

WESTERN CANADA

BY

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THE GRAIN GROWERS' GUIDE, LIMITED
WINNIPEG, CANADA
1921

INTRODUCTION.

It is only a comparatively few years since the vast plains which now comprise the prairie provinces of Canada were inhabited by Indians and buffalo. Within the past generation this country has been settled by over 200,000 farmers. With the exception of those who came from adjoining districts immediately south of the international boundary these farmers have had to face conditions that were entirely new to them. The farm practices to which they were accustomed were altogether different from those required by the soil and climate of the western plains. There has been, therefore, a strong demand for information as to the best kinds of grain and other crops to grow and the best system of cultivation under which to grow them.

Among the experimenters and teachers who have done such splendid work in discovering and making known the best farm practices for the Canadian west Professor Bracken has taken a place in the front rank. For ten years before his appointment to the position of President of the Manitoba Agricultural College he was Professor of Field Husbandry at the College of Agriculture, University of Saskatchewan, Saskatoon. The plan of the experimental farm at that institution, one of the most comprehensive and scientific on the continent, was devised by him. The results obtained from his own experiments, and the experiments at other stations both in Canada and the United States, together with the experience of successful Great Plains farmers, have been drawn upon to furnish the material for Crop Production in Western Canada, published last year, and Dry Farming in Western Canada. The two books furnish a reliable guide to success in the production of field crops under Great Plains conditions.

THE PUBLISHERS.

Winnipeg, January, 1921.,

PREFACE.

When the manuscript for "Crop Production in Western Canada" was first prepared it included not only the chapters relating to Crops and Cropping Practices which appear in it, but also several others dealing with the soil and its management under Western conditions. When it was discovered that the whole would make a book containing nearly 800 pages, it was considered inadvisable to publish it in one volume. Accordingly the material was divided and that having to do directly with crops was published in 1919 under the title referred to. The part which treats of the soil and its management appears in this volume.

The substance of the different chapters of the book is drawn from lectures and addresses delivered either at the University of Saskatchewan or at Agricultural Meetings at different places in Western Canada or the Western States during the past ten years. For the contributed portions the author is very greatly indebted to Professor Hansen of the University of Saskatchewan for the chapter on "The Soil"; to W. H. Fairfield, Superintendent of the Experimental Farm, Lethbridge, Alta., for that on "Irrigation" and to ten of the leading agronomists of the Great Plains Region of Canada and the United States for that on "Lessons from Experience". He is also indebted to the Canadian and United States Departments of Agriculture, to many State Experiment Stations, several Dominion Experimental Farms, all of the Western Provincial Departments of Agriculture and the Dominion Meteorological Service for date or illustrations used, or for assistance given in the preparation of the manuscript. To the many private individuals who in one way or another have been of assistance, his thanks are also due.

The many imperfections of the book are known full well to the writer. It is being published not because it contains the last word on successful farm practice in the west, but rather because it presents under one cover a more or less complete statement of our *present knowledge* concerning the methods of producing crops at a profit under relatively dry conditions. It is hoped that the book may be found of some value to all farmers and students who are interested in the agricultural problems of the Prairie Provinces.

J. B.

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Dry Farming in Western Canada

CHAPTER I.

THE DEVELOPMENT OF DRY FARMING

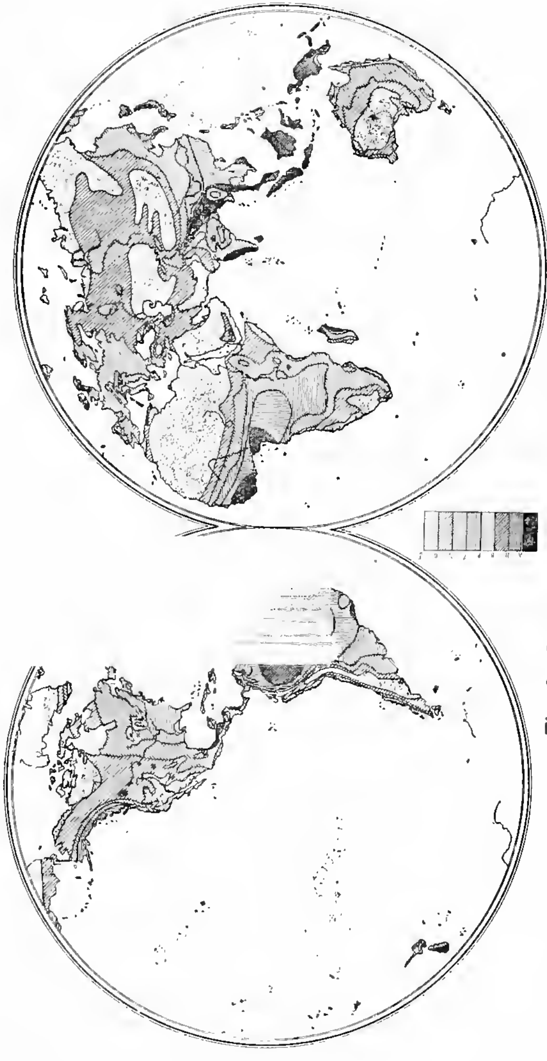
Previous to fifty years ago lands having less than 20 inches of precipitation per year were generally considered unfit for crop production, except where artificially watered at great cost by irrigation ditches. Within the memory of men now living, the practice of crop growing in semi-arid regions,—those receiving between 10 and 20 inches of rainfall per year—has developed, until at present much of the so-called "dry land" of earlier days is in many countries being successfully cropped as a result of the intelligent application of successful dry farming practices.

One quarter of the earth's surface receives less than 10 inches of precipitation annually. Rather more than one-quarter receives from 10 to 20 inches. On about one-fifth of the land area between 20 and 40 inches falls and on one-fifth between 40 and 80 inches, while the balance, about 5 per cent. of the total, has a precipitation of over 80 inches per year. The climate of Western Canada falls in the second class; judged by the rainfall it is, except for some small areas, "semi-arid".

1. Dry Farming Defined.—Dry farming is a popular term used to designate the methods of crop and soil management found to be profitable in areas of light rainfall. The specific practices which together comprise the system are not new, but the organization of them and their intensive application in areas of low rainfall have resulted within the last generation in giving to the system the special name "dry farming". This system has accomplished much in the semi-arid regions of North America, even though its most intelligent practice does not make crops grow in the absence of rain. Dry farming is nothing more nor less than the employment of common-sense methods of meeting the rainfall conditions that exist by practices that have been shown to result in increased yields or greater profit.

To those who have the inclination to search them out the secrets of dry farming, if such its principles may be called, are as an open page; to others the attempt to farm in areas having less than 15 inches of precipitation is not likely to prove an easy road to wealth unless they are fortunate enough to have successful neighbors whose methods they may imitate. An understanding of its principles combined with the will and experience necessary to their application are fundamental necessities to successful dry farm practice.

The factor that generally controls the yield on the poor soils of humid climates is plant food; in northern climates the absence of sufficient heat is frequently the limiting factor; while in dry areas the thing that limits the yield more frequently than any other is lack of sufficient moisture. The more important practices of crop



After Widstoe.

Fig. 2.—Precipitation Zones of the World.

growing in humid regions relate to the maintenance or increase of the supply of plant food in the soil; in northern climates the chief consideration, at least in the growing of cereals, is to get them ripe before fall frost comes; but in dry areas cropping practices are primarily concerned with making the best possible use of the moisture that falls.

The principles underlying crop production are the same the world over, but the relative supply of plant food, heat and moisture under different climatic and soil conditions determines the relative importance of the different farm practices that are commonly used in growing crops. The supply of the factor that generally limits the yield in any given region largely determines the general trend of farm practice there, and, as in the case of the semi-arid regions, sometimes gives to the practices followed the name by which the system is commonly known.

2. History of Dry Farming.—Before the present dry farming movement began, the Chinese on the dry lands of Western China and the American Indians in the arid States and in parts of Mexico are known to have grown crops under very dry conditions. It is reported also that crops were produced in the dry parts of northern Africa without irrigation. The ancient civilization of the Orient, the Euphrates Valley, Palestine and Egypt developed in dry climates, but chiefly in areas where irrigation was practised. It is probable that many of the dry farming practices are very old, but such methods as may have been used in early days must have been largely lost to Americans, most of whom came from humid countries.

The recent development in America does not appear to have been based on any knowledge of ancient methods. Here the system grew up independently in each of four different parts of the continent, (1) in the State of Utah, in the southern part of the inter-mountain region, (2) in western Kansas and Nebraska, the central part of the great plains, (3) in Western Canada, in the northern great plains, and (4) in California and Oregon. In each of these areas a system of crop growing developed apparently without knowledge of the methods followed in any of the others, until the popular "dry farming" movement was initiated within the last thirty years.

To the Mormons of Utah belongs the distinction of being the first civilized people to grow crops on "dry" land in America. Upon their arrival in Salt Lake City in 1847 only irrigated land was used for crop growing, but in the sixties it was observed that cultivated land above the ditch was capable of producing fair crops without irrigation. In the early eighties dry farming became an established system in many of the unirrigated portions of the state.

In California dry land cultivation commenced in the late sixties. Two decades later the colonization of much of the dry land of Nebraska and Kansas was attempted without success, but in the late eighties more satisfactory practices came into vogue and the tide of emigration commenced to return to the abandoned homesteads of the earlier era only to be turned eastward again by unfavorable seasons in the middle nineties. It was about this time that H. W. Campbell of "Dry Farm" fame was getting his early experience in the dry part of South Dakota. The ideas he developed there and later in Nebraska, where summer tillage frequently gave him largely increased yields, were organized and published at various times during the first few years of the new century.

In Western Canada the colonization that followed the building of the Canadian Pacific Railway in the eighties slowly spread itself westward from the Red River Valley. The first settlements developed along the North Dakota boundary, along the main line of the Canadian Pacific Railway west to Qu'Appelle and Moose Jaw and to the northwest in the Yorkton and Prince Albert districts. It was in the Qu'Appelle Valley that the first organized effort to introduce the summerfallow into general farm practice originated. At the time of the last Riel rebellion in 1885 most of the settlers hired out their horses and oxen with the military transport, the financial allowance being so much more than they hoped to get from the cultivation of their land. A few remained behind and after putting in what crop they could, commenced to plow the land that was still unsown. The following year, 1886, it was observed that the land which had borne no crop the previous season, but which had lain fallow, produced a much better crop than the other. This marked the beginning of the summerfallow as a recognized good farming practice in the central Canadian West. The methods of fallowing were later studied and improved upon by Mr. Angus McKay, who, from 1886 to 1917, was Superintendent of the Experimental Farm at Indian Head.

It is interesting to note that while the farmers of Saskatchewan have been given credit for being the first to practise the fallow system extensively in Western Canada, the benefits of this practice were not unknown to the Selkirk settlers, the first white people to take up land in the Canadian prairies.

In "The Beginnings of Agriculture on the Prairies" Dr. E. H. Oliver, who carefully examined the early records of the Selkirk settlers, states as follows: "After a series of trials on the part of the settlers it was found that fall plowing and fallow yielded the best crops. Alexander Ross, who could secure only 52 bushels from 10 bushels by the spring plowing of a worn-out field, was able, out of the second field, left fallow for two consecu-

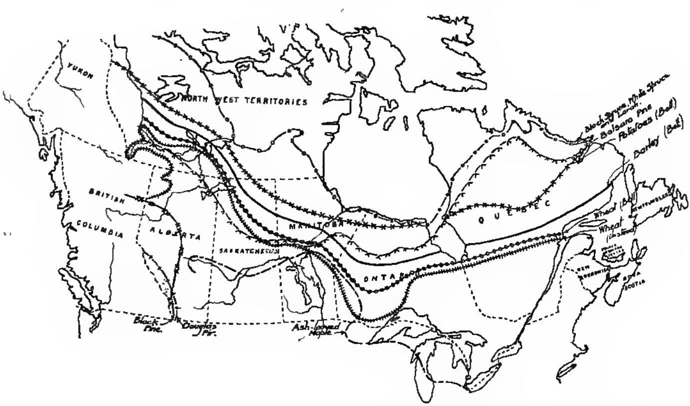


Fig. 3.—Map Showing the Northern Limits of Some Crops and Trees.

tive years, during which it was plowed three times, to secure no less than 280 bushels from 8 bushels sown." It thus appears that while the practice of fallowing was brought forcibly to the attention of the Saskatchewan pioneers after the last Riel Rebellion and that it was not until this time that it became a general practice, yet its value was not unknown in the West as early as the middle of the last century.

In recent years the United States Department of Agriculture, the different State Experiment Stations, the Experimental Farms of the Canadian prairies and the Dry Farming Congress have each studied the practices of Dry Farming and each has contributed much towards putting the system on a permanent basis. How much of its success is due to the organization and application of the facts of the science of crop production, and how much to other factors such as the higher prices of the last twenty years, and the contribution of the implement

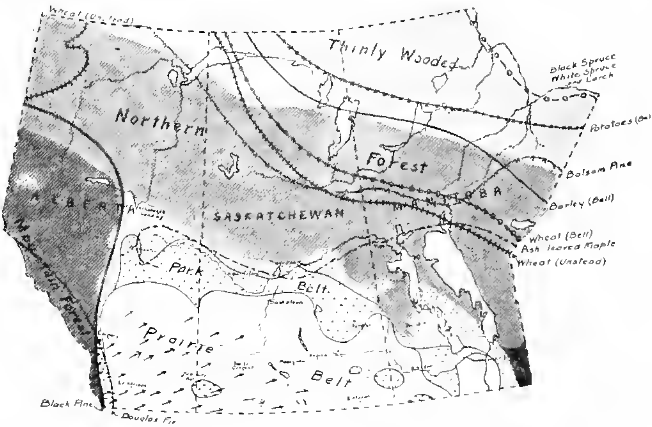


Fig. 4—Nature's Map of the Prairie Provinces.
(Arrows indicate the chinook belt.)

companies in the way of labor saving machinery, history alone will determine.

3. Where Dry Farming Applies.—One or more of the established dry farming practices should be used wherever moisture is the limiting factor in the yield of crops. This condition, of course, obtains chiefly in the areas of low rainfall, but may be found in other places where excessive evaporation or periods of drought or other cause results in moisture becoming the limiting factor.

The precipitation zones of Western Canada are indicated in the following chapter. The boundaries of these are based upon the limited rainfall and snowfall data available. They will, no doubt, be modified and more accurately located as more records become available, but in the meantime they furnish us with the approximate boundaries of the precipitation zones.

The areas of different evaporation cannot be mapped owing to lack of data. The Chinook region, is, however, generally believed to have the greatest evaporation, and the northeastern portion of the Prairie Provinces to have the least.

Judging from the precipitation records and the data for spring and fall frosts as well as from the costly experiences of farmers, it would appear that while several of the practices of dry farming should be applied wherever land is tilled, the extreme practices of this system should be applied in Western Canada only in the Chinook belt, in a modified form they should be used in the prairie area outside the Chinook belt, while in a still more modified form they may be used in eastern Manitoba, the park belt and the wooded areas. (See "Nature's Map of the Prairie Provinces").

It should perhaps be emphasized here that in growing grain crops in places where fall frosts are more to be feared than drought, less attention should be given to moisture storage and more to getting crops ripe. Both moisture conservation and early maturity may be desirable but where added moisture results in too late ripening it must be sacrificed in areas where crops are grown for their seeds. If forage crops only are to be grown, or where grain crops are to be grown for hay, dry farming may be practised even in the far North, because with these crops maturity is not an essential condition for either a good yield or good quality.

CHAPTER II.

THE CLIMATE OF WESTERN CANADA

IN ITS RELATION TO CROP PRODUCTION.

Under good systems of management three sets of factors determine the productiveness of crops in any region:

1st. The climatic conditions.
2nd. The soil conditions, and
3rd. The suitability of the crops grown.

4. Climatic Conditions the Chief Causes of Low Yields.— In the year 1914 the small amount and the unfavorable monthly distribution of precipitation caused a crop failure in the drier parts of Alberta and Saskatchewan. In 1907 and 1911 early fall frosts lowered the net profit on the western grain crops to perilously near the zero mark. In 1918 a July frost completely destroyed many thousands of acres of wheat in the blossom stage in the northern parts of the Prairie Provinces; while in 1916 a combination of high temperatures, high precipitation and high atmospheric humidity in the months of June, July and August provided very favorable conditions for the development and spread of rust and thus lowered the value of the Western Canadian wheat crop between fifty and one hundred million dollars.

The climatic conditions, at least in the first few years of land cultivation, are among the chief causes of poor crops, and unfortunately they are largely beyond man's power to change. This, however, is but another reason why our climate should be better understood. If we cannot change its undesirable features perhaps we can avoid them; if it has any favorable aspects perhaps we can take greater advantage of them. A knowledge of the essential facts concerning our climate should enable us gradually to choose more suitable crops and to adapt our rotation and management practices to the climatic conditions that have been fixed for us and that cannot be altered by us.

5. The Factors of Climate.—The term "climate" means the sum total of the atmospheric conditions that make up our "weather". Weather is "the condition of the atmosphere at a given time or over a limited period", while climate is a more general term meaning the average condition of the weather for the different seasons of the year.

The chief determiners of climate are latitude, altitude and relationship to large bodies of water, forests and mountain ranges. It is sufficient here to say that ours is a "continental" or inland climate, in a northern latitude, and far removed from the moderating influences of large bodies of water, but influenced considerably by our nearness to the Rocky Mountains, and by gradual variations in altitude ranging from less than 1,000 feet in the east and far north to more than 4,000 feet in the upper parts of the foothills.

The chief factors of climate in order of their relative importance to the agriculture of Western Canada are:

1. Precipitation: (a) amount per year; (b) geographic distribution; (c) monthly distribution; (d) form (rain, snow, hail, dew); (e) variations from the average; and (f) evaporation.

2. Temperature: (a) the number of days between spring and fall frosts; (b) the average monthly temperature; (c) the range of annual and daily temperature.

3. Wind: (a) velocity; (b) temperature; (c) humidity, and (d) direction.

4. Atmospheric humidity.

5. Light during the growing season.

6. Altitudes and forests.

6. Importance of Precipitation.—Moisture in the soil is essential to crop production. It is needed both as a plant food and as a carrier of plant food. Under semi-arid conditions more than a quarter of a ton of water is taken in through the roots and passed out through the leaves in order to carry enough food into the plant to produce one pound of "dry matter".

One acre inch of water weighs about 113 tons. Assuming that 700 pounds* is the average requirement for one pound of dry matter in wheat and, for easy calculation, that half the dry matter of wheat is in the stems and leaves, it would take 1,400 pounds of water to pro-

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*Recent investigations by Hopkins at Olds, Alberta, indicate that much less than this amount is required on rich prairie soil in high latitudes.

duce one pound of threshed grain, or over one ton to produce 1½ pounds of wheat. At this rate if it were all conserved and utilized, one acre inch of water would produce over 2½ bushels of wheat and 8 inches would produce at least 20 bushels per acre.

Our precipitation is about twice 8 inches, or more, and we crop our land only three times in four years, or

Fig. 5.—Precipitation Zones in Canada.
Approximate boundaries based on Meteorological Service data. (See Figure 110 for more recent detailed map).

twice in three years, yet our average yield equals less than the amount eight inches of moisture might produce. The loss through "run-off", seepage, evaporation and transpiration through weeds accounts for this poor showing.

From these figures it will be apparent that the precipitation in Western Canada is one of the chief limiting factors in crop yields; it suggests the desirability of more efficient control of the limited amount of moisture that falls.

7. Amount of Precipitation per Year.—The average annual precipitation in representative districts in Western Canada for 25 years as compared with that in some other agricultural regions is indicated by the accompanying chart.

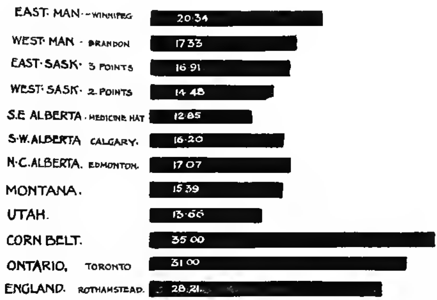

Fig. 6.—Average Annual Precipitation. Points in Western Canada Compared with the States, Ontario and England.

These figures show:—

(1) That the precipitation in Western Canada is rather more than in some countries where agriculture is practised, but is very little over half as much as in some of the older agricultural regions from which our settlers have come.

(2) That nearly the whole of the Canadian west receives more than 13 inches and less than 20 inches per year.

(3) That the area of lowest precipitation is in southeastern Alberta and southwestern Saskatchewan, and the supply increases in every direction from this centre. The increase is greater both east and west than north.

The two chief inferences from the data are,—1st, that the storage, conservation and efficient utilization of moisture are of very great importance, and 2nd, that extreme practices of "dry farming" would seem desirable in the drier areas.

8. Geographic Distribution of Precipitation.—The figures reported in the preceding section show that all parts of Western Canada are not equally favored with respect to precipitation. The precipitation map shows the outlines of what may be called the moisture zones in the three Prairie Provinces. While insufficient data are available to insure that the boundaries represented are absolutely correct, yet the map is at least a safe general guide to the precipitation zones.

9. Monthly Distribution of Precipitation.—The total precipitation per year is not a satisfactory measure of

Fig. 7.—Monthly Distribution of Precipitation in Canada.
Note relatively heavy rainfall in the summer months in the Prairie Provinces as compared with low precipitation at Vancouver for the same months and the average distribution throughout the year at Toronto.

the moisture supply available for crops. The proportion that falls in the season the crop is growing is of far greater importance than the annual amount. The following table gives the average precipitation per month for several years at a number of points.

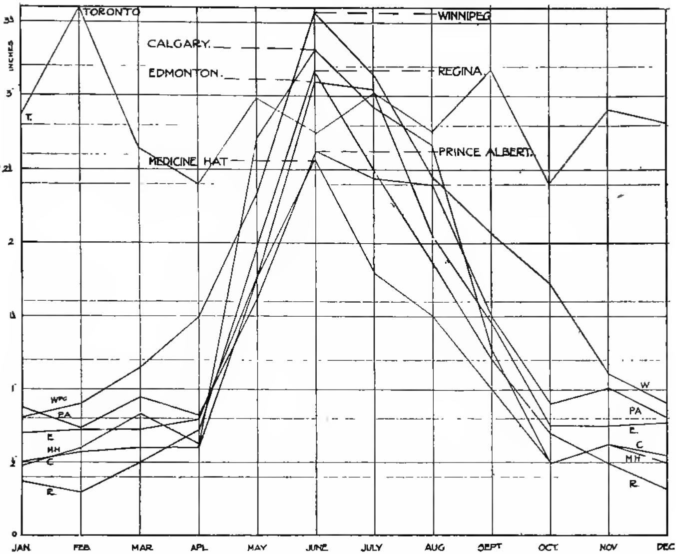

Fig. 8.—Monthly Distribution of Precipitation at Different Representative Points.

TABLE I.—*The Average Mean Monthly Precipitation at Representative Points in the Prairie Provinces.**

Station	Jan.	Feb.	Mar.	Apr.	May	June	July
Calgary	.47	.59	.74	.63	2.72	3.32	2.93
Edmonton	.69	.72	.73	.79	1.78	3.10	3.05
Medicine Hat	.56	.58	.61	.61	1.78	2.57	1.80
Prince Albert	.88	.74	.95	.83	1.53	2.63	2.44
Regina	.37	.29	.49	.73	1.98	3.17	2.49
Winnipeg	.85	.90	1.15	1.48	2.35	3.58	3.15

Station	Aug.	Sept.	Oct.	Nov	Dec.	Year
Calgary	2.67	1.28	.49	.74	.55	17.13
Edmonton	2.05	1.46	.75	.74	.77	16.63
Medicine Hat	1.52	1.00	.51	.72	.49	12.75
Prince Albert	2.40	1.49	.89	1.04	.79	16.61
Regina	1.86	1.19	.70	.48	.36	14.11
Winnipeg	2.45	2.07	1.73	1.10	.91	21.69

* From Canada Year Book reporting Dominion Meteorological Service data—Calgary 20 years, Edmonton 25, Prince Albert 20, and Winnipeg 70 years. Regina data from "The Climate of Western Canada" by Stewart

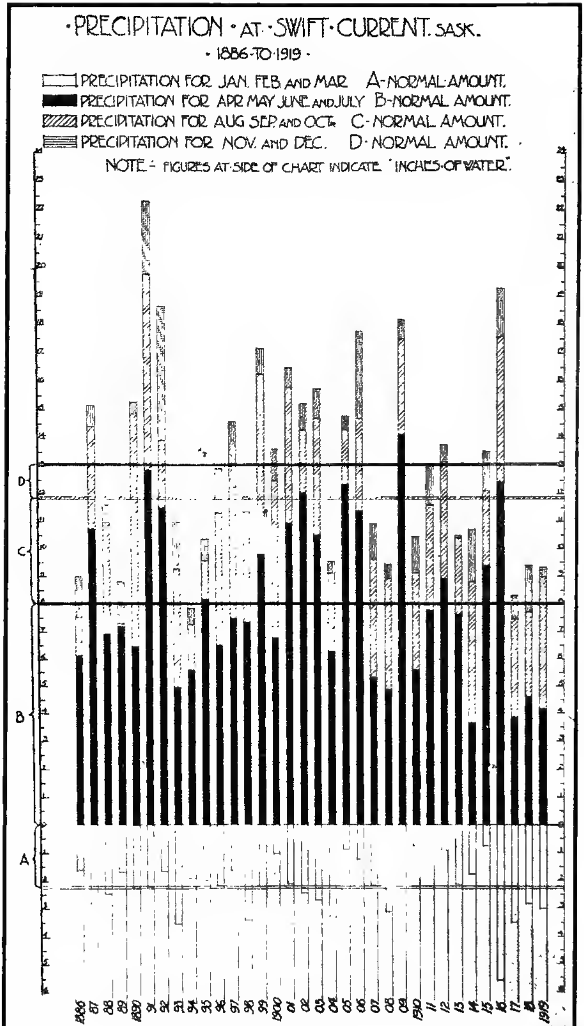

Fig. 9.—Precipitation at Swift Current, Sask.
Charts showing the actual precipitation per year and per season during 1886 to 1919 and the average per year and per season during that period. (See similar illustrations for other points in Western Canada in appendix).

From the figures in table I. a number of very important observations may be made. Among these are:

(1) From 50 to 60 per cent. of the total precipitation falls in the four "growing" months, May, June, July and August. In the districts of heaviest precipitation this is nearly as much as is received in the same period in Ontario cr in the midland counties of England.

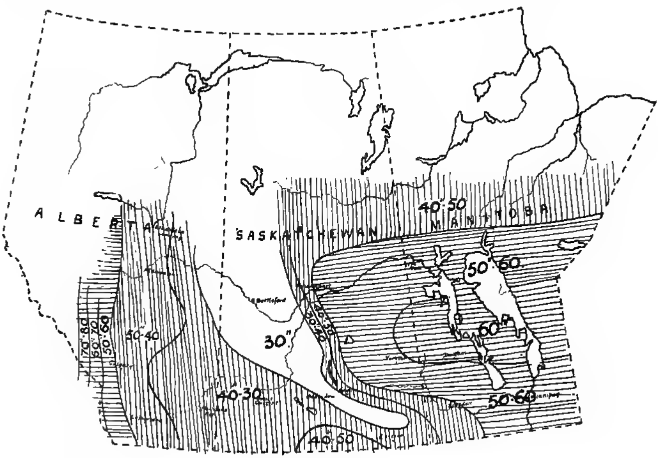

Fig. 10.—Average Depth of Snowfall in Western Canada. —From Meteorological Service Reports.

(2) June and early July is the rainy season. This fact is of considerabale importance in relation to the conservation of moisture by fallowing. It is the chief factor that determines the best time to plow the fallow and the character of the other necessary work that should be done on it.

(3) The spring and autumn seasons are usually quite dry. The former suggests the necessity of having the

seed bed in a good moist condition at seeding time, while the dry autumn results (a) in unusually favorable conditions for harvesting, curing and threshing grain crops, (b) in seriously lessening the amount of fall pasturage secured from perennial crops, and (c) in lessening the value of fall plowing as a means of conserving moisture and causing weed seeds to germinate.

It is interesting to note also that, as compared with either Toronto or Vancouver, (see map), while our total precipitation is much less, the monthly "distribution" is very favorable. In fact, with either the Vancouver or Toronto type of distribution here, we should be unable to produce crops profitably.

The monthly distribution and average annual snowfall at representative points is as follows:—

TABLE II.—*Monthly Distribution of, and Average Annual Snowfall.**

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Calgary	4.9"	6.3"	7.1"	3.8"	2.4"	...	....	...	2.1"	2.7"	8.2"	6.4"	43.9"
Edmonton	6.0	7.3	6.3	3.5	1.4	...	....	...		4.2	5.6	6.5	39.
Medicine Hat	6.8	7.7	6.0	2.5	.6	...	....	...	.5	1.4	7.6	5.2	38.4
Prince Albert	9.0	7.0	8.1	4.4	1.4	...	....	...	.1	2.5	8.8	6.7	48.0
Qu'Appelle	5.8	8.7	8.9	8.0	2.1	...	....	...	1.1	5.5	8.2	6.0	54.3
Winnipeg	8.7	9.4	8.8	4.3	1.3	...	....	...		1.3	9.8	7.6	51.2

The average depth of snow in the southern parts of all three prairie provinces is clearly indicated in the snowfall map. The melting of the snow is more frequent and

* From "The Climate of Canada", by Stupart.

the evaporation of the resulting moisture is greater in the prairie areas than in the wooded and semi-wooded parts, and the most frequent melting and greatest evaporation occurs in the Chinook belt of southern Alberta and southwestern Saskatchewan.

10. The Form in which the Precipitation Occurs.—Precipitation includes all the moisture that falls from the clouds to the earth. Rainfall is the most important but snowfall is also important. Hail and dew are other forms.

Snowstorms occur earlier than November and later than March, in fact, flurries may occur after the crop is up or before it is threshed. And snow that falls after March and before November may interfere with farm operations but it always functions as rain so far as the farmer is concerned and is generally very much appreciated by him when it comes in the spring.

The snowfall generally ranges between 30 inches and 60 inches per year, although less than 15 inches was reported twice at Battleford and more than 80 inches twice at Winnipeg. The area of lowest average snowfall runs in a northwesterly direction from southeastern Saskatchewan to northeastern Alberta, including Arcola, Regina, Saskatoon and Battleford. The amount increases rapidly in a northeasterly direction from this area but less rapidly in a southwesterly direction until western Alberta is reached. It has already been pointed out that from 50 to 60 per cent. of the total precipitation falls as rain in the May-August period, and that April, September and October precipitation is chiefly in the form of rain. In the prairie area any snow that falls in October usually melts in a few days but it has been known to remain on the ground from the early days of this month and to occasion considerable loss as a result of interference with the harvest of potatoes and roots as well as with the late threshing of cereals. The possibility of snowfall at this time should also have an important bearing on the plans of the stockman for the feeding and management of his animals.

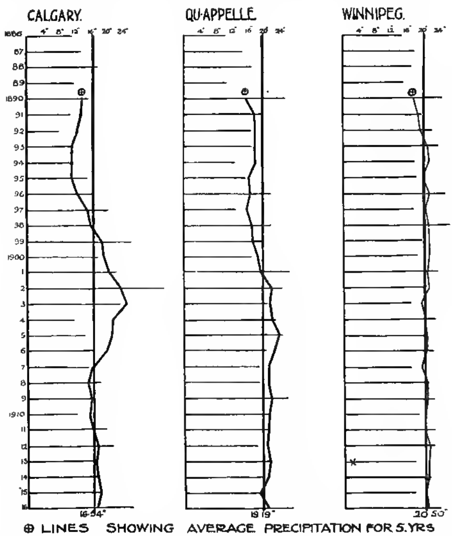

Fig. 11.—Variations from Normal Precipitation. The heavy vertical lines indicate the average precipitation at Calgary, Qu'Appelle and Winnipeg. The horizontal lines show the actual precipitation by years. The crooked lines represent the average precipitation in five-year periods and illustrate the variations from the normal.

Hail storms are most frequent between the middle of July and the middle of August. They may occur early in June or as late as the last of September. As to whether some districts are "subject" to hail and others not, there is much discussion but little reliable data. Most hail insurance companies charge slightly higher premiums in some parts of the foothill country and immediately east of it than in the central and eastern parts. The possibility of hail suggests the advisability of not putting all one's eggs in a single basket, in other words of having some source of revenue other than a grain crop. We cannot insure against drought or frost but insurance of grain crops against hail damage is possible and advisable for all who cannot afford to lose a crop.

11. Wide Variations from the Average Precipitation.—Three instances will serve to illustrate the fact that wide variations from the average precipitation are likely to occur. The average at Calgary for 31 years is 16.54 inches but in one year (1892) it was only 7.91 inches while in another (1902) it was 34.57 inches. The average for Qu'Appelle is 19.19 inches, but in 1886 it was 10.14 and 1916, 26.54. The average for Winnipeg for 31 years is 20.50, but in 1886 only 14.84 inches fell, while in 1899 the precipitation was 27.19 inches. Even the five-year averages depart widely from the normal, the variation appearing to be greatest in western Alberta and least in eastern Manitoba. Because of these wide variations from normal precipitation a more diversified system of cropping is likely to prove less risky and therefore in the long run is to be preferred.

12. Evaporation.—One of the chief reasons why crops have suffered less from drought in the northern end of the Great Plains region than in those parts of the south where the precipitation is the same, is the lower evaporation in this latitude. Higher yields are invariably secured in the north than from the same precipitation on equally good soils in more southern latitudes. The amount of total precipitation is not as satisfactory information as the amount of the "net" precipitation, which is the total less the evaporation from the soil. Unfortunately data on evaporation is not yet available for points in Western Canada.

13. Dry and Wet Years at Saskatoon.—The monthly distribution of precipitation at Saskatoon for the two years 1914 and 1915 and the average for the years 1904-1914 are as follows:

TABLE III.—*Monthly Distribution of Precipitation at Saskatoon in* 1914 *and* 1915.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1914	.90	.40	.48	.40	1.65	1.88	.85	.41	1.44	2.60	1.05	.60	12.66
1915	.50	.30	.00	.12	1.31	1.96	2.62	1.23	1.31	.47	.48	.51	10.81
1904 to 1914	.67	.56	.74	.70	1.04	3.45	2.45	2.20	1.25	.77	.66	.68	15.17

The total precipitation while not very different in the years 1914 and 1915 was rather greater in 1914, yet the wheat yield was 15 bushels less in 1914 than in 1915. The former is even yet remembered as the "dry" year, while the latter was with one exception the best year we have ever had. The difference in yields was due chiefly to the unfavorable distribution of moisture in 1914. Note that the "June" rains were but little more than half as heavy as the average and that the October and November rains which came after harvest were nearly three times as heavy as the average. The heavy crop in 1915 was probably due in large measure to the heavy precipitation in the fall of the preceding year. This kept the crop growing well through the early summer of 1915, and the timely and sufficient showers of late summer "filled" the heads.

14. Temperature Necessary for Germination and Growth.—The temperatures in degrees F. at which seeds germinate and at which crops grow best is indicated by the following data from Haberlandt:—

TABLE IV.—*Temperature Necessary for Germination and Growth.**

Crop	Germination				Growth		
	Min.	Opt.	Max.		Min.	Opt.	Max.
Wheat	41	84	108		32-40	77-88	88-98
Barley	41	84	99		"	"	"
Beans	49	93	115	Peas	"	"	"
Corn	49	93	115		40-51	88-98	98-111
Pumpkins	52	93	115		51-60	98-111	111-122
Melons					60-65	88-98	

It will be observed that the grain crops and peas will germinate and grow at relatively low temperatures, while corn demands more heat and truck crops, like melons, still higher temperatures both for germination and for growth.

15. The Measure of the Heat Supply.—The chief source of heat is the sun, although the stars and the interior of the earth also slightly increase the surface temperatures. The sun's heat reaches the earth by direct radiation, by radiation and conduction from the atmosphere, and by warm rains. The soil temperature is affected also by the heat given off from decaying plant tissues. The measure of the heat supply is the temperature, and the temperature data that chiefly concern the farmer are, (1) the average and extreme dates of the last spring and first fall frosts, (2) the average temperature of the growing season, (3) the extremes of temperature in the growing season, and (4) the total amount of heat received during the growing season. The time and severity of the last spring and first fall frosts fix the length of the growing season for cereals and together with the average temperature of the frost-free season determine, approximately at least, the total units of

* As quoted by Lyon, Fippin & Buckman in "Soils, their Properties and Management."

heat received from the sun during the growing season. At the same time the extremes of low temperature within the growing period limit the successful growth of the warm weather crops such as corn, sorghum, Sudan grass and certain of the heat-loving vegetables.

16. The Temperature Zones of Canada.—The average temperatures for the year and for the summer for the whole of Canada is shown in Fig. 12. From this it will

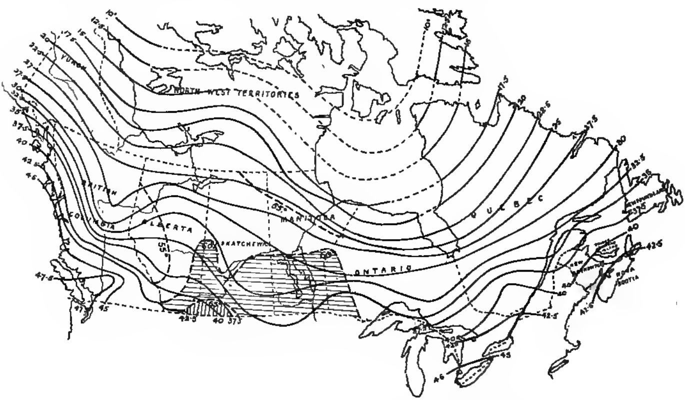

Fig. 12.—Temperature Zones of Canada.

The shaded area represents the average summer temperature and the unshaded portions the average temperature for the year. From Meteorological Reports.

be observed that southern Alberta and southwestern Saskatchewan and the southern part of the Red River Valley are the warmest for both the year and the summer, and that the temperature decreases in a northeasterly or a northerly direction, but that in the direction of northern Alberta and northwestern Saskatchewan the temperature decreases less rapidly than in northern Manitoba.

17. Spring and Fall Frosts in Western Canada.—The number of days between the last spring frost and the first fall frost and the average date of each is perhaps the most useful temperature information the grain

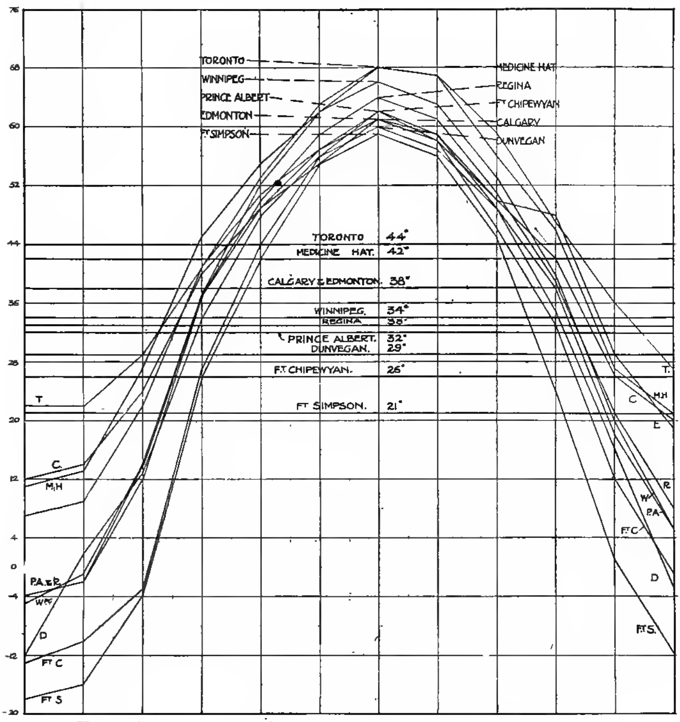

Fig. 13.—Average Temperature by Months at Representative Points.

grower and truck farmer could obtain. The meteorological records show that southeastern Alberta, southwestern Saskatchewan (and the Red River valley of Manitoba) have a longer frost-free period than any other part of the West and that the number of days between frosts decreases in all directions from there but less rapidly in an easterly direction. The driest part of the West is also the warmest. Too great heed cannot be given to these facts. They suggest that extreme dry farming practices are applicable in the dry warm area, but that "northern farming" or a system that will lessen the danger from frost should be practised in the more humid parts that have but a short time between spring and fall frosts.

The records of the Provincial Department of Agriculture at Regina for the ten years ending 1917 show that in the Province of Saskatchewan the soil was sufficiently thawed out by April 18th that the seeding of wheat became general on that date. During these ten years the earliest date on which wheat seeding was general was April 9th and the latest date, May 10th. No reliable records are available to show the average date at which tillage of the soil is prevented by freezing in the fall. Generally in the central west plowing may be continued till the end of October, sometimes till early December, but in exceptional years the ground has frozen hard as early as the first week of October. When the ground is dry in the fall low temperatures do not harden it as they do moist soil, consequently tillage may be continued much later than when the soil is wet.

The temperature records for Saskatchewan for the twelve years 1904 to 1915 report only one July frost. It is known, however, that in some low spots in at least two of these years small patches of wheat were frosted when the plants were in bloom in July. The only July frost that did serious harm to grain crops over a large area occurred in 1918, when a considerable percentage of the crop in the northern parts of the Prairie Provinces (chiefly Alberta and Saskatchewan) was injured by a heavy frost on the night of July 24th.

The purpose of instancing these facts is to show that the "average" time of frost is sometimes widely departed from, both in the favorable and unfavorable directions. This suggests even more forcibly than the short time between frosts, the desirability of (1) growing "safer" crops, and (2) developing a more diversified agriculture, particularly in the temperature zones showing the greatest variations from the average.

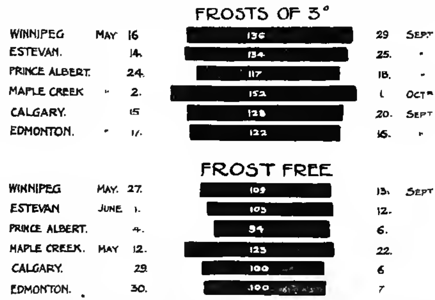

Fig. 14.—Frost-Free Period at Different Points. Above, length of period between spring and fall frosts of three degrees. Below, length of period between frosts. Twelve year average.

18. **Frost Resistance of Different Crops.**—Cereals will withstand heavy spring frosts but not fall frosts. Root crops and rape will withstand heavy fall frosts but suffer considerably from heavy spring frosts. Corn and potatoes will withstand neither, although potatoes will live through frosts that kill corn. Flax and peas suffer considerably from both spring and fall frosts, while perennial grasses and legumes will withstand very low temperatures at either season.

19. **The Average Temperature of the Growing Period.**—The average temperatures at representative points for each month in the year are indicated on the diagram,

and the actual figures are quoted in the table that follows. These show very favorable temperatures for growth in summer even at far north points such as Fort Simpson. The more rapid fall of autumn temperatures and the lower temperatures in spring, in the northern latitudes, indicate a shorter growing season. By comparing the monthly rainfall and monthly temperature illustrations it will be seen that the months of highest temperature follow closely the months of greatest rainfall. To this fortunate "accident" of climate is largely due such success as has attended the efforts of the crop grower in the Canadian West.

Table V.—*The Average Mean Monthly and Annual Temperatures at Representative Points.**

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Yr.
Calgary	12	14	24	40	49	55	61	58	50	42	26	20	38
Edmonton	7	9	22	41	51	57	61	59	50	48	29	19	38
Medicine Hat	11	13	27	45	55	62	68	67	56	46	27	21	42
Prince Albert	4	2	12	37	49	57	62	59	49	38	18	5	32
Regina	4	2	14	37	50	59	64	61	51	39	21	8	33
Winnipeg	5	1	14	37	52	62	66	63	53	40	20	5	34
Dunvegan	12	2	13	34	48	56	60	57	49	35	16	3	29
Ft. Chipewyan	13	10	5	27	44	56	62	58	46	33	12	1	26
Ft. Simpson	18	16	4	26	42	55	59	56	45	24	1	12	21

20. The Total Heat Received During the Period of Growth.—The total amount of heat received during the growing season may be determined by multiplying the number of days of growth by the difference between the temperature required for plant growth and the average daily temperature for the period. The result is spoken of as the "accumulated temperatures" which is the sum of the "day degrees" of temperature between the time in

* From Canadian Year Book reporting Dominion Meteorological Service data—Calgary 20 years, Edmonton 25 years, Prince Albert 20 years and Winnipeg 70 years. Data for other places taken from the "Climate of Canada", by Stupart.

the spring when plant growth starts and the time in the fall when it stops. Unstead worked this out from the meagre data that were available with the results indicated on the map.† In arriving at these results he arbitrarily took the time in the spring

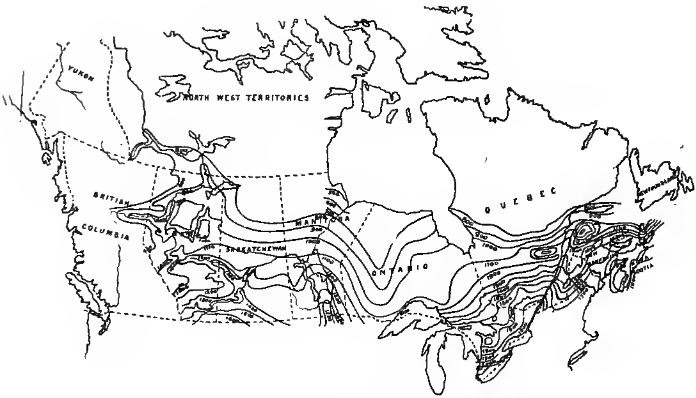

Fig. 15.—Temperature Zones of Canada.

As determined by the accumulated temperatures between time in the spring when growth of cereals starts and time in the fall when it normally ceases.—After Unstead.

when the average daily temperature rises above 5°C. or 41°F. and the time in the fall when it descends to 10°C. or 50°F., as being the time when plant growth starts and stops respectively.

In the report of the same investigation he pointed out that at Ottawa, Red Fife would mature with an accumulated temperature of 1330 degrees, Ladoga with 1210 degrees and Early Riga with 1030 degrees. With our longer hours of sunlight here and the very early varieties that are now available the possibility of grow-

† Reported in "The Geographical Journal", April and May 1912.

ing wheat very far north in Alberta seems promising. How profitable it may be, the average date of the first fall frost and the percentage of seasons that are free from summer frosts will largely determine.

21. Wind Velocity.—The wind velocity averages higher on the open plains than in the park belt and wooded areas. In some seasons it does serious injury to tender plants and shrubs by causing the soil to drift. According to Cross* the average velocity ranges in different parts of the West from 5.1 to 13.3 miles per hour, while the average maximum ranges from 30 to 57 miles per hour.

22. The Chinook Wind.—The temperature of the southwesterly winds is the highest and that of the northeasterly the lowest. The Chinook, a warm southwest wind, is often responsible in winter for removing the snow covering very soon after it comes. This is perhaps favorable for the rancher but not so for the crop grower. In summer this wind sometimes does serious injury to crops in southern Alberta and southwestern Saskatchewan, occasionally as far east as Moose Jaw and Saskatoon. It is reported that it is occasionally felt in milder form as far north as the Peace River Valley and upper Mackenzie basin.

23. Humidity of the Wind.—Little data is available concerning the humidity of the atmosphere in these winds but experience has shown that the southwest and west ones are very dry while those from other directions are generally more humid, especially the east winds.

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* In "Climate and Rainfall", by J. F. Cross in "Prairie Provinces of Canada", Sells Ltd.

24. Wind Direction.—Mr. J. F. Cross,* Superintendent of St. John's College Observatory at Winnipeg has this to say on the general subject of winds in the Prairie Provinces:

"The typical wind of the prairie section is northwest, that of the Chinook (southern Alberta and southwestern Saskatchewan) southwest. Modifications of these arise in several districts owing to local peculiarities, and velocities also vary considerably. . . . Generally, however, in Manitoba the direction tends north or south with almost continuous moderate velocity and a number of light gales; in Saskatchewan the westerly type begins to appear, while in northern Alberta the most prevalent wind is due west. In southern Alberta and especially in districts adjacent to the Rocky Mountains the direction is usually southwest and the velocity rarely exceeds 30 miles an hour. The force of the air movements on the whole is greater in places of low latitude. Hurricanes are, however, practically non-existent in the Canadian West, the one notable exception being the cyclone which visited Regina during the summer of 1912 and caused considerable damage in the business section of the city."

25. Atmospheric Humidity.—The meteorological data on the atmospheric humidity of the West is very meagre. In brief, it indicates that our atmosphere is very dry, the driest being in the areas of lowest precipitation and highest temperature, viz., southeastern Alberta and southwestern Saskatchewan.

A dry atmosphere increases evaporation. This is noticeable, chiefly in the "Chinook" region where after

* In "The Prairie Provinces of Canada".

melting the snows of winter, the warm dry wind sucks up the moisture very rapidly. The dry atmosphere is, however, not always a misfortune. This is one of the causes of high quality in wheat and also one of the chief causes of the relatively small damage from rust and other fungous diseases in the dry parts of the West. Carleton,* referring to this point, states that "A heavy stand of wheat in humid districts is favorable to rust. Under these conditions it should be noted that the atmospheric humidity is the influencing factor. . . . . .

"In this district (the spring wheat belt of Canada and the United States) because of the deep black soil and dry, hot summers, there is grown the highest grade of common spring wheat in the world excepting the spring wheats of the middle Volga district of Russia, which are very similar."

26. Long Hours of Sunlight in the Growing Season.— Light is essential for plant growth. Without it plants cannot manufacture their food. Man cannot control the light except in a negative way by preventing weeds and other obstacles shading useful plants. Two phases of this question are, however, very interesting. The first is the length of the day in summer in northern latitudes, and the second the relative lack of clouds in this climate.

The number of possible hours of sunshine daily during June, July and August at various places is indicated on the sunshine map. The long days of summer and the relative lack of cloudiness in Western Canada encourages rapid growth and makes possible the maturing of crops in much less time than people of southern

* In "The Small Grains", by Carleton.

climates can imagine. These conditions, together with the favorable monthly distribution of precipitation, are largely responsible for the measure of success that has been attained in crop growing in our northern semi-arid climate.

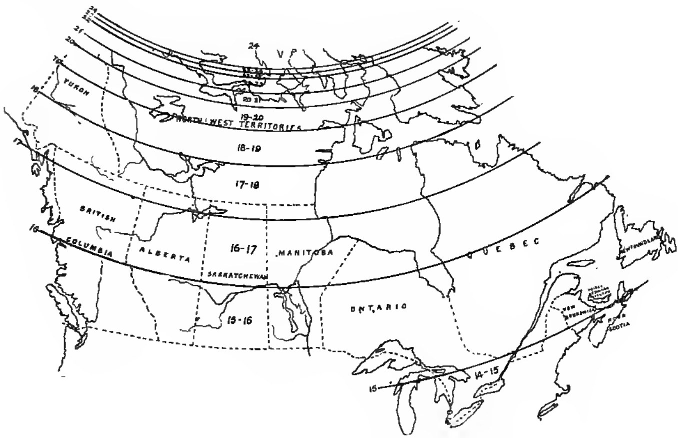

Fig. 16.—Hours of Possible Sunshine Daily in Summer.

26a. The Effect of Latitude and Altitude on Temperature.—Where no other factors interfere the average decrease in temperature is approximately three degrees for every 100 miles one goes in a northerly direction. It is seldom, however, that this ratio is not affected by changes in altitude or relation to forests or large bodies of water.

The lowering of temperature as a result of increase in elevation averages one degree for every 300 feet. The effect of latitude and altitude is clearly shown by the height of the permanent snow line above sea level. At the north pole this line is at sea level. At the southern boundary of Canada it may be seen in the Rocky Mountains at an altitude of 6,000 to 8,000 feet and at the equator it is found only after reaching the height of 16,000 to 18,000 feet.

26b. The Effects of Forests on Climate.—The effect of forests on climate is to lessen the extremes of precipitation, evaporation, wind velocity and to some extent the temperature. How much the forests of North-western Canada affect our climate it is difficult to estimate. In the practice of farming its greatest influence is probably found in lessening the wind velocity and thereby the evaporation and danger from soil erosion. This favorable effect is, of course, greatest in the wooded areas and least in the prairie and Chinook belts.

CHAPTER III.

THE SOIL

By Roy Hansen, M.S., Professor of Soils, University of Saskatchewan, Saskatoon.

27. The Role of the Soil.—The existence of mankind is dependent upon three things: the earth, the atmosphere and the sunshine. Of these, only the earth is subject to the will of man, to conserve or destroy according to his knowledge or ignorance. And of the earth, it is with the shallow surface crust, but a few inches in thickness, which we designate as "the soil", that we are most concerned. The soil must support the plant world which in turn supports the animal world, including mankind. Thus the food we eat, the clothes we wear, and the timber that provides us shelter come ultimately from the soil. The soil, therefore, is our greatest resource, the very foundation of life and prosperity.

The growing plant in its endeavor to reproduce its kind, the chief function of all life, had need of five essentials: (1) a place to take root, that it may support its aerial parts; (2) food, as important to plants as it is to animals; (3) moisture; (4) heat; (5) light.

With the exception of light the soil is concerned in each of these essentials. The root system of the plant is determined by the texture of the soil. The soil must furnish the mineral plant food elements and nitrogen. It absorbs and retains the rainfall to be given up to the plants as needed. It absorbs and transmits heat upon which plant life is dependent. These factors we can in a large measure control by our farm practices. In order to know the best practices to pursue, it is essential that we know why and how the soil responds to different treatment.

History and Physical Properties.

28. Origin.—Geologists tell us that the earth was at one time a molten mass cast off with its whirling motion from the sun. Through many centuries this mass slowly cooled, the molten materials forming a crust of solid rock and the vapors condensing to water to form lakes and oceans. The rock was broken down to a disintegrated mass by the grinding action of the glaciers and the slower process of weathering. Part of this disintegrated material was carried away and redeposited by the wind or water, becoming again cemented in stratified form into rock. Part of it remained in place and formed the beginning of the soil, accumulating slowly through the ages by Nature's processes.

The forces of disintegration and transportation have been at work during all time. The power of freezing and thawing in crumbling down rock is familiar to all. The deep crevices in granite rock with the pile of crumbled-off material at the base tells the story of Nature's work. The effects of water with its driving force as rain, and its dissolving and wearing action in flowing over rock surface are well evidenced in the caverns and caves it cuts in stratified sandstone and limestone deposits. The wind picking up particles of sand, grinds and wears the rocks to powder. The atmosphere with its moisture and gases aids in this process of solution and disintegration.

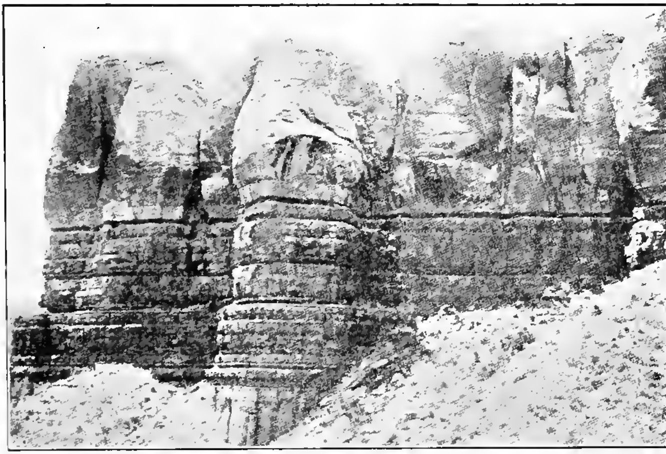

Fig. 17.—Rock Weathering.
A step in soil formation.—Chamberlain & Salisbury, courtesy Henry Holt & Co.

With the coming of life upon earth, first the bacteria perhaps and then higher plants and animal life, new forces of disintegration came into play. The bacteria were able to feed upon the rock materials, building living tissue from the solid minerals which they dissolved and assimilated. Plants and then animals took part in the process, exerting in part mechanical or physical force, in part chemical force and in part biological force. With the decay of vegetable and animal matter organic acids were liberated and these assisted in the process.

Thus the process went on, the rock materials supporting plant life, and the latter contributing further to soil building.

The ultimate outcome was the soil, made up as we now know it, of stones, gravel, sand, silt, clay and organic matter. These then were the final products, though we must not think of the process as being finished. Nature is constantly at work levelling mountains, disintegrating rocks, and transporting and depositing the materials without heed to the desires of man, indeed often contrary to his wishes.

29. Soil Classification.—According to the manner of formation and deposition and the agencies that played the leading part, soils are classified as indicated in the following outline—

- (1) Sedentary, formed in place:
  - (a) Residual, formed in place from disintegration of rocks.
  - (b) Cumulose, formed in place by the partial decay and accumulation of vegetable matter.
- (2) Transported Soils:
  - (a) Glacial soils, deposited by glaciers.
  - (b) Loessial soils, deposited by the wind.
  - (c) Alluvial soils, deposited by the action of water.

Sedentary Soils.—As the name indicates, these are formed in place, no appreciable transportation from the location of the original rock upon which they rest having taken place. Sedentary soils are further subdivided into (1) residual, soils formed in place from the disintegration of rocks; and (2) cumulose, soils formed in place by the partial decay and accumulation of vegetable matter (plant remains). Limestone soils, productive soils covering extensive areas in the southern and eastern states of the United States, are examples of residual soils. Frequently the limestone has completely leached away, the soil consisting entirely of the impurities of the original limestone and plant remains. Cumulose soils are illustrated by mucks and peats which have been formed under peculiar conditions, (i. e. poor drainage as in swamp and bog land) allowing the partial decay and accumulation of plant remains, the growth of moss, swamp grass, etc., on top exceeding the rate of decomposition of the old remains, thus resulting in the deposition of a soil consisting largely of organic matter.

Transported Soils.—These are likewise formed by rock distintegration, but the materials are removed from their original resting places. Chief among the agencies of transportation are the wind, the glaciers, and water.

Material picked up and deposited by the wind is termed loess. Loessial soils occupy a large area in the prairies of the United States, and in depth they vary from a few inches to perhaps 200 feet.

The material brought down and deposited by the glaciers is called glacial till or boulder clay. Soils so formed are more varied in character, containing frequently rounded stones and gravel along with much silt and fine sand, the result of the grinding action of these huge ice sheets, and frequently huge boulders left upon the open prairies.

Soils deposited through the agency of water, such as the deltas of rivers, old lake bottoms, etc., are termed alluvial soils, and these generally rank among our most fertile soils. The delta of the Nile and the Red River

Valley of the North are typical examples, the latter being at one time the bed of the old Lake Agassiz.

30. Soil Types.—Soils are further divided into types depending upon the content of the various soil materials. Thus we have gravels, sands, silts, clays, gravelly loam, sandy loam, silt loam, clay loam, muck, peat and loam. By a loam is meant a soil having a good balance of the various constituents, that is, not enough clay to render it plastic, not enough sand to make it too loose and open, and with a sufficient supply of organic

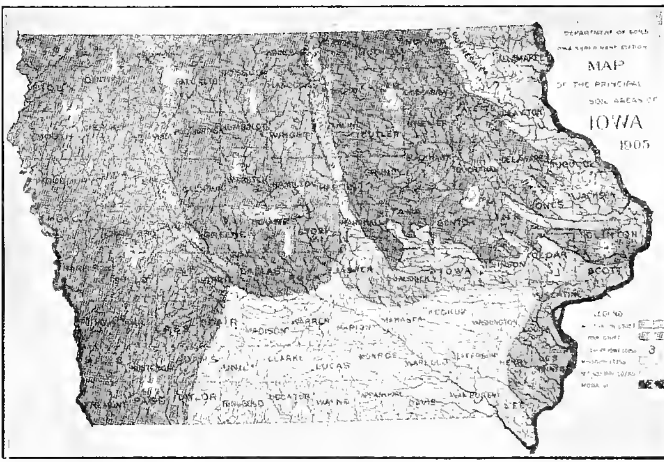

Fig. 18.—Soil Surface Map of Iowa.

The soils in each county in most of the States are being mapped and classified and the local agricultural conditions studied in order that intelligent direction may be offered farmers for increasing production. The problems of Western Canada need such a systematic study.—Courtesy of the Iowa Experiment Station.

matter to give a good friable texture. The percentage of various soil materials determines the physical character of the soil, i. e. the texture, the ease of cultivation, the temperature, the water-holding capacity and the porosity (air-space).

31. Physical Properties of Soils.—The above classification depends upon the size of the soil particles and upon the organic matter content, these factors determining its physical properties. Sandy soils have large particles predominating and this results in their looseness and openness, their non-adhesiveness. Water drains readily through such soils, and less is retained for crops. Air circulates more freely, the pore spaces are larger and because of this, and the fact that they hold less water, sandy soils are "warmer", "earlier", and therefore best adapted in the humid sections to truck farming and early vegetable gardening.

Clays, on the other hand, are plastic, difficult to work when wet. This is due mainly to the extremely small soil particles and in part to the plastic nature of the material, kaolin or fire-clay, which makes up a considerable part of such soils. Clays retain more moisture, the particles being smaller and hence more numerous per given volume; the water film surrounding the particles is more extensive in area, hence the ability to hold more water. Air circulates less freely. The total air space is greater in clays (porosity is inversely proportional to the size of the particles), but the movement of air finds greater resistance. A further fact about clays is that though they retain more moisture, they give it up with less ease to plants than do sands. Plants will wilt in a clay soil, whereas in a sand of equal total moisture content, they would show no signs of lack of moisture. Thus in general clay soils are "colder", "later", more retentive of moisture and more difficult to work.

Humus, the accumulated residue of the decomposition of plant remains, plays an important role in the physical properties of soils. Being somewhat plastic and spongy in nature, it binds the sand particles together, giving such soils greater adhesiveness and hence better tilth. In clay it binds the small particles together into larger aggregates, thereby lessening the plasticity and rendering them easier to work. Due to its porous nature it increases the water-holding capacity, facilitating the absorption and retention of water. It increases the pore-space, allowing the air to circulate more freely in the heavier types of soil, thereby increasing the warmth, and making the soil "earlier". The importance of keeping up the humus content from the standpoint of the physical properties of the soil is, therefore, important; the role from the chemical and biological standpoints will be discussed later.

The capillary rise of water in soils is controlled by the size and compactness of the soil particles. Although water rises more rapidly in a sandy soil because of less resistance, the total height to which it will rise and the force exerted in the upward rise are greater in the heavier types. Soil-packing, therefore, results in better capillary contact besides assisting in the decay of vegetable matter by the closer contact with moisture.

32. Dry-Farming and Soil Physics.—Dry-farming puts into practice our knowledge concerning the physical properties of soil. For example we plow for summer-fallow before the last of the heavy summer rains come in order to render the soil more open and retentive of moisture. The use of the soil packer on fall and spring plowing is to lessen the air space in the soil and to aid in bringing the moisture up to where the seed is to be planted; and the object of surface cultivation, aside from controlling weeds, is to provide a satisfactory seed bed containing the right amounts of moisture, heat and air for germination and growth. Surface cultivation also provides a mulch which lessens to some extent the cracking of the soil and thereby checks evaporation.

Soil Fertility or Chemistry.

33. The Food of Plants.—Food is as important a consideration to plants as it is to animals. Animals require for food vegetable matter, such as starch, sugar, fat, protein, etc., the highly organized, complex materials built up by plant life. While animals frequently eat animal flesh, plant life is the primary source of food. The nutrition of plants, however, is different. They require as food the simple, inorganic materials derived from the solution of rock materials or from the decay of plant or animal remains. This food is taken up in water solution, and by the plant is built up into tissue, i.e. sugar, starch, cellulose, protein, the things for which we prize plants as food for human or stock consumption.

34. The Essential Elements.—The earth's crust is composed of about 80 elements in varying amounts and combinations or compounds. Of the 80 elements, 40 are more or less common, and 15, because of their wide occurrence in plants, soils, water and in the atmosphere, are important in soil fertility. Of these 15 elements, 10 are essential for the growth of plants; deprived of any of them the plant would succumb, or would, at least, be unable to reproduce its kind. These elements which are divided into three groups for the purposes of our discussion, are as follows:—

Group 1.	Group 2.	Group 3.
Carbon	Calcium	Nitrogen
Hydrogen	Magnesium	Phosphorus
Oxygen	Iron	Potassium
	Sulphur	

Carbon, Hydrogen, Oxygen.—Carbon is derived from the carbon-dioxide of the air. By means of their "breathing pores" the leaves of plants take in this gas and in some way combine it with water to make sugars. Oxygen is likewise derived from the air, both as carbon-dioxide and free oxygen gas, and from water, of which it is a constituent part. Hydrogen is derived from water. These three elements, carbon, hydrogen and oxygen make up from 90 to 95% of mature plants and this fact, together with the fact already noted that they are derived from the atmosphere and water, has led to the error of minimizing the importance of the other seven essential elements.

Calcium, Magnesium, Iron, Sulphur.—Of the remaining seven essential elements, four, calcium, magnesium, iron and sulphur, though necessary to plants, occur in relatively large amounts in the soil in proportion to the amounts required by plants. Therefore they do not concern us, since they are not likely to limit our crop yield. The soil is the source of these elements for plants (some sulphur comes down with the rain).

Nitrogen, Phorphorus, Potassium.—The elements of this group, nitrogen, phosphorus and potassium, are, for common farm crops, derived from the soil. (Legumes can take nitrogen from the air, as will be discussed later). Potassium occurs in liberal amounts in most soils; in some types, particularly muck and peat, it is frequently lacking and must therefore be supplied if maximum yields are to be obtained. In normal soil, however, it is seldom lacking. Nitrogen and phosphorus on the other hand are very frequently deficient, and they are, therefore, among the most common world-wide soil problems.

35. The Essential Elements in Saskatchewan Soils.—In the table that follows is given the average content in Saskatchewan soils of five essential elements. The figures reported represent the averages of the analyses made by the Department of Chemistry of the University of Saskatchewan, of 16 samples of soil, 8 being virgin prairie soils. The plowed acre taken to a depth of 6, 2/3 inches is taken to weigh 2,000,000 pounds, the analyses being computed on this basis.

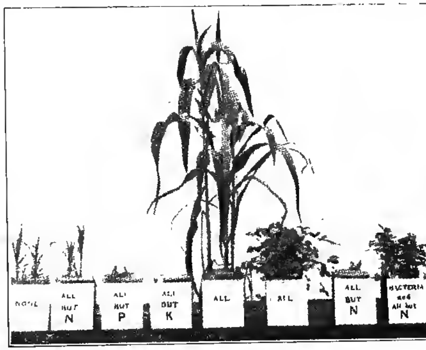

Fig. 19.—Pot Cultures.

Showing the effect of the presence and absence of plant foods: N. nitrogen; P. phosphorus; K. potassium. Note that inoculated clover grows normally without commercial nitrogen, the plants securing their supply from the air. Without inoculation or commercial nitrogen the plants fail.—Courtesy Illinois Agricultural Experimental Station.

The second column of figures indicates the amounts of these elements required to produce 30 bushels of wheat including both grain and straw. Knowing the soil content and the amount required for a 30-bushel crop, we can calculate the numbers of 30-bushel crops that are theoretically possible (column 3).

TABLE VI.—*"Supply and Demand" of Essential Elements in Average Saskatchewan Soil.*

Essential Elements	Pounds in 2,000,000 of surface soil from an average of 16 soils	Pounds in 30 bus. of wheat including straw	No. of 30 bus. crops of wheat possible
Nitrogen	8604	57.6	150
Phosphorus	1830	9.6	191
Potassium	34925	34.8	1004
Calcium	31074	6.3	4932
Magnesium	11738	4.8	2445

While such an average analysis of soils does not represent the true average for the province and while 16 samples are not enough upon which to base final judgment, the results do have instructive value. It is apparent that nitrogen and phosphorus, of the essential elements, will first limit crop yields. Undoubtedly the deficiencies are already felt in the poorer, longer-cropped soils. This method of computation is subject to several further qualifications however.

First, the nitrogen supply is subject to additions and deductions other than cropping (exclusive also of fertilization and green manuring). Certain free-living aerobic bacteria (Azotabacter) living in the soil have the power of extracting nitrogen from the air; certain amounts of nitrogen are brought down in the rain, chiefly as ammonia and nitric acid. On the other hand certain bacteria may cause the loss of soil nitrogen into the air (denitrification) and what is most important, great losses of soil nitrogen occur through surface erosion, and through leaching. The latter is relatively more important in humid regions. But in general even under semi-arid conditions the losses from all sources other than cropping greatly exceed the gains. Thus 150 crops of thirty bushels each (4,500 bus.) is by far too liberal an estimate from the nitrogen standpoint.

Second, with phosphorus, and this applies equally to nitrogen, even under otherwise ideal conditions, we could not continue to remove 30-bushel crops of wheat successively until the phosphorus was exhausted. Under humid conditions phosphorus becomes a serious limiting factor when the supply is below 1,000 pounds. The yield is determined by the total supply of plant food, and, as will be discussed later, its "availability". In general the yields will become decreasingly smaller as the phosphorus or nitrogen (or both) is exhausted.

36. Average Saskatchewan Soil vs. Other Soils.—In the following table the "average" Saskatchewan soil is compared with some well known fertile soils:

TABLE VII.—*Average Saskatchewan Soil versus Other Soils in pounds per acre* 6 2-3 *inches deep—approximately* 2,000,000 *pounds.*

Soil	Nitrogen	Phosphorus	Potassium
Average Saskatchewan Soil	8604	1830	34925
Rich, well-balanced normal land in the Corn Belt	8000	2000	35000
Average prairie soil of the Red River Valley in Northwestern Minnesota*	8200	3340	45100
Fargo black clay soil (North Dakota) representative of a large part of the Red River Valley. Old wheat land†	8300	1518	.....
Red River Valley virgin sod	14000	1949	.....

* Hopkins' "Soil Fertility and Permanent Agriculture".
† Doneghue, North Dakota Agricultural Experimental Station Bulletin 126.

From this table it would appear that our average soil compares very favorably with some of the well known fertile soils. But again it should be pointed out that this "average" soil does not fairly represent the province; undoubtedly some of our extensive types, as the sandy loams for example, do not measure up to this standard. Furthermore, even on the fertile corn belt land, soil enrichment has been found both practical and profitable.

(See table XIV.).

37. Organic Matter and Soil Fertility—Organic matter is supplied to the soil in general farm practice in the following ways:—

1. Crop residues;
2. Green manuring;
3. Pasturing;
4. Applying farm manure.

By crop residues are meant the stubble of cereals, straws, corn stalks, etc. In the corn belt the corn stalks in common practice are broken over, disked and plowed under, and the spreading on the land and plowing under of straw is not uncommon. While these practices may not be possible here, as much organic matter from these sources should be returned as is practicable, either by feeding and returning as manure or bedding down stock, and thus incorporating the straw with the manure. The burning of straw piles represents not only a great waste of organic matter and nitrogen, but of other essential elements as well. This is indicated in table VIII,

Table VIII.—*Fertility Lost by Burning Straw.*

Essential Elements	Pounds in 1 ton wheat straw	Pounds in 1 bu. wheat, grain only	Maximum bushels wheat possible from 1 ton straw
Nitrogen	10.0	1.4	7.1
Phosphorus	1.6	.24	6.7
Potassium	18.0	.26	69.2

Thus, if we assume that the fertility elements lost by burning the straw could be applied to the production of wheat, we find that in each ton the nitrogen would be sufficient for 7.1 bushels of wheat, the phosphorus for 6.7 bushels, and the potassium for 69.2 bushels. These losses, together with the loss of other benefits of organic matter, are the results of burning the straw. Where straw or manure is spread on the land and then burned over only the nitrogen and organic matter are lost. Phosphorus, potassium and other mineral elements are not destroyed by burning. The ashes are valuable as fertilizer if spread evenly over the land.

Green manuring is the practice of growing crops for the express purpose of plowing them under to improve the soil. In the older countries legumes are most commonly used, though buckwheat and rye, the latter used as a cover crop, are widely used. Since this country will never be thickly populated with stock and since the depletion of organic matter in the soils is already becoming apparent, green manuring must, of necessity, come into common practice, if the organic matter in our soils is to be maintained.

Pasturing, from the standpoint of soil fertility, is the most economical method of returning manure to the land. The expense of hauling and spreading is saved, and the losses by fermentation (fire-fanging) as occur in the manure pile in the farmyard, are avoided.

Spreading manure is a time-honored custom, and in most communities the benefits are fully appreciated. Table IX. brings out the fertility value of manure from the standpoint of its content of the essential elements. The figures are computed on the basis of average barnyard manure.

TABLE IX.—*Fertility Value of Barnyard Manure.**

Essential Elements	Pounds in 1 ton average barnyard manure	Pounds in one bushel wheat, grain only	Pounds in 1 bu. wheat, grain and straw	Possible bu. wheat, grain only	Possible bu. wheat, grain and straw
Nitrogen	10.0	1.4	1.92	7.1	5.2
Phosphorus	3.0	.24	.32	12.5	9.4
Potassium	8.0	.26	1.16	30.8	6.9

Thus one ton of average barnyard manure contains as much nitrogen as 7.1 bushels of wheat, as much phosphorus as 12.5 bushels, and as much potassium as 30.8 bushels. If we assume no losses, but that the fertility elements contained in a ton of manure go to make up grain and straw, the nitrogen would be sufficient for 5.2 bushels, the phosphorus for 9.4 bushels and the potassium for 6.9 bushels.

In live stock farming the organic matter recovered in the manure represents less than one-half of that fed. Further loss occurs in the barnyard, due to fermentation through the action of bacteria, and through leaching. In this connection Hopkins' "Soil Fertility and Permanent Agriculture" says: "As an average in livestock farming, the animals retain about one-fourth of the nitrogen and phosphorus and destroy two-thirds of the organic matter of the food consumed, and large loss is likely to occur in the manure produced, especially in nitrogen and organic matter, a loss in one half of these

* Figures from Hopkins' "Soil Fertility and Permanent Agriculture."

constituents being easily possible during three or four months, in part from fermentation, which may occur even under cover, and in part from leaching where manure is exposed to the weather or where little or no absorbent bedding is used."

Concerning manure the North Dakota Experiment Station* finds that, "approximately one-half of the fertilizing value of manure is lost in rotting, so that it probably requires 2 tons of fresh manure to make 1 ton of rotted manure. Considering the cost of extra handling of rotted manure it would be more profitable to haul the manure directly from the barn to the field. It can be applied to best advantage to pasture in the rotation or plowed under for corn".

38. Functions of Organic Matter.—Organic matter returned to the soil functions in several ways:

1. By improving the physical tilth by increasing the humus content as already discussed (i.e. increases the water-holding capacity; increases the pore space, hence the "warmth" and "earliness"; renders clays easier to work; gives better adhesiveness to sands, etc.).
2. By supplying the essential elements it contains.
3. By assisting in dissolving the insoluble plant food elements through the action of the acids produced in the decay of the organic matter.

The first two items have already been discussed, the third will be taken up under the action of bacteria in the soil.

39. Losses of Organic Matter in the Soil.—That the present system of farming which makes no adequate provision for the return of organic matter is rapidly de-

* Doneghue, North Dakota Agricultural Experimental Station Bulletin 126.

pleting the humus and the nitrogen content has been shown by Shutt, Dominion Chemist, from the following figures*:

TABLE X.—*Nitrogen-content of Virgin and Cultivated Soils, Indian Head, Saskatchewan.*

	To a depth of 4 inches		To a depth of 8 inches	
	Per cent.	Lbs per acre	Per cent.	Lbs per acre
Virgin Soil	.409	3,824	.371	6,936
Cultivated Soil	.259	2,421	.254	4,750
Difference or loss due to removal in crops and to cultural methods.	.150	1,403	.117	2,186

Doneghue of the North Dakota Experiment Station arrived at similar conclusions with the fertile Red River Valley soil, under a system of continuous wheat-growing, as indicated in table XI.

TABLE XI.—*Composition of Old Wheat Soil in Comparison with Virgin Sod.*†

Surface Soil, 0-7 inches	Total Nitrogen pounds per acre	Total Phosphorus pounds per acre
Virgin sod	14,000	1,949
Old wheat land	8,300	1,518
Losses due to removal in crops and to cultural methods.	5,700	431

Doneghue concludes that, "The black clay soil of the Red River Valley has deteriorated in fertility and crop-producing capacity under a continuous system of single cropping with wheat. Such land on the Experiment Station contains approximately one-fourth to one-third

* Western Prairie Soils.
† From North Dakota Experimental Station Bulletin 126.

less nitrogen and one-fifth less phosphorus than virgin soil of the same type on this farm. The yield during the last eight years of the experiment has been 28 per cent. less than during the first eight years of the 24-year period."

In Saskatchewan six different soils which had been under cultivation for a number of years were compared to six virgin soils of the same type which adjoined or surrounded the cropped land. This gives six comparisons of cropped and virgin land, showing the effect of the present system of farming under actual field conditions. The analyses reported were made by the Department of Chemistry of the University of Saskatchewan.

TABLE XII.—*Losses in Plant-food elements in Saskatchewan Soils through Present Methods of Soil Management. Pounds per* 2,000,000 (0-6 2-3 *inches.*)

Locality	Nitrogen		Phosphorus	
	Lbs. per 2,000,000	Loss	Lbs. per 2,000,000	Loss
Melfort, virgin	12300		1720	
" cropped 29 years	11480	820	1520	200
Kinistino, virgin	14420		2300	
" cropped 34 years	11500	2920	2140	160
Rosthern, virgin	8800		2880	
" cropped	6360	2440	1620	1260
Yorkton, virgin	10800		2220	
" cropped 31 years	9740	1060	1880	340
Regina, virgin	6800		1740	
" cropped 12 years	5980	820	1440	300
Indian Head, virgin	9100		2820	
" cropped 30 years	3960	5140	1680	1140
Average loss through cultivation in six soils		2200		567

Humus, the residual material from the decomposition of organic matter in the soil, is rapidly dissipated when humus-forming materials (organic matter) are not supplied. Nitrogen in the soil is contained in the organic matter and by decomposition of the latter is made available to plants. Thus the loss of 2,200 pounds of nitrogen, the average of the six comparisons, represents the dissipation of a great amount of organic matter. The practice of summerfallowing especially hastens the decomposition and dissipation of organic matter, and if the practice is a necessary evil, provision must at least be made in the future for supplying the humus-forming materials. The actual amount of nitrogen removed by crops is probably less than one-third of the figure given, the other two-thirds, 1,467 lbs, being lost mainly through surface washing, soil blowing or drifting, and perhaps leaching.

The phosphorus loss, 567 pounds, is far greater than could be explained by removal in crops. Phosphorus being contained principally in insoluble form in the soil, is not lost by leaching. Surface-washing and perhaps soil-blowing or "drifting" are largely responsible for the losses not accounted for in the crops.

The figures in table XII. are not to be taken at their absolute value, however. We cannot be certain that a sample of soil from cropped land had at one time the same composition as a sample of virgin land adjoining. However, when repeated comparisons show the same result, we have a good "indication" of the results of our farm practices. That a tremendous loss in organic matter does occur is a matter of common observation, and the bad effects are plainly evident in working the land.

40. The Rothamsted Experiments on Soil-Fertility.—The best information on the value of soil treatment as opposed to no treatment in good systems of crop rotation is from the Rothamsted Experiment Station near London, England. Two rotations are compared as follows:

Rotation I.	Rotation II.
Turnips	Turnips
Barley	Barley
Clover (or beans where clover failed)	Fallow
Wheat	Wheat

The first is termed the legume rotation, the second the fallow rotation. Both rotations are arranged so that complete fertilization can be compared to no treatment. The complete fertilization consists of the addition of essential plant food elements in the form of common commercial fertilizers. Nitrogen, phosphorus, potassium, magnesium, sodium and sulphur are included, in the form of ammonium sulphate, acid phosphate, potassium chloride, etc. The fertilizers are applied once in four years (for the turnip crop). The experiment has been carried on for sixty years, the results appearing in table XIII.

TABLE XIII.—*Rothamsted Experiments, Agdell Field.*

	Unfertilized		Fertilized with Minerals and Nitrogen	
	Legume Rotation	Fallow Rotation	Legume Rotation	Fallow Rotation
Turnips	2651 lbs.	3785 lbs.	34,906 lbs.	36,695 lbs.
Barley	24.7 bu.	25.2 bu.	38.9 bu.	36.2 bu.
Clover (7 crops)	2094 lbs.	....	5,379 lbs.	....
Beans* (8 crops)	13.0 bu.	....	22.8 bu.	....
Wheat	25.0 bu.	27.1 bu.	34.6 bu.	31.8 bu.

This is perhaps the world's best evidence on the food requirements of plants. On the unfertilized fields the crop yields steadily decreased. On the fertilized fields the yields have been maintained at a high average, the turnips averaging during the last 20 years of the 60-

* Beans grown when clover failed.

year period more than double what the unfertilized land was capable of at the beginning. The rotations alone, therefore, would not maintain yields without fertilization. Plants as well as animals require food.

41. Illinois Experiment.—The Illinois Agricultural Experiment Station is conducting an experiment on the typical brown silt loam prairie land of the Corn Belt. Five fields are under cultivation, "wheat, corn, oats and clover being rotated for five years on four fields, while alfalfa occupies the fifth field, which is then brought under the four-crop system to make place for alfalfa on one of the other fields for another five-year period, and so on*". Sixteen years' results have been published†, the averages appearing in table XIV.

TABLE XIV.—*Illinois Experiment: Urbana Field. Brown silt loam prairie: Early Wisconsin Glaciation.*

Serial plot No.	Soil treatment applied	Average Annual Yields—bushels or (tons) per acre					
		Corn	Oats	Wheat	Clover	Soy-Beans	Alfalfa
		19 crops	17 crops	7 crops	8 crops	4 crops	6 crops
1.	None	56.6	47.6	21.9	(2.10)	(1.60)	(2.33)
2.	Residues	56.8	49.1	26.3	1.34	21.3	(2.14)
3.	Manure	64.6	54.0	24.6	(2.31)	(1.68)	(2.10)
4.	Residues, lime	59.8	50.9	28.3	1.60	20.7	(2.32)
5.	Manure, Lime	66.8	56.2	30.6	(2.74)	(1.72)	(2.76)
6.	Residue, lime, phosp.	75.4	64.2	42.5	2.16	22.6	(3.56)
7.	Manure, lime, phosp.	72.6	63.5	40.1	(3.62)	(1.92)	(3.58)

1. Figures in parenthesis represent tons of hay.
2. Soy-beans planted when clover failed.

By comparing plots 2, 4, and 6 with 3, 5, and 7 respectively, we have direct comparisons between two

* Hopkins, et al, Soil Report No. 18 Champaign County Soils.

† Hopkins, et al, Illinois Agricultural Experiment Station Bulletin 219. Illinois crop yields from Soil Experiment Fields.

systems of farming,—grain farming and live-stock farming. Hopkins* explains this method as follows:

"Under the live stock system of management the nitrogen and organic matter of the soil are maintained by applying as much manure as can be made from the produce grown upon the land. On this basis no more manure is applied to a plot than can be made from the produce of that plot. For every ton of produce grown, an equivalent amount of average farm manure is returned during the rotation. Under a good system of live stock farming it has been found that about one ton of average manure can be made from one ton of feed and bedding. A large amount of the grain produced is fed, in the live stock system, the legumes harvested as hay, and the hay, straw and stover used for feeding and bedding purposes."

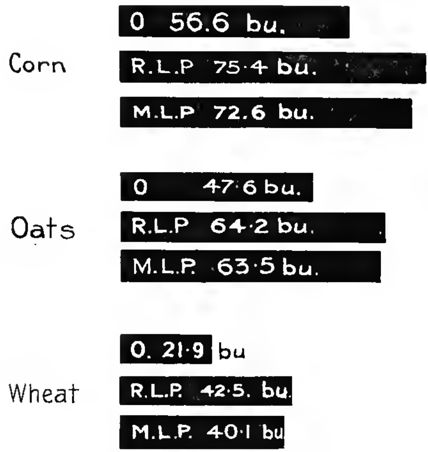

Fig. 20.—Illinois Fertilizer Experiment.

O. Untreated land; R. Residues; M. Manure applied; L. Limestone; P. Phosphorus. Showing increased yields by rational soil treatment. Note that the grain system of farming (R.L.P.) is in every case slightly ahead of the live stock system (M.L.P.).

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* Ibid.

"In the grain system of farming, no manure is applied to the land. The nitrogen and organic matter of

Fig. 21.—Illinois Soil Experiment.
Farm manure applied. Average yield 34.2 bushels per acre.—Courtesy Illinois Agricultural Experiment Station.

the soil are maintained by plowing under all crop residues (straws, corn stalks, all of the legume crops from which the seed has been removed, and also cover crops of legumes). The regular legume crops are so managed that a seed crop is secured if possible, and all resulting residues are returned to the soil. . . . . When alfalfa is included in the rotation it is harvested for hay in both systems . . . . . . The residues from grain and legume crops may be plowed under directly, or they

Fig. 22.—Illinois Soil Experiment.

Farm manure and rock phosphate applied. Average yield 51.8 bushels per acre. Phosphorus increased the yield 17.6 bushels per acre. The lessons taught are being put into practice by Illinois farmers. Figures 21 and 22 illustrate the result of scientific investigation, and though it should not be inferred that these results will accrue from the same treatment in Western Canada, the need for work of a similar nature is apparent. —Courtesy Illinois Experiment Station.

may be used as a top-dressing for the protection of winter crops and eventually turned under."

The methods of soil enrichment illustrated by this experiment have come into common practice in Illinois and several of the adjoining states. Thus nitrogen and organic matter are supplied by manure and crop residues (including legumes used as green manure, etc.). Commercial nitrogen, such as sodium nitrate, does not pay under extensive systems of farming. When the land is acid (sour) ground natural limestone, made from crushing limestone found in natural deposits, is most effectual and economical. To supply phosphorus, finely ground, natural raw rock phosphate is applied, being the cheapest form, and, under humid conditions when applied with actively decaying organic matter, being as effective as the more readily available but more expensive acid phosphate.

The practices of the more humid Corn Belt will not apply in full to Western Canadian conditions. Under semi-arid conditions, our soils cannot handle the amounts of crop residues or manure that are turned under in the humid regions. However, with the depletion of organic matter and nitrogen our system must be changed. Mixed farming is undoubtedly becoming more general and the manure should be carefully conserved. But this will never entirely supply the soil needs for organic matter and nitrogen. The use of leguminous crops in the rotation will be a big step in advance.

It is interesting to note in the Illinois Experiment that where the needs of the soil are fully provided for (plots 6 and 7) the grain system is equal, if not slightly superior, to the live stock system of farming. Thus, it is possible in the Corn Belt to farm entirely without live stock. The Canadian prairies may always be devoted chiefly to grain farming, and if our agriculture is to be permanent and profitable, we must plan our systems for conditions as they actually exist. Only by long-continued, carefully conducted experiments such as the

Rothamsted and Illinois experiments can our problems be solved.

42. Soil Acidity and Liming the Land.—Soil acidity (sourness in soil) is a common problem in the humid climates, especially in the older agricultural regions such as England, the continent of Europe, and eastern United States. Where soils are acid, finely ground natural limestone rock has been found to be the cheapest and most effective. It is applied at the rate of one to two tons per acre, depending upon the degree of acidity in the soil. The soils of the arid and semi-arid regions are more likely to be alkaline than acid (alkaline is the opposite of acid) due to the fact that alkaline salts and limestone are not leached away as in humid sections. Limestone is present in sufficient quantity in most Western Canadian soils, so that this question need give us no concern.

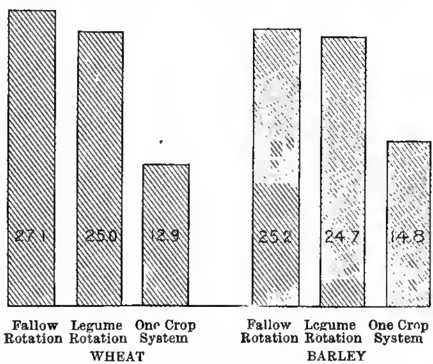


Fig. 23.—Rothamsted Experiments.

Chart showing yields of wheat and barley (bushels) in good systems of crop rotation, and in one-crop systems. Figures represent 60-year averages in rotation systems, and 55-year averages in one-crop systems.

43. Crop Rotations and Soil Fertility.—From Table XIII. we see that barley grown at Rothamsted, England, (Agdell field), in a rotation without fertilization produced as an average of 60 years, 24.7 bushels in the legume system and 25.2 bushels in the fallow system. In this same rotation wheat produced 25.0 and 27.1 bushels respectively.

In another field (Broadbalk Field) wheat has been grown continuously for 55 years unfertilized, the average yield being 12.9 bushels. In still another field (Hoos Field), barley has been grown continuously for 55 years, unfertilized, the average yield beeing 14.8 bushels. This is positive proof of the benefit of crop rotation over a one-crop system. It was pointed out, however, from table XIII., that crop rotation without fertilization would not maintain the crop yields. The matter of crop rotations is discussed fully elsewhere and it is intended here only to emphasize the fact that whereas a rotation is much superior to a one-crop system, provision should be made in the rotation for the return of organic matter and nitrogen and the mineral plant-food elements, especially phosphorus, if deficient. Crop rotation with no return of plant food is only a more efficient way of robbing the soil; it makes possible greater crops, which means the withdrawal of greater amounts of plant food and therefore more rapid depletion of the soil's fertility.

The Soil a Living Mass.

44. Importance of Microörganisms in the Soil.—We have seen that animals are dependent upon the higher plants. In turn the higher plants are dependent upon microörganisms. If the action of the latter were stopped for any considerable length of time, life would become impossible upon the earth; our very existence depends upon them.

The question might well be asked: What would be the condition of the earth, if, through the many ages, the dead bodies of animals and plants had simply remained upon the surface of the earth and had not decayed into an unrecognizable, powdery mass in the soil? The layer of trash would soon become so deep that seedlings upon the ground would find it impossible to push their way up into the sunlight; there would be no room for animal life; the earth would become uninhabitable. The lower organisms perform a great service in reducing the remains of plant and animal life to the black residue in the soil which we call "humus". The humus represents but a small portion of the great bulk, the greater part being released into the air in the form of gases and water vapor, through the action of our infinitely small friends.

But this does not tell the whole story. We have shown that plants require food as well as animals, and that this food is derived from the soil, air and water. The materials from these sources would have long since become exhausted if it were not possible to use them over and over again. Thus we speak of the "cycles" of the plant-food elements, and in these the lower organisms play the leading part. In the decay of plant and animal matter, carbon dioxide gas is given off, and this carbon-dioxide can again be used by living plants as before explained. In a similar manner nitrogen may be used over and over again, and likewise phosphorus, though instead of a gas these substances are converted into nitrates and phosphates, in which form they become available to plants. The cycle is not always so simple. It is the business of the microörganisms to prepare the food for the higher plants, and the plants and animals in turn furnish the food and energy through which microörganisms can do their work. The one depends upon the other.

People have become accustomed to thinking of the bacteria and fungi wholly as enemies; we think only of the ravages of disease. The science of bacteriology has developed more along this line. In our farm practices i.e. plowing, cultivation, manuring, etc., we give little heed to the consideration of the effects of these operations on the bacterial activities of the soil. It is fortunate indeed that the practices which favor the production of crops from the plant standpoint are also favorable to the activity of the beneficial bacteria.

45. The Soil a Living Mass.—The soil is inhabited by five kinds of microörganisms, bacteria, fungi, algae, yeasts and protozoa. The first four are vegetable or plant forms of life, the last, protozoa, are miscroscopic animals. Of the five groups the bacteria and fungi are most important. It is with the bacteria that we are mainly concerned, though the fungi take part in many of the useful activities in the soil.

The numbers of the bacteria in soils vary with the type of soil, season of the year, moisture present, etc. The number may vary from several million per gram in a thin, poor soil, to a thousand million per gram in sewage farmed land. If, on ordinary soil, we assume a content of 60,000,000 per gram, 27,216,000,000 per pound of soil, not at all an unreasonable or unusual number, we find that the surface 6 2/3 inches of soil over an acre (2,000,000 pounds) would contain a live weight of bacteria equal to 250 pounds. This would represent a volume of about 3.8 cubic feet. These figures bring out the very great numbers of the bacteria and their extremely small size. Due to the very great numbers ever present, the soil has frequently been spoken of as a "living mass".

In general, light sandy soils have fewer numbers than the heavier, richer, types. The amount of food (organic matter) has an important bearing on the number of bacteria. Also virgin soils have lower counts than cultivated soils, due in part at least to the fact that cultivation, especially deep plowing, increases the depth of their operations by giving better access to air (oxygen). The greatest numbers occur between the fourth and sixth inch levels in average soils. This, of course, varies greatly. Soils may be sterile at three feet if impervious in nature, and are not infrequently sterile at a depth of eight or ten feet. As would be expected the highest numbers are found in the spring and fall. Owing to the heat and lack of moisture, the numbers are reduced in midsummer. In winter many of the vegetative forms are killed and great numbers go into a spore or resting stage to await more favorable conditions.

46. Functions of the Bacteria in the Soil.—The functions of the bacteria in the soil may be classed under four heads:

1. Destruction or decay of dead matter.
2. Preparation of available plant food for plants.
3. Parasitism (disease).
4. Symbiosis.

The activity of the bacteria in bringing about the decay of plant and animal remains has already been alluded to. In farm practice this accounts for the decay and incorporation with the soil of the stubble, straws, corn stalks, manure, etc., that are plowed under. These substances under the action of the bacteria are decomposed, part becoming dissipated into the air as gases and water vapor, the residue, humus, becoming a part of the soil mass.

47. Preparation of Available Plant-food.—The growing plant has need of an ever-present supply of plant food that is soluble and may be taken up readily by the roots. The bacteria are always at work preparing this food, and should their activity be stopped for any considerable period of time, the plant would suffer and die of starvation. Though concerned in the liberation of all plant-food elements, the relations of the bacteria to nitrogen are especially important.

48. The Nitrogen Cycle.—Farm crops depend upon the soil for their nitrogen, and this nitrogen must be in the form of nitrates to be utilized by plants. (Legumes are an exception and when inoculated, they may draw upon the nitrogen gas of the air). Chile salt-peter (sodium nitrate), a common fertilizer, represents such a form which is available to plants. The nitrate is absorbed by the roots and is built up into protein in the plant. The latter may be eaten by an animal, the protein then becoming a part of the animal body or may be voided in the manure. The original bit of nitrate may, therefore, exist in altered form as a part of the prairie sod, of the wheat stubble, or of the animal flesh or manure. If returned to the soil and plowed under, before it can again be used by plants, it must go through a preparatory process. First the plant or animal remains must undergo decay or decomposition, the nitrogen being converted into ammonia. A great many kinds of bacteria in the soil may take part in this process, the end product in every case being ammonia. Certain bacteria in the soil (the nitrous acid bacteria) seize upon this ammonia and convert it into nitrite, a nitrogen com-

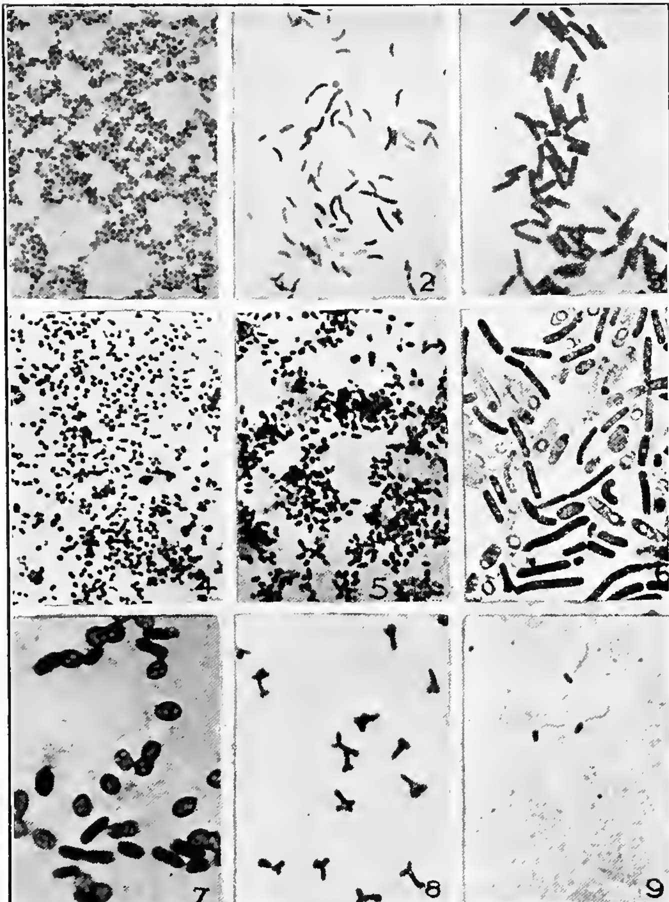


Fig. 24.—Soil Bacteria Magnified Over 1000 Diameters.

1. Micrococcus ureae, produces ammonia from urea; 2. Bacillus florescens, produces ammonia in soil; 3. Bacillus subtilis, produces ammonia in soil; 4. Nitrosomonas (after Winogradsky), changes ammonia to nitrite; 5. Nitrobacter (after Winogradsky), changes nitrite to nitrate; 6. Clostridium pastorianum, showing spores, free-living nitrogen-fixing organism; 7. Azotobacter chroöcoccum, free-living nitrogen-gathering bacteria; 8. Nodule bacteria from vetch, showing characteristic branched forms; 9. Nodule bacteria, from soy-bean, showing flagella.

pound containing oxygen. Another species of bacteria (the nitric acid bacteria) then converts this nitrite into nitrate, through the further addition of oxygen to the nitrogen. As nitrate,, the nitrogen may then be used again by plants.

Certain losses of nitrogen through bacterial action are likely to occur, especially in the manure pile. "Firing" or "fire-fanging", due to the rapid decomposition of the manure, results in the escape of nitrogen to the air in gaseous form. The process is called denitrification and is due to bacterial action. A similar process occurs in soils, especially when water-logged, but the losses from this source in well-tilled soils are not appreciable.

On the other hand, additions to the soil's supply of nitrogen may occur in several ways. Small amounts are brought down from the atmosphere by the rain and snow, chiefly as ammonia and nitric acid. In the soil certain bacteria (Azotobacter) living upon the carbonaceous material in the soil, have the ability to extract free nitrogen gas from the air and build it up into their bodies. These sources, however, are not of great magnitude. A third source, the fixation of nitrogen by leguminous plants, will receive due consideration.

49. The Mineral Plant Food Elements.—In the decay of organic matter, carbonic acid and many other organic acids are formed. In the nitrification process nitrous and nitric acid are formed, not as free acids but united with the basic substances, among them the essential plant food elements as calcium, magnesium and potassium. These substances, occurring in the soil in insoluble compounds, are rendered soluble by this process. Phosphorus occurring chiefly in the soil as the insoluble tricalcium phosphate becomes soluble and available to plants through the solvent action of the organic acids. By the nitrification process it is converted from the insoluble form to the soluble acid phosphate in which form it may be used by plants.

These principles find application in practical agriculture. The results of the Ohio and Illinois stations have shown that the crushed raw rock phosphate applied with liberal amounts of farm manure (or crop residues) gives yields that are equal to the acid phosphate, and at considerably less expense. The failures to secure results upon soils deficient in phosphorus by the use of raw rock phosphate have been due to the failure to provide decaying organic matter. Nature has wisely locked up the phosphorus in the soil in insoluble form so that it will not be wasted, but has beneficently provided a means whereby it may become available to plants. The "why" in agricultural practice is as important as the "how"; it is the safest guide to a permanent and profitable system.

50. Parasitism (disease).—That the soil harbors many disease-producing microörganisms is now a matter of common knowledge. Among the bacterial plant diseases crown gall, pear blight, black leg and soft rot of potatoes, are typical examples, and among the fungous diseases flax wilt, wheat rust, and the smuts. These organisms, however, are not related to the fertility of the soil.

51. Nitrogen-fixation by Leguminous Plants.—Three-fourths of the atmosphere by weight is nitrogen gas; over one acre of land there are 70 million pounds of nitrogen, enough for nearly a million bushels of wheat if it were available to that crop. But wheat cannot utilize directly the free nitrogen gas of the air.

Certain plants, the legumes, have the ability when inoculated to draw upon the air for nitrogen. Red clover, sweet clover, alfalfa, peas, beans, and vetch are examples of leguminous plants. These plants do not have the power in themselves to take up free nitrogen gas. It is through certain bacteria, the nodule bacteris, which live in the soil that this is made possible. These bacteria

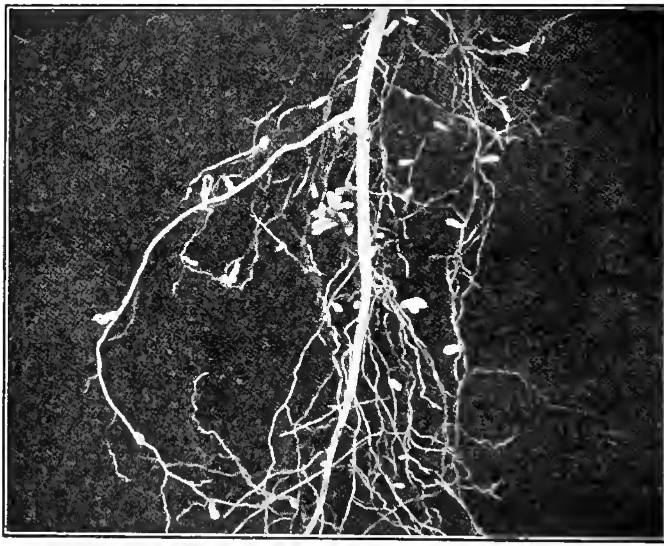


Fig. 25.—Nodules cn the Rocts of Alfalfa.

These nodules are the homes of millions of alfalfa bacteria which gather nitrogen from the air and turn it over to the plant.—Courtesy Wisconsin Agricultural Experiment Station.

attack the root-hairs of the legume plant, causing the formation of gall-like structures called nodules upon the roots. In these nodules the bacteria live and multiply, extracting from the plants the sugars and other materials necessary for their life processes. In return they absorb the nitrogen gas from the air, which circulates through the soil, and turn it over to the plant in a form that the plant can utilize. Without the presence of bacteria and without the presence of the nodules this process would not go on. The legume plants would behave like ordinary crops, using only the nitrate-nitrogen found in the soil.

This process is termed symbiosis, which means that the two organisms, the bacteria and the plant, live together to their mutual benefit. Thus the bacteria are provided with a home (the nodule) and food (sugar), and in turn they supply the plant with an inexhaustible nitrogen supply. Neither is injured by the union, but on the other hand both are greatly benefited.

If legumes are grown in soil which contains no nitrogen but are inoculated and given all the essentials for growth except nitrogen, the plants will live and thrive normally, extracting in this case, through the aid of the bacteria, their entire nitrogen supply from the air. If, on the other hand, the soil contains nitrogen, it will draw in part upon this and in part from the air. Accordingly as the soil is richer in nitrogen, especially as nitrate, the plants will draw more heavily upon the soil and less upon the air for their nitrogen. Hopkins has figured that upon normal soil of average fertility, red clover when inoculated secures about 2/3 of its nitrogen from the air and 1/3 from the soil. When cut for hay the part removed contains 2/3 of the nitrogen present in the entire plant, the roots and stubble containing 1/3. Thus when the hay is removed, as much nitrogen is removed as was obtained from the air. The stubble and roots turned under do not produce any gain for the soil, the same amount being turned under as came originally from the soil. This, however, is a great advantage over other hay crops where every pound of nitrogen removed represents a loss to the soil. But every ton of clover tops contains forty pounds of nitrogen, so that every

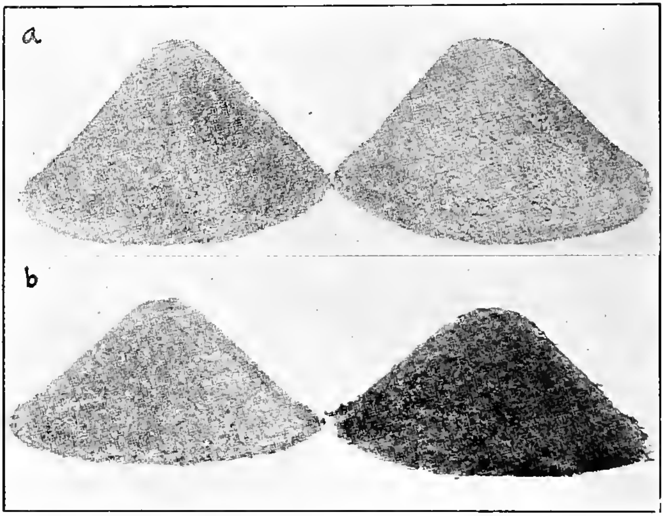


Fig. 26.—Bacteria in Relation to Soil Building.

(a) Two piles of pure white sand. (b) The pile of sand on the left on which four crops of uninoculated legumes have been grown and to which nothing has been added is still white infertile sand. The pile on the right on which four crops of legumes and legume bacteria have been grown and to which nothing else has been added is well on the way to **become a fertile soil as is shown by its dark color.**

ton of clover turned under for the purpose of soil enrichment represents a gain to the soil of forty pounds of nitrogen.

Sweet clover tops contain on the average 40 to 50 pounds of nitrogen per ton, so that every ton of sweet clover tops turned under for soil enrichment is worth four to five tons of manure from the standpoint of nitrogen (manure contains 10 lbs. of nitrogen per ton). This together with the tonnage that it produces, explains why sweet clover is becoming so widely grown for improving the soil in the humid sections. The succulence of the plant renders it easily and quickly decomposed by the bacteria, making possible the turning under of very great amounts. This then furnishes a large amount of organic matter, and the nitrogen through bacterial action becomes available to succeeding crops. The result is that the corn or wheat crops following are frequently doubled, and the effect is not limited to the one year following, but is apparent for several years through increased yields. Such practice must come into vogue in the Prairie Provinces when the organic matter and nitrogen supply need replenishing.

It should again be emphasized that in order to secure nitrogen from the air the legumes *must be inoculated.* The bacteria may already be present in some soils and if so they will make their presence known by forming nodules on the roots of the young plants. If the nodules are not formed, it is positive proof that the bacteria are not present, and upon such soils artificial inoculation, either applied as a culture to the seed or applied by spreading and disking in some well-infected soil from a field known to be inoculated must be resorted to.

In applying inoculation to the seed different kinds of nodule bacteria must be used for certain legumes. Alfalfa and sweet clover require one kind, peas and vetch take another, while the true clovers, red clover, mammoth clover, white clover, alsike clover, require still another. The bacteria which produce nodules on the roots of alfalfa and sweet clover will not produce nodules on the roots of peas, vetch or the true clovers. The groups are absolutely distinct.

The Factors of Soil Fertility.

52. The Measure of Fertility.—The measure of the fertility of the soil is the crop it produces or can be made to produce. This is not the result of any one factor, but of a combination of factors.

The physical make-up of the soil determines in part at least the extensiveness and effectiveness of the root-system of the plant. It is concerned with the ability of the soil to absorb and retain moisture. It affects the tilth, the air supply and the warmth of the soil.

The chemical composition of the soil determines its potential possibilities. Since we know the kinds and amounts of plant-food elements that our crops require, and since chemical analyses will tell us the total amounts present in any particular soil, we have an index to the fertility of that soil. We have a means of discovering the deficiencies, and when confirmed by actual field tests, this is the safest guide to good practice.

The bacteria are concerned with the liberation (making available) of plant food. This is brought about through the organic matter supplied. The value of organic matter is therefore apparent. It furnishes the food and energy for the bacteria which when thus supplied make plant food available (soluble) for the plant. In addition the actively decaying organic matter is the source of humus in the soil.

Permanency in agriculture depends upon the control by man, in so far as is possible, of the factors essential to the production of crops. The stock of materials in the soil when diminished to the point that crop yields are limited, must be replenished. By making provision for the return of organic matter we provide for the needs of the plant for available plant food. It should be the business of every progressive farmer to give as much thought to the soil he is working as he does to his farm machinery or animals. Just as his farm animals and machinery fail to give good returns from bad treatment, so the soil will likewise fail to produce profitably under irrational treatment.

CHAPTER IV.

THE MOISTURE PROBLEM

Water is required in large amounts by growing plants and the source of all moisture for crops, except under irrigation, is the clouds. The average precipitation is a general guide to the amount that is likely to fall in any year. Areas having more than 30 inches precipitation are spoken of as humid; those having between 20 and 30, sub-humid; between 10 and 20 inches, semi-arid; while those having less than 10 are called arid. Most of Western Canada is semi-arid; our average precipitation is low and the water requirements of growing crops is high; the chief cause of low yields is lack of moisture.

The moisture problem briefly stated consists of (1) storing as much moisture as possible in the soil, (2) conserving it as well as we can, (3) keeping it available to the seed and plant roots, and (4) making the most efficient use of it.

53. Storing Moisture in the Soil.—When moisture falls upon the land in the form of rain it is either absorbed by the soil or it finds its way to ditches, ravines or sloughs. The problem of storing moisture is one of preventing the "run off" which occurs chiefly at two seasons, one during the heavy midsummer rains and the other when the snow melts in the spring. The amount of "run off" is largely determined by (1) the topography of the land, and (2) the openness or receptivity of the soil.

The topography cannot be altered but some loss of water may be prevented by tilling crosswise of the main slopes. The more open the soil is at the time of the heavy rains or when the snow is melting the more

Fig. 27.—Wheat Under Irrigation near Strathmore, Alberta.

moisture it will take in and the less "run-off" there will be.

The storage of moisture in *"old" land* is accomplished by:

1. (a) Fallowing the land once in two, three, four or five years, depending upon the average precipitation and evaporation.
   (b) Plowing or otherwise cultivating the fallow early to lessen the possible "run-off" after heavy rains.
2. Using such intertilled crops as may not require all the water, thus permitting of the storage of some;
3. Using crops that may be harvested early, thus per-

mitting the land to lie fallow and accumulate moisture for a longer time in the fall;

4. Increasing the organic matter content of light soil types so as to increase their moisture-holding power and decrease the loss of moisture by percolation.

The storage of moisture in *new* or *prairie land* or *sod land* is accomplished by

1. Breaking and leaving idle for a year (less in some areas) in order to make the land receptive for the summer rains;
2. Breaking early in order that the loss of moisture through the growth of native vegetation may be prevented;

The storage of moisture in *stubble land* is accomplished by

1. Leaving a long stubble to hold snow which on melting adds water to the soil; or
2. Cultivating with discs or even by shallow plowing early in the fall so that the soil may be put in a condition to absorb more of the water from melting snows. (Note that (1) and (2) are not possible on the same area).

54. Conserving Moisture in the Soil.—Moisture that has been stored in the soil may be lost in one or more of only three ways:

(1) by seepage or drainage through the soil,
(2) by evaporation from the surface into the atmosphere,
(3) by passing out through the stems and leaves of growing plants in the natural processes of growth.

The loss through seepage or drainage is very little in dry climates except on light or coarse grained soils or soils having a subsoil that is sandy or gravelly. On such soils the lessening of seepage can only be brought about by increasing the organic matter content a practice which is seldom profitable except on the better grades of these types of soil. The dry farmer should avoid soils that are so light and loose that loss by seepage is probable.

The loss of moisture by evaporation from the soil into the atmosphere is very great. No data giving the actual amount of loss from a soil surface in this climate are available, but when it is realized that from 60 to 100 inches of water evaporates from a water surface in a year in the southern portion of the Great Plains, the extent of the evaporation from a soil surface may be imagined. The very great loss by evaporation may be lessened (1) by the use of a mulch on the surface of the land, and (2) by increasing the moisture-holding power of the soil by maintaining or increasing its supply of humus or partially decomposed organic matter. While it is a fact that a soil mulch lessens the amount of water that leaves the soil by evaporation in humid climates, there is some question as to its effectiveness in dry climates and also as to how much expense a farmer is justified in assuming in order to make a relatively small saving. (See "The Application of the Capillary Theory to Dry Farming Practices" in Chapter XVI.)

The loss of moisture through its use by growing plants is very great. As little as 250 pounds of water and as much as 1,000 pounds have been found to be taken into the roots of plants and transpired into the atmosphere through the leaves in the process of taking in food materials sufficient to make one pound of dry matter. So long as the plants using it are useful to man this large amount of water is not a loss, even though it may have disappeared from the soil. But when useless plants or weeds use up the moisture it is a serious economic waste.

Recent investigations in soil moisture conservation emphasize the belief that under normal soil conditions weeds are not the secondary but the chief means by which moisture is lost from the soil. They also indicate that tillage for moisture conservation should have as its practical aim (1) the control of weed growth, and (2) the prevention of soil cracking or soil baking, or the

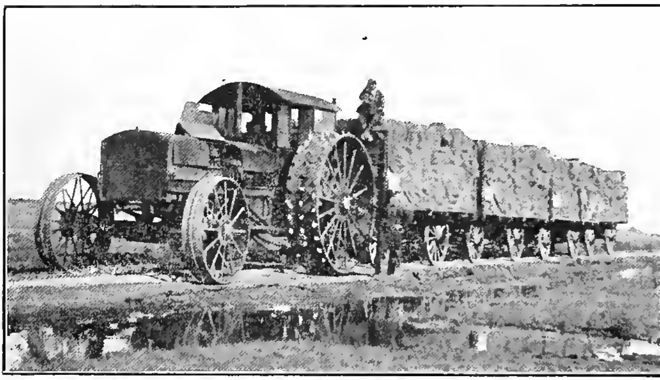


Fig. 28.—Hauling Alfalfa Grown Under Irrigation at Coaldale, Alberta.

drying out of the furrow slice. If these aims are fully attained it seems probable that any extra tillage will not result in a sufficiently increased return to pay for the extra work.

The practices by which the moisture stored in the *fallow* can be conserved are:

1. Early harrowing or packing after plowing in order to lessen excessive evaporation from the furrow slice.

2. Sufficient surface cultivation to kill weeds, grass and volunteer grains, which use up water in the process of growth.
3. Sufficient surface cultivation to prevent the soil from cracking, and thereby increasing the evaporating surface.

The conservation of moisture "stored" in *breaking* is accomplished by:

1. Packing or "planking" immediately after breaking —so as to lessen the loss of moisture from the furrow slice and the subsoil by the drying winds.
2. Disking and harrowing as necessary to control weeds and grass.

The conservation of the limited moisture supply in *stubble land* can be effected by:

1. Fall plowing of grassy land to kill the grass and thus save the water the grass demands for growth,—a practice which may be neutralized in the very dry parts by increased evaporation from the overturned furrow slice.
2. Early harrowing or packing of all spring-plowed land in order to protect the furrow slice and subsoil from the drying effect of the winds.
3. Harrowing early in the spring before sowing, or harrowing such crops as cereals, corn and potatoes after they are up in order to control weed growth or prevent the soil cracking. This practice cannot be followed indiscriminately on all soils, as on some it will result in increasing the danger of soil drifting.

55. Keeping Soil Moisture Available.—Making the best possible use of the moisture stored and conserved in the soil is not the least important of the problems of the dry farmer. It may be considered under two heads:—

1. How to keep a supply of it continuously available to the seeds in the soil or to plant roots, and
2. How to make it serve its purpose most efficiently.

Of the three forms in which moisture occurs in the soil, viz., free water, capillary water and hygroscopic water, only that in the capillary form is of immediate value to growing plants. The small portion known as hygroscopic moisture, which is present about the soil particles when they are air dry is held so firmly that plants cannot extract it. The free water, that portion found filling the spaces between the particles of a soil which is flooded, is of very great value as a source of supply even though it cannot be drawn upon directly and is sometimes harmful to plants. Free water when present in the subsoil may be changed to capillary or film water, in which form it may move up or down or in any other direction or be held by the soil even against gravity. It is in the capillary form only that water may be drawn upon by plants.

In the practice of crop growing it frequently happens that something is done which either lessens the chance of the plant getting at the moisture in the soil or what is of equally serious concern, makes it difficult or impossible for the moisture in the subsoil to move to where the seeds or plant roots are. Thus when coarse manure or long stubble are plowed under in fall or spring in preparing for a crop the next season, loose open spaces are created between the seed bed and the subsoil and the availability of even the capillary moisture is interfered with. Similarly when coarse clods are plowed under, or the plowing left in rolls, or the furrow left on its edge, or the land plowed when it is too dry, or allowed to bake after being plowed when too wet, open air spaces are created below the furrow slice which seriously lessens not only the moisture movement from the subsoil to the seed or to plant roots but also the ability of the roots to reach out after moisture. Moisture cannot rise through large, loose, open spaces in the bottom of the furrow slice, nor can plant roots grow down through them satisfactorily. Obviously, these practices, unless modified, are unsuited to dry farm conditions.

Fig. 29.—A Well Tilled Field of Potatoes.

Three stages of development in the growth of a field of potatoes.—Courtesy Dr. Seager Wheeler.

The chief means by which the moisture stored and conserved in the soil is kept available, or at least not rendered unavailable, are:

(1) By not plowing under thick layers of dense grass or other rubbish, unless time sufficient for its decay is allowed before seeding the next crop.
(2) By not plowing under a heavy stubble in fall or spring unless the land is to be thoroughly compacted so that the moisture in the subsoil may rise into the furrow slice to meet the needs of the crop.
(3) By seeing that in all fall or spring plowing the overturned furrow is brought firmly in contact with the subsoil, so that there may be the least possible interference with the free movement of moisture upwards from the subsoil.
(4) When applying manure, to put it on thinly and firm the soil about it before crops are sown, so that it will quickly decay and not interfere with the movement of soil moisture. Coarse, strawy manure and stubble are often worse than useless until they have decayed, after which time they exert a very beneficial effect on the moisture-absorbing and moisture-holding capacity of the soil.
(5) By leaving the soil in such condition that the seed can get the necessary moisture for germination without having to be sown too deeply.
(6) By preventing the formation of a "hard-pan" below the furrow or by remedying it if it is already there.

56 The Efficient Utilization of Soil Moisture.—The soil moisture will be utilized most efficiently if three things are done: (1) the supply of available plant food kept up, (2) drought-resistant crops grown, and (3) suitable crop management practices followed. The first of these is discussed in the next section and the other two in the chapter that follows.

57. Soil Fertility and Soil Moisture.—One of the chief functions of the water stored in the soil is to dissolve plant food substances and carry them through the root

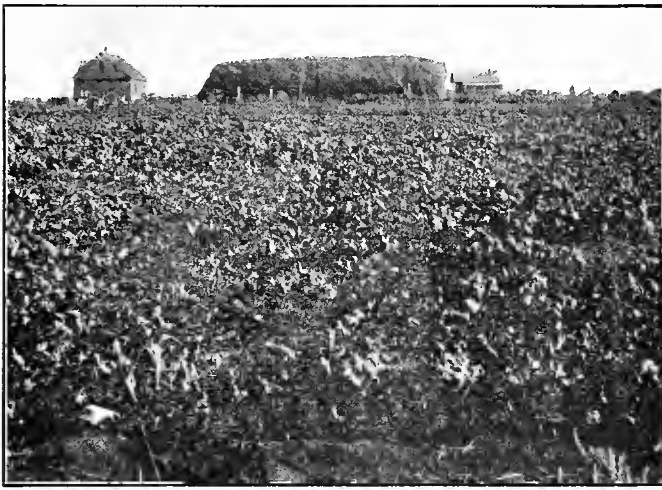


Fig. 30.—Sugar Beets Growing cn Irrigated Land North of Brooks, Alta.

hairs into the plant. The more of such material a unit of water can carry into the plant the more bushels per acre the limited supply of water may produce. It has been found that when equal amounts of water are supplied to rich and poor soils the former produces the larger yield. Widtsoe* states (1) that on a naturally fertile Utah soil 908 pounds of water were required to produce each pound of dry matter in corn, (2) that

* From "Dry Farming" by Widtsoe.

when this soil was manured only 613 pounds were required, and (3) that when commercial fertilizers were applied only 585 pounds of water were necessary to produce a pound of dry matter. Similarly he found that "on sandy loam, not cultivated, 603 pounds of water were transpired to produce one pound of dry matter in corn; on the same soil, cultivated, only 252 pounds were required. On a clay loam, not cultivated, 535 pounds of water were transpired for each pound of dry matter, whereas on the cultivated soil only 428 pounds were necessary. On a clay soil, not cultivated, 753 pounds of water were transpired for each pound of dry matter; on cultivated soil, only 582 pounds."

While our soils are new and rich an average rainfall will generally produce a fair yield. As soon as they become less "fertile" the same amount of rain is likely to produce a smaller crop. The results of theses investigations clearly show that the more fertile a soil is, the greater yield it will produce from a given supply of moisture. This is one reason why dry farmers should strive to maintain the "fertility" of their soils.

CHAPTER V.

DRY FARM CROPS AND CROPPING PRACTICES

The chief crops that have been grown in the past in the three Prairie Provinces and the approximate acreage of each is shown by the following table::—

TABLE XV.—*Acreage devoted to different crops in Manitoba, Saskatchewan and Alberta in the year* 1916.*

	Manitoba	Saskatchewan	Alberta.
Wheat—Winter	3,829	15,258	18,177
" —Spring[1]	2,721,896	9,016,851	2,586,798
Oats[2]	1,443,599	3,791,807	2,124,981
Barley[3]	687,503	367,207	336,586
Rye[4]	30,050	22,759	17,975
Flax	15,684	542,034	95,063
Peas	1,600	650	
Mixed Grains	1,400	14,150	4,550
Hay and Clover[5]	77,642	25,154	173,461
Potatoes	31,989	46,989	29,216
Turnips, Mangels, etc.	3,118	1,621	1,700
Fodder Corn	9,830	2,253	675
Alfalfa	4,422	3,086	20,612

1 Chiefly hard red spring, practically no Durum.
2 Chiefly late maturing sorts.
3 Chiefly Six-rowed bearded hulled.
4 Both spring and winter.
5 Mostly native prairie—considerable Western Rye—Brome and Timothy.

The above table is included here in order that the reader may note the relative importance attached by the present generation of farmers to the different crops now

* From Canada Year Book, 1916-17.

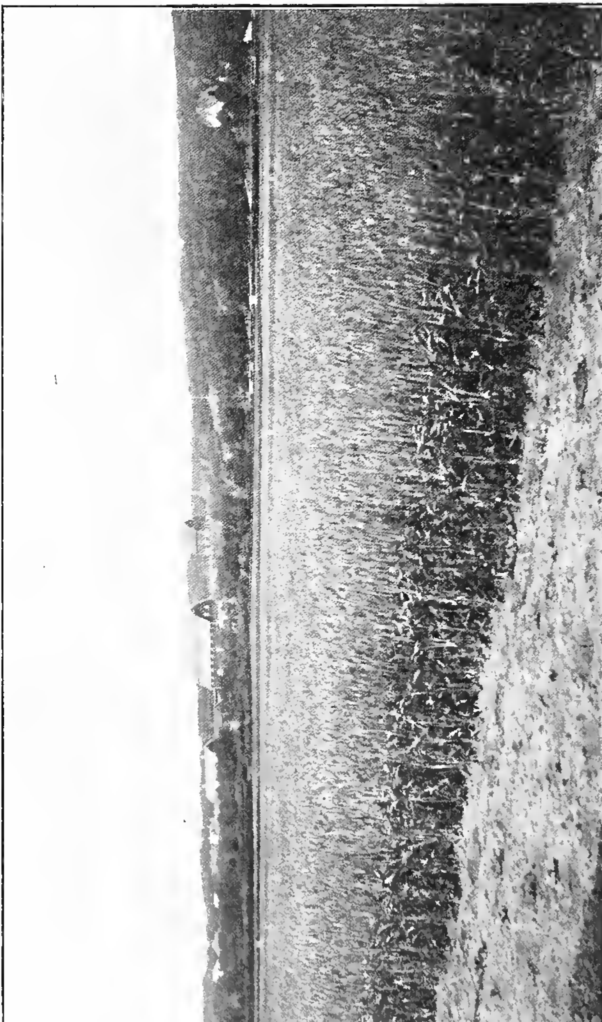


Fig. 31.—A View of a Portion of the Experimental Farm at Brandon. Marquis Wheat in the Foreground.

grown. What we are about to say in this chapter should not be interpreted as suggesting that radical changes should be made in the crops now used in those portions of the West that enjoy a rainfall of sixteen inches or more, or that are outside the prairie area. The suggestions that follow are meant rather as a guide to those men in the dry belt who have found that the commonly grown crops have not given satisfactory returns.

58. Drought Resistant Crops.—The dry farmer should keep in mind that some plants are better able to withstand drought than others. The factors that constitute drought resistance are not all well understood but several are now quite well appreciated by dry farming investigators. For instance, it is now well known (1) that different crops require different amounts of moisture to produce a unit of dry matter, (2) that certain types of crops are able to withstand more drought than others, (3) that the growth of some classes of crops so parallels the monthly distribution of rainfall that they produce larger yields than others, the growth habits of which are different—in other words they avoid drought—and (4) that crops which permit of intertillage may develop better under similar precipitation than those not adapted to this method of culture.

Recent investigations have shown that among our commonly grown crops millet, sorghum and corn require the least moisture per unit of dry matter produced; that the legume crops, like alfalfa, peas and clovers require the most—and that the grain crops—wheat, oats, barley and rye and flax—are intermediate in moisture requirements.

Carefully conducted experiments have also shown that some crops will withstand drought better than others. For instance, brome grass and Western rye grass for some reason withstand more drought than any of the other commonly used grasses. Alfalfa will with-

Fig. 32.—Winter Rye at Indian Head, Saskatchewan.

Although lower in price than wheat winter rye is a promising crop for the drier areas.

stand more drought than clovers, Durum wheat more than common wheat, and Emmer more than oats or barley.

It is well appreciated by western farmers that annual crops yield much more than perennial ones, and that those crops which can be sown early and that reach their greatest growth during the late stages of the rainy season, and that ripen before the dry autumn months are the most satisfactory to grow. This is why oats, an annual crop, is more generally used as hay than the grasses which are perennial. It explains why sweet clover yields more on dry land than alfalfa and it is the reason the grain crops are the ones best suited to our climate.

The value of intertilled crops, particularly those that are harvested early, as a preparation for grain crops, has long been appreciated by farmers in dry climates. Very large yields after corn and fair returns after potatoes are of common occurrence. The difficulty has been to grow these or similar crops profitably in a large way at the present time. The economic conditions now existing favor extensive rather than intensive methods for the average farmer in the West, although as land becomes higher in price and labor and equipment relatively cheaper, more intensive methods will probably pay better than extensive ones.

The drought resistant or drought avoiding crops that are little grown but that promise much for the dry farming districts of Western Canada and that warrant very careful trial are:

Grain crops for sale—Durum wheat.
Rye—Winter and Spring.
Flax.

Grain crops for feed—Two-row barley.
Rye—Winter and Spring.
Emmer—(Value not determined.)
Early Maturing Oats—(Value not determined).
Corn—(Value not determined).

Forage crops for permanent pasture—Western rye grass and brome grass.

Forage crops for hay—Western rye grass, brome grass, oats, rye and sweet clover.

Forage crops for soiling—Alfalfa in rows and corn.

Forage crops for summer pasture—Sweet clover.

Forage crops for fall pasture—Rape and winter rye.

Forage crops for winter fodder—Corn and the straw of cereals.

Forage crops for succulent winter feed—Corn, oats and sunflowers.

59. Durum Wheat.—This is a bearded wheat, long and stiff in the straw, non-shattering and rust and drought

Fig. 33.—Flax in Bloom in Southern Saskatchewan.
As a first crop after breaking, particularly on heavy land, flax is very popular.

resistant. It is, however, a macaroni wheat and has not as yet been grown to any extent as the market demand has been for the common wheats. It has done exceptionally well in western North and South Dakota and eastern Montana and has averaged slightly more per acre than the common spring wheat at Saskatoon. The price is generally slightly lower than for hard red spring. This wheat is deserving of careful trial. Kubanka is at present the best variety of this class of wheat.

60. Winter Rye.—This is a promising crop for grain, hay and pasture. The relatively low price of rye grain prevents it competing successfully with wheat where the latter can be grown satisfactorily. On some types of soil and in some seasons, however, the larger yield of rye is more than sufficient to offset this disadvantage.

61. Spring Rye.—This crop is earlier, hardier and more drought resistant than wheat, but like winter rye the price is relatively low as compared with that of wheat. On some of the lighter soil types in the dry areas this crop deserves more extensive use.

62. Flax.—As a dry land crop flax deserves greater consideration than it has received in the past, particularly on breaking or sod land, and on heavy land that does not blow. Care should be taken to secure clean seed, free from disease and to sow thinly on firm soil.

63.—Two-Row Barley.—Most agronomists have heretofore recommended only six-row barleys for Western Canada. The results of careful tests at Saskatoon and at points in western North Dakota and Montana indicate, however, that some of the two-row sorts are probably to be preferred in the southern parts of western Saskatchewan and eastern Alberta. Hannchen, a two-row but short-strawed variety, has averaged over fifteen per cent. more than the highest yielding six-row variety at Saskatoon. White Smyrna, a two-row, short-strawed variety is highly recommended in Montana.

64. Emmer.—This is a wheat the seed of which retains the hull when threshed. It is used in the dry parts of some of the states for horse feed but has not so far been grown much in Western Canada. Its usefulness is, therefore, still in doubt. Where oats do not do well on account of dry weather it should be carefully tested. At

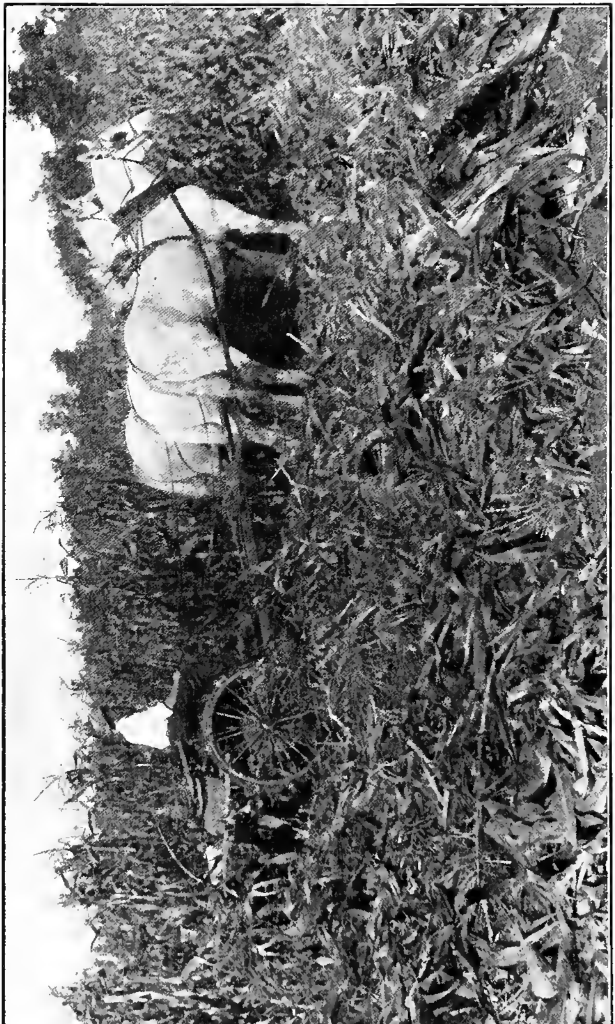


Fig. 34.—Harvesting Corn at Brandon, Manitoba.

In Southern Manitoba corn promises well as a partial substitute for the summer fallow.—Courtesy Brandon Experimental Farm.

present oats is the commonly used grain for horse feed and where it will produce a larger yield than Emmer is to be preferred.

65. Early Oats.—In most parts of Western Canada late oats are much more productive than early oats. Is this true in the driest areas? We do not know. The early oats are more productive in some of the states south of us. There is perhaps not much promise in early oats but it is possible that they may avoid the droughts and hot spells in August and yield as well as late oats. Banner and Victory are our best late oats, Gold Rain and Ligowo, the best medium late ones, and Daubeney, one of the best early ones.

66. Grasses for Hay and Pasture.—The most drought resistant grasses for the West are Western Rye Grass and Brome Grass. The latter is the best pasture grass, but on account of its creeping underground stems is, like quack grass, somewhat difficult to eradicate. While these are the best grasses for the dry parts, it does not follow that they are always profitable ones to grow. Economic and soil conditions will determine this point. Nevertheless, wherever perennial grasses are required for hay, pasture or soil improvement purposes one or other of these two will be found best. Brome has proven to be more drought resistant than Western Rye Grass.

67. Alfalfa.—This is the best perennial legume for all parts of the western provinces. It does not yield well under dry conditions and only the hardiest varieties, such as "Grimm", will withstand our winters. Under dry conditions it yields more when sown thinly in rows and cultivated than when sown broadcast but, of course, the tillage increases the cost. This crop has not been very extensively grown where the precipitation is less than sixteen inches, but a small acreage sown in rows for soiling dairy cattle or other stock will be found to be very satisfactory even in the driest parts.

68. Millet.—The millets are grown only on a very small acreage. Their chief use is as "catch crops" in seasons when the hay crop promises partial failure. They do best in warm, moist seasons. In early spring they make but little headway, and they suffer injury from the first fall frost. They promise most as catch crops in the dry belt and do best when sown early in June.

Fig. 35.—Cutting Sweet Clover at Saskatoon, Saskatchewan.

Sweet clover is probably the best biennial legume forage plant for regions having less than sixteen inches of precipitation.

Where oats can be grown satisfactorily for hay it is questionable whether it pays to grow millet.

69. Sweet Clover.—This crop has been little grown as yet by western farmers. It is, however, the most suitable biennial legume for the dry parts, in spite of its coarseness and bitterness. In those areas where the grasses do not yield well, and particularly where the soil is lacking in organic matter or for any reason is in poor tilth, this crop promises much as a forage and a soil improver. Only northern grown strains should be used, the tenderer ones from the south often failing to live through our severe winters.

70. Rape.—As late summer and fall pasturage for beef cattle, sheep and swine, rape sown in rows two to three feet part and cultivated has proven an excellent crop.

71. Corn.—The future of corn in the dry belt is quite promising. The yield of grain is low and the value of the forage in the very dry parts is not high in relation to its cost, yet the crop leaves the soil in such a favorable condition for subsequent grain crops that its more general utilization for fodder, silage, pasture or grain seems almost essential on the lighter, warmer soils in the drier sections of the southern prairies. It is altogether probable that corn will to a limited extent be used in such areas as a partial substitute for the fallow. Corn ground that has been kept clean has yielded practically as much grain as the fallow at several stations in the semi-arid belt of Canada as well as in the United States.

72. Sunflowers.—This crop has averaged nearly twice as large a yield as corn at Saskatoon during the past six years. Until the last two or three seasons it has not been considered of any value as fodder, but recent trials in Montana, and at Saskatoon as well, indicate that it can be quite satisfactorily ensiled and that the cattle eat it apparently with relish and do well upon it. The sunflower is so productive and so hardy that if it proves as good a silage crop as the early trials indicate, it will be a safe and probably a profitable crop to grow.

73. Suitable Crop Management Practices.—The crop management practices the farmer in the dry portions of the Canadian West should avoid are late seeding, thick seeding, shallow seeding, late harvesting and the use of varieties that shatter easily or that are too short in the straw. Each of these in dry seasons and in dry areas is likely to result in lessening the yield.

74. The Time to Sow.—The chief factors in determining the best time to sow are the temperature and moisture conditions of the soil and the danger from spring and fall frosts. If crops are sown too early they may be injured by late spring frosts or the seeds may die before the seedlings get above ground. Aside from this danger the seeding of our hardy cereals — wheat, rye, oats and barley — should be done early. If the seeding can be done early enough the moisture from the melting snows will germinate the seed, otherwise in fall or spring plowing the germination may be seriously retarded owing to lack of moisture in the furrow slice. Climatic and soil conditions vary greatly from season to season and thus influence greatly the time to put in a crop. As

Fig. 36.—Sudan Grass at the Manitoba Agricultural College.

This grass is very productive in warm moist climates, but does not do particularly well in Western Canada, except in very warm, moist seasons.

a general rule, however, the following dates of seeding and planting will be found satisfactory:—

April—15th to 30th—Wheat.

April—25th to May 10th—Peas.

May—1st 10 days—Oats and Carrots.

May—1st 3 weeks—Barley and Spring Rye.

May—10th to 30th—Flax, Potatoes, Mangels and Swedes.

May—20th to June 10th—Corn, Sunflowers.

June—1st 3 weeks—Grasses, Clovers, Alfalfa (Grasses and clovers may be sown with nurse crops at an earlier date).

75. The Amount to Sow.—Thin seeding is a recognized dry farm practice. The drier the district the less seed need be used while the more humid the district and the shorter the growing season the greater the quantity that should be sown. Campbell recommends as little as 18 to 20 pounds of winter wheat, 22 to 25 pounds of spring wheat, 20 to 25 pounds of oats, and 35 to 40 pounds of barley per acre in the dry parts of the Western States. The United States Department of Agriculture recommends the following rates for Montana: Wheat, 1 bushel; oats, 1 to 1¼ bushels; barley, 1 to 1¼ bushels; flax, 15 to 20 pounds. For the dry parts of Western Canada rather heavier seedings than those recommended for Montana should be used. Of course, in the more humid sections of the West considerably heavier seedings are necessary since a thinly seeded crop takes rather longer to mature and therefore runs a greater risk of injury from fall frost or rust than one sown with more seed. The amounts that have proven best in the average of many tests at Saskatoon which is on the edge of the driest part are as follows:—Wheat, 1 to 1½ bushels;

oats, 2 to 3½ bushels; barley, 1¼ to 1¾ bushels; and flax, 20 to 30 pounds.

76. Sow Into the Moisture.—In dry areas the limiting factor in germination is usually moisture. In this climate very little rain falls in the early spring and if germination is to be assured seeding into the moisture is necessary. Man's part is to prepare the land in such a way that the top of the moist soil is not at too great a depth from the surface.

77. Non-Shattering Varieties.—Very great losses frequently occur through the shelling of over-ripe or easily

Fig. 36a.—Harvesting Short Wheat with a Header in Southern Alberta.

This method of harvesting has not come into general use in the west, but with short crops in areas of lowest rainfall it has some advantages over the ordinary method of harvesting.

shattered heads as a result of heavy winds at harvest time. In order to lessen this danger two practices may be followed, 1st, use crops that do not shatter readily, and 2nd, cut before the crop is dead ripe. Among the wheat varieties that shatter least are the Durum types and Marquis. Kubanka seldom shatters even under the worst conditions while Marquis is known to be more non-shattering than any other of our commonly grown varieties

78. Short vs. Long Straw.—In dry areas and particularly in dry seasons the short-strawed varieties of crops are often found to yield less than longer-strawed ones. It is possible that the actual production may not be less but the amount harvested and threshed frequently is. This is probably due to the inefficiency of our harvesting machinery; the result however is the same. The longer and heavier-strawed varieties probably as a rule use more moisture in manufacturing straw than do the others; nevertheless, it is a fact that in some seasons and on some soils varieties like Red Fife which have a long straw are preferred to varieties like Marquis which have a short straw.

CHAPTER VI.

THE PRINCIPLES OF TILLAGE

Tillage is the manipulation of the soil by means of implements for the purpose of making a more favorable environment for the growth of useful plants.

79. The Chief Functions of Tillage.—During the long ages in which our best crops have been developed by man as he sought plants to supply food for himself or his domestic animals, the ability possessed by the original wild forms to rustle for themselves has largely been lost. None of our cultivated plants can compete with the wild forms and continue to exist without the aid of man. The first function of tillage is to furnish the protection these highly developed plants require from the aggressive competition of wild and useless forms.

The first home of the human race was where food plants grew wild and furnished sustenance for man without his care. As population increased and food became scarcer these plants were fostered by growing them under more favorable environment. The ancient civilization of Egypt grew up where the Nile overflowed its banks and watered the thirsty fields, while that of the Orient developed around the coastal plains above which the mountain streams were harnessed and made to water the tilled fields. In the recent history of the race men have grown crops on lands that could not be watered except directly from the clouds in the form of precipitation. And in very recent times we have even ventured to grow crops in areas where the rainfall is so light that crop failures sometimes occur. In such areas the storage and conservation of moisture in the soil is essential to crop production, and tillage is the chief means at man's disposal for accomplishing it. This constitutes the second function of tillage.

In our cropping and soil management practices we sometimes create in the soil an artificial condition unsuitable to the growth of plant roots. If these practices result in the loss of organic matter, the soil becomes hard and "bakes" easily or blows with the wind. Under such conditions tillage has a third function, viz., to improve the tilth or physical condition of the land as by the pulverizing action of the plow, or the firming action of the packer or the loosening effect of the cultivator.

In growing crops all portions of the plants are not always removed from the land. The stubble at least, generally remains and must be disposed of. Where strawy manure is applied in an endeavor to maintain the organic matter of the soil or for other purposes it too must be gotten out of the way of seeding machinery. The fourth function of tillage is the disposal of this stubble and manure by plowing it under where it will decay.

The last important function of tillage is to prepare a satisfactory seed bed or place for the seed to germinate. It is necessary to leave the surface soil in such condition that when seed is placed in the ground by the seeding implements used, it will find in sufficient quantities the factors necessary for germination, viz., moisture, heat and air.

80.—Objections to Excessive Tillage.—Of all the means at man's disposal for improving soil conditions and fostering the growth of useful plants, tillage is the most expensive, the most practised, usually the most important, and generally the least understood. In this as in other soil management practices the causes of lower returns must first be determined and then the best means of counteracting them put into practice.

To till the ground when it accomplishes no good purpose is useless and expensive and may be harmful. Intensive tillage to control weeds sometimes fails of its purpose because it keeps the surface layer of soil too dry for germination, while the same practice carried to excess in an effort to conserve moisture often defeats the larger purpose of producing high yields, by putting the soil into a condition in which it will blow. Jethro Tull's teaching that "tillage is manure" is true only up to a certain point. Excessive tillage is not only not manure, but it is often useless, always expensive and generally economically unsound.

Since society has developed into groups of people, some doing one class of work and some another, crop growing has become a business and crop production, including tillage, has a business or a cost side to be considered. Tillage costs money; up to a certain point suitable and timely tillage always pays; beyond that point it is not good business. It need hardly be pointed out that the common error is not in excessive tillage, but in its being untimely, unsuitable or inefficient. The problem of tillage is one of timeliness, suitability for the purpose intended and efficiency of the operation.

81. Implements of Tillage.—The implements used in tillage are of three general classes, (1) plows, (2), soil looseners (including weed cutters), and (3) soil firmers. The value of any of the three classes is determined by (1) its efficiency in performing the work desired, (2) its draft, (3) its cost, and (4) its durability. It is not our purpose to discuss the draft or cost or durability of the different types, although these are very important phases of the subject, but to consider very briefly the functions of the different classes of tillage implements and their relative suitability for specific purposes.

Plows.

82. The Function of the Plow.—The function of the plow is to cut off all the roots of plants, to turn the fur-

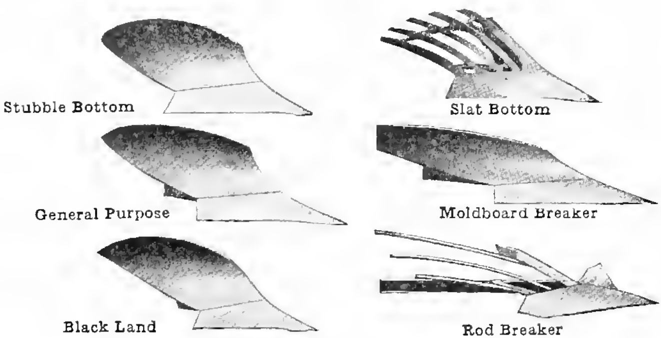
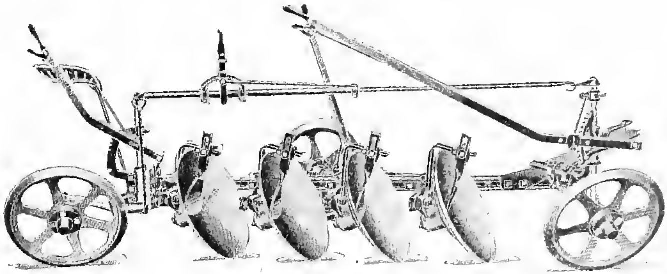


Fig. 37.—Types of Bottoms.

row upside down and completely cover all vegetation and litter, to pulverize the soil, to break up a hard subsoil, to leave the surface as smooth as possible (in this climate) after the operation and to do any or all of these at the lowest possible cost. In plowing, plants are killed by cutting off the roots below the crowns and by turning their vegetative parts under the furrow slice. The roots are cut by the sharp share and the vegetation is turned under by the upward sloping, outward curv-



37a.—The Disc Plow.

ing mouldboard (Fig 37). The covering is facilitated by having a straight-edged furrow which the coulter (Fig. 37C) makes. The effectiveness of the covering may be increased by the jointer or skim coulter, or by drag chains. The surface litter, of whatever form, is disposed of by thorough covering.

The soil is pulverized least by a long sloping mouldboard (breaker bottom) and most by an abrupt mouldboard (stubble bottom). The former is used in sod plowing because it turns a sod furrow better and the draft is lighter. The latter is used in stubble land because it turns the stubble furrow better and pulverizes more. (Fig. 37.).

When it is desired to loosen up heavy subsoil deep plowing may be practised or a subsoil plow or subsoil attachment (Fig. 37B) may follow in the furrow of the ordinary plow.

Kinds of Plows.—There are mouldboard and disc plows; and among the mouldboard types there are sod and stubble plows of many patterns. Each of these may be fitted with coulters, jointers and weed rods or drag chains, and the coulters may be "rolling", "knife"

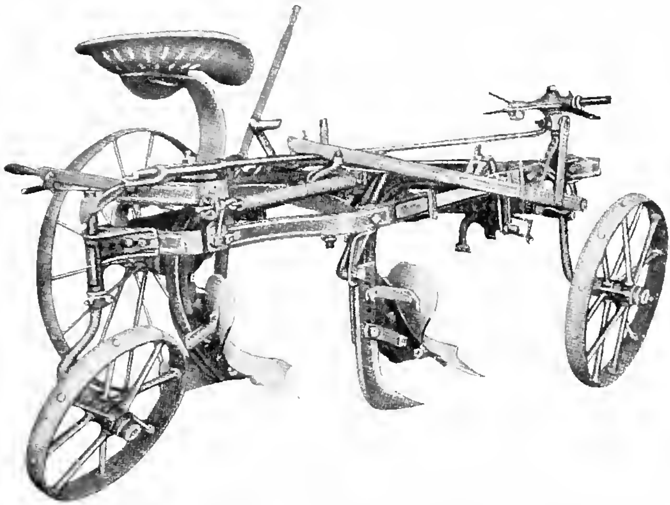


Fig. 37b.—Subsoil Attachment on Mouldboard Plow.

or "fin". But all are plows and all have the same functions.

The Pulverizing Action of the Mouldboard Plow.—Just how the mouldboard plow pulverizes the soil is well illustrated by King (Fig. 38A). If one takes a paper-covered book and bends it abruptly as when about to scan its pages rapidly, it will give him some idea of what happens to the soil as it passes up over the mouldboard of a stubble plow. The relative change in position of the particles in the furrow slice is shown by comparing the line 3-3 before the soil is pulverized with the line 1-1 after it has passed the slope of the mouldboard.

The ideal soil condition for plowing varies with the kind of soil and its moisture content. Soil that is too wet or too dry does not pulverize well, particularly if it is of a heavy type. Such soil is out of "condition" and as a result gives less favorable returns. In autumn in

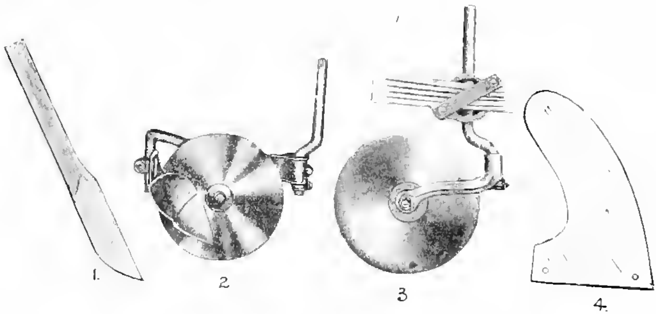


Fig. 37c.—Types of Coulters.
1. Blade coulter; 2. Revolving coulter and skimmer; 3. Revolving coulter; 4. Fin coulter.

the dry parts of Western Canada some of our soils are not in good condition for plowing. In spring and summer a better condition usually obtains.

The type of mouldboard to use should be governed by (1) the kind of soil, (2) whether it is in sod or stubble, and (3) its normal moisture content. There is a type of mouldboard suitable for almost every soil. The more abrupt the slope the better the scouring quality, but, of course, the greater the draft on account of the extra pulverization that is accomplished. The common types are the sod bottom (including rods for heavy gumbo), the stubble bottom (including slats for hard scouring soil) and the general purpose bottoms. These different bottoms are generally interchangeable with each other on the same make and size of plow.

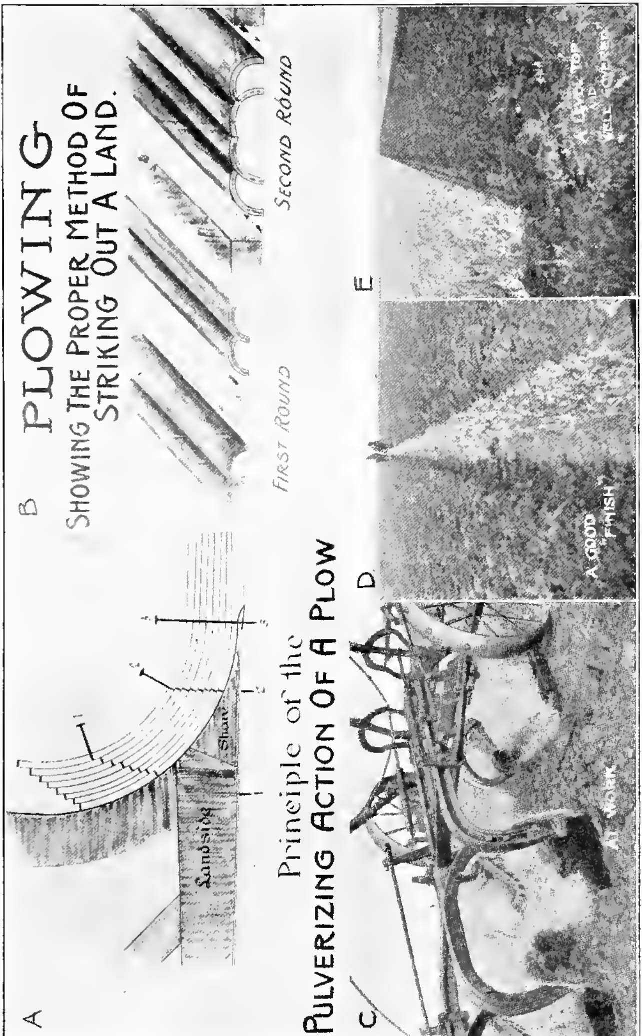


Fig. 38.—The Plow and Plowing.

In some sticky soils the ordinary mouldboard plow will not "clean", and in breaking the prairie, plows having rods (Fig. 37) instead of sheet mouldboards are used. These clean better and result in less friction and therefore lighter draft than the sheet mouldboard type and are the best to use in breaking "loose top" and some other sticky soils.

83. The Disc Plow.—On stubble fields in heavy land where the mouldboard plow will not clean, the disc plow (Fig. 37A) is used. This does not cut grass roots nor cover weeds, nor pulverize the soil as well as a mouldboard plow where the latter will clean. Where a mouldboard plow will not clean it is not satisfactory for any of these purposes. It requires more frequent sharpening than the disc, and it pulls harder; but where it can be used at all satisfactorily the mouldboard type is generally to be preferred over a disc plow.

84. Coulters.—Coulters are used on mouldboard plows to cut the edge of the furrow, thus at once lessening the draft and making it possible to do a better job of cutting roots and covering rubbish. There are different kinds of coulters such as "fin", "knife", "rolling coulter" and "skim coulter" or "jointer". The rolling coulter is mostly used in the West. It should be set about half an inch outside the line of the landside and should cut at least one-third the depth of the furrow. In trashy ground it should be set well forward to give more clearance, while in stony ground it should be set well down as well as ahead. The skim coulter does good work under some conditions in helping to cover weeds. Combination skim and rolling coulters are very common as are also those of the fin and knife type. (Fig. 37C).

Soil Looseners.

Among the soil looseners—and these include intertilling machines—are those having discs, cutting blades or stirring points. Those having revolving discs are known as disc harrows, while most of those having stirring points are called drag harrows. Those having cutting blades may have spring teeth, "duck" feet, or long slanting knives and are generally spoken of as

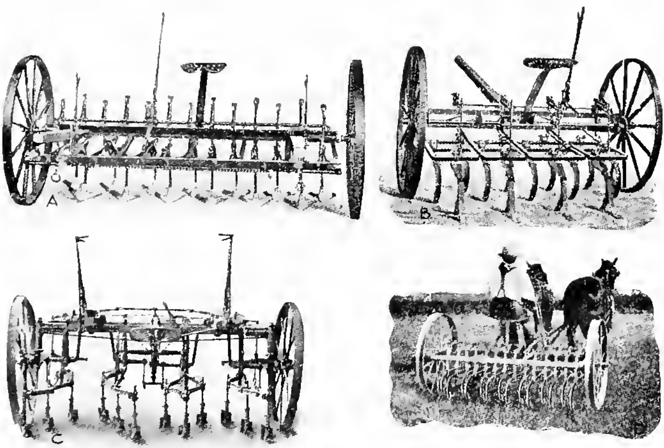


Fig. 39.—Types of Cultivators.
(a) Wide-bladed or duck-foot cultivator; (b) Spring-tooth cultivator; (c) Narrow-bladed two-row intertillage cultivator; (d) Alfalfa renovator at work.

cultivators. But all are soil looseners and their chief functions are to control weed growth and to loosen the surface soil in order to kill weeds or make a soil mulch or admit air.

85. Cultivators.—The cultivators have cutting points of various widths and designs. The wide bladed or "duck footed" types (Fig. 39A) are chiefly used to cut off weeds below the surface and the narrow bladed types (Figs. 39B, 39D) to loosen up hard ground or to dig out the creeping roots of such plants as quack grass.

A type of cultivator developed for stirring the soil and cutting weeds between rows of plants like potatoes and corn and known as an intertillage cultivator, differs from the others in form of carriage but not in function nor in mode of action. (Fig. 39C.).

86. Disc Harrows.—The disc harrow (Fig. 40 A. & B.) is used chiefly to loosen up the surface of soddy ground like breaking, or to cultivate the surface of stubble fields to conserve moisture or kill weeds, or to form a seed bed on stubble or plowed land. In view of its peculiar structure it ridges the land if "lapping half" is not practised or a double disc used. The alfalfa renovator (Fig. 40D) is especially designed (1) to dig the fibrous rooted grasses out of alfalfa and (2) to loosen up the surface of alfalfa fields without too serious injury to the plant roots.

On account of its rolling action the disc harrow can be used under many conditions. In the West its chief function has been working down the virgin prairie sod. The standard disc harrow has either full round discs or cutaway blades usually 16 inches in diameter, sixteen in number and spaced six inches apart. This is the four-horse size. The sixteen-inch discs rotate at greater speed than the larger ones and thus pulverize the ground more; they have less bearing surface on their edges and therefore more penetration.

Single disc harrows should have one lever for each gang. When "lapping over", i.e., allowing the disc to extend half way over the work of the previous round, is practised the ground is left level and not ridged. The gang working on the once disked ground finds a different resistance from the one working on the undisked ground, hence does not "balance". By setting the gang on the loose soil at a different angle the imple-

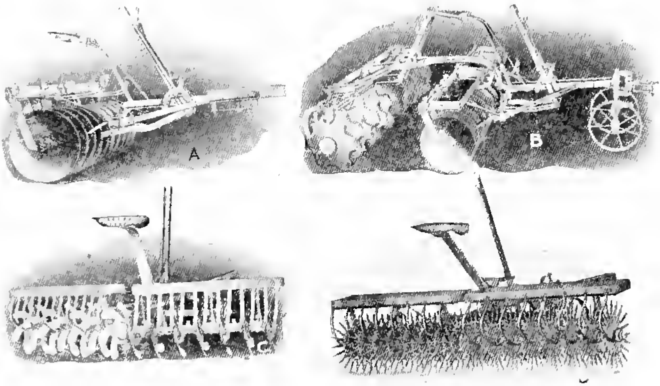


Fig. 40.—Types of Disc Harrow.

(a) Full bladed disc; (b) Double disc; (c) Spade harrow; (d) Spiked disc or alfalfa renovator.

ment may be made to pull straight and thus do better work. In hillside work the machine has a tendency to crowd downhill. This can be overcome when levers are provided for adjusting each gang separately.

The full bladed and cutaway discs are the two most common types. The former does better work although excellent results have been obtained from a double disc with full blades on the front and cutaway blades on the rear.

In recent years a disc attachment for seeders has been largely used. The "single disc" drill (Fig. 43C) is a disc harrow which cultivates the soil to some extent as well as sows the seed. The double disc on the other hand is not a harrow or cultivator but only a seeder. (Fig. 43D).

87. Drag or Smoothing Harrows.—The purpose of the drag or smoothing harrow is to prepare a level and uniform surface after other kinds of tillage, or to destroy young weeds by exposing their roots to the sun and air, or to form a mulch on the surface to conserve moisture or to aid in covering the seed after sowing. The drag harrow may be heavy or light, have wooden or steel frames and the teeth may be stationary (Fig. 41A) or

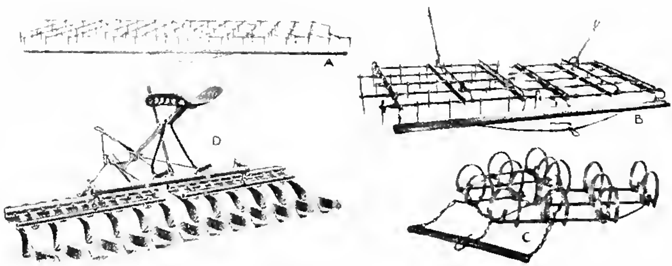


Fig. 41.—Types of Harrows.

(a) Steel harrow; (b) Adjustable harrow; (c) Spring tooth harrow; (d) Acme harrow.

adjustable (Fig. 41B). The light lever harrow with teeth sloping slightly backward is frequently used in the growing crop of grain, corn or potatoes for killing small weeds.

The spring tooth harrow (Fig. 41C) has the same function as the spring tooth cultivator. It is lighter in draft but less efficient.

The acme harrow (Fig. 41D) smooths the surface, cuts small weeds and forms a mulch, but it is not well adapted to general use under average farm conditions.

Soil Firmers.

Among the implements that firm the soil and thus crush lumps or lessen the air spaces, or pack the soil about the seed, are the home-made planker or scrubber and the press attachment for drills. All of these are soil firmers or clod crushers of different degrees of efficiency and of vastly different cost. One may fit certain specific soil conditions better than another. Each has a place in the economy of some particular farm and most

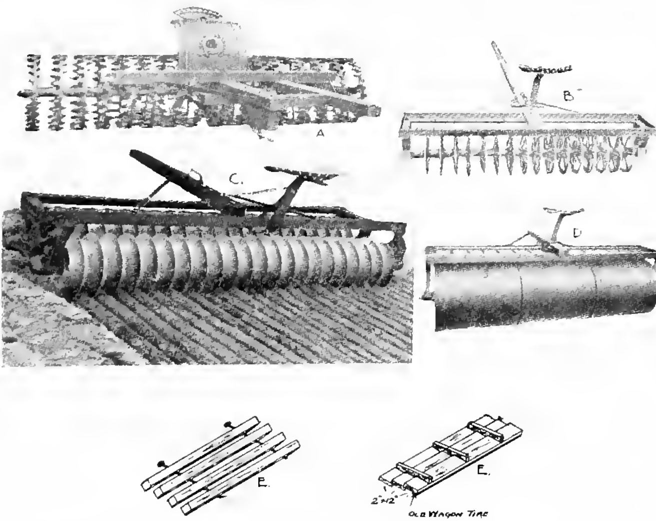


Fig. 42.—Types of Soil Firmers.

(a) Surface packer or pulverizer; (b) Subsurface packer; (c) Culti-packer; (d) Smooth roller; (e) Float and planker.

of them when used intelligently will prove a profitable investment. Yet no one is absolutely essential on any farm. The work of firming the soil can be accomplished with other implements though generally not so efficiently as with the machines designed for that purpose.

There are six more or less distinct types of soil firmers, (1) the surface packers, "pulverizers" or clod crushers (Fig. 42A), (2) the sub-surface packers (Fig. 42B), (3) the so-called "culti-packer" (Fig. 42C), (4) the smooth roller (Fig. 42D), (5) floats and plankers (Fig. 42E) and (6) the press attachments for grain drills. (Fig. 43A).

88. The Purpose of Soil Firmers.—The chief function of all six types of soil firmers is to aid in facilitating the movement of moisture from the subsoil to the furrow slice or in bringing the moisture of the soil into closer contact with the seed or roots of plants. On "breaking", any one of the first four types may be used to press the furrow slice against the subsoil; the surface and sub-surface packers are generally considered best but the home-made float or planker requires less power and is cheaper. After stubble plowing one or other of the packers is usually preferred. In the drier parts the subsurface packer is commonly used and in other areas on late plowed fallows and on fall and spring plowing it is preferred by some. It is, however, less of a general purpose packer, and is in reality less used in the West than the surface or corrugated packer. The "culti-packer" is an excellent implement to pack the soil about the seed after seeding, but for any other purpose it is not considered to be superior to the surface packer.

The plankers are chiefly used as levellers, but on breaking their value is in flattening out the plowed furrows. They are sometimes used on stubble fields after seeding where some additional soil over the seed is desirable and where, owing to the stubble, harrows do not work satisfactorily.

The smooth roller is but little used in the West. Its function is similar to that of the surface packer but it is less desirable than the latter since it leaves the surface too fine and with too little mulch and in a condition favorable to blowing. The surface packer leaves a granular mulch and a surface that is not so likely to blow.

89. Drills as Tillage Machines.—The chief function of a seed drill is to place the seed in the soil where it will get

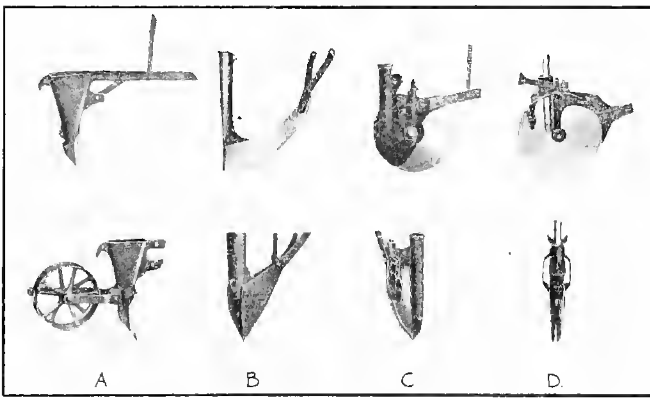


Fig. 43.—Types of Drills.

(a) Hoe drill with press attachment; (b) Shoe drill; (c) Single disc drill; (d) Double disc drill.

the moisture, heat and air conditions necessary for growth. Its efficiency as a seeder, aside from its mechanical faults or virtues is determined by the depth it will place the seed and the firmness of the soil about the seed after the operation. There are four chief types of drills, the "shoe" drill, the "hoe" drill, the "single disc" and the "double disc". (Fig. 43).

The shoe drill (Fig. 43B) can hardly be called a tillage implement. The hoe drill (Fig. 43A) is to a slight degree a cultivator of the narrow tooth type. The single disc drill (Fig. 43C) is not only a drill but a disc harrow as well, of rather low efficiency, while the double disc is a drill only. (Fig. 43D).

Where some cultivation is needed, such as on some unplowed stubble fields, the single disc is perhaps best. On soils that are well prepared and not too hard and where drifting is feared the old hoe or the shoe drill are quite satisfactory, particularly on light soils. Where soils are well prepared, yet quite firm, the double disc is probably the best to use.

The shoe and hoe drills pull easier and generally require less repairs than the discs but on all except light soil or well prepared land they are not at present as popular as the discs.

90. Press Drills.—The press attachment is a packer and perhaps the most efficient one from the point of view of the seed. It packs the ground where it needs packing at the time it needs it, and leaves unpacked the portion that is best left loose. But the press drill as at present constructed is costly, heavy to pull, somewhat difficult to operate, particularly in sticky soil, and is likely, as a rule, to require more repairs than most other types of drill. It is coming into quite general use on soils that drift and is often found on medium type soils in the dry belt. (Fig. 43B).

CHAPTER VII.

BREAKING THE VIRGIN PRAIRIE

"Breaking" is the western term for the first plowing of the native prairie land. It is the first tillage operation undertaken by the settler in order to make the raw prairie sod suitable for the growing of cultivated crops. The breaking is usually followed by more or less tillage the same season and may include a second plowing, which is spoken of as "backsetting". When this second plowing is not given the surface tillage usually consists of packing or "planking", disking and harrowing. If the intention is to backset, the breaking is done shallow, but if not, it is the custom to break more deeply.

When the breaking is done in the spring, it is sometimes sown to grain the same year. In the dry districts this practice frequently results in partial or complete failure but in wet years or in the more humid parts fair yields are sometimes secured. The plan usually followed is to leave the land without a crop until the next season.

In the early days, when the tillage of prairie sod was not so well understood, new breaking was not expected to give a good crop. Even now new settlers frequently fail to get good returns from their first efforts. There is, however, no good reason why the first crop should not be an excellent one in the average year.

91. Why We Till Prairie Sod.—The function of tilling prairie sod in semi-arid climates is threefold: —

1. To store and conserve moisture in the soil.
2. To kill the native vegetation, and
3. To prepare a suitable seed bed.

92. How Moisture is Stored and Conserved in New Land.—The storage and conservation of moisture is necessary

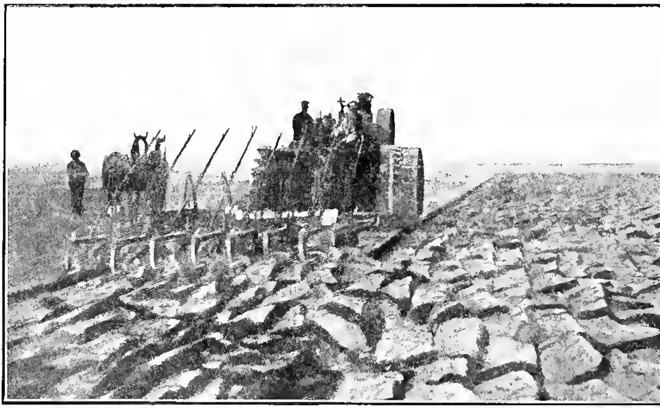


Fig. 44.—Breaking with Tractor.

No skips or misses but land too dry for a smooth job.—Courtesy Dominion Experimental Farms.

before profitable crops can be raised on new land. This is accomplished by (1) killing the native vegetation early in the growing season, (2) by preventing the "run-off", and (3) by preventing the excessive drying out of the furrow slice.

All prairie land is covered with a growth of grass and other plants native to the district. These use up moisture in just as large quantities as weeds or domestic crops. (See Sec. 168). Most of them make their greatest growth early in the season, hence the sooner the plowing is done the greater the amount of water conserved.

Native prairie does not readily take in all the water that falls upon it especially if the land is rolling or hilly. Plowed land on the other hand absorbs water more readily than unplowed land. Breaking early in the rainy season gives, therefore, greater opportunity for the soil to absorb moisture and breaking crosswise of the slopes, if possible and practicable, facilitates the absorption of a greater part of the run-off from melting snow the next spring.

The loss of moisture by evaporation from the furrow slice and from the subsoil of a freshly broken field is very great for the reason that, not only the top of the furrow, but generally its sides and often its bottom, and the furrow bottom as well, are exposed to the drying influence of the wind. This loss of moisture is lessened by (1) turning the furrow perfectly flat, (2) bringing it against the subsoil with a packer or planker, and (3) disking to fill in the cracks between the furrows as soon as the latter are sufficiently decayed to permit of this being done without turning up unrotted sods.

Plowing the prairie sod results in partial or complete killing of the native plants and in making the soil receptive to rains, thus at once preventing loss by transpiration and by run-off. Then, by packing and disking the loss of moisture by evaporation is lessened and more is conserved for the use of the subsequent crop. The longer the disking is left undone after breaking the better the land will "work up" but the sooner the loose layer can be created on the surface the more moisture there will be saved.

93. Killing the Native Prairie Plants.—The native vegetation consists chiefly of grasses and various shrubs, such as rose bushes and wolf willow. Some of these plants are fibrous-rooted while others, such as native

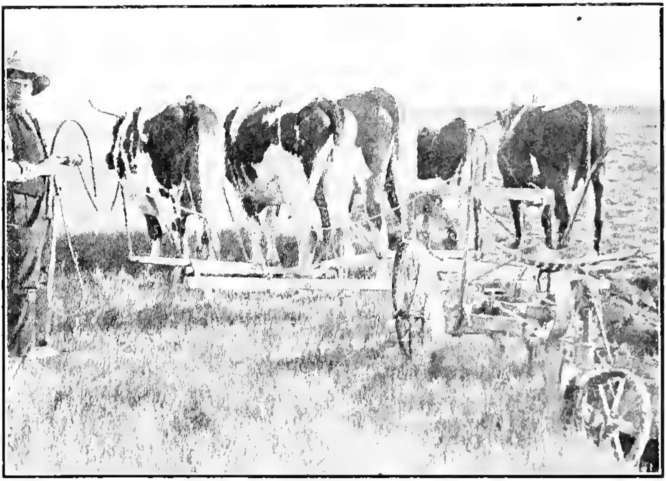


Fig. 45.—Breaking with Oxen.
Not an unfamiliar sight in the early days of land settlement in the west.

quack and the rose bushes have underground stems or "creeping roots". These plants can be killed only by plowing. Fibrous-rooted plants can be killed by once plowing if followed by reasonable surface cultivation. Creeping-rooted ones are less easily disposed of, and in order to completeley eradicate them it is necessary either to break and backset or to break in a dry time and let the furrow slice dry out before it is surface-cultivated.

It is obvious, therefore, that on land that is to be plowed only once, the best practice for conserving moisture is not the most efficient for killing the creeping-rooted grasses; plowing once will be successful in the latter respect only in proportion to the dryness of the season. In other words if the season is a wet one, the perennial plants are not likely to be eradicated by plowing once. It is apparent, therefore, that the specific practices to be followed must be determined by the local and seasonal conditions of soil and climate.

It is, however, always a good policy to plan to get rid of creeping-rooted plants the year the breaking is done

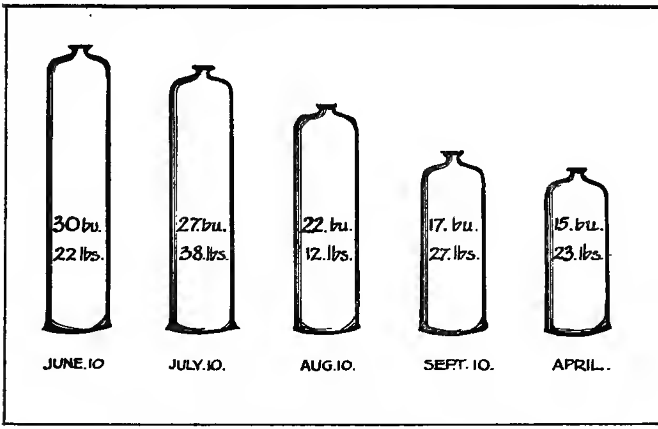


Fig. 46.—June Breaking Pays in the Dry Belt.

This chart illustrates the average yield secured on breaking done during June, July, August and September and the following spring on a clay loam soil in West Central Saskatchewan.

if at all practicable, otherwise they will be a drain on the productiveness of the land and in any case will have to be eradicated later at probably an added cost. As a rule if creeping-rooted plants are present and known to be difficult to eradicate, breaking and backsetting is to be recommended; if they are not present or are found in such small numbers that they are not difficult to control, deep breaking with adequate cultivation will prove a somewhat less expensive method of preparing sod land, and in many places, especially in dry areas, equally effective.

Plowing late in June or early in July, rather than at an earlier date, favors the eradication of all creeping-rooted plants for the double reason that subsequent to these dates the rainfall is generally less and the vitality of the plants lower than before.

For the same reason plowing once is more likely to be adequate in dry areas than in wet ones, and plowing twice more advisable in moist areas than in dry. If a long breaking season is contemplated a practice very much to be commended is to break shallow up to the 15th or 20th of June (in the dry parts) and after that date break deeply. The early shallow breaking may then be backset after the sod decays, and the later deeper breaking may be prepared by disking. Land carrying a tall or dense growth of scrub cannot be satisfactorily plowed a second time in the same season.

94. Preparation of the Seed Bed.—After killing the native plants of the prairie and storing a supply of moisture for the crop, it is important that the soil be left in such condition that the requirements of germination and future growth may be easily and abundantly supplied to the seeds and roots of the crop. To insure that these requirements be met it is necessary (1) that the furrow slice be firmly in contact with the subsoil so that the subsoil moisture may not be prevented from moving to the seed and roots of the crop; (2) that the soil be prepared in such a manner that sufficient moisture for germination will be within one to three inches of the surface so that too deep seeding may not be necessary, and (3) that a mellow layer of soil be formed on the surface to function efficiently as a seed covering after the passage of the drill. The use of the packer, disc and harrow in the order mentioned and at the right time is the best way to accomplish the desired results. Ordinarily, the land is firmed down by a packer or planker soon after plowing, disked as soon as the sod has partially rotted and then harrowed to prepare a uniform and level surface.

95. Some Desirable Practices in "Breaking" Prairie Sod.—Most of the practices to be discussed under this heading might easily be inferred from what has already been

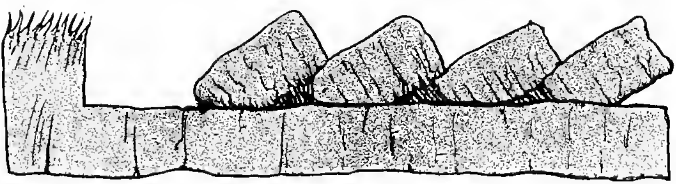


Fig. 47.—Improper Breaking for Dry Areas.
The furrow slice instead of lying on the corner of its neighbor should lie flat.

said. In discussing them it should be kept in mind that a practice that is best in one district may not be good in another. Each so-called "desirable" practice should therefore be considered in its relation to the needs of the situation, the presence of creeping-rooted plants and the average rainfall being the chief determining factor.

96. Break Early to Obtain Maximum Yields.—The decrease in yield of wheat on breaking done after the tenth of June at Saskatoon has been found to average one bushel per acre per week. In more humid districts the decrease will probably be less and in drier districts greater than this figure. The following table gives the average acre yield of different crops on breaking done at different periods throughout the year.

TABLE XVI.—*Showing the influence of time of breaking on the yield of different crops in Saskatoon—average of three years test in crop seasons of* 1915, '16 *and* '17.

Date of breaking	Wheat bus. lbs.	Barley bus. lbs.	Flax bus. lbs.	Potatoes bus. lbs.	Corn lbs.
June 10............	30 - 22	39 - 33	19 - 27	215 - 26	30819
July 10............	27 - 38	36 - 30	18 - 24	210 - 16	30239
August 10.........	22 - 12	26 29	13 - 20	157 - 22	22608
September 10......	17 27	22 13	13 - 20	155 - 38	20727
Early Spring*	15 23	19 - 44	13 - 43	143 - 28	18780

There are two fundamental reasons why early breaking increases the yield, the first being an increase in the soil moisture content and the second, a better state of soil tilth. The increase in soil moisture is due chiefly to the fact that native plants have been prevented from using it up and also to the greater facility with which the cultivated land is able to absorb moisture and prevent its evaporation. The better soil tilth is due to the fact that land that is broken early has a much better chance to disintegrate since it has the necessary moisture to promote decay and is exposed to the action of the weather for a greater length of time.

97. Plow all the Land.—Good plowing when breaking prairie sod is probably more important than any other phase of the breaking operations. Poorly plowed breaking does not kill all the grass with the result that no crop is produced where the "skips" occur, and in the second and often in subsequent crops this grass increases and seriously lessens the yield. Poor breaking is the chief reason for grass in stubble fields which in turn is one of the chief causes of low yields on such land.

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* Refers to season the crop is sown. The other dates refer to the previous year.

98. Turn the Furrow Over Flat.—The furrow slice should be turned over flat on the furrow bottom, otherwise the sod does not rot satisfactorily and the furrow slice itself dries out too much. It has been observed

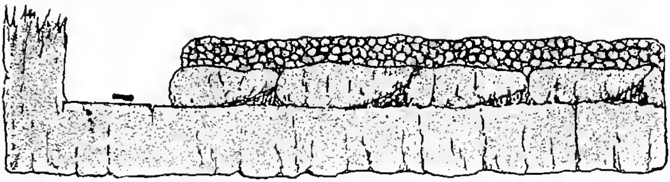

Fig 48.—Improper Breaking—after Discing.
Showing the loose, open spaces under the furrow slice which are so undesirable in dry areas.

that where good plowing is done and the furrow slice turned down flat, rather than on edge, the sod rots better and larger returns are secured.

99. Pack or Plank after Breaking.—For the same reason that sod or prairie land should be turned over flat, it should also be pressed firmly against the subsurface soil. For this purpose the land packer or the home-made planker give excellent results. In the dry summers of 1914 and 1917 the only breaking on which the sod thoroughly rotted was that which had been well packed. In a wet season the necessity for packing is not so great.

On land that contains some creeping-rooted grasses but which it is not considered necessary to backset the same season, and in low-lying areas particularly, it is sometimes advisable to leave the breaking unpacked for a few days to permit the furrow slice to dry out and thus aid in killing the grass.

100. Disk Deep Breaking as soon as Possible after it can be done without Turning up Sods.—Moisture evaporates rapidly from the smooth surface and sides and from the bottom of the sod furrow. As soon as disking can conveniently be done without turning up unrotted sods, it should not be delayed. On some soils it can be done very soon after breaking, but on others this operation often has to be left until the sod is at least partially decayed. In practice it is usually found advisable to break while

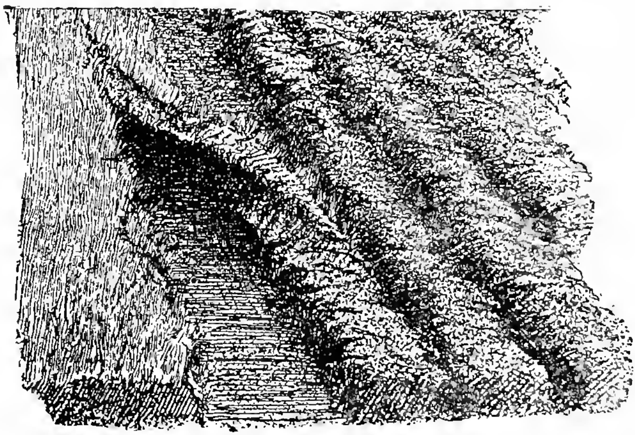

Fig. 49.—In Breaking the Furrow Slice Should be Turned over Flat.

the soil is moist and the land can be easily and quickly plowed, and to do the disking later when it is difficult or impossible to plow.

101. Cultivate Sufficiently during the Season to Prevent the Growth of Native Plants.—If prairie land is broken and the surface left uncultivated a considerable amount of moisture is lost as a result of the drying effect of the wind. At the same time if any of the native plants still persist they not only establish themselves in the soil but they pump out very large quantities of water. The use of the discs and harrows often enough to prevent the growth of these plants and to keep the soil from drying out is essential after the sod has decayed sufficiently to permit these implements to do good work.

102. To Control Creeping-Rooted Grasses Break Early and Backset.—It has been pointed out that the primary object of tilling prairie land is to kill the native vegetation and increase the moisture content of the soil. Unfortunately, the same practices do not always result in accomplishing both purposes, since the drying out of the furrow slice is the most effectual way to kill creeping-rooted grasses. Under most conditions and in most years both of these objects can be attained by breaking and backsetting. Single plowing can be depended upon to eradicate creeping-rooted grasses only if the district is dry or if it is a dry year in a more moist area, or if it is done late.

The first crop after breaking and backsetting is often not much larger than the first crop after deep breaking that has been surface cultivated, but the second and later crops are invariably better from the twice-plowed land. In the year 1913, the second crop of wheat on land that was broken and backset yielded 14 bushels, 36 pounds of wheat per acre, while the second crop on adjoining land that had been broken deep and surface cultivated was but 4 bushels, 11 pounds per acre. The difference was due altogether to the presence of native quack grass in the once-plowed breaking. Single breaking and disking is less expensive than breaking and backsetting, and when done in good time on soils free from quack and sweet grass often gives as good results. Backsetting in our opinion is advisable only in areas or on soils where once-plowing does not ordinarily kill the grass.

103. Don't Backset if Sod has not Rotted.—In very dry summers it is more difficult to backset and less difficult to kill the prairie grasses than in wet summers. In 1914, as in some other dry years, it was physically impossible

Fig. 50.—A Good Job of Breaking on Medium Light Soil.

in many areas to backset any breaking except that which had been done early and well packed down. In addition to this difficulty, it was noticed that even where backsetting was done the unrotted sod produced a very unsuitable seed bed and one that required an unreasonable amount of surface tillage before it was considered satisfactory.

104. Land Intended to be Backset Should be Broken Shallow; that not to be Backset, Deeper.—Deep breaking controls native plants better than shallow breaking but it cannot be backset satisfactorily. If it is the intention to backset, it is therefore advisable to break shallow. In some parts it is a fixed practice to plow shallow in the early part of the breaking season and deeper at the latter end. The early breaking can then be backset after the breaking season is over. "Shallow" and "deep" are used here as relative terms. A depth of two to four inches is generally considered shallow breaking and four to six inches deep breaking. "Backsetting" should usually be about two inches deeper than "breaking".

105. Harrow and Pack Backsetting.—The moisture stored in the subsoil of plowed land must be kept available to the seed and plant roots. In order that this condition may obtain, firming the loose soil after backsetting is advisable. The general practice in the early days was to harrow such land thoroughly. It is now

Fig. 51.—Breaking Scrub Land in Manitoba.

generally considered advisable to pack it after smoothing down with the harrow. If this is done in the fall, the last tillage operation in the fall should be harrowing or cultivating.

106. "Scrub" Land must be Treated Somewhat Differently.—On land that carries a growth of bushes and small wood, backsetting is seldom practicable for the reason that the growth plowed under does not decay in time to permit it to be backset. Under these conditions very deep plowing followed by packing and thorough surface cultivation is the best procedure.

Early breaking on "scrub" land has all the advantages of early breaking on prairie land, but because of the fact that most of our "scrub" land is in the more humid parts of the country or in areas of low evaporation, it is not essential that the plowing be done as early as in the prairie sections. At the same time it is well to keep in mind that the earlier the work is done the more moisture there will be conserved and the earlier the rubbish is plowed under the quicker it will decay and leave the soil in good physical condition.

107. Leave Breaking Uncropped until the Following Season.—In nearly all cases it will be found more profitable to leave the plowed prairie land uncropped until the following year rather than to sow it the year it is broken. If a man is beginning farming operations with little capital and must have some cash return or grow feed for stock in the first season it may be good business to sow some crops on new breaking. This, however, should seldom be practised in the eastern Chinook region. It gives best results in the park belt and eastern portion of the prairie area. In any case the work should be done early and well. The practice is risky but occasionally results satisfactorily. It is not one to be recommended in the drier districts because it fails too frequently, and whether it fails or not, leaves the land in poor condition for the next crop.

Flax has proven the best cash crop for spring breaking in the prairie area, and oats the best feed crop in all parts. Corn does very well on spring breaking and has the advantage of leaving the soil in good condition for another crop. Potatoes are sometimes planted under the sod with fair results in favorable seasons.

108. The "Breaking" up of Cultivated Grass Land.—In general the practices found advisable in breaking prairie sod apply also to the plowing up of cultivated grass land. The drier the district the greater the necessity of June breaking. In parts of Manitoba, northern Saskatchewan and northern Alberta plowing immediately after the hay crop is removed in July is found to give very satisfactory results except in abnormally dry years. Packing or planking after breaking is advisable. Backsetting is never necessary if the grass is western rye or timothy or mixtures of either of these with clover. But if brome grass or Kentucky blue grass is grown backsetting will be necessary to control it. The former is much more persistent than the latter, but even the Kentucky blue grass is difficult to kill with only one plowing. We have also found that the hardy alfalfas cannot be satisfactorily killed by once-plowing. A shallow plowing early in the season followed by packing, and then backsetting after the ground has well settled and before the growth of unkilled plants becomes too strong, is a good procedure with this crop. Where backsetting is not necessary the general practice is to pack the land, double disc it as soon as convenient, and harrow to give it a uniform and level surface for seeding.

CHAPTER VIII.

PREPARING PARK BELT LAND FOR ITS FIRST CROP

The southern part of each of the Prairie Provinces is an open plain, for the most part free from trees. On the northern border of this treeless region the character of the vegetation changes until an intermixture of trees, shrubs and open prairie is found which gives to the landscape an added beauty and suggests the name by which it is commonly known, the park belt.

109. Location and Extent.—The southern edge of this belt touches the international boundary line near the eastern boundary of Manitoba and passes generally in a northwesterly direction, reaching its most northerly point in the western part of central Saskatchewan, from which point it turns gradually southward until it touches the foot hills of the Rocky Mountains in southern Alberta. No clearly marked boundary between the prairie and park belt exists. In some of the prairie area there are places where "scrub" and even small "bluffs" may be found. Likewise in the park belt there are frequently found large areas of open prairie. To the north of the park belt very little open prairie is found, the vegetation is more dense and the trees are as a rule larger than in the park belt. The width of this intermediate zone or park belt varies from a few to many miles.

110. General Characteristics.—Within the boundaries of the park belt may be found as many different soil types and almost as great a variety of climatic conditions as exists on the prairie to the south of it. In

Fig. 52.—Typical Scene in the Park Belt of Manitoba.

some respects, however, all parts of this region are comparable; they present the same problems to the settler; the growing season is generally shorter and the evaporation less than in the prairie areas adjoining; hay and pasture crops as a rule do better than in the open plains immediately to the south; the production of coarse grains, mostly oats, is the general but not exclusive practice, the early ripening varieties of wheat and some barley also being grown; and the practice of mixed farming is the general rule.

111. Climatic Conditions.—The precipitation is generally thought to be higher than in the open plains, although the meteorological records do not make this very evident. The evaporation of moisture from the soil is probably less owing to the lower average temperature and lower wind velocity. The frost-free season is shorter than on the prairies and the danger from early fall frosts and summer frost is greater.

112. Character of Vegetation. — In addition to the grasses and leguminous plants which usually occupy the open spaces many species of shrubs and trees are to be found. From the point of view of the settler the latter may all be classed as either brush, or trees of different size. By brush is generally meant the small shrubs that may be cut with a scythe, a scrub hook or a mowing machine, or which may be plowed under with a heavy plow. The small trees are those that after being cut with an axe or burned off leave a root which is not too large to prevent plowing. The larger trees vary from four inches to a foot or more in diameter and unless burning is practised these have either (1) to be chopped down and the roots grubbed out, (2) to be pulled over by horses or engine power and the roots removed from the soil, or (3) to be cut down by brush-

Fig. 53.—Removing Small Trees with Tractor.

cutters or by hand labor and the ground then plowed by using specially built scrub plows, after which the roots are removed.

113. Methods of Removing "Scrub".—Where labor is cheap the best and most satisfactory way is to have the scrub grubbed out by hand, using grub hoes and axes. In a few districts cheap labor may yet be secured; where contracts have been let to half-breed workmen, the results have been very satisfactory.

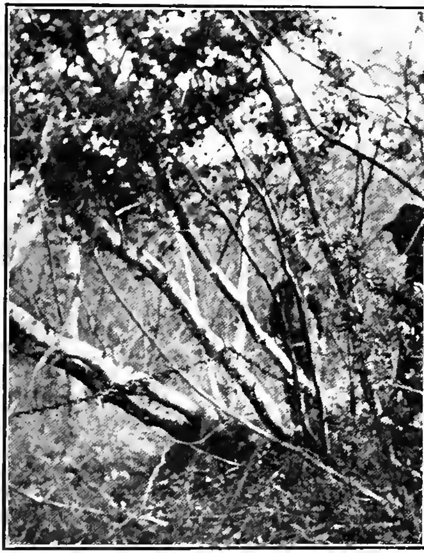

Fig. 54.—Pulling Trees with Tractor. Showing method of attaching chain.

When cheap labor cannot be obtained scrub may be pulled with a team of horses. A strong chain or steel cable is put around a tree or clump of small trees at a height of six or eight feet; these trees are then drawn out. The roots below the stump are forced out of the ground when the tree is drawn over, and if they are too heavy for the horses to pull clear of the soil they are chopped off below the stump. When this method is employed, a good teamster is needed if one does not wish his horses spoiled for steady drawing.

A plan similar to the above but in which tractor power rather than horse power is used is coming into more general use. This has proven a very satisfactory method, and when labor is high priced, has been found quite economical. By this method quite large trees with their stumps are pulled out, the land being then broken easily with a scrub-breaking plow.

Another method is to cut the brush off level with the ground either with the axe or a brush cutter and then to plow the land with a scrub breaking plow which will plow right through the stumps, and turn them over leaving them on top to be picked up later and carted away.

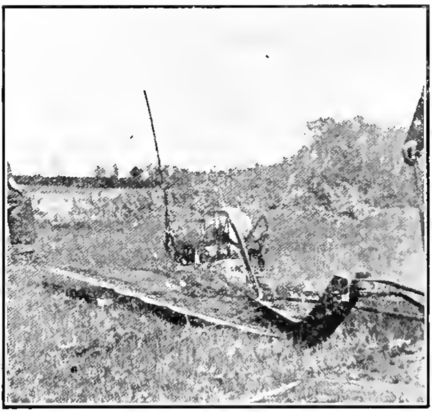

Fig. 55.—Scrub Cutter.

Sometimes used for removing trees in Park Belt land.

In each of the methods so far referred to, the brush and roots are piled and then burned.

Another method frequently followed is to burn over a piece of land for several springs in succession in order to clear it of all the trees and underbrush, and then break the land with a brush breaker hauled either by horses or tractor power. This is a good way when one is not ready to break the land the first year it is burned over.

114. Plowing Scrub Land.—The common practice in breaking scrub land is to plow about five inches deep, but if the roots are large deeper breaking is necessary. The best depth to plow depends on the size of the roots in the ground, it being necessary to plow that depth

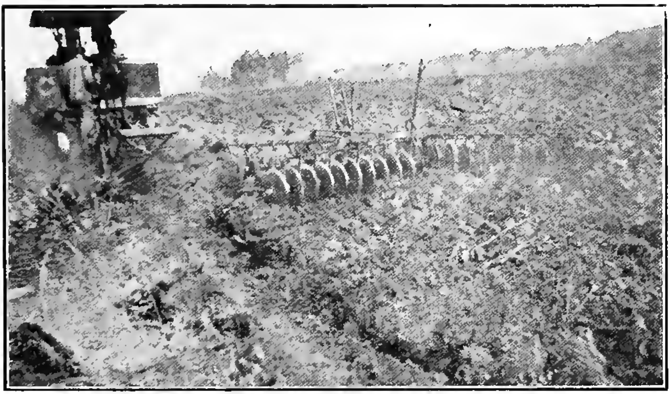

Fig. 56.—Plowing and Disking Burned-over Scrub Land.

which will enable the implement to turn a good furrow. Under some conditions a furrow ten inches deep and two feet wide is turned.

The plowing is usually done in June and July. The drier the district the earlier the land should be broken and the more moist the district the longer it may be delayed. In the more favored parts and in favorable seasons elsewhere the land is sometimes broken early and after being well worked down is sown to oats for feed. Where the soil is rich and the rainfall sufficient this is a good practice. In fact in some places it is considered the best plan, as otherwise the first crop following is heavy and weak in the straw and more subject to lodging or fall frosts. In the drier districts no crop the first year is the general rule.

Backsetting scrub land is not generally practised until one or more crops have been grown. It is seldom necessary and it is usually difficult or impossible. When all roots and brush are removed either before or after, or at the time of the first plowing, backsetting is possible and is occasionally practised.

115. Surface Tillage After Plowing.—After scrub land is plowed any loose brush and exposed roots should be removed and the land worked down to a level surface

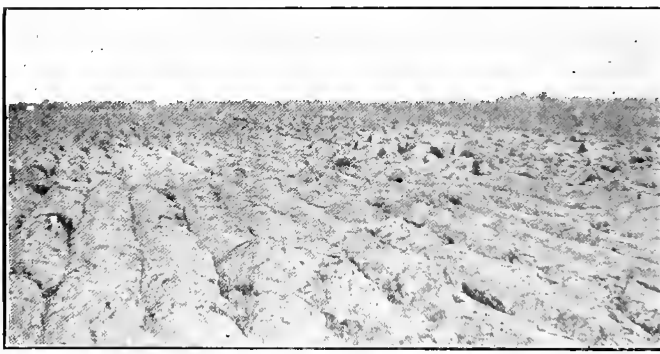

Fig. 57.—How Scrub Land Looks After Plowing.
This area did not contain many stumps of trees over five inches in diameter.

with a packer or heavy planker followed by discs and harrows. The sooner this can be done the easier the vegetation may be killed and the less the land will dry out. Scrub-breaking usually requires considerable disking before the surface is level enough to make a satisfactory seed bed. Aside from getting the land levelled down, it should be tilled sufficiently to keep down all vegetation and to leave the seed bed in good condition for spring seeding.

116. Cost of "Scrubbing" and "Breaking".—The cost of scrubbing, breaking and getting scrub land ready for a crop varies widely, depending chiefly upon (1) the percentage of open land, (2) the size, kind and condition of the scrub, (3) the cost of labor, (4) the method followed, and (5) the type of soil. Ordinarily it ranges from $5.00 per acre to $20.00 per acre more than the cost of breaking and preparing prairie land. Heavily timbered land with no open areas costs much more than these figures. Very little of such land has yet been brought under cultivation.

117. The Choice of the First and Subsequent Crops.—When spring breaking is cropped the year it is done the crop used is invariably oats. It is usually put in for "sheaf feed", but in occasional years the crop matures and yields enough to be well worth threshing.

When not cropped until the following year both wheat and oats are commonly used. Where there is but little danger of fall frost before the crop is ripe, wheat, preferably an early variety, should be chosen. If there is fear of damage from fall frosts oats are to be preferred. Among wheats Marquis is quite commonly used. Some of the earlier and lighter yielding varieties, such as Prelude and Red Bobs, are also grown to some extent. In addition to the varieties of oats commonly used in the open plains—Banner, Victory and Gold Rain—Abundance is grown to a considerable extent in the park belt. Ligowo, an earlier, lighter-yielding oat, is also grown to some extent. Daubeney and Alaska, very early but inferior yielding oats, are also used. Where the season is not too short the Gold Rain variety has much to recommend it.

Although too few tests of barley varieties have been made to warrant any conclusive statement, it appears that the six-row varieties are likely to be best for this region. Manchurian and O. A. C. No. 21 are the standard sorts, although a true six-row sort known as "California" barley offers much promise. The best of the very early, but lower-yielding and shorter-strawed barleys, is the Early Six.

Fig. 58.—Removing Roots and Brush.
On the more heavily wooded Park Belt land the removal of roots and brush after plowing and disking is a necessary operation.

Spring and winter rye are also grown on a small acreage of the park belt. Prolific is a promising sort of spring rye, while N. D. No. 959 is probably the best winter variety.

Among peas the early varieties are to be preferred. Arthur has been commonly recommended in the past. Early White is recommended for Saskatchewan conditions and Alberta Blue is spoken of very highly in Alberta.

The best grasses for the central part of the park belt are Western Rye and Brome. In the western and the eastern ends of this area Timothy is used to a considerable extent. Where pasture is desired and Brome grass is not popular Kentucky Blue grass is frequently used.

Red Clover is coming into use in a small way in the park belt areas where Timothy is recommended, while Sweet Clover is likely to prove more satisfactory in the drier parts.

Roots and potatoes find a very favorable environment in the park belt, particularly, in those parts having more than fifteen inches precipitation.

118. The Best System of Farming.—The best system of farming in the park belt is coarse grains and stock, or mixed farming. Except for some local areas like the Dauphin district of Manitoba, the park belt district is not as well suited to wheat growing as the open prairie, and it is far superior to the latter for the growing of oats, barley and forage crops. It is also better protected from the winds of winter and better watered, thus making it more favorable for stock growing than the open plains.

It seems clear that this region is eventually destined to be among the safest farming districts of the West. In the early days of settlement the returns are slower in coming than on a prairie farm, but once a park belt farm is improved and a good system of farming established, it immediately becomes a safer business proposition than the average farm of the open plains.

CHAPTER IX.

THE TILLAGE OF STUBBLE LAND

Land that has borne one or more crops of wheat, oats, barley, rye or flax is commonly spoken of as stubble land. The control of the yield of crops on such fields is one of the most pressing problems in production now facing the grain grower of the open plains. In view of the fact that at least two-thirds of the present cropped acreage of this area is stubble, it would seem that the preparation of this portion of our cultivated land should receive very much greater consideration than it has ever been given before.

The surplus moisture stored in fallowed land is at least a partial insurance against failure of the next season's crop as a result of drought. The same is true, in a lesser degree, of prairie or sod land that has been "broken" and left unsown till the following year; but on land that has produced one or more crops the soil moisture is largely exhausted, and the next succeeding crop is almost wholly dependent upon the amount that falls as rain or snow after harvest time. Because of this it is probably true that we shall never, on the average, get as good returns from the stubble crop as from that sown on fallow or "breaking" or after "hoed" crops. Nevertheless, much can be done to increase the productive power of such land.

119. The Causes of Low Yields.—The causes of low yields on stubble fields are usually few in number. The most common ones are:—

1. The low moisture content of the soil.
2. The presence of grass, shrubs and weeds.
3. A poor seed bed.
4. Insufficient "available" plant food.
5. The stubble itself.
6: Unavailable soil moisture.

The first is the most general, but any one or all of the others may be contributing causes of poor crops. A few

Fig. 59.—Harvesting Wheat near High River, Alberta.
On the left may be observed a fairly typical surface covering of wheat stubble.

of these cannot be controlled absolutely, but all can be materially influenced by man and some are entirely within his control. Each is affected by tillage, but, unfortunately, the tillage operation which produces a favorable condition in one often produces an unfavorable condition with respect to another. Hence no fixed procedure can with profit be followed on all fields. The actual causes of low yield on a given field must first be determined and then the cultural treatment that is likely to control these particular causes must be given, if the largest net advantage to the farmer is to be derived.

120. The Control of Soil Moisture.—The low moisture content of the soil is the principal cause of low yields on stubble land. "A dry season", "too little rain", "hot winds" are generally given as causes of partial failure. So far as this portion of the general problem of managing stubble fields is concerned only two things can be done—(1) endeavor to prevent the moisture already in the soil from escaping, and (2) try to get more in.

The moistutre in stubble land escapes in only two ways—by evaporating directly into the air and by being transpired by weeds or other volunteer plants growing on the land. The loss by evaporation from most stubble fields in dry climates is very little, probably not sufficient to warrant any but the cheapest form of tillage or mulch making, if for this purpose only. The loss of moisture through the growth of weeds is very great and this can and should be controlled by killing the weeds when they are small.

Getting additional moisture into stubble fields in fall and spring is a more difficult problem in this climate than keeping in what may be already there. Our autumn, winter and spring seasons are dry. In the seven months from September to March, inclusive, only about one-third of the year's precipitation falls, and a large portion of this is in the form of snow and, therefore, not easily controlled. To prevent the "run off" in spring, plowing is preferable to surface cultivation or no cultivation, and fall plowing is better than spring plowing. But "fall plowing dries out" and if left unplowed "the stubble holds snow." If in plowing in the fall to store moisture which seldom falls we prevent the accumulation of snow in the stubble and also lose some moisture that is already in the soil, what is the net result?

121. The Control of Weeds, Grasses and Shrubs.—The surface of stubble fields is often infested in the fall with weed seeds of various kinds. They seldom germinate until the following spring when they make their appearance in the growing crop, using up tons of moisture, lessening the yield and increasing the cost of cutting, stooking, threshing and marketing the crop. As a rule such plants mature and drop their seed either before or at harvest time, making the problem of coping with them still more difficult.

In the control of annual weeds in stubble fields that are to be cropped again the object should be to get as many as possible of the weed seeds germinated in the fall, as most of them will die when subjected to the low temperatures of winter. Some form of cultivation will best accomplish this result, while thorough late fall cultivation or fall plowing will completely control the biennial weeds which make the early part of their growth in the late summer or fall. If, because of dry weather, fall cultivation does not prove effective in starting the weed seeds to grow, it will in any case induce early spring germination and enable one to kill the young plants by subsequent cultivation. This is of great importance on land that is to be fallowed. Apart from destroying the weeds themselves, anything that can be done to insure a uniform and vigorous stand of grain in the spring will be of great value in crowding out weeds in the stubble crop.

The perennial plants, among which the native quack, sweet grass and prairie rose are the most common, are serious pests in many stubble fields. They spread not only

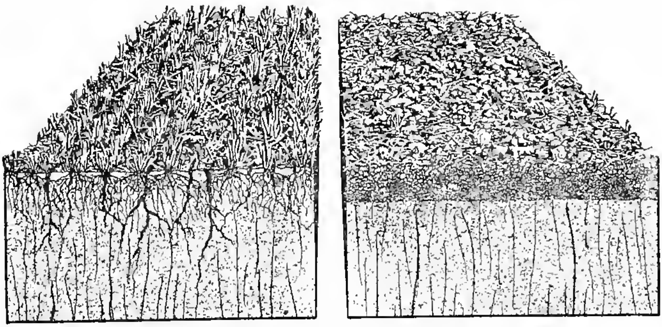

Fig. 60.—Effect of Disking Stubble Land.
Diagram showing on the left uncultivated stubble, and on the right double disked stubble. Note the absence of cracks in the subsoil of the cultivated land.

by seeds but by underground creeping stems. These weeds cannot be controlled by burning or disking or other surface cultivation. Plowing, preferably in the dry season, when the roots can be exposed to the hot sun and drying wind, is the only remedy for those legacies of poor breaking. Other plants of a similar nature are brome grass, Canada thistle and sow thistle.

122. Securing a Good Seed Bed.—A good seed bed is one that provides the conditions necessary for germination—heat, air and moisture—in optimum amount, at the right depth, at the time the seed is sown. Too often the surface of our stubble fields is too hard to get the seed into, or too dry to cause germination, or covered with disked stubble through which the drill cannot satisfactorily force the seed, or the surface soil is in such condition that it does not cover the seed satisfactorily after seeding. The surface soil can be made more mellow by surface cultivation or by plowing; the moisture content can be more or less controlled by the same means; the stubble, if too long, may be either burned or plowed under or left uncultivated and the condition of the surface or seed bed can be improved by *suitable* tillage if necessary.

123. Importance of "Available" Plant Food.—All of the plant food in a soil cannot be drawn upon by the growing crop. Since plants "drink" their food it is clear that only that portion of the fertilizing constituents that becomes soluble or available can be used by them.

The agencies causing the breaking down of plant food constituents in soil are more or less dormant during the dry autumn and long winter with the result that the amount of available plant food in stubble fields is relatively small. By far the most important of these agencies is moisture in the soil. In stubble fields the amount of moisture is very low at best and the supply cannot be materially increased; but any form of tillage that results in getting more moisture into the land or in preventing weeds or evaporation drawing upon what is already there, will tend to increase the total amount of "available" plant food for the use of the stubble crop.

124. The Stubble—A Nuisance, Yet Important.—The stubble of cereal crops is made up of elements derived by the plant from soil and air. If the stubble is burned the most valuable fertilizing element secured from the soil, viz., nitrogen, passes off into the air. The burning of stubble also dissipates "organic matter," the constituent that helps to keep soils from blowing, the one that increases the water-holding capacity of the soil and at the same time makes it easier to work. The amount of this constituent in decayed form in a soil is the greatest single index to its "fertility".

But the stubble lessens the efficiency of tillage and seeding operations, and long stubble if plowed under may seriously interfere with the upward movement of soil moisture from the subsoil and with the downward penetration of the roots, thus lessening the yield. Except on drifting soils or on heavy, tight clay, stubble is

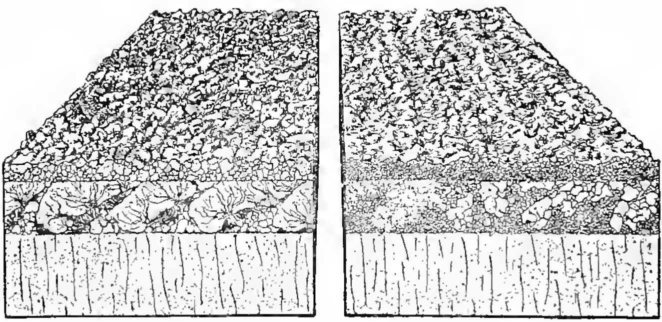

Fig. 61.—Effect of Disking Before Plowing.

Diagram showing on the left, land plowed and then harrowed; on the right, land disked, then plowed and then harrowed. Note the air spaces in the former which result in the drying out of the furrow slice, unless the land is firmly packed.

a nuisance until it decays. It decays rapidly in humid but very slowly in dry climates. In the West we need to maintain the organic matter content of our soil, but we hesitate to fill it with too much undecayed stubble, except in the fallow year.

125. Subsoil Moisture Must be kept Available to Plant Roots.—Moisture and "plant food" are both necessary for crop growth. The former is often found in relatively large quantities in the subsoil, from which area it may rise to the plant roots by "capillarity". But frequently in our tillage operations we create a condition where the subsoil moisture does not rise fast enough to meet the needs of the crop above, in which case lower yields result. Such a condition is produced when the furrow slice of plowed land is not pressed firmly against the subsoil. Moisture will not rise satisfactorily through a layer of lumpy or loose soil, or worse still, through an air space. The chief reason why more fall and spring plowing is not practised in the dry parts of Western Canada is because plowed land has too often been left in a loose condition with stubble and air spaces under the furrow slice, thus largely cutting off the supply of subsoil moisture, with the inevitable result of decreased yields.

126. Some Common Methods of Preparing Stubble Land for a Crop.—Among the methods followed in the different parts of the West for preparing stubble land for a crop are the following: —

1. Seeding on the untilled stubble without previous or subsequent tillage.
2. Seeding as above followed by "floating" or "planking".
3. Disking or cultivating in fall followed by harrowing.
4. Disking or cultivatting in spring followed by harrowing.
5. Burning the stubble in spring and seeding either with or without disking or cultivating.
6. Fall plowing left rough "to hold snow", then harrowed down in spring before seeding.

7. Fall plowing, harrowing, packing and harrowing in fall.
8. Spring plowing and harrowing.
9. Spring plowing, harrowing and packing.
10. Spring plowing, packing and planking.

The usual treatment after seeding is to pack or harrow or both.

127. Results of Some Tillage Experiments at the University of Saskatchewan.—On the investigation field at

Fig. 62.—Typical Scene at a Plowing Match.

the University of Saskatchewan wheat stubble was tilled in from sixteen to fifty different ways during each of five years and the average yields ranged from 11½ to 23½ bushels. In some seasons the range between the lowest and highest yield was 30 bushels per acre.

As a result of carefully observing the climate and soil conditions and of keeping an accurate record of the behavior and yield of the crops in seasons of different character during a period of nine years, we have learned that many unfavorable conditions in stubble fields can be diagnosed and both the yield and net profit increased by suitable tillage. No hard and fast rules can be laid down for other soil and other climatic conditions but a few general principles that are of wide application may be drawn from the work. In the discussion that follows some of these are pointed out.

128. The Necessity for Plowing Grassy Stubble.—The average yield of wheat for five years on untilled grassy stubble was 8 bus. 9 lbs. less than on untilled stubble that was free from grass. There are times when it may not be best to plow clean stubble fields; but there is never a time or condition that makes it advisable to leave grassy stubble unplowed.

In 1914 grassy stubble surface cultivated in the fall, produced 3 bus. 45 lbs. less wheat and 13 bus. 5 lbs. less oats per acre than fall plowed land that was surface cultivated; and spring plowing produced rather more satisfactory results than fall plowing in that year. On another piece of untilled grassy stubble the average yield of wheat in 1914 was 5 bushels per acre. Adjoining land in the same grassy condition was plowed shallow, double disked, packed and harrowed in the fall of 1913 and as a result yielded 13 bus. 30 lbs. in 1914.

It was observed that in all cases where grassy stubble was plowed the yield was increased and the grass was either totally killed or very much lessened. When the same land was left unplowed, in many instances it became overrun with native quack or, in low placess, with sweet grass, and the cost of redeeming it was thus materially increased.

Cereal crops cannot compete successsfully for moisture and plant food with established perennial plants. Neither burning nor surface cultivation will kill the latter, and when they are present in any quantity in stubble fields plowing for the succeeding crop either in fall or spring becomes a necessity.

129. The Desirability of "Working Down" Plowed Land as soon as Possible after Plowing.—The farmer in humid regions wants air in his soil in the fall. In order to prevent the furrow settling down and becoming hard and more or less baked, he leaves the fall-plowed land loose and untilled. Dry farm soils, however, usually do not suffer for want of air. The dry land farmer is more concerned about saving moisture than about getting more

Fig. 63.—Tractor Plowing on Stubble Land.

air into the land. The dry parts of Western Canada do not enjoy a humid climate, and unharrowed or unpacked fall or spring plowing instead of settling down and baking usually dries out.

On a new soil that did not blow the increase in yield from one operation of the heavy harrows or two of the light lever harrows the same day the plowing was done, was 1 bus. 57 lbs. in the average of a large number of tests over a period of several years. It is evident that on soils that blow as well as on those that run together and bake readily in the spring similar results would seldom obtain. On normal soils, however, and particularly on spring plowing either harrowing or packing as soon as possible after plowing is a very important and necessary operation.

Various methods are followed to try to prevent the drying out of the plowed furrow. The simplest is harrowing as soon as the plowing is done; another is to harrow at once, then pack and then harrow; a third, to pack with a packer attachment to the plow, then follow with a plank drag or scrubber and then the harrow. On fall plowing that has been well worked down ridging with a cultivator is sometimes practised.

The practical man must, however, keep in mind that while normally the more intelligent tillage that is applied the greater the yield is likely to be, yet a paying increase in yield from the excessive tillage of stubble land in dry areas is not by any means assured, while the extra cost cannot by any chance be evaded. The question is not one of yield alone, but one of net return. There yet remains much work to be done before the most efficient combination of tillage practices and sequence of operations can be definitely stated for all soil types in all climatic zones of the West.

130. The Furrow Slice Should be Placed Firmly Against the Furrow Bottom.—In humid climates the practice of turning the furrow over flat is not considered advisable for the reason that the soil is likely to run together and become too hard. In semi-arid regions, except on a few types of heavy clay, the danger is not in its running together too much but in its not running together enough. In addition to turning the furrow as flat as possible it is important that it be placed firmly in contact with the subsurface soil. This can be done by using a land packer or by thorough surface cultivation, or, if the plowing is done early enough, the rains accomplish the same end and at no cost.

A summary of all our work with the "surface" land packer on fall and spring plowing shows that packing deep plowing increased the yield of wheat 2 bus. and 6 lbs. per acre, and packing shallow plowing, 40 lbs. per acre, while packing unplowed stubble land decreased the yield three years out of four. It was observed that where packing was done the crop was invariably more uniform and earlier. It is generally considered advisable, except on soils inclined to drift, to follow the packer with the harrow, particularly if the packing is done after seeding.

131. Burning Stubble is Permanently Wasteful of Soil Fertility, but Often Immediately Profitable.—The five-year average yield of all stubble land that was surface cultivated in any way was 22 bus. 25 lbs. of wheat, while the average for the same length of time on land that was burned and then surface cultivated was 22 bus. 49 lbs. per acre.

A very much greater increase from burning has been reported from the Qu'Appelle Valley and the Regina Plains, where the soil is heavier, and where the stubble grows longer and holds more snow. It would seem that on heavy, rich soils, where the straw grows tall, burning in the spring after the long stubble has been left to gather snow, is a practice that, for immediate profits on new land, is conducive to good net returns. On the other

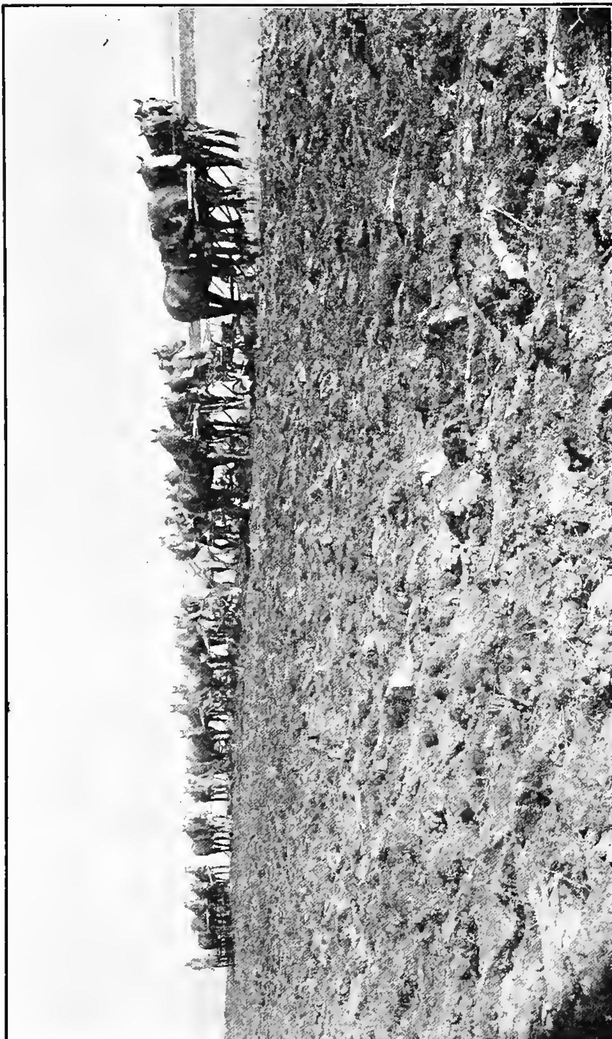

Fig. 64.—Horses Plowing on Stubble Land.

hand, this method does not give opportunity for controlling the spread of annual and biennial weeds. In regions where spring burning has been followed for any length of time these are very abundant.

In some older districts where weeds are prevalent, and where the soil blows so badly that the drift covers stubble fields and renders spring burning impracticable, fall burning and surface cultivation is sometimes practised. A good burn cannot always be obtained in the fall, and in addition this practice is generally more dangerous to property. Fall burning offers better opportunity to kill weeds, but less to hold snow and accumulate moisture.

The chief faults of stubble burning—and they are very serious faults—are the great waste of organic matter and nitrogen and the lack of opportunity spring burning offers for the control of weeds. The figures quoted above and the apparently favorable increase in the results from burning stubble are to a considerabale degree misleading. There are no long time records of the yield on land burned off from year to year as compared with similar land that has not been burned off. All available records of such tests in Western Canada have the fundamental fault that they are not taken from continuously burned versus continually unburned fields, but rather from plots that have been similarly treated until the spring the crop is planted. This is obviously not a fair comparison of the residual effects of stubble versus the ash of stubble.

The experience of the Northern States in burning stubble and of the corn belt States in burning corn stalks is to the effect that while there is apparently a slight immediate advantage in burning, this is more apparent than real, and the subsequent effects are such as to condemn the practice wherever found. The best evidence indicates that the sooner we can find a substitute for burning stubble the better it will be for the land, as well as for the people who occupy the land after us.

132. Surface Cultivation Sometimes Preferable to Plowing.—In the year 1912 on rich friable land that was free from weeds and grass, as large returns were secured in a second crop after a good fallow from sowing wheat on untilled ground, as was secured from the most intensively cultivated field. The practice of plowing for a second crop is not so necessary in a dry climate on soils in good physical condition as those of us who come from a more humid area are likely to suppose. In the absence of grass and in the presence of short stubble, soils of good physical condition often produce as large net returns with cereal crops when thoroughly double disked early in the fall or in the spring immediately before seeding as when fall-plowed. This is particularly true in the drier parts of the prairies on land that is well fallowed every third year. Disking fields that have a long stubble is objectionable since it places the stubbles in a horizontal rather than an upright position and thereby lessens the efficiency of the seeder. Under such conditions the stubble is often, in practice, either burned off or the field left uncultivated. "Stubbling in" either on cultivated or uncultivated stubble is not advisable, except on clean land in a good state of tilth. On old land plowing is generally advisable—fall plowing being preferable in the humid regions and in wet autumns, and spring plowing in the dry regions and following dry autumns.

The average yield of wheat on surface cultivated stubble at Saskatoon on clean land has been 22 bus. 25 lbs.

and on plowed stubble, 23 bus. 16 lbs. On older and more weedy land the increase from plowing is very much greater although on new clean land the second crop after fallowing is sometimes more profitable if left unplowed.

133. Early Fall Preferable to Late Fall Cultivation.—In the 1911 wheat crop early fall plowing increased the yield 1 bus. 36 lbs. over fall plowing done three weeks later. In 1913 the increase due to the earlier work was 1 bus. 12½ lbs., while in 1914 it was 3 bus. 4 lbs. per acre. The increase from early double disking was 1 bus. 10 lbs. per acre. It is often impossible to plow land early after harvest on account of its hard, dry condition. It is sometimes impossible to get time to disc it, but if it is planned to carry out either of these practices the sooner it can be done the better the results are likely to be.

134. Avoid Working Tight Clay Soils when too Wet.—In the spring of 1913 some sticky clay portions of our investigation field were plowed when the soil was too wet, with the result that they "baked", and the yield was cut down to less than half that secured on other lighter soils worked at the same time. Light soils are not likely to be hurt by working them too soon after heavy rains, but medium soils may be, and some heavy soils are invariably injured by this practice. The chief objection to plowing the heavy soil in the Red River Valley in the spring is that it is likely to bake and as a result give a very unsatisfactory germination and early growth.

135. Harrow the Growing Crop only when there is Cause for so Doing.—Weeds growing in a crop decrease the yield. Moisture that evaporates produces no wheat. After a crop is up many weeds may be killed, and evaporation from a too firm soil may be lessened by harrowing. If weeds are present and the surface soil quite firm it is generally advisable to harrow. If weeds are not present and the soil contains sufficient moisture to produce a good crop, harrowing is not advisable except as a preventive measure against weeds in potatoes or corn. Neither is harrowing advisable where there is any tendency of the soil to drift.

Harrowing a growing crop is a practice in which judgment must be used. A thin stand means later maturity. Harrowing invariably pulls out some of the plants, thus leaving a thinner stand. This is particularly true on light, loose soils, or on fields carrying considerable rubbish in the form of stubble. On fields in this condition, harrowing, if done at all, must be practised with care. A light lever harrow with the teeth tilted slightly backwards is often to be preferred for this work.

136. General Observations on Plowing Stubble Land.—The best time to plow, whether in fall or spring, and the best depth to plow, whether deep or shallow, varies considerably under different conditions. It has been pointed out that each of these four practices has in different seasons produced the largest yields. The plowing that proved best generally was that done at the time the soil was in the best condition.

Early shallow fall plowing, well worked down, has given at Saskatoon slightly larger average yields than spring plowing of any depth; but spring plowing has given us larger average yields than late fall plowing. The data at present available do not favor the teaching often advanced that deep fall plowing is always best for the second or third crop after fallow in climates such as ours where dry autumn, winter and spring seasons are the rule. At the same time, when plowing is done in the fall it does not have to be done in the spring. It is well to keep in mind that until spring plowing is finished it is not ready for a crop and may not be ready until it is too late for good results. Fall plowing is quite generally practised in the more humid parts of the West, but in the drier areas it is not considered a desirable practice unless the soil is in good condition at the time of plowing.

Deep fall plowing gave us good returns when the soil was in condition, and when the autumn was moist and the winter snowfall heavy. Very favorable yields were

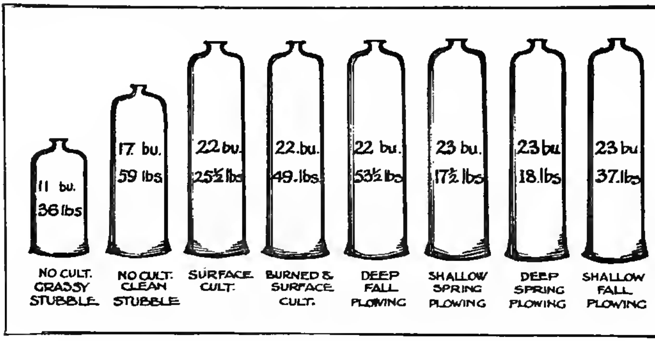

Fig. 65.—Summary of Tests.
Different methods of cultivating stubble land at Saskatoon.

also obtained from deep fall plowing on land that was infested with quack grass and native shrubs, and also where long stubble could not be burned, providing in each case the land was well worked down afterwards; but it gave us poor results when the fall and winter following were dry, as most of our fall and winter seasons are, and very poor results when a heavy stubble was plowed under and the land not worked down after plowing.

Deep fall plowing as a general rule, is likely to produce less favorable yields in our climate than in a humid one, and less in the dry parts of the West than in either the eastern or northern parts. It would also seem from the point of view of weed control that deep fall plowing before weed seeds have germinated should be discouraged.

Spring plowing permits of the stubble holding snow when there is any to hold and gives less opportunity for the plowed soil to dry out. In other respects what has been said of fall plowing applies in a general way to spring plowing. It has been observed, however, that spring plowing for oats gives more favorable results than the same cultivation does with wheat, and invariably it produces more of any cereal than fall plowed land that is left untilled and allowed to dry out. Favorable results from spring plowing for barley have been reported by many different farmers.

It might here be emphasized again that in the drier parts both fall and spring plowing should be firmed and well harrowed down, otherwise very disappointing yields may often result.

137. The Importance of "Net" Returns.—From what has been said it is apparent that fair yields can be produced on stubble fields. Our aim, however, must be to produce "net" profits rather than "gross" returns. A large yield is not always the most profitable. On the other hand a poor yield, even though no cultivation has been given, may not pay the interest and maintenance charges on the necessary investment in land, buildings, machinery, fences and stock.

As long as land is cheap and labor and equipment are high in price intensive methods on stubble land are not likely to prove as profitable as carefully thought out and intelligently practised extensive ones. Nevertheless, if overhead charges against the investment are to be met the conditions that cause poor crops must be controlled. At the present time in Western Canada intelligent, timely and sufficient tillage is the greatest means at our disposal for controlling, not only the factors that limit the yield, but the net revenue as well.

CHAPTER X.

THE SUMMER FALLOW

Summerfallow is the name given to that portion of the farm which is left uncropped for a season and the soil managed in such a way that a surplus supply of moisture may be stored in it. Whatever the future of this practice may be, summerfallowing is at the present time at least the most fundamental practice of dry farming in the northern great plains area. Nor are its advantages limited to the storage and conservation of soil moisture. The fallow may be used to kill weeds and cause the decay of stubble and manure when plowed under; it results in the development of available plant food; and on the pioneer grain farm it is at the present time practically an economic necessity since without the fallow it would be impossible to satisfactorily prepare all the land for a crop in our short autumn and spring seasons.

The summerfallow is at present an established practice in all the drier parts of the Prairie Provinces. The objections to it are many and they will no doubt force a readjustment of our present system but until some modification of it is found to be profitable every grain grower in that portion of the open plains having less than sixteen inches of precipitation should plan to fallow a half, a third or a fourth of his land every year.

138. The Function of the Fallow.—The chief and perhaps most legitimate function of the fallow is the storage and conservation in the soil of a portion of one year's moisture as a partial insurance against failure of the next year's crop as a result of drought. In some places such as the Red River Valley of Manitoba the fallow is

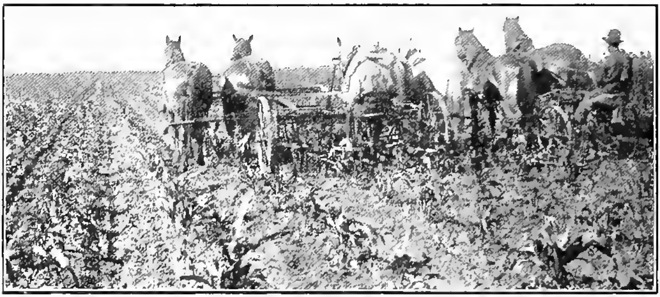

Fig. 66.—Cultivating Corn, Gladstone, Man.
The corn crop is replacing a part of the fallow on some farms.

made to serve the purpose of weed destruction. In others it is used largely because it enables the farmer to make a more economical distribution of the season's activities. Whatever its purpose in the mind of the man planning it, the results of fallowing, when properly carried out, are that (1) the field contains more moisture than otherwise, (2) many weeds have been killed, (3) a large amount of *available* plant food has been accumulated, (4) the decay of rubbish and stubble is accomplished, and (5) the land is ready for seeding whenever spring opens up.

139. The Practices of Fallowing.—The two chief practices of fallowing are (1) plowing in June or early July (later in the most humid parts) so as to make the soil receptive for the heavy rains of the rainy season, (it plows easiest, time and power are available and the land is in the best "condition" at this time), and (2) surface cultivating the land to prevent the loss of moisture through weed and other volunteer growth. Other additional practices sometimes followed consist of disking or skim plowing either in the fall or early in the spring before the usual plowing, and of packing the land some time after the plowing has been done. An occasional farmer now fallows without plowing, using only the disc, cultivator and harrows.

From the point of view of moisture conservation, the essential things about a fallow are (1) to plow reasonably early in the rainy season, (2) to kill weeds as soon as practicable after germination, (3) to surface cultivate enough to prevent the soil cracking.

Where weed control is more important than moisture conservation *early* fall cultivation such as disking, cultivating or skim plowing is desirable to start weed seeds growing. Spring cultivation after the first crop of weeds starts in the spring is equally important, and plowing shortly after the second crop is up is advisable. The subsequent cultivation should be such as will encourage weed seeds to grow and the young plants to be killed as soon as possible after germination.

As to whether a particular practice of fallowing will *pay* depends wholly upon the circumstances under which it is to be used. No code of rules for fallowing are applicable to all soils in all climates. The needs of the specific field must first be known, and then such remedies applied as will best suit the conditions that exist.

Disking in fall before fallowing will start some seeds to germinate if the soil is moist, and make the next plowing easier, but it costs money.

Plowing the fallow early results in the storage of more moisture and encourages weed growth but necessitates added surface cultivation to kill weeds and thus adds to the cost.

Plowing deep takes more time and money than plowing shallow. It kills grass better than shallow plowing and has some other minor advantages, but it does not always give better returns than plowing a medium depth. On deep soils deep plowing in the fallow year is commonly practised but on shallow soils that have a light subsoil it is objectionable in the dry parts because it encourages soil drifting.

Subsoiling is seldom practised. In several tests on normal soils it has not paid its way. It is possible that on some "hard-pan" subsoils it might be worth while, but this has not yet been demonstrated.

Plowing twice is advisable only where grass is prevalent or where weeds have gotten ahead of the surface tillage machines. Skim plowing in the fall followed by the regular plowing in late June and by subsequent cultivation is recommended for the Red River Valley where the control of sow thistle and wild oats is important and for all other areas where quack grass or sweet grass are prevalent in the land to be fallowed. Harrowing immediately behind the plow lessens the loss of moisture by evaporation from the furrow slice, and results in the formation of a better seed bed but it may make the soil too fine and dry and thus encourage drifting.

Packing the fallow is often a desirable practice but it may not be essential except on land (1) that is plowed late, (2) that plows up in rough condition, (3) that grows a late crop, or (4) where firming the soil over the seed is desirable.

Under the last mentioned condition packing is desirable on soils that are (1) too loose to insure rapid germination, (2) too loose to prevent excessive drying around the plant roots in a season of drought, and (3) not firm enough to aid in the rise of moisture from the subsoil. Packing is to be preferred on late plowed fal-

Fig. 67.—Potatoes Under Irrigation North of Brooks, Alberta.
Inter-tilled crops make fallowing unnecessary on irrigated land.

lows and in dry years. It is most objectionable when practised on soils that bake. A fallow that is plowed early may become sufficiently firm as a result of necessary surface tillage to make packing unnecessary.

The surface cultivation of the fallow may be by harrows, discs or cultivators. The more soddy the land is the more the discs will be needed; the more grass there is and the greater the development of annual weeds, particularly on soils that drift, the more desirable the cultivator is, while on land that seldom or never blows the harrows will prove the more efficient implement if used in time. Generally harrowing and either disking or cultivating should alternate each other. As the tendency of the soil to drift increases, harrowing should be practised less frequently, and the cultivator should gradually replace the disc.

As to the condition in which the fallow should be left in the fall the type of soil is the determining factor. A fallow left loose and more or less rough on top, or ridged as after a cultivator will not run together so much and is to be preferred on very heavy clay soils that bake. Those soils that slake down in good condition in the spring may be left in small ridges. These will hold some snow, will facilitate mulch making with the harrows in the spring and, if harrowed at the right time, will result in a better seed bed and no more blowing than the level surface. The chief objection to the smooth surface is that it frequently holds very little if any snow and there is therefore a very small accumulation of moisture from this source.

140. Objections to Fallowing.—But someone says, "I summerfallowed and my crop did not ripen—it got touched with the frost because it was late in maturing", another, "I don't believe in letting one-third of my land worth $40 or $60 an acre lie idle—it isn't good business." Another one says, "The fallow is wasteful of fertility—nitrogen and organic matter—and should be discontinued", another "Will not hay crops or hoed crops accomplish all these things claimed for the fallow?", and another, "I did all these things people advise and in the spring after the seed was sown and just as the crop was coming up, the wind rose and the surface soil, because it was so fine, 'drifted' away and the resulting crop was 'patchy', uneven and unsatisfactory", and another, "I can't get the weed seeds germinated before the early part of June in dry seasons and object to plowing them under because they will live and grow when plowed up again", and yet another, "I summerfallowed and my crop was so heavy and rank that it 'lodged', was poor in qual-

Fig. 68.—Harvesting Mangels in Manitoba.

ity as a consequence and cost me double what it should have to harvest it", and still another, "I plowed my fallow early in June and it kept my teams busy all summer cultivating it to keep down the weeds; I prefer to do it later because the weeds don't grow so much and it takes less horse power and time to keep it back—I reduce the cost of fallowing by doing it later", and another, "The maintenance of a mulch as a means of lessening evaporation does not pay unless there are weeds to be killed at the same time."

141. Defense of Fallowing.—One or more of the objections mentioned may become serious faults of fallowing in some areas and on some soil types in occasional years. The fallow either in an extreme or modified form may, however, be defended in spite of its numerous shortcomings.

If frost cuts down the yield or quality of the crop, the cause of the low yield is not the shortage of water but the shortage of heat, in which case the practices of "northern farming", those that promote early maturity, should be given first consideration, and not the practices of dry farming which are primarily concerned with controlling the moisture supply. Among the methods of northern farming may be mentioned: the use of early classes of grain, early maturing varieties within the class, early seeding, thick seeding, packing the land, less frequent fallowing, later and shallower plowing of the fallow, and the use of frost resistant crops.

If it isn't 'good business' to let the fallow field be 'idle' then it should be cropped. But one should first be sure it is not good business. It frequently does not pay on heavy, moist lands and on some soils that blow, but under present economic conditions it is good business in the warmer sections of the dry parts of the West that are not subject to early fall frosts. When land becomes more expensive and capital, equipment and labor less costly some substitute such as corn or a pasture fallow may be used where it can be grown and utilized satisfactorily. It is possible that in some sections the time for a change has come.

If the fallow dissipates organic matter and nitrogen—and it does to a very serious degree—then we shall have to dissipate organic matter and nitrogen until we find a better way, because we must have water in the soil and the fallow is the best way to get it there. As soon as organic matter and nitrogen and not water commence to limit the yield of crops, we shall have to restore them to the soil. Most men recognize this serious objection to fallowing, but before dispensing with the fallow they want to be shown a better way. It is to be hoped therefore that on all soil types careful tests of organic fertilizers (such as manure) and the use of legume crops (nitrogen gatherers) may be conducted from time to time in order that we may know, for each of the different types of soil, whether the use of any or all of these means of improvement will pay.

If crops require 250 to 1,000 pounds of water per pound of dry matter produced, and if the function of

Fig. 69.—Sheep Pasturing in Rape.

the fallow is to store and conserve water, then neither grass nor even hoed crops will replace the fallow, even though crops be rotated; but both, and particularly the hoed crops, will lessen the frequency of the fallow. The yield of wheat on corn ground at many different points has equalled the yield on fallow. Wherever this is true, and wherever the corn can be grown at no loss, or even at a loss smaller than the cost of the fallow, it will eventually supersede the fallow. In the meantime two factors must be determined for each part of the country, (1) the relative yield on fallow and corn ground, and (2) the relation of loss or gain on the corn to the cost of fallowing. The method that gives the greatest net return should eventually enter into general farm practice.

If drifting soil interferes with the development of the crop, then the drifting soil needs greater attention than the fallow. Excessive harrowing should be lessened or dispensed with altogether and 'organic matter', 'humus', 'root fiber', the substances that were in the land when it did not blow, should be put back. To lessen blowing it may be found advisable to grow a thin cover crop or pasture crop on the fallow, to grow winter rye, or in extreme cases, to seed the land down to hay. But after any or all of these it will still be necessary to practise summerfallowing or a modification of it occasionally on our drier soils.

The plowing under of ungerminated weed seed should never be practised. Every effort should be made to cause the early germination of weed seeds. Early fall disking or shallow plowing will help to do this, but if in very dry seasons the seeds do not start it would be wise to delay plowing the fallow a short time in order to give them opportunity to do so. If on account of the presence of ungerminated seeds the plowing of the fallow be delayed, it should be disked and then plowed at a later time.

If the crop on fallow grows too rank and 'lodges' or too late and suffers from frost, then one should consider whether he should not fallow less frequently or plow shallower or later, or whether the pastured fallow would not be best. The practices recommended are for extremely dry conditions and not for all areas irrespective of climatic conditions.

If weeds grow more luxuriantly on an early fallow and the cost of keeping them down is thereby increased—it is but nature's evidence that such a fallow is achieving

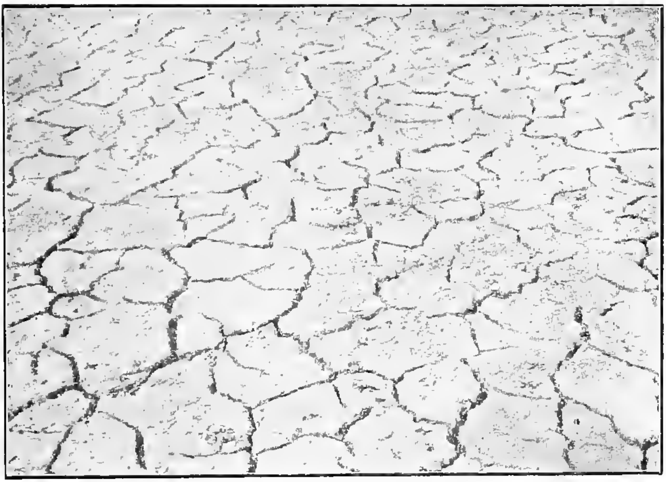

Fig. 70.—Cracks in Heavy Land.
These increase the evaporating surface of the soil.

its legitimate function—the storage and conservation of soil moisture. The cost of the added cultivation is, of course, an extra charge against the fallow. When this is necessarily excessive and particularly on soils that are inclined to blow it is often advisable to delay the plowing. If this is done, however, steps should be taken to prevent an excessive weed growth which wastes moisture, and to keep the soil loose on top and receptive to rains. There is some evidence that if such steps are taken, early plowing is not essential. Under other conditions where the moisture supply limits the yield of crops it has yet to be demonstrated that early fallowing, even at a greater cost, does not pay.

There is but little doubt that under humid conditions soil mulches lessen evaporation. Whether it *pays* under dry conditions to harrow or cultivate in the absence of weeds is another question. Many farmers as well as investigators believe in intensive methods for the conservation of soil moisture, but some recent investigations go to show that if sufficient cultivation is given to prevent weed growth and to prevent the soil from baking or cracking, additional tillage to save moisture by mulching is not likely to conserve enough to *pay* for the extra work.

142. General Conclusions.—In conclusion, then, the dry lands of earlier days are producing crops because men have found out how to get moisture into the land and keep it there at not too great a cost. They "store" it (1) by letting the soil lie idle one year in two or three, or four or five, as necessary, and (2) by putting it, early in the rainy season, in such a condition that it will absorb the rains that fall and not let them "run off" the surface. This is done by plowing, usually in June or early July. The moisture is conserved after it has been "stored" by controlling weed growth, and by lessening "evaporation", the two things which dissipate moisture from the soil. Weed growth is controlled by timely and suitable tillage with harrows, discs and cultivators. If this tillage for weed control does not also control evaporation sufficiently it is questionable whether extra work with this object in view will pay except on soils that bake, or where land has been freshly plowed.

To be most effective a fallow should be surface cultivated the fall before, plowed in June or early July in the drier parts and as late as early August in the Red River Valley; on some soils it should be harrowed immediately after plowing, and surface cultivated as necessary (1) to control weeds, (2) to prevent the soil from baking or cracking, and (3) to have the soil firm to within two or three inches of the surface. In regions where the rainfall is greater and where fall frosts are likely to do damage, such extreme practices as result in later maturity of seed crops should be modified in order to meet the more humid and colder conditions found. On soils that drift the surface tillage must be such as will conserve moisture and kill weeds without making the surface too fine and dusty. On heavy soils where the crop frequently lodges later plowing of the fallow or the use of a pasture crop on it is desirable. On fields containing much quack or other creeping-rooted grasses twice plowing may be desirable—once shallow in the fall and then deeper the next season, or once early in June and again later in the summer.

The frequency of the fallow may be lessened by the use of intertilled crops, the practice of suitable rotations, the maintenance of the humus content of soils and by a more intensive agriculture, but these are not likely to replace it or a modification of it in the drier parts of the prairies until land is more expensive and labor, capital and equipment cheaper.

At present the fallow or corn is absolutely essential in southwestern Saskatchewan and southern Alberta; a fallow is to be desired occasionally in all the prairie region west of central Manitoba; but it need be less frequent in the park belt and only very occasionally practised in the wooded areas and in eastern Manitoba. Indeed, on some of the richer soils in the more humid sections it may, under good management, be practically dispensed with.

The fact that the fallow dissipates the two most valuable constituents of fertile soil, viz., organic matter and

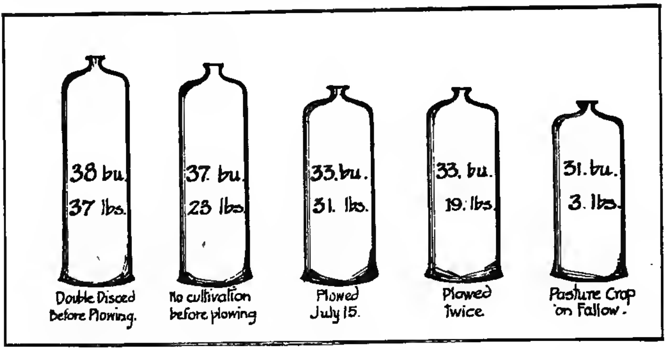

Fig. 71.—Summary of Tillage Tests on Fallow Land at Saskatoon.

nitrogen is a matter of serious concern. It means that subsequently these will have to be maintained in the soil by the return of manure or fertilizers or by plowing under legume crops.

There is little doubt but that as time goes on modifications of the present system will be found that will suit many conditions in the Canadian West better than the present general practice. Sorghums are more or less completely replacing the fallow in the drier States and corn in the northern States. Even in parts of Manitoba corn is now being used as a substitute for the fallow, and on some soils in the very dry parts of Alberta and Saskatchewan this crop offers considerable promise for the future. The use of such a hoed crop carries with it most of the advantages of a fallow since it makes possible the storing of moisture, the killing of weeds, and the developing of available plant food. Other practices that offer some promise as partial substitutes for the fallow are (1) sunflowers planted in wide rows, (2) potatoes and roots, (3) the early breaking of grass land, and (4) the plowing in late summer or early fall of land sown to cereals and cut early for hay or other purpose.

The advantages gained in the better hay and pasture areas by the early "breaking" of grass lands, or by the later summer plowing of land sown to early maturing feed crops make these practices fairly comparable in effect to the fallow at least in the more humid parts; while the introduction and use of intertilled crops, such as corn, where it does well, of grain crops such as Western Rye, Brome and Timothy, and of legume crops like Alfalfa and Sweet Clover, offers some promise of enabling us to develop a system that will have the chief advantages of the fallow without at the same time dissipating organic matter and nitrogen so rapidly.

CHAPTER XI.

CROP ROTATIONS

143. What a Crop Rotation is.—A crop rotation is a more or less regular succession of crops of different kinds on a given field or farm, designed to result in a larger net return or some improvement of the soil.

In the older agricultural areas the crop rotations always make liberal use of leguminous crops. In fact, no rotation is considered rational that does not include them. The ancient Romans appreciated the value of legumes for the effect upon the soil and succeeding crops. Writing in the first century A. D., Columella said, "Where no kind of manure is to be had—the cultivation of lupines (legume plants) will be found the readiest and best substitute." At an earlier date Saserna wrote, "Some of the leguminous plants manure the soil and make it fruitful, whilst other crops exhaust it and make it barren."

144. The World's Best Evidence on Rotations.—The best information the modern world affords of the value of suitable crop rotations is to be found in (a) the results of the long and accurately conducted tests at Rothamsted in England and at different places in America, and (b) the practice of crop rotations in all the old agricultural regions of the world.

Wheat grown continuously at Rothamsted, England, for sixty years has produced an average yield of 14 bus. per acre. On adjoining land in a rotation of turnips, barley, clover and wheat, the wheat produced an average yield during the same time of 25 bus. In the same rotation barley yielded almost 25 bus. per acre while on a continuously cropped plot it yielded only a fraction

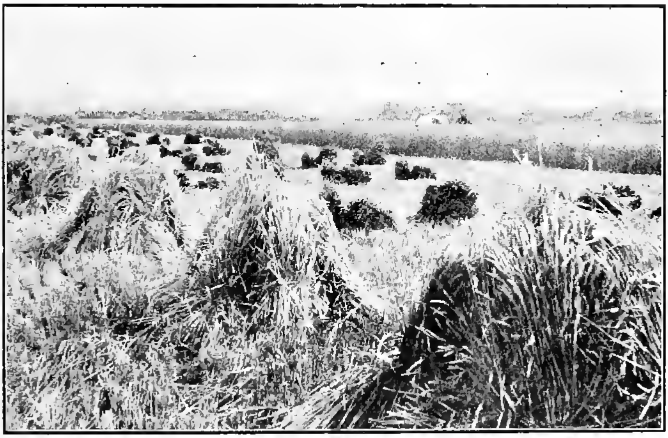

Fig. 72.—Wheat After Alfalfa on Brandon Experimental Farm.

over 14 bus. During the last 20 years of the sixty-year period wheat in the rotation averaged 24 bus. while on the continuously cropped land it averaged only 12 bus. This is probably the best information the world affords on the relative values of a good crop rotation and continuous cropping.

Corn grown continuously at Urbana, Ill., for 29 years produced an average yield of 27 bus. On adjoining land in a rotation of corn and oats it gave an average of 46 bus., while in a rotation of corn, oats and clover the average yield of corn was 58 bus. per acre. This is the oldest experiment of this kind on the continent of America and the evidence it provides as to the value of a suitable crop rotation may well be taken to heart by all students interested in the development of a permanent and profitable agriculture.

The average yield from wheat grown continuously for 13 years on the rich Red River Valley soil of North Dakota at Fargo was 13 bus. 8 lbs. per acre, while the average yield of the same crop in all the different rotations under test for the same length of time and under the same conditions was 19 bus. 8 lbs. This is the nearest to Western Canada of any rotation test that has been conducted for more than a few years. The soil and climatic conditions at Fargo are not very different from those in the Red River Valley of Manitoba. The data secured at Fargo emphasize the fact that even on our relatively new soils continuous cropping for a few years results in a considerable decrease in the productive power of the soil, and the result should not be disregarded by the students of Western Canadian agriculture.

In China and Japan where the land has been cropped longer probably than in any other part of the world a rotation is always practised, and it always includes a legume crop, generally the soy bean. In Italy, where agriculture is very intensive, a crop rotation including legume crops has been practised for many centuries. In England, Germany and France and all of the other agricultural regions of Europe more or less systematic rotations are the rule. In the corn belt of America the one-crop system is fast giving way to a rotation including an intertilled crop, a grain crop and a legume crop (clover and soy beans or cow peas.) In Ontario the continuous growing of hay in some parts and wheat in others has practically disappeared until now a hoed crop, a grain crop, a hay crop and a pasture crop follow one another in the order named on nearly every farm.

The above data are among the best available on the value of succession cropping as compared with the continuous use of one crop on the same land. The brief summary is not fair to the continuous method since in the succession plan the crops other than wheat are not necessarily as valuable as wheat. Yet the relative yields are so vastly different that none will attempt to say the practices that produced the larger ones are not by far the better for the countries where the tests were made.

145. Results of Tests at Saskatoon and Brandon.—The influence of the preceding crop on the yield at Saskatoon was studied during the years 1915, 1916 and 1917 with the following results:—

TABLE XVII.—*Showing results of three years' tests at Saskatoon of the influence of preceding crop on the yield.*

		Av. yield wheat	Av. yield oats	Av. yield barley	Av. yield rye	Av. yield flax	Av. yield peas
		bus. lbs.	bus. lbs.	bus. lbs.	bus. lbs.	bus. lbs.	bus. lbs.
After	Wheat...	20—51	64—24	35—47	22—14	15—31	17—11
"	Flax	23—22	62—18	38—31	24—06	14—09	20—33
"	Peas ...	28—30	68—21	41—12	24—18	17—36	20—17
"	Turnips and Potatoes*	29—40	66—05	40—36	24—16	16—04	17—46
"	Corn	35—57	71—23	46—38	26—35	19—42	22—14
"	Fallow ..	33—02	77—07	39—33	27—42	14—55†	23—35

The test has been under way only three years and the data are not therefore conclusive. Nevertheless it

* In the early years of the project half of this plot was planted to turnips and swedes and half to potatoes. In 1917 and 1918 one plot was provided and the yield of all crops was very much higher on the potato ground than on the turnip ground.

† Flax did not mature satisfactorily on fallow in 1915 hence the low average yield.

emphasizes the value of intertilled crops such as corn and potatoes, and such leguminous crops as peas. The effect of perennial legume and grass crops was studied only in the year 1917 when the yield of every crop was greater after these than after any annual crop or on fallow. In this test the alfalfa land yielded slightly more than the grass land.

The following yields are reported from trials made with wheat at the Brandon Experimental Farm in 1915:—After alfalfa 61 bus. 10 lbs.; after red clover 58 bus. 30 lbs.; after alsike clover 57 bus. 40 lbs.; after western rye grass 49 bus. 40 lbs.; after red top 47 bus. 20 lbs.; after timothy 43 bus. 60 lbs.; after Kentucky blue 38 bus.; after brome grass 29 bus. 20 lbs.

146. Advantages of Suitable Crop Rotations.—(1) A rotation including different crops reduces the risk of a complete failure. In this climate where drought, frost or hail occasionally causes a partial or complete loss of the grain crop a greater diversification of crops is less likely to result in serious loss than where only one class of crops is grown. This is particularly true where forage crops are used and where live stock is kept.

(2) A good rotation aids in fighting weeds. When grain crops only are grown, certain weeds, such as wild oats and mustard, that ripen earlier than the grain, spread rapidly. When hay crops only are grown certain perennial weeds, such as thistles and daisies, have opportunity to spread. If grass and cereals are alternated, and particularly if a fallow or an intertilled crop is added, all of these weeds can be more easily controlled. The use of perennial grasses for hay has in many parts proven a very efficient means of controlling wild oats.

(3) Some crops increase the organic matter of the soil. The roots of grass crops are much more extensive, at least in the surface soil, than those of the grain crops. The grass forms a "sod", the grain crops, a stubble. Brome grass has some disadvantages, but it adds more root fiber to a soil than any of our other crops. Western rye grass and timothy add root fiber also, but much less than brome.

(4) Some crops increase the nitrogen as well as the organic matter of the soil. Legume crops such as alfalfa, sweet clover, red clover and peas, if inoculated, may leave the soil richer in nitrogen than before they were grown. Crops with large fleshy roots like alfalfa and sweet clover also add much organic matter to the soil. If a quarter of the land is occupied by one of these crops, and the stubble and roots plowed under, and if an occasional catch crop of some similar legume is plowed under, it is possible to maintain the nitrogen and organic matter content of the soil.

(5) Changing crops lessens plant diseases. Certain diseases such as flax wilt, potato scab and clover sickness are carried over in the soil. These diseases may cause a partial failure in the crops upon which they prey, but have no effect upon other classes of crops. By practising a rotation all may be grown upon the same farm with little danger from this cause.

(6) Suitable rotations may lessen soil drifting (1) by having the ground covered with a growing crop at the season when drifting occurs or (2) by increasing the cohesive power of the soil. Soil drifting is usually most serious here in May. If the ground is covered with grass or other hay crops, or even winter rye, it will be protected. If the soil is rich in organic matter, as after a

grass crop, the particles will be so held together by the "root fiber" that little or no blowing will take place.

(7) Different plants draw nourishment from different depths of soil. The grasses and cereals are considered to be shallow feeding crops. Alfalfa, sweet clover and turnips are deep feeders. The use of both

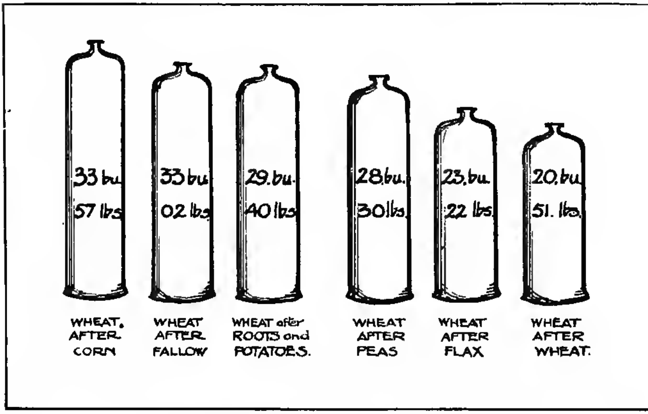

Fig. 73.—Summary of Rotation Tests at Saskatoon.

types of crops increases the feeding ground and makes possible the utilization of the soil to better advantage.

(8) A good crop rotation systematizes the farm work. In a good rotation the fields are approximately the same size,* the amount of each kind of work is about the same each year, and each season of the year; and the labor and power requirements do not vary from season to season and can be more easily and accurately estimated and provided for beforehand.

* On more or less broken land fields of uniform size and good shape may be imposible to arrange. This, of course, is not an essential, although a very desirable condition when practicable.

(9) A well planned rotation may result in a better distribution of labor. At present our labor requirements at harvest time are large and at other seasons of the year small. Until some modification of our present system of cropping is made, this difficulty will increase rather than diminish. The use of more crops might distribute the harvest season from the last week in June to October whereas now the grain crop harvest is practically confined to the six weeks between August 15th and the end of September. If biennial or perennial crops are grown instead of some of the annuals, the acreage to be prepared each year is less, the seed may often be sown with a grain crop, the period of harvesting is prolonged, and the stock may aid in harvesting, thus lessening the labor required. Some provision for winter work must also be made if this problem is not to be a permanent one. What work will ultimately be provided is not clear, but some form of live stock enterprise seems the most promising.

(10) Continuous cropping is reported to result in the development of poisonous substances in the soil. Recent investigations have been interpreted as showing that when one crop is grown continuously on a piece of land, the soil becomes toxic or more or less poisonous to that particular crop. It is offered in explanation that the roots give off substances which are poisonous to the plants. It is stated that these substances are not poisonous to other kinds of crops and that by changing from one crop to another the ill effects are not found.

147. Requirements of Rotations in Western Canada.—Under our present system of farming not only is the risk of partial failure very great but the organic matter of the soil is decreasing, soil drifting is increasing, plant food materials are being dissipated, weeds and insect pests are becoming more prevalent, and on all except the very richest and deepest types of soil the productive power of the land is going down.

These results of continuous cropping are not peculiar to Western Canada. One or more of them have been observed in every old agricultural region where the continuous use of one crop or one class of crop has proceeded for any length of time. Its ill effects may be seen to-day in the hay fields of old Ontario, in the tobacco fields of Virginia, in the cotton region of the South, in the corn belt of the central States and in the wheat areas of the northwestern States. In the early history of each of these regions the one crop that did best was grown to the exclusion of all others because it gave better returns. In the end the evils of the system came to outweigh its advantages and a change to suitable rotations had to come about. In the pioneering stage of development in the prairie and park belt region of the West, grain growing is perhaps a necessary and a profitable practice, even though in some places and in some seasons it is attended by considerable risk. When settlers come with little capital they must first make more capital before they can get the equipment necessary to practise a better system. This capital under present economic conditions must come very largely from selling the stored fertility of our cheap land. To this extent the practice of continuous grain growing is justifiable, but after the capital is available for buildings, fences, a water supply and stock, some provision for establishing a less wasteful system should be made.

148. Difficulties in Establishing Good Rotations in the West.—(1) The chief immediate difficulty is the cost of the necessary fences, buildings and stock. As a rule most pioneers are not capitalists, and until they can make some money they cannot undertake the improvements they would like to make. This, of course, is only a temporary objection, but under some unfavorable soil or climatic conditions might become permanent, in which case state co-operation in the way of cheap loans for necessary permanent improvements might well be considered.

The practice of loaning money to farmers for development purposes for a long period of years at a low rate of interest on the amortization plan has some objectionable features, but as a means of developing and at the same time conserving our soil resources it is one of the most statesmanlike measures that has ever been taken by any of our local legislatures. In this way the state may aid in conserving its own resources, and unless it does this and more, the state rather than the settler must be held responsible for such uneconomic practices as the individual farmer may find himself forced to pursue.

(2) Delayed returns is another difficulty. The grain grower waits only a year for his cash crop. The mixed farmer waits a year for a portion of his crop, then perhaps feeds it to live stock, sometimes waiting two years or more before selling. The delayed returns enforce economy and result in greater savings, but in some cases at least, the savings are too dearly bought. The delayed return is not a serious objection to rotation practice but is a considerable difficulty with the pioneer or the man who is deeply in debt.

(3) The low yield of hay under prairie conditions does not encourage its use. The favorable effect of hay crops on the maintenance of organic matter and the con-

trol of weeds, suggests the need for them in any good rotation. Unfortunately, under dry conditions these crops are often so low in yield that in the drier prairie areas men will not grow them until forced to do so by drifting soil or by weeds.

(4) The lack of a suitable legume is a hindrance to good rotations in many parts. Alfalfas hardy enough to

Fig. 74.—Oats on Irrigated Alfalfa Sod.
—Courtesy Department of Interior.

withstand the prairie winter are now available for all except the higher altitudes. But the crop is so expensive to get under way, and yields so little in dry years and is so difficult to break up that it is not a good rotation crop. Peas do well in the more moist regions but suffer from drought in the dry belt and from fall frosts in the north. Red clover is not hardy enough for commercial use, except in favored areas and in mixtures of grass. Sweet clover seems now to offer the greatest promise as a rotation legume for the prairies. Hardy strains of red clover may be found satisfactory in the park belt, but this has not yet been conclusively demonstrated. Alfalfa promises much under irrigation, and alsike clover also seems to offer some possibilities there.

(5) The lack of an intertilled crop suited to all conditions is another difficulty. The hoed crop of Ontario, the corn belt, and the northern States is corn, that of England is turnips. In the warmer parts of the West on warm soils corn promises much as a forage crop, but in the higher altitudes and northern latitudes, particularly on the heavy soils, its future is not promising. Turnips and other root crops can be grown where corn is unsuited, but the labor cost under present conditions is too high to make a large acreage a commercial success. There is now no doubt but that corn will have a permanent place in the cropping system of the southern parts of Manitoba, Saskatchewan and Alberta, but unless economic conditions change, the acreage of roots will never become large enough to make this type of plant an important factor as a rotation crop. The same is largely true of potatoes. Rape has been grown in cultivated rows for pasture in a very large way by some farmers, but this practice has not developed to any extent. With dense population and cheaper labor these crops, and sunflowers as well, may find a larger place in Western rotations.

149. Classes of Crops used in Rotations.—The crops used in all good rotations may be divided into four classes: (1) cash crops, (2) intertilled crops or hoed crops, (3) legume crops or nitrogen gatherers and (4) grass crops.

The chief cash crops of this country are the grain crops—wheat, oats, barley and rye—and flax, although hay and potatoes are also grown as money crops in some places. The most important intertilled crops are corn, potatoes and roots. The most suitable legume crops are alfalfa, sweet clover (red clover in some areas) and peas, while Western rye grass, brome grass and timothy are the best grasses.

The grain crops lessen plant food and organic matter, return nothing to the soil and permit annual weeds to flourish. The intertilled crops remove plant food and very greatly lessen organic matter but the intertillage they require conserves moisture, develops available plant food and aids in weed control. The legume crops feed heavily upon mineral plant food elements but will maintain or increase the nitrogen supply if grown frequently enough. The grass crops use up plant food but increase the root fiber or organic matter in the soil, and by occupying it for a year or more tend to smother out annual weeds.

150. Planning a Rotation.—The establishing of suitable rotations in all new agricultural countries has been a slow process. So many different factors enter into the problem that the conservative farmer prefers to let some one else do the testing, at least so long as his present methods are profitable. Chief among the factors that must be considered when one is planning a rotation are:—

1. The need that exists for improving one's own soil conditions and controlling weeds.
2. The future requirements of the soil from the fertility standpoint.
3. The particular effect of different classes of crops on the land.
4. The relative suitability of different classes of crops to the climatic and soil conditions that obtain in the district.

5. The economic distribution of labor throughout the year.
6. The extent to which financial considerations make necessary the growing of cash crops.
7. The availability and cost of capital.
8. The extent to which the rotation is likely to lessen the risk of farming and insure commensurate returns for the extra investment required.

151. Some Well Known Rotations.—The most common rotation in England is turnips, grain, clover and grain; the old Norfolk rotation of Rothamsted is turnips, barley, clover and wheat.

The most common rotation of Ontario and the mixed farming districts of the northeastern States is hoed crop, grain, hay and pasture, although many modifications of this are practised. Corn, oats, hay (timothy and red clover) and pasture is the chief rotation of the stock-growing and dairying districts.

In the corn belt of the United States, corn often alternates with oats, but the best rotation from the point of view of soil productiveness is one or two crops of corn followed by oats and then clover.

In the spring wheat regions of the Great Plains Region of America the pioneer rotation is fallow followed by grain for two or three years. In the northwestern States this is generally giving way to corn followed by two or three grain crops. In the Southern Great Plains Region the sorghums are gradually replacing the fallow, while in the Prairie Provinces of Canada no improvement in the original fallow and grain rotation has yet established itself, although several modifications of it are in a fair way to do so in some parts.

152. Rotations now used in the West.—The cropping systems now followed in the Canadian West vary in different parts. The following are some of the most common:—

1. Fallow, wheat, and wheat or oats. This rotation is used in the drier parts of the prairie area. In the extremely dry areas a few men fallow the land every second year.

2. Fallow, wheat, wheat, and oats or barley—used in the more moist parts of the prairies.

3. Fallow, oats, wheat, oats, and barley—used in the higher altitudes or northern areas of prairie or park belt where the frost-free period is somewhat shorter than in the southern part of the prairie belt.

4. Oats and barley for hay, wheat, wheat, oats or barley—used in the more humid short season parts where the fallow crop is often too late to be profitable.

5. Fallow or breaking, wheat, oats, hay, pasture—used to some extent in mixed farming areas where the precipitation is low.

The rotations of the future for the prairie areas must include a grain crop, a legume crop, and a fallow, or where it can be profitably grown, an intertilled crop. In the early years at least they will necessarily include one or more cash crops.

What the cash crops will be, climate and soil conditions will determine. Wheat, oats, barley and rye, in some areas flax, and in some alfalfa, timothy and potatoes may be used. The grass crops will likely be confined to Western rye grass, brome grass and timothy, although some Kentucky blue grass, red top and meadow fescue may be grown. The most profitable legume crops for short rotations are sweet clover and peas, and for long rotations, alfalfa. The most promising intertilled crop in the South is corn. No hoed crop suited to large acreages is available for the North, although a small acreage of roots and sunflowers may very profitably be grown in this area.

153. Rotation Tests at Brandon.—The general conclusions from eight years' work with different crop rotations at the Experimental Farm at Brandon have been summarized by Mr. W. C. McKillican, the Superintendent of the Farm, in a discussion of the rotations known as "E", "F", "G", "H", "I" and "W" as follows:—

"The rotations under test at Brandon are as follows:—

154. "Typical Grain Farming Rotations.—

Rotation "E":—

1st year—Wheat.
2nd year—Wheat.
3rd year—Oats.
4th year—Fallow.

"This is the typical grain farming rotation of Manitoba. No manure is applied at any time. This rotation has the fallow for a cleaning season, has three cash crops, but no fodder crop unless the oats are used in that way, and no leguminous crop. By means of the fallow it conserves moisture and makes plant food more readily available for the crop that follows, and attempts at least to control weeds. It makes no attempt to return anything to the soil, so that gradual depletion and increased tendency to blow are the inevitable results. During the time that prairie soils are giving up their virgin fertility, good results are obtained from this rotation, but it cannot continue indefinitely.

Rotation "D":—

"This rotation has exactly the same order of crops as

"E", but has this difference, that once in four years an application of manure is given. This manure should help to keep the soil from less rapid exhaustion than where there is none applied. However, in the actual results at Brandon the increased returns from the manure have not as yet been sufficiently great to pay for the cost of application. It is expected that greater comparative returns from the manure will be obtained after the cumulative results of longer application are felt.

155. "A Well Balanced Rotation.—

Rotation "F":—

1st year—Wheat.

2nd year—Wheat.

3rd year—Corn.

4th year—Oats or barley (seeded down).

5th year—Hay (clover and grasses).

"This rotation fills the requirements as well as any for Manitoba conditions. Two crops of wheat and one of oats or barley place a good proportion (three-fifths) of the land in grain, which is the cash crop of Manitoba. The year of corn provides a cleaning season and also a large amount of fodder. The year of hay adds to the fodder supply and includes a leguminous crop. The hay land plowed in July and well cultivated makes a very good preparation for wheat. The corn land makes a good preparation for oats or barley and also for the grass seed sown with these crops. The proportion of corn is too large for most Manitoba farms, but this could be reduced in actual practice by having the field partly in corn and partly in summerfallow. Manure is applied before the corn crop in this rotation.

"This rotation has given very good results at Brandon. Not only does it provide for the maintenance of the soil, but it is giving greater returns at present than either rotation "E" or "D". The average profit of this rotation for the five years—1914—1918—was 81 per cent. greater than that obtained from "E" the straight grain growing rotation.

156. "The Most Profitable Rotation at Brandon.*:—

Rotation "G":—

1st year—Wheat.
2nd year—Wheat.
3rd year—Oats or barley.
4th year—Hay (clover and grass).
5th year—Pasture.
6th year—Corn.

"This rotation is somewhat similar in character to the last one. It includes the same kinds of crops, but changes the order somewhat, the wheat coming after the corn instead of after the hay and the coarse grain crop following the wheat instead of coming after the corn. This arrangement makes an excellent and extremely profitable wheat crop, but it gives less suitable conditions for seeding down. It gives better conditions for corn (on sod) than the other where the corn follows the wheat. It has a year of pasture and in that differs from

* Writing of this rotation at the Scott Experimental Farm in Western Saskatchewan, Superintendent Tinline says: "While the profits from the hay are not large, and the pasture barely pays expenses, yet the increased profits from the succeeding grain crops, together with the decreased cost of keeping weeds under control, has made this rotation unusually profitable. The average net profit for the past four years amounted to $7.88 per acre as compared with $5.46 from the grain rotation—fallow, wheat, and wheat."

"F" which makes no provision for pasture. Manure is applied for corn as in "F".

"This rotation has also given good results at Brandon: Its average profit for five years excels that of the straight grain growing rotation by 155 per cent.; it has been the most profitable rotation tried on the farm. However, seeding down with the third crop of grain would not be successful in all parts of Manitoba and that feature might rule it out in some places. The large proportion of corn would also have to be modified in actual farm practice as in the preceding rotation.

157. "Rotations without Corn.—

Rotation "H":—

1st year—Wheat.
2nd year—Wheat.
3rd year—Fallow.
4th year—Oats.
5th year—Hay (clover and grass).
6th year—Pasture; and—

Rotation "I":—

1st year—Flax.
2nd year—Oats.
3rd year—Fallow.
4th year—Wheat.
5th year—Hay (clover and grass).
6th year—Pasture.

"These two rotations are very similar in type, the only difference being a change from wheat to flax as the first crop and the interchanging of the wheat and oat crops. They differ from "F" and "G", in that they do not include corn, but keep to the summerfallow as the means of cleaning the land. They include fodder and leguminous crops and are therefore more permanent in their character than rotations "E" and "D". Manure is applied on the pasture and plowed in.

"These rotations have been more profitable than "E" and "D", but not so profitable as "F" and "G". On the other hand, the absence of corn makes the labor problem more easily handled than where corn is largely grown. Taking "E" as the standard again, rotation "H" has beaten its profits on a five-year average by 49 per cent., and rotation "I" has done a little better.

158. "A Rotation for a Dairy or Stock Farm.—

Rotation "W":—

1st year—Wheat.
2nd year—Wheat.
3rd year—Corn.
4th year—Oats.
5th year—Barley.
6th year—Alfalfa (sown alone).
7th year—Alfalfa.
8th year—Alfalfa.
9th year—Alfalfa.
10th year—Alfalfa plowed up after first cutting.

"This rotation is not intended for the ordinary mixed farm but for a dairy or pure-bred stock farm where the production of a large amount of high class fodder is more important than wheat. It includes all the requirements of a permanent rotation and should build up the fertility of the land more than any of the others. Manure is applied twice in the circuit, for corn, and as a top dressing on alfalfa.

"Being so long, it has not got a proper start as compared to the other rotations. Its profit per acre for the same five years exceed "E" by 145 per cent., being second only to rotation "G" in profitableness. The indications are that it will soon take the lead."

159. Observations on Rotation Tests at Brandon.—"From observing the results obtained from these rotations and from farming conditions in Manitoba generally for a number of years, the following conclusions among others have been reached:—

1. A good mixed farming rotation not only provides for the future condition of the soil, but it gives a larger per cent. profit than straight grain growing.

2. Corn is an exceedingly valuable rotation crop, not only for its fodder value, but because the grain crops following it are the most profitable on the farm.

3. It is impossible to control soil blowing and wild oats by a straight grain and fallow system, no matter how well you cultivate. Grasses control both satisfactorily.

4. The longer the start of mixed farming is postponed the more difficult it is to start.

5. The most profitable way to use grasses is in a short rotation. Left in sod too long they become unproductive and hard to break up.

6. There is no best rotation for all farms. Each individual case must be studied by itself and a rotation devised that will suit the kind of soil, the degree of weed infestation, the rainfall that may be expected, the convenience to market of the farm, and the plans, opportunities and limitations of the man who supplies the brains."

160. Mixed Farming Rotations at Lacombe.—The mixed farming rotations being compared at the Lacombe Experimental Farm in central Alberta have been summarized by the ex-superintendent, Mr. Hutton, as follows:—

"Since corn is a practical crop over a relatively small section of the West where mixed farming is most generally practised, and since the growing of roots on such a scale as would be necessary is prohibitive owing to the high cost of labor and the difficulty of housing, the rotation scheme has at once been set aside by many farmers.

"The fact that within the last half dozen years the growing of oats alone or peas and oats sown together, for use as ensilage, has been successful, puts an entirely different light on this phase of agriculture. While the objection may be raised that the growing of green feed does not clean the land to the same extent as is done where corn or roots are raised, yet the growing of green feed for ensilage does clean the land to some extent, since two or three crops of weeds may be destroyed before the crop for ensilage is sown. It is a thoroughly practical crop and provides ensilage that is at once highly palatable and nutritious. It readily forms a part of any rotation and is more economically produced than roots and much safer than corn since there is no area where its culture can be questioned because of unsuitability to climatic conditions.

"Among the rotations which are at all suitable where mixed farming is practised are the following:—

"Rotation "L":—

1st year—Hay.
2nd year—Pasture. Manure 12 tons per acre.
3rd year—Pasture.
4th year—Wheat.

5th year—Oats.
6th year—Barley, seeded down to timothy, alsike and red clover.

Rotation "K":—

1st year—Hoed crop.
2nd year—Wheat.
3rd year—Barley, seeded down.
4th year—Hay. Manure 12 tons per acre.
5th year—Pasture.
6th year—Pasture.

Rotation "O":—

1st year—Hoed crop.
2nd year—Wheat.
3rd year—Oats.
4th year—Summerfallow.
5th year—Barley, seeded down.
6th year—Hay.
7th year—Pasture.

161. Criticisms of these Rotations.—"The rotation first named, known as Rotation "L", has been modified slightly at the Lacombe Experimental Farm, and is now operated on a block of 240 acres and is known as the 'Main Farm Rotation'. The chief objection to the rotation as it is shown above will be pointed out when considering the modifications that have been introduced.

"In discussing Rotation "K" the objections already raised to the growing of hoed crops on a large scale obtain. Where corn is a doubtful crop, as it is over a very large proportion of the West, particularly those areas adapted to mixed farming, no other hoed crop is practical. No one would think of having a sixth of his farm in roots or hoed crops other than corn.

"The objections to Rotation "O" lie in the fact that it requires one-seventh of the land in hoed crop and also one-seventh in summerfallow. For areas such as this (central Alberta) . . . the summerfallow provides too much free fertility and stores sufficient moisture to produce a tremendous growth of straw, with the result that the crop invariably lodges, does not fill well and ripens irregularly. It is admitted that a better crop than barley could be selected to follow the summerfallow, but no matter what cereal is sown the crop will lodge nine years out of ten.

162. A Rotation with many Advantages— " The rotation modifications as introduced in Rotation "L" are as follows:—

1st year—Hay. Manure 12 tons per acre.
2nd year—Pasture.
3rd year—Pasture. Plow six inches deep July or August, pack, cultivate and fall cultivate thoroughly.
4th year—Oats, or oats and peas, for ensilage.
5th year—Oats.
6th year—Barley, seeded down, timothy and alsike clover.

"At the Lacombe Experimental Farm, as already stated, this rotation covers about 240 acres of land, and from the 40 acre field seeded to green feed we have this year filled one silo 12 x 30, one 16 x 36, and had sufficient crop on the field to have filled a third silo as large as the largest of those in use. The dairy consumption per head for dairy cattle, where the silage constitutes the chief part of the ration, runs only from 40 to 45 pounds. Since from eight to ten tons are taken from each acre the stock-carrying capacity of the land is readily seen to be tremendously increased, as from two to two-and-a-half head of mature animals to the acre can be comfortably carried through the winter.

"This rotation has several distinct advantages, particularly for those areas where well-tilled summerfallows result in too great a growth of straw the following year. The fall cultivation given the summer plowed sod is sufficient to produce a maximum crop without carrying so much fertility and moisture as to cause the crop to lodge seriously.

"The application of farm-yard manure at the rate of 12 tons per acre maintains soil fertility while the plowing under of the sod once in six years adds root fiber to the soil. One advantage in connection with the application of manure on the sod consists in the fact that during the rainy season weed seeds contained in the manure germinate, but fail to develop for the reason that the manure soon dries out and the young plants are destroyed.

"There being but one year of the rotation in hay a maximum crop results; the application of the manure on the sod induces a free growth of grass for pasture, both the year the application is made and the one immediately following. . . . As has already been pointed out, the year following the breaking of the sod there has also been produced a maximum crop every year the rotation has been under way. If good cultivation is given land under this system the fifth and sixth years also produce satisfactory results."

163. Rotations with Sweet Clover.—A few farmers are testing a two-year rotation consisting of wheat seeded to sweet clover, the sweet clover to be pastured in fall and spring and then plowed under in June. They plan to reserve as much sweet clover for hay and pasture as may be necessary. Some combination of crops including sweet clover offers much promise for the whole prairie area. If a strain of this crop, hardy enough to live through our winters after being sown with a nurse crop, can be developed, a very promising rotation for much of the prairie area will be (1) fallow or hoed crop, (2) grain, (3) grain, (seeded with sweet clover or a grass mixture), and (4) sweet clover. Such a rotation might be shortened up to three years if thought advisable by omitting one of the grain crops. (See "Crop Rotations" in "Dry Farming Practices in South Dakota", chapter xvi).

164. An Adjustable Rotation that may be made to meet almost every condition of climate and soil is as follows:—

First Year	Second Year	Third Year	Fourth Year
Fallow or Corn or Annual Pasture or Mixed Cereals and Peas or some of each	Wheat or Winter Rye or Flax or Any Suitable Grain	Wheat Oats Barley or Rye, seeded down to clover or grass or both	Hay or Pasture or Plowed under or Some of each Continue second year if necessary.

165. Crop Rotations for Special Conditions.—A crop rotation planned to control annual weeds should have a grass crop. One to control soil drifting should have a grass crop or a crop such as winter rye or sweet clover that occupies the land when blowing ordinarily occurs. A rotation in dry areas should include either a fallow or an intertilled crop, such as corn, at frequent intervals, while one in a short season in humid regions need have no fallow if mixed grass and legume crops are grown occasionally and the sod plowed immediately after harvesting the hay.

The difficulty in applying these practices to western conditions lies in the delayed returns and relatively low yields from the crops classed as grass, legume or hoed crops. In proportion as each is unprofitable in any community it will, of course, have to be omitted from the rotation, and some other measures taken for meeting the soil conditions the rotation is designed to correct.

166. The Effect of Rotations on Soil Fertility.—It is sometimes stated that a good crop rotation will maintain the fertility of the soil. This is quite erroneous. A good rotation will result in keeping up the productiveness of land much longer than continuous cropping either with or without fallowing, but it will maintain the plant food content of only one element, viz., nitrogen, and this only if legumes are grown frequently enough and a portion of the crop turned under occasionally. It is generally considered that the nitrogen can be maintained without fertilizers if about one-fourth of the land is kept in legume crops and a part of the crop or an occasional catch crop of some other legume plowed under and the crop residues returned to the land. The other important elements of plant food are, of course, used up faster in a rotation than in continuous cropping and eventually they will have to be kept up by using manure or commercial fertilizers or both. The value of a good crop rotation is not in its maintaining the plant food content of the soil (except nitrogen) but in its other beneficial effects. To permanently maintain productiveness without live stock, not only is a good rotation necessary but also the use of commercial fertilizers. In systems of live stock farming when all the crop residues, such as straw and stubble and manure are returned to the land, soil productiveness may be maintained for an indefinitely longer time than in systems of grain growing that do not include legume crops and commercial fertilizers. Yet even live stock farming is not a permanent system, except when butter and nothing else is sold from the farm.

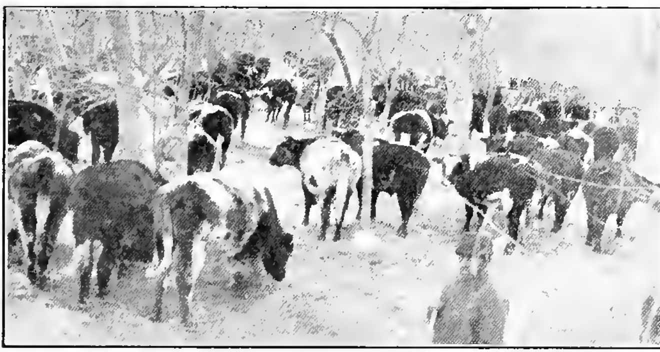

Fig. 75.—Cattle Wintering Outside, Protected only by the Trees.
—Courtesy Man. Dept. of Agr.

Unfortunately the most permanent system is not always the best for immediate results. The farmer naturally and perhaps legitimately considers that system best which gives the most profit at the present time. The problem of the future lies in finding for each soil and climatic zone the system that is at once the most profitable and the most permanent.

167. General Conclusions Regarding Rotations.—No permanent profitable rotations have yet established themselves in this country. It is probable that in addition to the money crops ordinarily grown, the fallow, or a modification of it, will necessarily form a part of the rotations of the immediate future at least in the prairie area outside southern Manitoba; that corn, potatoes, roots or early plowed grass land may become partial substitutes for the fallow or an addition to the rotation in some areas; that alfalfa in the irrigated sections, sweet clover in the prairie area and possibly red clover in some favored humid regions will be the most satisfactory legumes; and that Western rye grass, brome grass and timothy will be the most suitable grasses. What the most profitable cash crops will be—whether wheat, oats, barley, rye, flax, potatoes, alfalfa or timothy depends chiefly upon the moisture and temperature and to some extent the soil and market conditions found in each climatic zone and on each type of soil.

A rotation designed to store moisture should include a fallow or an intertilled crop, or in more moist parts, a hay crop cut early, the land to be plowed immediately; or it may include any two or all three of these.

If the chief purpose of the rotation is to control soil drifting it should include any one or any combination of the following,—a grass crop which protects the land and at the same time adds fiber to it, a cover crop, such as winter rye which only protects the land, or a crop such as sweet clover which protects the land and adds fiber and nitrogen to it.

The length of the rotation or the period between fallows or hoed crops will vary with the rainfall. In dry areas one or other of these means of storing moisture in the soil will necessarily come at least every third year but in the more humid regions it need not be used so frequently. In the latter the fallow may eventually be partially or wholly replaced by hoed crops or the early breaking of grass land.

CHAPTER XII.

WEEDS AND THEIR CONTROL

Weeds are plants which interfere with the growth of crops or lower the profits of farming or mar the appearance of the landscape.

In a sense farming is a continual warfare against these intruders, the contending forces being man and crops on the one side and weeds on the other, with nature a neutral onlooker, but one ever ready to lend her aid to the side showing the greatest persistence. Most of our important farm crops have largely lost the power to compete with weeds. They have been so altered from their original wild state by man that were they left to themselves they would become extinct in a few years. Our cropping methods must therefore be intelligently directed if the fight for the profitable possession of the land is not to be lost.

There is no easy road to weed control. Nevertheless a knowledge of the habits of weeds and the needs of cultivated crops places a man in an enlightened position in the struggle. It remains only for him to create conditions unfavorable to the one and favorable to the other. Intelligent direction is much to be preferred over ill-planned hard work. The chief difficulty is encountered on old farms where the sins of the preceding generation of farmers are being visited on the present occupants of the land. Under these conditions it is generally a difficult problem to control weeds and at the same time make a profit from the farming operations.

168. Why Weeds are Harmful.—

(1) Weeds dissipate soil moisture (approximately 500 lbs. for every lb. of dry matter they produce).

(2) They use plant food that otherwise might go to the production of crops.

(3) They lower the yield of crops by crowding and shading.

(4) They lower the value of grain by causing it to be "docked" or to grade "rejected".

(5) They render seed unfit for sowing or cause extra expense in cleaning for seed purposes.

(6) They increase the cost of tillage, twine, stooking, threshing and freight.

(7) They lower the value of the farm.

(8) Some weeds are poisonous.

169. Some Good Points About Weeds.—Yet weeds are not always harmful nor even useless. The weeds that grow on fallowed land pump tons of moisture from it, but when they are plowed under they add organic matter to the soil. This is seldom a sufficient excuse for weeds in dry areas, even though the backward farmer may find some consolation in the fact. The moisture saved through the prevention of weeds growing on a fallow is generally of more value to the soil than the organic matter the weeds would produce. Nevertheless, the plowing under of weeds increases the ultimate producing power of the land, and on soils that need organic matter the practice is not an unmixed evil. Weeds also, under some conditions, reduce the loss of nitrates from the soil.

On some of our heavy soils in older districts where wheat lodges or ripens late, French weed or stinkweed is frequently very prevalent. No farmer there will say he prefers an infested to a clean farm, but many a wheat grower because of the fact that this weed in a fallow crop results in earlier maturity and in less lodging of the grain, eases his conscience by considering only its advantages. Such men are usually better philosophers than farmers. Yet there are many people who believe that the weed menace is a blessing in disguise compelling as it does considerable tillage to keep it in control. Whether one believes in this strange doctrine or not the bald facts remain that farms do become weedy, and that farmers must control weeds if they are to make a living.

170. Principles of Weed Control.—Weeds spread by means of seeds or by creeping root stalks or by both, but in no other way. Weeds that spread by seeds can be controlled by preventing seed formation. Weeds that spread by creeping root stalks can be controlled by (1) preventing seed formation, and (2) killing the plants already established in the soil. But a man gets weeds from outside his farm as well as from his own land. Hence, if his plans are to be efficient, he must also take steps to prevent the introduction of weeds to his farm from elsewhere.

The principles of weed control may then be stated simply as follows :—

1st. Prevent the weeds from developing seeds.

2nd. Kill the perennial weeds.

3rd. Prevent the introduction of weed seeds.

There are many different ways of putting these principles into practice but in the business of farming the cheapest and most efficient methods are the best.

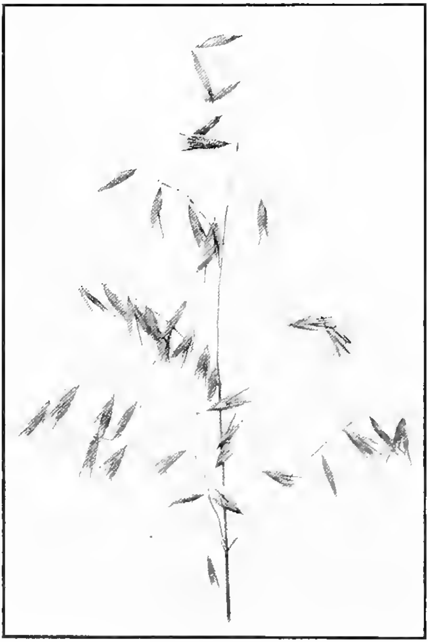

Fig. 76.—Wild Oats.

Under different soil and climatic conditions and with different weeds, different practices have naturally developed. The relative suitability of each method to any given farm or district must be determined by the man on the ground and his judgement will be more reliable if he is informed on (1) the appearence of noxious weeds and their seeds, (2) the habits of growth of the common weeds and how each spreads and (3) the most successful methods of combating each type of weed.

171. Identification of Weeds and Weed Seeds.—Space does not permit of including illustrations or even giving descriptions of the more important weeds and weed seeds of the West. Information concerning the identification of these may, however, be found in one or more of the following bulletins:—

1. *Farm Weeds* — Clark, Dominion Department of Agriculture, Ottawa.
2. *Better Farming* — Bulletin No. 31, Saskatchewan Department of Agriculture, Regina.
3. *Weeds of Alberta*—Alberta Department of Agriculture, Edmonton.
4. *Plants Injurious to Stock*—Bulletin No. 7, Department of Agriculture, Ottawa.
5. *Weeds and Weed Seeds*—Bulletin No. S. 8, Dominion Department of Agriculture, Ottawa.
6. *Weeds Used in Medicine*—Farmers' Bulletin No. 188, U.S.D.A., Washington.
7. *Lessons on Weeds* — Bulletin No. 30, Manitoba Agricultural College, Winnipeg, Man.

172. Duration of the Growth of Weeds.—The duration of growth of different classes of weeds varies considerably, some completing their life cycle in one season, some in two or parts of two, while others live three years or more. Thus we have annual, biennial, winter annual, and perennial weeds, each type requiring a different treatment for its control or eradication. Annuals die at the end of the first season's growth, winter annuals start in the late summer or early fall and die the next year, biennials die at the end of the second year, while perennials may live an indefinite number of years.

Annuals, winter annuals and biennials can be completely controlled by preventing seed formation and the introduction of weed seeds to the farm, but to control perennials not only must seed formation and the introduction of seeds be prevented but the plants already established must be killed. In the second column of the tables in Sec. 174 the classification of our worst weeds according to duration is indicated.

173. Habits of Root Growth and Time of Seeding.—In addition to knowing the "duration of growth" of weeds, it is essential also to know the habit of root growth of each, because on this point depends very largely the nature of the means of eradication.

There are three more or less distinct forms of roots, (1) fibrous roots, (2) tap roots and (3) the so-called "creeping roots" or underground stems. Annual weeds usually have fibrous or tap roots, biennials generally have tap roots while perennial weeds may have fibrous, tap or creeping roots. The following are typical weeds of each of these types:

Fibrous rooted annual...	Wild Oats.
Tap rooted annual......	Lamb's Quarters and Most Mustards.
Tap rooted biennial......	Tansy Mustard and Blue Burr.
Fibrous rooted perennial.	Wild Barley.
Tap rooted perennial....	Curled Dock.
Creeping rooted perennial.	Canada Thistle, Sow Thistle, Quack Grass.

The creeping rooted perennials are the most difficult to kill because of the fact that from each joint of the so-called "root" there may be sent up new plants even after the parent stem has been plowed down.

174. How Weeds Spread.—Nature is the chief agency in the spread of weeds but man is largely responsible for the present condition of our cultivated fields.

Among the influences by which man aids weed distribution are (1) importing weedy foodstuffs including hay, (2) sowing impure seed, (3) neglecting road allowances and railway rights-of-way and freight yards, (4) using weed-infested, undecayed farm yard manure, (5) custom threshing, and (6) by tillage machinery in moving from dirty roads or fields to clean fields.

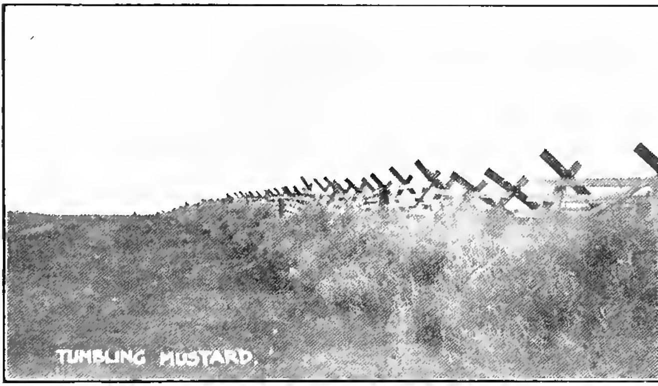

Fig. 77.—Tumbling Mustard Piling Up Against a Fence.

The Russian Thistle, another weed of tumbling habit is a serious menace to farmers in South Western Manitoba, South Western Saskatchewan and Southern Alberta.

The chief natural agencies resulting in the distribution of weeds are the wind, water, animals and birds. The wind scatters (a) fluffy or hairy seeds such as Dandelion, Canada thistle and Sow thistle, (b) winged seeds such as Dock and Parsnip, (c) seeds having extended edges such as Penny Cress, (d) plants that roll like Russian thistle and Tumbling mustard, (e) sticky seeds like Plantain adhering to weeds that blow, and (f) weed seeds in drifting soils. Irrigation water, flood streams, and rapid "run off" water also distribute many seeds. Barbed seeds such as Burdock and Blue Burr, attach themselves to animals and are thus distributed in the same way. In undecayed manure many undigested seeds are spread around and many small seeds are dispersed by dirt on the feet of birds.

The tables on the following pages give the duration of growth, time of ripening, brief note on the flower, and the method of spreading, of each of our common weeds.

COMMON WESTERN WEEDS

Common Name	Duration	Time of flowering	Time of Ripening	Flowers, Etc.	Method of Spreading
Ball mustard	Annual or Winter Annual	June-August	July-September	Small yellow clusters	Seeds
Black Eyed Susan or Cone Flower or Yellow Daisy	Biennial	June-August	August September	Large orange, black centre	Seeds
Bird Rape	Annual	June-July	July-September	Bright yellow	Seeds
Blue Burr or Stick-seed	Annual or Winter Annual	June	July	Very small blue	Seeds
Blue Lettuce	Perennial	June-July	July-August	Pale blue	Seeds and root stocks
Canada Thistle	Perennial	June-August	July-September	Small purple	Seeds and root stocks
Couch, Quack or Twitch Grass	Perennial	June and later	July-September	Dark green leaves	Creeping root stocks and seeds
Cow cockle	Annual	July	August	Rose pink	Seeds
Curled or Sour Dock	Perennial	June	July		Seeds and crowns of old plants
Dandelion	Perennial	July-August	August-frost	Yellow	Seeds
Darnel (common)	Annual	July	August	Grass like head	Seeds
Dodder	Annual	July-November	September-frost	Very small turning plant	Seeds
Evening Primrose. (white)	Perennial	July-August	September	Large white	Seeds and deep running root stock
False Flax	Annual and Winter Annual	June-August	July-September	Small yellow clusters	Seeds
Foxtail (green)	Annual	June-September	July-October	Timothy-like head	Seeds
Great Ragweed or Kingweed	Annual	July	August	Very small yellow	Seeds
Hare's Ear mustard	Annual and Winter Annual	June-July	August-September	Small pale yellow clusters	Seeds
Lamb's Quarters (pig-weed)	Annual	June-frost	August-November		Seeds
Loco Weed	Perennial	June-July	July-September		Seeds

COMMON WESTERN WEEDS—Continued

Common Name	Duration	Time of flowering	Time of Ripening	Flowers, Etc.	Method of Spreading
Night Flowering Catchfly or Sticky Cockle	Annual and Winter Annual	Juns-Fall	July-Fall frost	White	Seeds
Ox Eye or White Daisy	Perennial	June	July	Large whits yellow centres	Seeds and root stocks
Pepper Grass (wild)	Annual and Winter Annual	June-July	July-August	Very small white	Seeds
Pigweed (red root)	Annual	July-September	August-November		Seeds
Pigweed (Russian)	Annual	Juns	July-August		Seeds
Plantain (common)	Perennial	May-August	July-October	Purple	Seeds
Poverty Weed	Perennial	June-August	July-September	Yellow	Seeds and root stocks
Pnrple Cockle	Annual and Winter Annual	July	August	Purple	Seeds
Russian thistle	Annual	July-September	August-November	Purplish	Seeds
Shepherd's Purse	Annual and Winter Annual	All summer	All summer	Small white clusters	Seeds
Sow Thistle (Annual or common)	Annual	July-August	July-September	Both pale yellow	Seeds
Sow Thistle (Perennial Creeping)	Perennial	June-August	July-September	Yellow fairly large	Seeds and root stocks
Stinkweed, Frenchweed or Field Pennycress	Annual or Winter Annual	Throughout the season	July-fall	Small white clusters	Seeds
Sweet Grass	Perennial	April-May	June-July		
Tansy Mustard	Biennial	June-July	July-August	Yellow clusters	Seeds
Tumbling mustard	Annual and Winter Annual	June-July	August-September	Very small yellow clusters	Seeds (plants blowing about)
Wallflower (small)	Biennial or Perennial	June-July	July-August	Yellow	Seeds

Water Hemlock or Spotted Cowbane	Perennial	June-August	August-September	Small white flowers in large clusters	Seeds and crown of roots
Wild barley or Skunk Tail Grass	Perennial	June-August	July-September	Bearded like Barley	Seeds
Wild Buckwheat or Field Bindweed	Annual	June and later	July-September	Small greenish	Seeds
Wild Mustard or Charlock	Annual	June-September	August-October	Small yellow clusters	Seeds
Wild Oats	Annual	June	July		Seeds
Wild Radish or Jointed Charlock	Winter Annual	June-September	August-October	Yellow	Seeds
Wood Whitlow grass	Winter Annual	June	June-July	Very small yellow	Seeds
Wormseed or Treacle Mustard	Annual and Winter Annual	June-Fall	July-frost	Very small yellow clusters	Seeds	

175. How to Prevent Weeds from Developing Seeds.—A knowledge of the appearance of the different weeds, their duration, habits of growth and means of spreading, enables a man to outline intelligently the practices he should employ in controlling them, under the particular soil and climatic conditions that exist where he lives. He will seldom use all of the means available to accomplish the end he desires but only such of the methods as best fit into his system of farming.

Among the chief means that are now followed on western farms for preventing weeds from developing seeds are:

1. Fallowing, to get the seeds in the soil germinated and the seedlings killed,
2. "Duckfooting" the fallow in late fall if biennials are growing on it,
3. Late spring cultivation after weeds have started, and before early maturing crops are sown,
4. Sowing annual hay crops such as oats or beardless barley, to be cut before weed seeds mature.
5. Using early maturing grain crops such as Winter rye and Early Six barley, which ripen before many of the weed seeds,
6. Harrowing growing crops of grain after they are up to kill the small weeds that may be starting,
7. Early fall cultivation of stubble land to encourage germination of seeds, which may then be destroyed by the low temperature of winter,
8. Plowing stubble land in fall or spring if biennial weeds are prevalent,
9. Sowing perennial hay crops which (1) smother many weeds, and (2) are cut before most weed seeds mature,

10. Mowing weeds on roads around fences and in waste places before seeds develop on them.

176. How to Kill Perennial Weeds.—Some of our perennial weeds are the most difficult of all to control, while some are quite easily eradicated. The tap or fibrous rooted perennials can be killed by deep plowing and careful covering of all vegetation, followed by surface cultivation. The creeping-rooted ones are not so easily dealt with. One plowing is seldom sufficient to kill them and frequently several plowings do not succeed in doing so. Three of the common methods employed in controlling the creeping-rooted perennials are as follow:—

Fig. 78.—Blue Burr.
A typical tap-rooted winter annual or biennial.

1. Shallow plowing in the fall and deep plowing the next summer after the weeds have made a fresh start. The first plowing followed by the cold win-

ter gives the plants a set-back and the deep plowing when they have not entirely recovered, gives them another. Surface cultivation as needed may then be given to prevent green leaves forming on any that may remain. This plan, or some modification of it, is generally used for the Perennial Sow Thistle.

2. Deep plowing as soon as the weather turns warm in May, then sowing thickly to a leafy crop like oats or barley. This often gives very satisfactory results with Quack Grass.
3. Mowing and removing the weeds just after blossoming when they are least able to stand a check, then deep plowing followed by deep, thorough and frequent cultivation to keep the land black. This is frequently used for the control of Canada Thistle.

177. How to Prevent the Introduction of Weeds to the Farm.—With the exception of a few native weeds all those now on our farms have grown from seeds that were introduced to it by human or other agencies. The prevention of weeds coming to the farm is the big problem of men on virgin soils, and not an unimportant problem for all other farmers. Among the means of prevention are:

1. Using only clean seed—unclean seed is chiefly responsible for the weed evil.
2. Buying only such feed grain as is free from Wild Oats, Mustard and other weed seeds, and such forage grasses as are free from Canada and Perennial Sow Thistles.
3. Controlling soil drifting. A man cannot, of course, farm his neighbor's land and he cannot keep the

weed seeds from blowing about. Co-operative community effort as well as better farming must be enlisted in the fight against weeds.

4. Cleaning the grain separator before it comes on the farm—the thresherman may resent this practice, but the farmer will suffer if it is not carried out.
5. Preventing stray animals roaming over the land—the dissemination of seeds in the manure of wandering stock is of common occurrence.
6. Preventing the roadside weeds going to seed—this may be the business of the community, but it is sure to be the individual farmer's loss if not looked after.
7. The intelligent enforcement of weed control legislation—laws do not kill weeds but they give power to communities to protect themselves from careless land owners and operators.

178. Means at Man's Disposal for Controlling Weeds.—The chief means at our disposal for controlling weeds already in the soil are tillage, crop rotations, smothering, hand pulling, pasturing and the use of chemicals.

Tillage.—In so far as controlling weeds is a function of fallowing it is accomplished by tilling the latter in such a way as (1) to germinate the weed seeds present, (2) to kill the weeds that grow and (3) if not successful in the latter, to prevent the weeds forming seeds.

The use of hoed or intertilled crops enables one, at some expense, to germinate seeds and to kill many weeds without leaving the land idle.

By plowing in fall or spring every year, biennials can be controlled absolutely and perennials can at least be kept in check. By disking early in the fall, annuals can be lessened but not entirely controlled. By using the duck-foot cultivator small weeds of all types can be killed. By harrowing, young weeds can often be lessened at a very low cost whether they appear in the fallow or growing crop.

Digging by hand is not a popular method of weed control but when Canada or Sow Thistle are first observed in small patches they should be "eradicated" by hand if the area is too small to cultivate satisfactorily with machinery.

Crop Rotations.—If we had good crop rotations we could control our weeds at a small fraction of the present cost. In considering this question four important facts should be kept in mind:

1. Perennial hay crops will control weeds having short-lived seeds, such as Wild Oats, providing the introduction of other Wild Oats seeds is prevented.
2. An occasional fallow encourages germination of weed seeds in the soil and permits killing the young plants shortly after they begin to grow.
3. Intertilled crops will lessen the necessity for fallowing to kill weeds but may not prove profitable on a large acreage under present economic conditions.
4. The use of early maturing crops that may be harvested before weeds ripen enables one to prevent seed development. Among these early crops are (1) grain crops to be cut for forage, (2) Winter rye and, (3) early barley.

Chemical Sprays.—A twenty per cent. solution of Iron Sulphate (100 pounds to 50 gallons of water per acre), applied on bright sunny days to mustard coming into bloom, will prevent much of it developing. Another solution used is a two per cent. solution of Copper Sulphate (10 pounds to 50 gallons of water per acre). These chemicals may be applied with either a hand or power sprayer. Some men claim that Iron Sulphate solution will kill all Mustards, Cow Cockle, Dandelion, Canada Thistle, Bindweed, Plantain, Ragweed and some other weeds; other investigators are much less optimistic regarding the efficacy of chemical sprays. In any case the practice of spraying for weed control is expensive and has not yet therefore come into general use.

Fig. 79.—Dandelion.
A typical tap-rooted perennial. A bad weed in lawns and waste places in Manitoba.

Pasturing.—When pasture is short, sheep aid in controlling Mustard, Plantain, Thistles, Lamb's Quarters, Shepherd's Purse and many other weeds but they seldom touch Stinkweed or Blue Burr.

Smothering.—Leafy crops on spring plowing aid in the control of Quack Grass by smothering. It is a fact also that many young weed plants are prevented from developing by the crowding and shading of a good stand of any crop. This is why we find so many weeds where the drill has missed a strip and so few relatively where no skips in seeding occur. This fact is of great significance and should be appreciated by every grain grower. If we can succeed in giving our crops a good "start", particularly after having given the weeds a "set-back", our problem will have been made much easier; and a good even stand of grain with no skips or misses is important for the same reason.

Tar paper is sometimes used to smother Canada or Sow Thistle when found in small patches.

Hand Pulling.—Hand pulling weeds is expensive and with labor at present prices is impracticable except on small areas such as the seed plot, or as a preventive measure on relatively clean land. Where only a few weeds are present in a field "an ounce of prevention" is worth many pounds of "cure", and roguing a field may be much less expensive than leaving the weeds to multiply and to add to the difficulties of future crop production.

179. The Control of Annual Weeds.—The wild oat is a typical annual weed, and incidentally, one of the worst we have.

The first and most important measure of control is to stop sowing them, a measure that is easy to plan but difficult to put into practice.

The second is to prevent their introduction to the farm in feed, in threshing machines, by wandering stock, etc.

The third is to prevent them from going to seed by (a) double disking or plowing shallow early in the fall so as to encourage germination and subsequent death by freezing, (b) killing as many as possible in the fallow year by disking after the first growth starts in the spring and plowing after the second growth starts, (e) growing a crop that may be harvested before the Wild Oats mature.

The above practices may be followed on any grain farm with no serious alteration of cropping plans and no lessening of the acreage sown. If the weeds are so

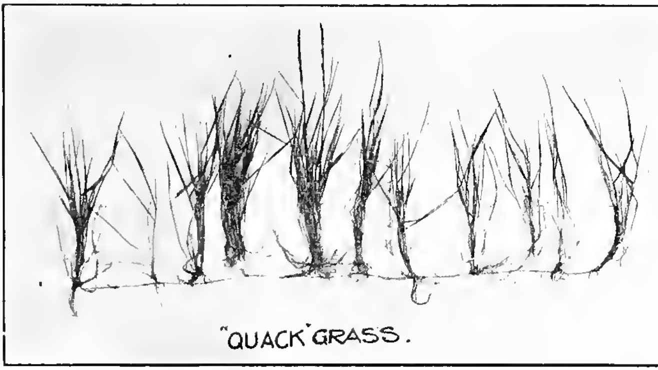

Fig. 80.—Quack Grass.
A creeping-rooted perennial that is difficult to eradicate.

prevalent that these measures are insufficient several others may be followed. Winter rye may be sown on the fallow to smother the oats the following year; or if the stand of rye is thinned out and wild oats grow, the crop may be cut for hay before the oats ripen. Early barley may be sown in the spring after a crop of wild oats has been killed by thorough disking or shallow plowing; and the barley may be cut for hay if the weeds develop, or left for grain if they do not. Early fall cultivation after this crop, providing there is sufficient moisture, will start many of the oats still left in the soil. A corn crop or a potato crop may be used instead of the rye or barley and with better results. If these measures do not result in more or less complete eradication, tame grasses should be sown and left down two years or more, and a year taken to break up the land before the next crop is put in.

The annual mustards and all other plants of similar habit may be controlled by the practices outlined for Wild Oats. Harrowing the growing crop after it is up, a practice that will not kill Wild Oats, is an additional means of killing the smaller seedlings of these annual plants. On account of the long time the hard seeds of many of these weeds may live in the soil, the use of perennial crops has not proven as useful a means of control as in the case of Wild Oats.

180. The Control of Winter Annual and Biennial Weeds. —Most of the so-called winter annuals, of which Tumbling Mustard and Stinkweed are typical examples, may develop as annuals if they happen to get a start early enough in the season. If they start in the spring they may be prevented from seeding by the practices suggested for controlling annual weeds. Those that start in the fall and those of the earlier plants that have not produced seed may be killed by the treatment outlined in the next paragraph for biennials.

Blue Burr and Tansy Mustard are typical biennial weeds. If clean seed is always sown, and if seeds of Tansy Mustard are kept from blowing in, and those of Blue Burr from being carried in by stock or otherwise, these weeds can be controlled by late fall or early spring cultivation of all fields whether fallow or stubble. Fall or spring plowing of stubble fields is to be preferred. Disking will kill the young plants only if the discs are sharp and the soil firm. Thorough cultivation of the fallow late in the fall with a "duckfoot" cultivator will kill most of the winter annual and biennial weeds that have started.

When dealing with either biennials or winter annuals it should be kept in mind, (1) that late fall cultivation

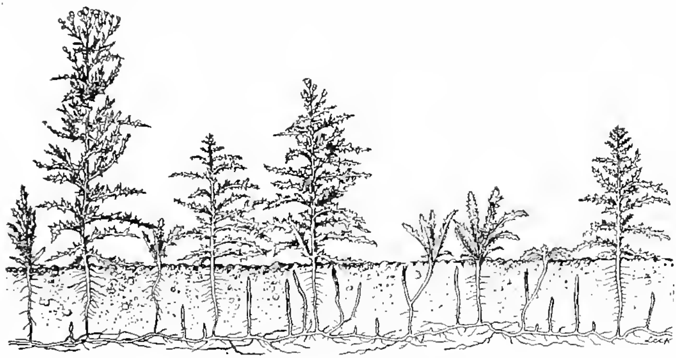

Fig. 81.—Canada Thistle.

A typical "creeping-rooted" perennial. The Sow Thistle which is somewhat similar in habit is more difficult to control in the Red River Valley.

is essential whether early cultivation has been given or not, and (2) that the use of biennial crops like Winter rye and sweet clover which aid in the control of annual weeds, only foster the development and spread of biennial weeds.

In some seasons some biennial weeds will germinate, and like annuals, produce seed in the same year. Fall cultivation will not control these. The usual cultivation given to control other annual weeds will, however, take care of them.

181. The Control of Perennial Weeds.—The native quack grass (Agropyron glaucum), is a typical perennial weed in many parts of the West. It is less difficult to control than the eastern species (*Agropyron repens*). The chief methods of combating it in breaking are:—

1. Plowing all the land and leaving no skips or misses.
2. Plowing shallow early in June and plowing again deep late in the summer.
3. On less "grassy" land in more dry areas, and particularly in dry seasons, deep breaking followed by timely and sufficient surface cultivation *may* kill the native Quack but seldom kills the Sweet grass so frequently found in low moist places.

The chief means of controlling Quack or other creeping rooted grasses in stubble fields, are:—

1. Plowing in the fall—a "dry" time.
2. Plowing in spring and seeding at once to a leafy crop such as oats or barley.

When present in the fallow, Quack grass may be controlled by,—

1. Plowing and digging out the roots with a spring tooth cultivator—always costly and not always an efficient method, but sometimes advisable and necessary.
2. Plowing twice, preferably shallow in the fall and deep in the late June or early July following.

Rose bushes can be controlled in much the same ways but when backsetting, or plowing stubble, or plowing fallow the second time, deeper work is necessary and more deep surface cultivation is desirable.

The Canada Thistle and Perennial Sow thistles in stubble are also very difficult to control. In addition to the practices suggested above for Quack grass, frequent and thorough surface cultivation with cultivators having sharp cutting blades is desirable. After giving the plants as serious a set back as possible by deep plowing, one should endeavor to prevent the appearance of any young thistles above ground. This requires frequent thorough cultivation, but, given favorable weather, will result in the gradual death of the creeping root stocks by starvation, because they cannot be nourished if green leaves are prevented from forming. A "green" fallow may be advisable occasionally throughout the fallow year for controlling wild oats but a "black" fallow is essential for the control of perennial weeds. If a field is infested with wild oats and perennial sow thistle the fallow should be planned to kill the most prevalent weed since the two cannot be satisfactorily eradicated the same year.

182. Poisonous or Otherwise Injurious Weeds.—Poisonous weeds are seldom found growing on cultivated fields. They are usually found in native pastures or low uncultivated areas where tillage is never given. The most commonly found poisonous plants are Water Hemlock, Dwarf Larkspur, Tall Mountain Larkspur, Purple Larkspur, Small Larkspur, Woolly Loco Weed, White Loco Weed, Poison Ivy, Lupines, Death Coma, Night Shade, Corn Cockle and Cow Cockle. The Crocus or Prairie Anemone is not poisonous but sometimes results in the death of sheep by the formation in the stomach of balls of the hairs that grow so profusely on the stems. Spear grass is sometimes injurious to sheep for a time when the "spears" are being shed, and to other animals when fed in hay, by the spears penetrating the flesh.

CHAPTER XIII

IRRIGATION FARMING IN WESTERN CANADA

By W. H. Fairfield,

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The application of water to the land by artificial means for the production of crops is a very ancient practice. Authentic records indicate that irrigation was used in Egypt over five thousand years ago, and in China and India at least as early. Even in North and South America remains of ancient irrigation ditches of great length have been found. "The development of irrigation from the time when man first watered his crop with a bucket, then a doon, next a paddle wheel and finally the gravity system giving water to enormous areas, is one of the wonders and proofs of the advance of civilization."

It is estimated that at present nearly two hundred million acres of land are irrigated, by far the larger part of which is in India, China and Japan, although large projects are found in United States, Egypt, Australia and Canada.

183. History of Irrigation in Western Canada.—In the early nineties, some years after completion of the main line of the Canadian Pacific Railway, preliminary surveys were inaugurated by the Government to determine the feasibility of diverting water from some of the mountain streams for irrigating a portion of the prairie land of southern Alberta. The first project of any magnitude was built by the Canadian North West Irrigation Company, now owned and operated by the Can-

Fig. 82.—Float Levelling Land for the Border System of Irrigation.

adian Pacific Railway Company, in the vicinity of Lethbridge where approximately 130,000 acres of land have been brought "under the ditch". Water was first carried by this ditch in the fall of 1900. Five or six years later the Canadian Pacific Railway Company inaugurated an irrigation project east of Calgary, diverting water from the Bow River, to irrigate, approximately, 880,000 acres in their block of 3,000,000 acres of land extending from west of Strathmore to east of Brooks.

Previous to this time there were a number of small projects taken out by private individuals, the greater number of these being in the southwestern part of Saskatchewan, in the vicinity of the Cypress Hills, where the water is used almost exclusively for the irrigation of hay lands.

184. Methods of Irrigation.—There are various methods of applying water to the crops. The one best suited to a particular locality, or a particular crop, depends upon a number of factors. Among these might be mentioned (1) the nature of the surface of the land, whether it has a steep slope or is fairly level, (2) the character of the soil, and (3) the kind of crop grown, including the value of the crop, the latter determining how much expense might be warranted for the construction of the system. Among the methods used are (1) Wild Flooding, (2) the Furrow System, (3) the Bedding System, (4) the "Check" System, (5) the Border System, and (6) Sub-irrigation.

185. Wild Flooding.—This is the earliest and crudest system known. By it the water is diverted from rapidly flowing streams by plow furrows or small cheaply constructed ditches and so spread over the bottom lands adjacent to the stream, the idea being either to increase the yield of native hay or to insure a crop of small grains. The water is taken out of the ditches at convenient points and allowed to run practically at will until it reaches the lower ground, or possibly goes back into the stream again.

186. The Furrow System.—This is used where the land has a steep slope, and often where the supply of water is limited. It is also employed in the irrigation of garden truck and all crops grown in rows. For the irrigation of grain crops with this system, shallow furrows three or four feet apart are made on the land after the crop is sown but before it comes up. The water is allowed to trickle down these furrows in such small amounts that washing of the soil does not take place and is allowed to run long enough so that the soil between the furrows is thoroughly wet. This method is not used on the prairies in Western Canada with grain or hay.

187. The Bedding System.—This is a method employed on land which has little fall. The banks or dykes are

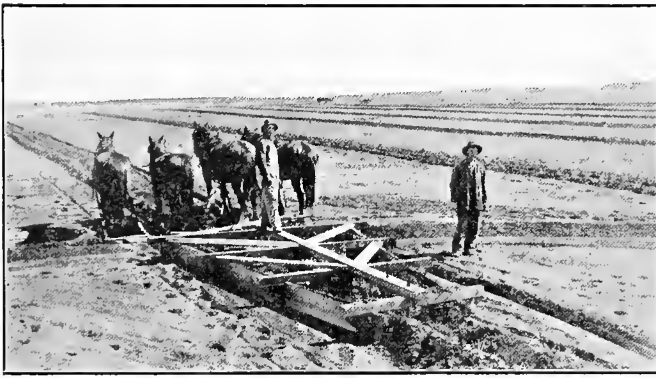

Fig. 83.—Making Borders for Border System of Irrigation.

raised so that the areas enclosed, from a fraction of an acre to an acre or more, are all covered with water. This is then drained into the next bed lower down.

188. The "Check" System is a form of bed irrigation and is used quite extensively on hay lands in the Cypress Hills district. The method followed is to dam the stream by building a dyke across the valley. By this method the water, especially during the spring freshets, is checked and forced back over the creek bottoms. The dykes are placed at different intervals, depending upon the fall of the stream, so that the bottom land may be completely submerged while there is sufficient water in the stream to allow this to be done. Proper sluice gates are, of course, installed in these dykes.

189. The Border System.—This is a modification of the flooding system and is very successful on hay and pasture lands and will doubtless be used to a greater and greater extent on the prairie farms as development goes

Fig. 84.—The "V" Ditcher at Work.
Making contour ditches for irrigating a grain field.

on. The field (before seeding) is laid out in strips, two or three or four rods wide, up and down the slope of the land. Separating these strips, ridges six to eight inches high are thrown up. They are so arranged that where water is turned into one of these strips it will spread out evenly between the ridges and irrigate the whole length of the strip uniformly with less labor than is usually required with the ordinary flooding method. The entire field, ridges and all, are seeded.

190. Sub-Irrigation, or upward irrigation is sometimes used where a very intensive scheme is inaugurated. This is done by the use of tiles laid in the ground just deep enough so that they will not be struck by the plow. These are kept full of water which percolates upwards and sideways from the openings at the ends of the tiles. This is not used on the prairies nor is it apt to be, for, although it has some advantages, the extremely high expense of installation makes it prohibitive.

191. Relative Suitability of Various Crops under Irrigation.—Owing to the fact that our climate is sub-humid or semi-arid rather than arid it is not necessary to irrigate all kinds of crops every season to obtain profitable returns. In this connection the hay crops are an exception since they rarely if ever produce abundantly in the dry parts without irrigation and they always respond favorably to the use of water. There is an old adage that comes from northern Italy where irrigation has been practised for several centuries, which says, "The more water the more hay". This is certainly true in the drier parts of Western Canada with grasses and, with slight modifications, with alfalfa, potatoes and truck crops. Alfalfa is the most promising irrigation crop. Timothy also does exceptionally well "below the ditch." The grain crops are somewhat less suited to irrigation in this climate, but respond well to the timely application of water.

192. Irrigating Timothy and Native Grasses.—The management of these crops is perhaps less difficult than that of any others now grown under irrigation in Western Canada. The profit depends solely upon an adequate supply of water evenly applied to the fields from the time growth starts in the spring, which is early in May, up to the latter part of June. The amount of water that may be applied to grasses is greater than for any other crops that are raised. The land selected for the growing of such hay should be reasonably level and should not have too great a slope. In other words, conditions must be such that water can be easily and often

Fig. 85.—Irrigator at Work.

applied and at not too great expense for labor. It is necessary if the best results are to be obtained that the surface of the soil should never be allowed to dry out. With the grasses a cool, moist condition at the surface is essential for maximum returns. It is also important that the field be given a thorough soaking in the fall so that the grass may grow vigorously in the spring even before the irrigation water is applied.

In the preparation of land for timothy some excellent results have been obtained in certain localities where the native sod has not been broken but the surface disked and the seed sown. The seed usually germinates on the application of water and the young plants grow vigorously if the surface of the soil is kept moist. The resulting hay is a mixture of native grass (principally Blue Joint) and timothy which makes an excellent forage, more nutritious and more palatable to stock than timothy alone.

193. Alfalfa under Irrigation.—Among all crops that are now raised under irrigation in the West none is so well adapted to this type of farming as alfalfa. The preparation of the land for this crop should be the same as when it is raised under dry land conditions except that a greater amount of seed should be used. From fifteen to eighteen pounds of seed is generally recommended. The thicker the stand obtained the greater the yield and the finer and better the quality of the hay will be. In all cases seed grown in Western Canada is to be preferred. In localities where winter killing is common only extremely hardy strains such as Grimm or Baltic shonld be used.

The irrigation of alfalfa is somewhat different from that of the grasses in that the field should be irrigated and thoroughly soaked as rapidly as possible and then the surface allowed to dry so that the soil can warm up. In the Lethbridge district, where the largest acreage of alfalfa in the West is now grown, it is not always necessary to irrigate for the first cutting but it is usually advisable. The common practice is to take two cuttings but three cuttings may be obtained in ordinary seasons by taking the first cutting about the 15th or 20th of June instead of from one to two weeks later. As soon as each crop is removed from the land the field should be immediately irrigated, i.e., there should be an irrigation for each cutting. Fall irrigation for alfalfa has been found as a rule to be a good practice, although in a few places where the land is extremely heavy late fall irrigation is of somewhat doubtful value.

194. Grain Crops.—There has been some contention as to the advisability of irrigating growing grain in certain localities where the season is short, and the grain slow in

Fig. 86.—Irrigating Wheat, Strathmore, Alta.

ripening, on account of danger from frost in the fall. In such localities this difficulty can be overcome by irrigating the land in the fall after the growing season is over. This is a commendable practice under all circumstances. But in dry seasons even when the land has been irrigated the fall previous, the growing crop must be irrigated again if maximum yields are to be obtained. In most districts where irrigation is now practised growing grain can be irrigated quite safely, and certainly advantageously, providing the water is applied before the crop has suffered materially from drought. The secret of raising grain successfully under irrigation is preparedness. The period in which water can be applied to a particular kind of grain to obtain the best results is limited to less than three weeks, consequently a man with a large acreage of grain must have his ditches made, and be prepared to apply the water expeditiously, as soon as the time arrives when he thinks it is wise to apply it. It is better not to put water on a grain crop till the stooling process has been completed, otherwise the application of water might affect the development of the crop at this point. As a rule one irrigation is all that is required, but in extremely dry seasons a second irrigation is necessary, if the best results are to be obtained. The method used is to flood irrigate from laterals put in at from forty to seventy yards apart in the field. These may be run lengthwise of the ridges or "hogbacks", or contour ditches may be put in at right angles to the fall of the land. The latter plan is usually preferable. It is better to have the ditches too close together than too far apart.

195. Potatoes.—It requires more skill and experience to raise potatoes successfully under irrigation than any other crop commonly grown. The secret appears to lie in being able to keep the plants growing vigorously from the beginning with no setbacks, and on the other hand in being able to apply the water so that too sudden growth will not be stimulated at any time. The first irrigation should be very light, and it should not be given until the small potatoes are set and perhaps the size of peas. This stage is usually about the time the first blossoms appear. If the crop is wet before this time there is danger of the plants setting more potatoes than they will be able to develop to a marketable size. To be sure that the potatoes are not wet too much when the first irrigation is given, it is well to run the water between every alternate row only, and turn it off just as soon as it gets through so as not to let the ground soak up any more than is neeessary. As soon as the ground dries sufficiently the land should be given a shallow cultivation.

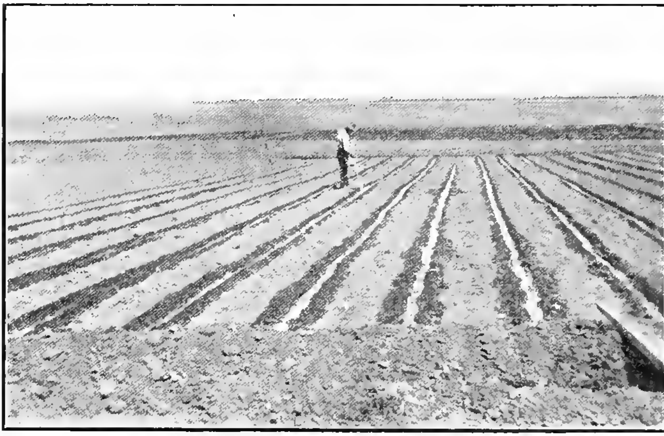

Fig. 87.—Furrow System of Irrigation.

About ten days after the first irrigation, the second should be given. This time the water may be run down between all the rows and should be allowed to remain running until the land is well wetted. After irrigation has once begun, the land should never be allowed to dry up completely. Unless heavy showers intervene, it will be found necessary to irrigate about every ten days in order to maintain a moist condition. After each irrigation as soon as the surface of the soil dries sufficiently it should be given a shallow cultivation. If for any reason after irrigation has once begun the land is permitted to become quite dry the potatoes should not be irrigated again. If they are, a second growth is almost certain to be induced, and this will injure the quality. The main cause of soggy potatoes, when grown under irrigation, is allowing the land to become somewhat dry so that the growth is checked, and then applying water and inducing a fresh growth of roots and tops.

196. Other Crops, Including Trees.—All garden truck, should be furrow irrigated with sufficient cultivation between irrigations to prevent the soil from crusting.

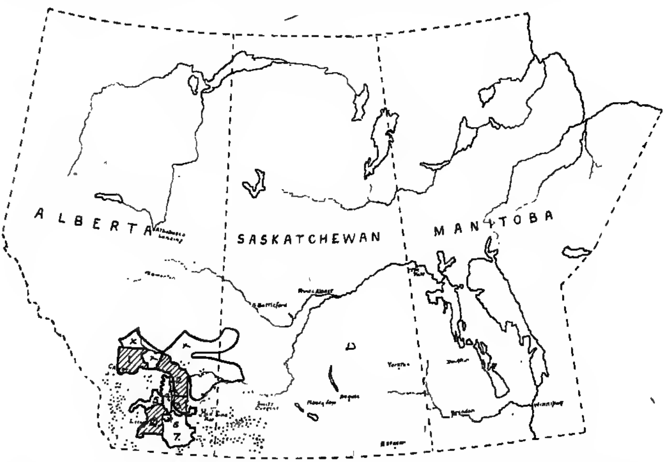

Fig. 88.—Map Showing Location of Irrigation Projects Under Way or Projected.

The dots indicate the number and location of small private irrigation schemes.

Strawberries and small fruits such as currants and raspberries should be irrigated often during fruiting time to keep them growing in a vigorous manner during the time the fruit is forming and ripening. With trees and shrubs generally the water should be applied liberally in the early part of the spring but should cease during the latter part of July and August so that the land may have a chance to dry out and so induce the new succulent growth to harden up properly for the winter. This is an important point and one that is often overlooked. Trees that are ordinarily perfectly hardy are made tender and suffer from winter killing owing to the fact that rapid growth is maintained right up to the time hard frosts may be expected. After the leaves start to drop in the fall it is well to give the trees and shrubs a liberal soaking.

CHAPTER XIV

THE CAUSES AND CONTROL OF LOW YIELDS

197. The Causes of Low Yields.—The major causes of low yields in the West at the present time are climatic—drought, frost and high winds. The many minor causes are the cropping and soil management practices man employs or fails to employ—in the operation of his farm.

In the final analysis all low yields trace back to one or more of six fundamental things:—

1. The purity or quality of the seed.
2. The suitability of the crop or the variety.
3. The supply and availability of the plant food in the soil.
4. The moisture in the soil.
5. The temperature of the soil and air.
6. The amount of air in the soil.

But while this list includes the immediate or fundamental causes of low yields, yet each of these is the direct result of certain other influences or practices to which is generally ascribed the cause of the decreased return. The former may be regarded as the immediate or fundamental causes, the latter as the practical causes of partial or complete failure.

The fundamental cause of low yield in a certain field may be lack of moisture. The practical cause may have been poor fallowing, weeds, warm winds, low precipitation or any of the causes that go to diminish the moisture content of the soil. The fundamental cause of low yield in another field may be insufficient available plant food. The practical cause may have been an infertile soil, unsuitable tillage, continuous cropping with no return of plant food or any of the other causes that decrease or leave undeveloped the plant food in the soil.

In this chapter we shall discuss the *practical* causes of low yields because it is with these the grain grower is most familiar and it is these he usually advances to explain why his crops are not satisfactory. Among these are:—

198. Poor Seed.—Poor seed is seed that will either not germinate or will not grow vigorously, that contains disease or impurities or that belongs to a variety that is not suited to the district where it is to be grown. The vigor of growth and percentage of germination can be determined by making a germination test. Its freedom from impurities including most forms of disease can be told by examining the seed or by its odor, but the presence of some diseases can only be detected in the field before the crop is harvested. The suitability of the variety to a district cannot be foretold by examining the seed. This point can only be determined from the experience of other farmers or from carefully conducted tests.

The seed may be so inferior that it will produce no crop, it may be so good that it will result in maximum returns or it may occupy any intermediate stage of perfection. No intelligent farmer takes chances on his seed being the cause of decreased yield. This is one of the factors of production that lies wholly within the power of the farmer to control.

199. Too Early or Too Late Seeding.—The best time to

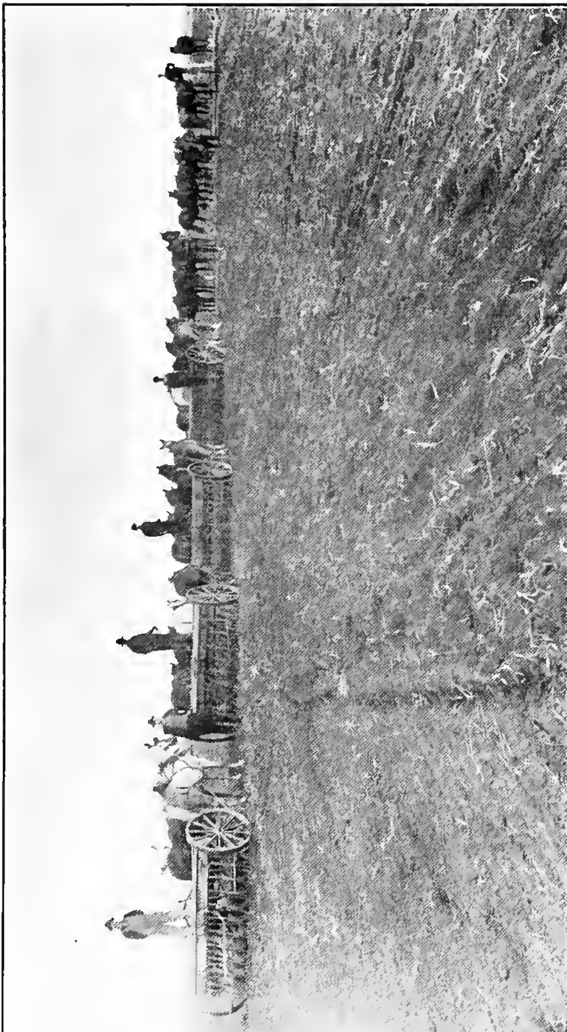

Fig. 89.—Seeding and Harrowing on a Large Grain Farm in Manitoba

sow is determined largely by the temperature conditions of spring and fall. When sown too early the seed may rot or the early growth freeze. If sown too late the crop may be injured by frost in the fall. Our grain crops are quite resistant to spring frosts but very susceptible to fall frosts. Corn and potatoes are very susceptible to spring frosts and suffer from the first fall frosts while roots and rape will stand very heavy fall frosts. The perennial grasses and alfalfa withstand both spring and fall frosts of considerable severity. As a rule all spring sown crops should be planted between April 10 and the end of June in the following order:—wheat, rye, peas, oats, barley, flax, roots, potatoes, sunflowers, corn and alfalfa. If no nurse crop is used grasses and clovers should be sown in June, otherwise they may be put in with spring sown nurse crops at an earlier date.

200. Too Much or Too Little Seed per Acre.—The amount of grain to sow per acre is greatly influenced by the moisture and temperature conditions prevailing. A thin stand is desirable in dry areas having a medium to long growing season while a thick stand is preferable in humid regions, particularly where the growing season is short. It is hardly correct to say that thin seeding is always desirable in dry areas and thick seeding in humid areas for the reason that the condition of the soil with respect to moisture and tilth at seeding time largely determines the stand. Thin seeding on a perfect seed bed may give a good stand, while thick seeding on poorly prepared land may result in a thin stand. It should always be our aim to have a good seed bed and then sow thinly in dry areas and on dry soils and proportionately heavier in more moist regions and those having a shorter growing season. A thin stand will withstand drought better than a thick stand but a thick stand will ripen earlier than a thin stand.

201. Unsuitable Varieties.—Varieties of any of our common grain crops that from any cause, such as lateness, low quality, weak straw, or susceptibility to frost or disease, are not well suited to our conditions, result either in low yields or in decreased prices. The standard varieties that are known to be suitable to the different parts of the West are as follows:—

Crop.	Best Varieties at Present.	Promising Varieties.
Wheat	Marquis and Red Fife	Kitchener for yield Red Bobs and Ruby for earliness
Oats	Banner, Victory and Gold Rain	
Barley	Manchurian and O.A.C. No. 21	Hannchen for grain Early Six for earliness
Rye—Winter	N. D. No. 959 and Saskatchewan	
Rye—Spring	Ottawa Select	Prolific
Flax	Premost	
Peas	Arthur	Early White, Alberta Blue and Carleton
Roots—Swedes	Bangholm and others	
Turnips	Green Globe and others	
Mangels	Yellow Intermediate and	
Average Soils	Globe types	
Deep Soil	Long Red and White Sugar	
Shallow Soils	Golden Tankard	
Carrots	Varieties of White Intermediate Type	
Potatoes		
Early	Early Six Weeks, Early Ohio	
Medium	Irish Cobbler, Rochester Rose	

Crop.	Best Varieties at Present.	Promising Varieties.
Potatoes (continued).		
Late	Wee McGregor, Carmen No. 1, Gold Coin and others	
Corn		
Early	Squaw, Patterson, Gehu	Quebec No. 28.
Late	North Dakota White, Longfellow, North Western Dent	
Grasses	Western Rye Grass and Brome Grass; Timothy for more humid parts.	
Clovers		New hardy strains
Sweet Clover	Grimm	New hardy strains
Alfalfa		Baltic and new strains of Grimm

New varieties are appearing from time to time and while the great majority of these are not equal to the claims made for them a few are quite sure to be superior to the old sorts. Nevertheless new settlers and inexperienced Westerners should use only standard varieties. It is of course desirable that the testing of new varieties be encouraged on all different soil types and in all climatic zones of the country for the reason that the Experiment Stations are so few and so far apart that their conclusions regarding the suitability of varieties are not necessarily applicable to all parts. At the same time a large acreage of a new sort should never be sown until it has given positive evidence that it is as good or better than the standard ones used.

202. Shattering.—After a grain or seed crop has started to mature a considerable loss often occurs as a result of shattering due either to winds or to the necessary handling at harvest time. This loss is greater in some classes of crops than in others and in some varieties

Fig. 90.—Manitoba Harvest Scene.
Above, harvesting oats; below, stacking wheat.—Courtesy Man. Dept. of Agr.

than in others. It is greatest in over-ripe crops and least in immature ones. The Durum or Macaroni wheats are our most non-shattering varieties. Marquis shatters less than any of our other commonly-grown sorts. Barley does not shatter seriously, but the heads break off easily after maturing. Rye shatters very easily if let get too ripe. The seed of the grasses and sweet clover when allowed to mature also shatters freely. Early harvesting, careful handling, and the use of non-shattering classes or varieties, are about the only practices that will offset this possible loss.

203. Late Breaking.—The results of experiments at Saskatoon during the last four years indicate that delay in breaking native prairie after the tenth of June decreases the yield of wheat one bushel per acre per week, or what is more important, decreases the profit from $8.44 per acre on June 10th breaking to $3.81 on August breaking and $1.09 on breaking done in the month of September. It is impossible on a farm to do every job at the best time, but when the best time is known a man can so shape his plans that as much as possible of the work can be done when it should be done.

These conclusions are probably applicable only to that portion of the open prairie lying between the 104th and 110th meridians. In proportion as the average rainfall of other areas is greater than that at Saskatoon, the breaking of the prairie land or the grass land may very profitably be delayed. In the most humid parts August breaking or even spring breaking may be cropped with some success.

204. Seeding on Breaking Done the Same Season.—The newcomer naturally desires a crop as soon as possible after taking up land. In the more humid parts a fair crop on the average may be obtained by good breaking done early enough to seed it about the last of May to an early-maturing crop. In the drier parts such a practice will only result in a profit about once in four years, the reason of the low return being the lack of moisture and available plant food in the soil from the previous year. In the more moist parts oats, barley and potatoes are frequently grown on breaking done the same season, but the practice even in these areas is to be encouraged only where the land can be well prepared by being broken not less than four inches deep, packed and disked and harrowed to form a good seed bed.

Where the rainfall is low and the evaporation great sowing a grain crop on spring breaking is not a good practice. It not only is a losing proposition three times out of four, but the land so used is seldom in good condition for a subsequent crop, nor is it likely to give a good yield until it is summerfallowed. In the dry parts flax is the crop generally used at present for sowing on breaking. Potatoes are sometimes grown on such land for home use, but such preparation is inadvisable for a large acreage of this crop. Oats also are occasionally grown on spring breaking for sheaf feed. Corn is seldom used on spring breaking, but unlike the other crops mentioned it will do quite well and at the same time leave the land in far better condition for a subsequent crop than any of the others mentioned.

205. Native Perennial Plants in Stubble Fields.—The long-lived perennial plants commonly found growing in prairie sod are often the chief causes of low yields in stubble fields. Quack grass, sweet grass and rose bushes are three widely spread members of this group. Such perennials are reproduced by creeping roots as well as by seed and can be controlled only by plowing. Plowing in a dry time is more effective than plowing in a wet season. To kill these plants in prairie sod it is often necessary to plow twice, or to "break and backset". To kill them when present in stubble fields either of two methods may be used: (1) fall plow and leave loose over winter, or (2) spring plow and sow thickly at once to a leafy crop like oats or barley. If present in land to be fallowed two plowings are advisable—shallow in fall and deep the following summer or shallow in late spring and deeper in late summer.

206. Plowing When the Soil is Too Wet or Too Dry.—When a soil is plowed when either too wet or too dry its physical condition may be seriously injured. The damage resulting from such a cause can seldom be remedied by tillage and is frequently not repaired by the weathering agencies until it is too late to get a good crop. It is true that many heavy soils when left in this condition "slake down" after rains and after the low temperatures and snows of winter; but some do not, and often the rains and snows of winter are very scarce and fail to accomplish the leavening influence of normal or wet seasons.

This injury is seldom serious on fallowed fields that are too wet or too dry when plowed for the reason that the weathering agencies have time to either partially or wholly repair the injury done by man in his untimely operations. Medium and light types of soil seldom suffer serious physical injury from this cause but heavy loams and clays frequently do. On some of the heavier soils in the drier parts fall plowing that is done when too dry turns up in chunks and dries out and often cannot be worked down well enough to give good results the following year. The "stubbling in" of fields is generally an undesirable practice but its chief justification in the minds of many farmers lies in the fact that there are times and conditions in some of our medium dry areas when land is put out of condition by fall plowing and, as a result, gives disappointing yields.

For economic reasons man must plow when time permits and this may not be the best time. Nevertheless, the condition of the soil at different seasons of the year and in different years should be an important consideration, when planning the season's operations.

207. Plowing Under Heavy Stubble or Coarse Manure.—These substances when plowed under add considerable organic matter to the soil but they do not decay rapidly in a dry climate and may therefore leave the soil so loose that the upward movement of moisture and the downward growth of plant roots is interfered with thus sometimes resulting in a decreased yield of the first crop after the application. This is one of our difficult problems. Continuous grain-growing dissipates organic matter; and coarse organic matter unless well intermixed with the soil and firmly packed down may injure the condition of the soil.

When organic matter is badly needed as on the lighter types of soil and those that drift neither stubble nor manure should ever be burned, but when either is plowed under the land should be worked down to a firm condition. Manure should never be applied thickly for grain crops in the Prairie Provinces. Ten loads per acre on a forty-acre field is much to be preferred over twenty loads per acre on a twenty-acre field.

208. Too Late Plowing of the Fallow.—In tests conducted at Saskatoon the yield of wheat decreased at the

Fig. 91.—Threshing Wheat in Manitoba.

rate of approximately one bushel per acre for each week's delay in plowing the fallow after the tenth of June. It was quite apparent that the longer the fallow was left unplowed after weed growth commenced the less moisture there was conserved and the less available plant food developed.

On very weedy soils it is generally advisable to get the weed seeds germinated before plowing the fallow. This often necessitates a delay in plowing. In such cases the bad effects from delayed plowing will be lessened if the weeds and volunteer plants are kept down by some form of surface cultivation such as disking or cultivating. On soils that drift easily late plowing of the fallow may be advisable. (See "Objections to Fallowing" and "Defense of Fallowing" in Chapter X).

209. Weeds.—Space does not permit of more than a brief reference to this point. The subject is, however, fully discussed in Chapter XII. At this time we shall refer only to the principles of weed control, the first of which is that annual weeds like wild oats and the common mustards can be controlled by preventing them from seeding; the second that biennials can be controlled by plowing the land every year; the third that perennials can be controlled by preventing them from seeding and by killing the established plants by tillage; and the fourth that eradicating weeds is of little practical value if others are introduced to the farm and sown with the seed, or distributed in any other way. Dozens of systems or combinations of practices are used and recommended for weed control. But all control methods trace back to one or more of these fundamental principles.

210. Insects.—Insects do much less damage to our crops here than they do in milder climates. Yet we are by no means free from their visitations. When any species is found to be increasing the methods of control may take any one or more of three forms:—first, the prevention of its reproduction or its spread; second, its destruction by poisoning if it is a "biting" insect; and third, its destruction by chemicals that kill by contact if it belongs to the "sucking" insects. In some cases none of these plans of attack are successful and other means of destruction are necessary. The common insect pests of the West and their control are very ably and plainly discussed by Mr. Criddle in Chapter XIV of "Crop Production in Western Canada", and by other entomologists in bulletins that may be secured free of charge from the Dominion Department of Agriculture at Ottawa or from any of the Provincial Departments.

211. Plant Diseases.—The most common diseases affecting grain crops in Western Canada are smut and rust. Flax wilt and certain fungous, bacterial and physiological diseases of potatoes and other crops also take an annual toll from the farmer's profit. Rust cannot be controlled but its ravages may be lessened by the use of rust resistant varieties as well as by all those cultural practices that result in earlier maturity. The eradication of secondary hosts of the plant such as the barberry and buckthorn lessens the probability of the appearance of the disease. The grain smuts, except the loose smuts of wheat and barley, can be lessened or entirely prevented by the formalin treatment of the seed. The loose smuts referred to can be controlled by the hot water treatment of the seed. The physiological diseases can be largely prevented by the choice of suitable varieties and the use of healthy seed. The bacterial and fungous diseases can be controlled only by the use of disease-free seed on a healthy soil or by chemical or physical treatment to destroy the bacteria or fungi present.

212. Heavy Spring Frosts.—In Western Canada most of the grain crops must be sown before danger of spring frosts is past. The only means of lessening the damage from such late spring frosts as may come are, first, to have seed of strong vitality in order that the young plants may have the greatest possible chance to recover, and secondly to have the soil in the best possible condition in order that the weakened plants may be well supported in their efforts to recover.

Damage may be prevented to some extent by somewhat later seeding and by seeding the hardiest kinds first and the tenderest last. But with grain crops especially it is generally wise to risk the spring frosts rather than to sow late and run the danger of fall frosts. The latter do very great damage occasionally, but spring frosts seldom do serious harm to cereals except when accompanied by a long period of dry weather or by soil drifting. If the tender crown is exposed by blowing the effect of spring frosts may be disastrous.

In order of hardiness in spring the cereals rank as follows:—Rye, wheat, oats and barley. Flax is not less tender than oats or barley, but if frosted, does not recover so well on account of its habit of branching above ground. It is therefore not usually sown until after the cereals. Peas withstand spring frosts quite well but if injured recovery is much slower and less complete than with the grain crops. Corn and potatoes are very tender but potatoes will recover from frosts that kill corn.

213. Hail Storms.—This is one of the factors affecting crops that man has no power to control. The only way in which he can play safe is by insuring his crop. It is seldom that more than two or three per cent. of our crop is damaged by hail. It is true that the average man pays more in premiums than he gets out in awards for hail damage but it is equally true that many uninsured farmers have gone bankrupt because they could not stand the loss of a crop.

The justification for insuring against hail is not in the probability of getting back more than is paid in, but rather of insuring one's self against serious inconvenience or even bankruptcy in case of loss of one or more crops.

214. Hot Winds.—The hot winds that occasionally occur in southern Alberta and southwestern Saskatchewan increase very greatly both the evaporation of moisture from the soil and its transpiration from the leaves of plants. If the velocity of the wind could be economically lessened in any way, such as by using wind breaks, much damage could be prevented. In actual practice the only ways of lessening the amount of injury from this source are to store as much moisture as possible in the soil, to use drought-resistant or drought-avoiding crops and to follow as efficiently as possible the established practices of "dry farming". In the very warm parts of the driest areas the use of early maturing cereals such as winter rye offers much promise as a result of partial avoidance rather than resistance to hot winds.

215. Dry Seasons.—The average precipitation in the West is about sixteen inches which is less than one-half of that received in the corn belt of the United States, or in Ontario, or in many parts of England. The monthly distribution of this precipitation is very favorable; nevertheless the low rainfall causes more low yields than any other factor at the present time. Since we cannot control the climate it remains for us to conserve as much as possible of the limited moisture that falls. Every extra inch of moisture that can be stored and conserved in the soil means on an average a possible increase of two to four bushels of wheat per acre. (See Chapter X).

216. Fall Frosts.—Low temperatures in early fall frequently work serious injury to all grain and other crops in the northern areas and occasionally also in other parts of the West. Our growing season is short and we cannot control the temperature of the atmosphere. We can lessen the damage from frost only by putting into use those practices that result in avoiding frost and by growing crops that take little or no injury from low temperatures. Among these practices are:—(1) packing the land, (2) thick seeding, (3) using early classes of grain such as oats, barley or rye, (4) using early varieties of grain such as Prelude, Ruby or Red Bobs wheat; Sixty-day, Orloff or Daubeney oats; Early Six barley; Long Stem flax; and Early White peas, (5) less frequent fallowing, (6) shallower plowing for the fallow, (7) later plowing of the fallow, (8) pasturing the fallow, (9) early seeding, (10) the use of press drills, (11) growing frost resistant crops such as Western rye grass, brome grass, grain crops for hay and Swede turnips for succulent winter feed, and (12) going into mixed or stock farming. The first ten of these practices aid us in avoiding frost, the last two enable one to farm so that serious injury will not result from this cause.

CHAPTER XV

THE MANAGEMENT OF SPECIAL SOILS

In Western Canada there are a number of soil types which differ from what may be considered normal soils. These generally require some special treatment for best returns. Although most of these soils have not been studied scientifically it has been thought advisable to add a brief discussion of their peculiarities and the methods now followed by farmers in managing Drifting Soils, Alkaline Soils, Loose Top Soils, Burnt Out Soils, Poor Soils and Cold Soils.

DRIFTING SOILS

Soil erosion as a result of wind action is one of the most serious problems facing the farmer on some types of soil in the open plains region of the West. It is the first and most emphatic evidence of either poor soil, unsuitable tillage or soil deterioration. During the past three years it has been responsible for the partial or complete destruction of thousands of acres of crop in many different portions of the plains area.

217. The Damage Caused by Soil Drifting is evidenced not only in injury to the crop that may be on the land but also to the soil itself. The seed may be uncovered or blown out of the ground and the young plants may be killed by having their roots exposed, or by being covered by the drifting particles, or by abrasions resulting from the long continued impingement of the drifting particles against the tender tissues of the plant. The soil itself is injured by the removal of much of the surface or more productive part. Aside from these more or less general effects of soil drifting there are other objectionable features such as the possible serious injury to adjoining crops or fields, the spread of weeds and the interference with traffic as a result of the accumulation of drifting soil in road allowances.

218. The Chief Factors Favoring Soil Drifting are a fine textured soil, low precipitation and frequent high winds in early summer before the land is protected by the growing crop. When to these are added too much or unsuitable surface tillage, and a system of farming which is wasteful of soil humus and returns little or no organic matter to the soil, we have a combination of conditions that is responsible, not only for the large losses from soil drifting that have already occurred, but also for preparing the way for still more serious losses in the future if some radical changes are not made in the methods of tillage and cropping heretofore practised in the affected areas. The greatest damage from this cause is to be observed in southern Alberta, portions of western and southern Saskatchewan and in southwestern Manitoba.

219. The Chief Causes of Soil Drifting are a high wind velocity and the low cohesion or binding force of the exposed soil particles. The wind velocity as well as the frequency of high winds and their general direction is a climatic condition which cannot be controlled; hence man's only recourse is, (1) to increase the cohesion of the soil particles or their ability to hold together and (2) to reduce the exposure of the surface soil by some form of protection.

220. The Means Employed to Prevent Excessive Damage from soil blowing therefore fall into two groups, (1) those that increase the resisting power of the soil, and (2) those that protect the soil surface from the wind. Among the methods used to increase the power of the soil to resist the wind are, (a) increasing the moisture content, (b) increasing the organic matter content, and (c) modifying the structure of the soil. The protection of the soil surface from the wind may be accomplished by: (a) growing a protecting crop, (b) letting the stubble of one crop remain until shortly before the time of seeding the next crop, or, as with corn stubble, through the whole of the next crop season, (c) applying manure or straw to the field, and (d) providing artificial protection such as the growing of windbreaks. We shall take time for a detailed discussion of only the more important of these practices.

221. Increasing the Moisture Content.—When a soil is moist its particles are not as likely to become separated and blow away as when the soil is dry. This fact is of value chiefly to the farmer on irrigated land where water may be applied at will. Under dry land conditions it becomes of value only in so far as one may by keeping the surface soil firm, also keep it moist to within a very short distance of the surface. The chief value of packing, in the control of soil drifting, is to be found in the fact that it aids in bringing moisture from below to the surface soil, thus increasing the resistance of the particles to the wind. On the other hand if there is not a fair supply of moisture in the lower soil, the breaking up and levelling of the coarse surface particles by the packer will tend to encourage soil blowing. For this reason packing is not a desirable practice in the control of soil drifting on all types of soil.

222. Increasing the Organic Matter Content.—This is the chief and probably the most permanent means of lessening the danger of soil drifting. The organic matter content may be increased, (1) by growing perennial or biennial hay crops, (2) by applying farmyard manure, or (3) by plowing under green crops. The choice rests between (a) growing grass crops, which in some parts are not considered profitable, or (b) going into stock or mixed farming and hauling manure to the land, or (c) plowing under green crops, which has never been shown to be profitable under semi-arid conditions, or (d) doing all of these things.

The use of hay crops for the purpose of adding humus or root fibre to the soil results in, (1) improving the soil as a result of their dense root systems, and (2) providing forage for stock from which manure for further improving the soil may be obtained. The low yields of hay from perennial grasses under semi-arid conditions is well known, nevertheless the use of such hay and pasture crops furnishes what is probably the best means of maintaining the organic matter of much of our lighter soils. Brome grass, owing to its very dense root system, is probably the best for this purpose. Sweet clover promises much, not only as a forage crop but also as a soil improver. It has one advantage over brome grass in that it is a legume. It therefore leaves the soil richer in nitrogen than does brome grass, but the latter probably leaves more root fibre.

The chief value of manure is not in its content of plant food; the organic matter which it contains increases the power of the soil to hold moisture and to resist blowing. On drifting soils the only argument against the use of manure when intelligently applied is the cost of applying it. The application of manure as a surface dressing on the more exposed portions that are likely to blow first is a preventive measure that should come into general practice.

The plowing under of weeds in the fallow year, or the early spring growth of sweet clover or of the perennial grasses, is probably the only green manuring it will be found profitable to practise in our dry areas at the present time. The growing of green crops through a whole season in order to have a large growth to plow under to increase the organic matter content of the soil will not likely ever come into general use in the West, for the reason that the organic matter thus added to the soil is secured at the expense of an enormous quantity of soil moisture which is itself generally the limiting factor in crop yields. On soils that are low in organic matter in areas of light rainfall, it is questionable how far this practice may be carried before its waste of soil moisture will result in making the remedy more to be feared than the disease.

223. Modifying the Structure of the Soil.—Soil drifting occurs chiefly on the fine textured soils—the sandy types and the heavy clays that slake down to a fine powdery condition on top. The fallow generally suffers the most, although fall plowed land is not free from erosion and spring plowed land on some soil types occasionally blows. The smaller the soil particles are and the drier they are the greater the probability of their drifting. The problem is therefore one of preventing the soil becoming too fine and too dry on top.

The drying out of the top layer cannot be prevented but the formation of a fine "dust" mulch may be—at least on most soils. The use of the unfortunate term "dust mulch" in so much of the Western Canadian and American agricultural literature, is responsible for at least a portion of the excessive drifting that has occurred in recent years. The "dust" mulch has no place in the agriculture of any dry country where high winds prevail. A rough cloddy surface developed by deep cultivation and preferably left in small ridges by a cultivator is to be preferred.

On drifting soils the cultivator should take the place of the disc and harrows on the fallow field. Harrowing once after the plow, in order to level the surface, is all the harrowing such a fallow needs if the soil is prevented from baking or cracking and the weeds prevented from growing by the use of the cultivator. More care in plowing in order to secure a level surface, and the use of the packer (preferably the sub-surface type packer or a disc run straight) behind the plow, are practices that are making harrowing less necessary and are proving to be more efficacious in lessening soil drifting. A ridged surface such as is left by the cultivator provides a refuge for the fine particles in the bottom of the narrow ridges, and in practice is found to result in less blowing and in the production of greater returns than a smooth surface. Working the soil when it is dry should be discouraged. When it is slightly moist below the surface a more granular or lumpy top can be developed than if tilled when dry. On smooth fields that are free from stones the revolving rod cultivator offers much promise. On the heavy clays of the Regina plains cultivating the fallow in the spring with a narrow tooth cultivator is found to lessen drifting.

The use of the press drill leaves the soil in better condition to withstand the effects of the wind than the use of most other types, although on some soils the hoe drill has been found to give very satisfactory results. The

Fig. 92.—Winter Rye Lessens Soil Drifting.

On the left a field of oats was completely destroyed by drifting. The rye was unhurt, except for 10 or 20 feet along the edge where the soil from the oat field blew into the rye field.

single disc drill is particularly undesirable on soils that drift.

Shallow soils or those having a sandy or gravelly subsoil or those having a deficiency of organic matter in the subsoil should not be plowed deep, or they will soon begin to blow. The surface layer of such soils is richer in organic matter and therefore much more resistant to the wind than the lower layers.

224. Growing Protecting Crops.—The most serious drifting occurs in May before the spring sown crops cover the ground; but winter drifting is not uncommon in years of light snowfall following a dry autumn season. In those areas where drifting is quite common the only fields that can be depended upon to wholly resist the wind action, under severe conditions, are those that are protected by a crop or by unplowed stubble.

225. Perennials as Protecting Crops.—The best protecting crops, although often the least profitable, are the perennials. Among these the grasses are to be preferred, although alfalfa and sweet clover (a biennal) are equally as good soil protectors. It is very seldom that crops sown on land broken up out of sod suffer from soil drifting. In 1919 such land produced almost an average yield at Saskatoon while many crops on fallow and fall and spring plowing were partial or complete failures as a result of high winds and dry weather.

226. Winter Rye Lessens Drifting.—Another commonly grown crop but one less sure of furnishing the protection needed is winter rye. This crop, like the perennials mentioned, may be sown in or following the rainy season when the soil seldom blows, and by covering the ground in May is, like the others, likely to lessen or entirely prevent any blowing. The question of growing winter rye is one that deserves consideration by all farmers living in soil drifting areas. Where drifting interferes with wheat raising to such an extent as to make it unprofitable, winter rye, in many cases, may be substituted to advantage. As a commercial crop, however, rye generally sells for twenty-five to thirty per cent. less than wheat, so that where the latter can be satisfactorily grown rye cannot compete with it as a profitable crop. The illustration (Fig. 92) shows very convincingly the relative resistance to drifting, of land protected by winter rye as compared with that seeded to oats, a spring sown crop.

227. Late Sown Oats for Soil Protection.—Where the conditions are not so serious as to require the use of one or more of these crops, but where some protection of the soil is desirable, a very thin seeding of oats or other cereal may be sown on the fallow in late July or early August and lightly pastured if necessary. These plants, of course, die in winter, but the roots and leaves remaining furnish considerable protection against the high winds the following May. An objection to this practice is to be found in places where biennial weeds are prevalent. If the latter start after the cover crop is sown in July they will, of course, be present in the crop the next year, as no opportunity to kill them in the fall offers itself, the ground being occupied by the cover crop which would be destroyed if cultivated. A volunteer growth of grain or annual weeds in late summer has a similar effect to the sowing of a thin crop of oats, but is subject to the objections pointed out above, viz., the possible presence of biennial weeds that will live over and appear in the next crop.

228. Stubble as a Soil Protector.—Where soil drifting occurs on fall plowed land in winter or in spring two alternatives present themselves, spring plowing or "stubbling in." In much of the very dry portions of the plains region, even aside from the question of soil drifting, spring plowing is rather to be preferred to fall plowing. Where these conditions obtain, of course, all the advantages are with the spring plowing because such land is protected in winter and generally blows less than fall plowing even in the spring. "Stubbling in" is only advisable on land that is free from weeds and grass and that is in good physical condition. In the dry parts and on new land it is more frequently followed than elsewhere. Such fields, of course, benefit as a result of protection in the early summer as well as in the preceding winter.

229. Corn Stubble Lessens Drifting.—On warm soils in the southern part of all three provinces corn may be

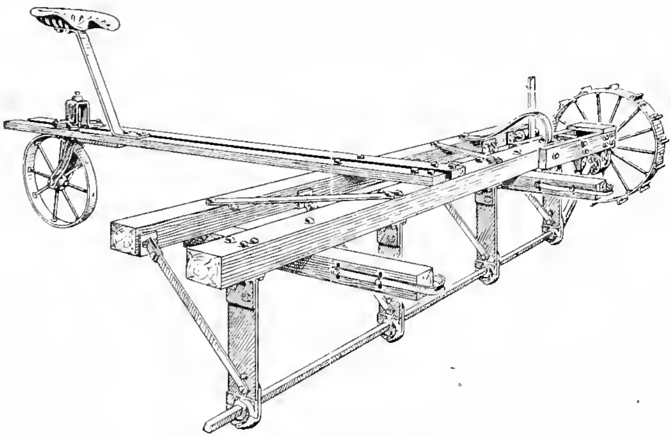

Fig. 93.—Rotary Rod Cultivator.
A new machine that is being tried out on soils that are inclined to drift.

used as a partial substitute for the fallow. Where fallow land in such areas drifts badly, the use of corn as a substitute for fallowing lessens the tendency to drift. Under severe conditions the corn ground will blow, but frequently the corn stubble furnishes sufficient protection to wholly prevent serious injury from this cause. Where corn is grown and the field kept free from weeds, plowing is, as a rule, not necessary or even advisable for the next crop. Disking the corn stubble generally gives better returns. This practice results in leaving the corn stubble on the surface of the soil where they form a considerable protection against soil drifting.

229a. Artificial Protection.—The value of windbreaks such as clumps of trees, hedges, fences, etc., is in direct proportion to their height and extent. Depending upon the severity of the storm the land adjoining such windbreaks is generally protected from ten to twenty times the height of the windbreak, although instances have been reported where such protection is felt over a much greater distance. As a means of lessening soil drifting windbreaks are practicable only for small areas. No doubt when shelter of this kind becomes established on all farms the wind velocity will be lessened somewhat, but the cost of planting and maintaining will probably be found to be too great to warrant planting out enough trees to make any appreciable effect on the wind velocity on large farms in the open plains. Where windbreaks such as hedges or fences are used to protect the farmstead or the garden, an outer row, a few rods from an inner one, should be provided in order to form a "trap" for the drifting soil, otherwise the drift will accumulate within the enclosure and become a nuisance in the carrying out of the necessary farm operations.

230. Miscellaneous Practices and Suggestions.—In fields where the soil has begun to blow much can be done to check it by going into the field and plowing either single furrows or narrow strips of four to six furrows from five to twenty-five rods apart, at right angles to the direction of the winds. These raised portions act as checks behind which the drifting particles lodge. This is an extreme measure and is only advisable where a small patch of drifting soil promises to do serious injury to adjoining areas that are not likely to blow if the drifting material can be kept away from them.

Arranging the areas to be seeded in long strips rather than approaching the square will also counteract the injurious effects of the soil drifting to a certain extent.

By sowing the grain deeper than usual, thus leaving the soil furrowed, tends to prevent soil drifting and lessens the probability of the seed or the plant roots becoming exposed.

The sandy soils take more permanent injury from drifting and are much less subject to favorable modification by tillage than the clay types; the maintenance or increase of the organic matter content by applying manure and growing grass or legume crops becomes therefore of much greater importance with these than with heavier soils.

The introduction of perennial grasses to the rotation in dry districts should be made gradually, otherwise there may be difficulty in adjusting the farm organization to the change. It is hardly necessary to point out that if the cropping system is altered to include the growing of the forage grasses and legumes, provision for the economical utilization of this forage should also be carefully planned, otherwise the benefit to the soil arising from the change may be secured at too high a price.

As curative measures after soil starts to blow there is very little effective treatment that can be given. Where isolated spots only are affected, such as light knolls or exposed elevations, spreading manure either in strips or over the whole surface will lessen the injury. Plowing a few furrows in strips a short distance apart on the lee side of such drifting areas, while a very drastic measure, is one that is advisable where a small area of drifting soil in a larger area of good soil is likely to result in injury to the whole if not controlled in the early stage of the blowing. The drifting particles that leave such light areas may during the course of several days of blowing affect several parts of the field, since they move readily from one place to another, doing injury at every move. It thus happens that from one small patch of poor land a large acreage may be severely damaged if drastic measures are not taken in the early stage of the storm.

231. Conclusion.—The fallow is the worst to suffer from soil drifting and the danger is greatest in May but may occur in winter. The damage is increased when such surface tillage as disking and harrowing, which tend to make the soil fine and loose on top, is practised; it is lessened by deeper tillage with cultivators which leave the soil in a rough, more or less lumpy condition, and preferably in shallow ridges. If this treatment is not sufficient to control the drifting a thin seeding of oats may be sown on the fallow in July and August, or in some districts corn may be used as a partial substitute for the fallow. In case one or other of these fails to produce the desired results, winter rye, which establishes itself in the fall and which has possession of the ground in May, and is therefore likely to prevent the blowing, may be used. Under more serious conditions of soil drifting it may be necessary to grow perennial or bienniel crops and sow cereals only on the sod land, or to so build up the organic matter content of the soil by using hay and pasture crops and farmyard manure, that when intelligently tilled the land will not be likely to blow.

Alkaline Soils

The "Alkali" spots so familiar in some districts, and which produce low returns or none at all are the result of an accumulation of soluble salts of different kinds. In the process of weathering through long periods of time chemical changes in the soil result in the development of certain chemical compounds which are soluble. Some of these are useful to plants but some are harmful. In humid climates the excess is removed by drainage through the soil. In semi-arid and arid climates an accumulation of the toxic salts occurs because there is insufficient rain to wash them through the soil. The result is they are slowly moved to the low spots by soil water as it seeks the lower levels, where, on the evaporation of the water the salts remain as "alkali" on or near the surface of the ground.

This condition is found chiefly in countries having a low precipitation, and occurs in areas where the drainage is poor and the evaporation high. It is a condition that is not general in Western Canada, but is found usually in small patches here and there over the whole West. These patches are invariably found (1) along the edges of old storage basins, (2) in low places where moisture accumulates and evaporates, and (3) in "springy" places below higher ground where salt impregnated water oozes from the surface and evaporates. Alkali frequently "rises" and often with serious consequences where too much water is applied in irrigation.

According to Shutt* the compounds known collectively as alkali comprise chiefly sodium sulphate (Glauber's salts), sodium carbonate (washing soda), sodium chloride (common salt), magnesium sulphate (Epsom salts), and occasionally the chlorides of calcium and magnesium.

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*In bulletin on "Alkali Soils", published by Dominion Department of Agriculture.

Black alkali is characterized by the presence of sodium carbonate (sal soda, washing soda) although this compound is almost always associated with one or more of the chlorides and sulphates mentioned in the preceding paragraph. Sodium carbonate is, as is well known, white, but from the fact that it acts upon and dissolves the decayed vegetable matter (humus) of the soil the incrustation is tinged dark brown or black—hence the name. Water standing in pools on soils impregnated with the carbonate is invariably of a darker color and much resembles a strong infusion of coffee.

232. Why Alkali is Harmful.—It is thought that the harmful effects of alkali result from one or more of four different actions: (1) the destruction of soil tilth, (2) the corrosive effect of those alkalies containing sodium carbonate, (3) the withdrawal of moisture from the plant cells by osmosis, and (4) the toxic effect of some of the salts.

233. The Reclamation of Alkali Soils.—In the dry lands where alkali spots are found the chief means to improve them are: (1) the application of manure, (2) surface drainage, (3) thorough tillage to lessen evaporation and (4) the use of grass crops where the alkali is bad or the spots too numerous or too large to attempt to reclaim. Manure improves the tilth and thus aids crops to establish themselves. Surface drainage removes the water carrying the alkali in solution and thus prevents a further accumulation of salts.

Thorough tillage aids in lessening evaporation and the consequent rise of alkali with the water as the latter comes to the surface. Manure also aids in lessening evaporation. Thorough tillage and manure, by helping to keep the soil filled with water, help also to wash the alkali down to lower levels and to dilute the solution in the surface soil, thus frequently making profitable crop growing possible.

On irrigated land, flooding and under drainage to wash out the soluble salts and carry them away in the drainage water is frequently practised. When the alkali contains sodium carbonate, land plaster or ground gypsum may be applied. This changes the black alkali to white alkali, a less harmful form and one that may more easily be removed by drainage. The removal of alkali by mechanical means is sometimes practised on high-priced land. Shutt points out also that on certain types of alkali or those consisting largely of magnesium sulphate (Epsom salts) the application of lime or marl before irrigation and drainage is beneficial.

234. The Use of Alkali-Resistant Crops.—None of the important field crops can be grown where the alkali is strong. Rye and barley are reported to be more resistant to alkali than the other cereals. Among wheats the macaroni varieties are said to be the best. Members of the beet family are the most resistant root crops for this type of soil. The legumes as a class do not do well on alkaline areas, although sweet clover is reported to be alkali-resistant. The forage crops or those grown for hay or feed rather than for seed are generally the best to grow on alkali land. Western rye grass and brome grass are commonly sown and used either for hay or pasture on soils of this nature.

Kearney in a summary of his studies on the alkali resistance of crops states in Bulletin No. 44 of the United States Department of Agriculture that "most field crops cannot be profitably grown when the quantities of white alkali salts (sulphates, bicarbonates and chlorides) in the depth occupied by the roots exceed one per cent. of the dry weight of the soil and only a few resistant species can be expected to give good crops when the quantity exceeds one-half of one per cent."

Loose Top Soils

This is a local name applied to a peculiar type of very heavy soil which both in the unbroken as well as in the cultivated condition frequentlty carries a loose or springy layer of soil three or four inches in depth. The vegetation is rather sparse, mostly grasses of a bunchy nature with considerable sage brush in some parts. Very few native trees or shrubs are found growing on it.

This soil bakes very readily after being wet and on drying opens up in large cracks often wide enough to let the plow wheel in to the axle. The rain water and some of the loose particles of soil pass into these cracks and on freezing and expansion later there results the roughened surface popularly spoken of as "hummocks". A considerable area of this type of soil lying west and south of Goose Lake in Saskatchewan was spoken of among the early ranchers as the Saskatchewan desert.

This soil when broken is dark in color, the loose spots appearing almost a slate blue. Even in dry weather it seems damp when plowed and if the dry weather continues after plowing, the soil of the furrow slice becomes very hard. After rains it "slakes" down forming a loose surface dry on top and wet underneath and inclined to bake and crack in the heat after heavy rains. The soil is very deep, rich and very fertile but cold and rather difficult to till.

235. How Loose Top Land is Broken.—This land is usually broken with rod plows instead of the ordinary mouldboard breaker. When the breaking is not done with engines a sulky drawn by five or six horses is used. The fact that so much power is necessary to cut and turn over one furrow gives some indication of the heavy nature of the soil. The use of the heavy float or plank drag or scrubber on the rough surface soon after plowing and before it bakes is becoming a general practice. This operation is followed, as opportunity presents, by double disking to form a seed bed and aid in killing grass. To finish the season's cultivation a single or double stroke of the harrow is given.

236. The Crops Grown.—Loose top land is frequently infested with wireworms which work havoc with cereal crops if they are sown first, but which injure flax very little. The first crop is therefore generally flax and the common practice is to use cereals as the second crop. Wheat is frequently sown on the flax stubble without any cultivation, although fall or spring disking is also commonly followed. The practices of breaking and the use of flax as the first crop are quite fixed and general but the best preparation for the second crop has not yet been determined to the satisfaction of many.

237. Fallowing Loose Top Land.—After taking two crops, the land is usually fallowed, the plowing being done with disc plows. Motor power is in common use. The level land, its freedom from sloughs and stones, and the heavy draft all tend to foster this form of power. The plowed land is subsequently cultivated much the same as other soils. At present discs and drag harrows are extensively used but cultivators are being introduced more and more.

238. The Rotation Used.—The rotation generally practised is a fallow and two crops, breaking, flax and wheat at first, followed by fallow, wheat and wheat, oats or flax is the general rule. The small seeded annual weeds are quite prevalent owing to the use of so much flax. The weed pest together with the relatively low precipitation, heavy soil and somewhat unsatisfactory yields from fall and spring plowing is tending towards the three year system,—of fallow, crop and crop—with no plowing for the second crop. A few men are following the two-year system and fallowing half the land each year.

"Burnt Out" Soil

A peculiar spotted condition of what seems to be otherwise a normal type of soil is to be found in some parts of southwestern Saskatchewan, southeastern Alberta and Montana. It is locally spoken of as "burnt out" land. Areas varying in size from a few feet in diameter to as many rods are found, scattered thinly in some areas and thickly in others, where in some manner the surface soil to the depth of six to ten inches seems to have been removed. Many settlers are of the opinion that these areas have at some time been "burnt out" leaving the prairie in the spotted condition it is found in to-day. The more probable explanation is that after a series of dry years with little vegetation on the land, it has become puddled after heavy rains, then slaked down to powder and eventually blown away by the wind. Whatever the explanation, it is clear that the surface soil has gone and that the soil now on top in these depressions appears to be quite similar in texture and composition to the subsoil of adjoining normal soil.

Most of these low spots are covered with grass but in a few areas they carry very little vegetation. After breaking some of them are reported to be more or less alkaline but many of the "burn outs" are found to be productive. The difficulty with and chief objection to them is that the texture is different from that of the good soil, hence the "burnt outs" are seldom in condition to work when the good land is, and the crop the former produces is either very small or very late, resulting in a lower yield or a lower grade. The difficulty is one of handling the land efficiently and of getting a high grade of grain.

239. The Management of "Burnt Out" Soils.—The lower levels of the "burnt out" spots and the lack of organic matter in them are the chief causes of inconvenience and loss, and suggest the basis of attack. After a survey of the methods of handling this land the following practices were found to be used by many of the most successful farmers with apparently favorable results:—

1. Levelling with floats and harrows to get some of the good surface soil into the "burn outs", thus lessening the difference in level and improving the tilth of these low spots.

2. Surface drainage to prevent water standing in the hollows too long after rains.

3. Heavy applications of manure either plowed under or used as a top dressing.

4. In a few cases shallow fall plowing, left loose, was recommended. Spring cultivation with a spring tooth cultivator or disc harrow seemed necessary in some areas whether the land had been well prepared the fall previous or not.

5. Deep plowing of the fallow, it was frequently stated, resulted in a more uniform and heavier crop.

6. Some men strongly recommended the use of the

spring tooth cultivator on the fallow in preference to the disc, which seemed to make the soil too fine and thus cause it to run together more when wet.

The plowing under of green crops, such as winter rye or sweet clover to increase the organic matter supply has not been tried out, nor has the application of slaked lime or finely ground limestone been tested. It is probable that while both of these practices might result in some improvement to the soil, it would be at present too costly a procedure for general use by pioneer settlers.

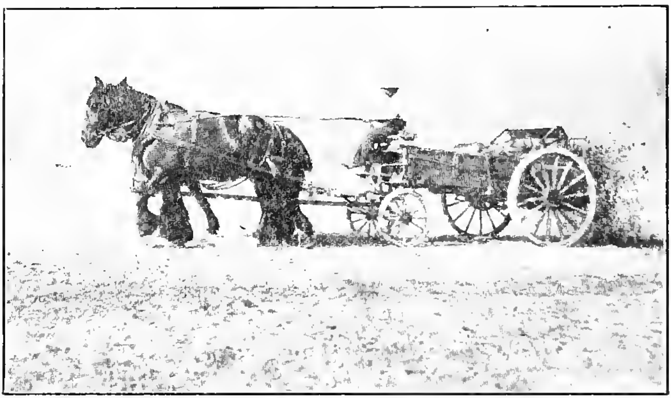

Fig. 94.—Hauling Manure with a Spreader.

The use of fresh manure in thin applications, preferably by a manure spreader, is a good practice.

Vigorous floating, planking and harrowing, deep plowing, not permitting the surface to get too fine in the fall, working the land only when in condition, surface drainage of the low spots by furrows and the application of manure seem to be the most promising methods of improving the productive power of this type of land.

Poor Soils

The soils of Western Canada are far from poor as a rule, but a few small areas of land have been settled upon that never should have been opened for homesteading. In a climate such as ours at this stage of our economic development some of the latter cannot be farmed at a profit, much less can they be brought up to a state of productiveness once their virgin fertility is lost.

Many of our soils become "poor" after cultivation for a few years with no return of organic matter. The process is so slow and so gradual that the pioneer farmer seldom notices it. A false sense of security in the lasting power of soils has ever blinded the first generation of farmers to the inevitable result of ruining the land. It is only where one notes the records of many years that the truth forces itself home. One instance out of many is sufficient to illustrate this point. The average yield of wheat in Kansas for twenty-five years previous to 1890 was 14 bus. 47 lbs., while for the twenty-five years subsequent to that date it was 12 bus. 27 lbs. The average for oats for the first period was 33 bus. 08 lbs., and for the last, 22 bus. 17 lbs.

In the early years of cultivation over much of the semi-arid plains of America manuring seldom produced large increases but after a few years cropping it has invariably been found to produce excellent results. As an example, on the Kansas land mentioned above, where manure produced very little increase in the early years, an application equal to 2½ tons per acre per year during the years 1911 to 1917 increased the yield 7 1-3 bus. or about one-half more than from unmanured land. Similar results have been reported from many places in the older plains States between Kansas and Western Canada.

239A. The Value of Manure.—What has been said about the advantages of organic matter in Chapter III and in other places applies in a greater degree to manure. The value of this fertilizer is not chiefly in the food

Fig. 95.—Cereal Test Plots at Beaver Lodge, Grande Prairie District, Northern Alberta.

material it carries but rather in its physical and biological effects on the soil. It not only adds some elements of plant food but it improves the structure of the soil, increases its moisture-holding power, lessens the tendency to blow and, perhaps most important of all, increases the activity and the number of the desirable soil bacteria that perform the important function of making plant food available.

According to Hopkins* "a ton of fresh-mixed cattle and horse manure contains about 500 pounds of dry matter, 10 pounds of nitrogen, 2 pounds of phosphorus, and 8 pounds of potassium. . . . By leaching and fermentation the dry matter, nitrogen, and potassium are lost in approximately the same proportion, but the phosphorus is lost only about half as rapidly, so that one ton

*In "Soil Fertility and Permanent Agriculture."

of average yard manure, resulting from perhaps two tons of fresh manure, contains about 500 pounds of dry matter, 10 pounds of nitrogen, 3 pounds of phosphorus, and 8 pounds of potassium, one-half of the dry matter, nitrogen, and potassium, and one fourth of the phosphorus having been lost.

"In an experiment conducted at Cornell University, 4,000 pounds of ordinary manure from the horse stable, worth \$2.74 per ton for the plant food content (at commercial prices) were exposed in a pile out of doors from April 25 to September 22. At the end of that time the total weight had decreased to 1,770 pounds, worth only \$2.34 per ton. In other words, the value of this pile of manure was reduced from \$5.48 to \$2.03 during five months' exposure. . . . In no case should manure be allowed to heat and ferment before being spread on the land, if its full value is to be secured."

Manure gives best results when applied thinly and worked well into the soil. It is usually applied (1) as a top dressing for grass land, or (2) plowed in before corn, roots, potatoes or barley, or (3) on some of the lighter types of soil plowed under in the fallow year. It may be objectionable (1) when applied thickly in dry areas and plowed under for a crop the same season, or (2) when plowed under on heavy soils in the fallow year. In the former case the soil may dry out, in the latter the growth may be too rank and weak and the crop may lodge.

239B. The Place of Commercial Fertilizers.—Commercial fertilizers have not yet demonstrated that they have a place in our cropping system. These substances do not, like manure, improve the tilth or physical or biological condition of the soil. They are valuable only for the nitrogen, phosphorus, potassium or lime they may carry. It is possible that on some soils the use of one or more of these fertilizers might pay even now, but in the few tests that have been conducted (usually on good soils) they have not produced sufficient increase to warrant their use, except perhaps in truck farming or potato growing. The time will come, no doubt, when it

Fig. 96.—Wheat Field at Fort Vermilion, Peace River.

700 miles by trail north-west of Edmonton, Alta.

will be necessary to apply phosphorus, the supply of which in our soils is not high; and we are shipping it away in large quantities in the grain we sell.

Nitrogen can be gotten from the air by growing legumes, and the potash supply in the soil is very high, but unfortunately there is no means of replenishing the phosphorus supply except by purchasing. It is interesting to note that the use of phosphate fertilizers in some places results in an earlier crop of grain.

Cold Soils

The practice of agriculture in warm climates is based on the experience of four thousand years or more. Likewise the practices of crop growing under irrigation have developed through an equally long time. Even modern dry farming practices are based upon the experiences of more than a generation. But the growing of crops in climates as far north as the northern settlements of Western Canada and Europe is a comparatively recent movement, and it enjoys neither the accumulated experience of years nor the benefit of such searching scientific investigations as has the agriculture of other climatic zones.

When the amount or the condition of the plant food in soil limits the yield, as in most warm humid areas, methods for permanently maintaining or increasing the yields are known. Similarly on dry lands where water limits the yield the science of dry farming has been quite thoroughly worked out. But in northern regions and in high altitudes where the growing season is short and where low temperatures limit the yield there is little to be learned from the investigations of science and still less from the practices of older agricultural countries. This means that successful methods have yet very largely to be worked out for the crop grower along the northern edges of settlement.

239C. Some Practices of Northern Agriculture.— At the present time some of the chief practices being followed where low temperatures limit the yield are as follows:

(1) Ranching, which permits of the extensive use of the native vegetation and such frost-resistant crops as our hardy perennial grasses;

Fig. 97.—The Windstorm at its Height.

Fig. 97B.—After the Windstorm.

(2) Mixed farming, which may provide for the utilization of the native vegetation, and which permits the use of (1) grain crops for hay, (2) Swede turnips for succulent winter feed, and (3) the profitable use of frost-damaged grain as feed.

(3) The use of early classes of grain crops, such as oats, barley or rye in preference to wheat; and the use of early varieties such as Prelude or Ruby wheat; sixty-day, Orloff or Daubeney oats; Early Six barley and Early White peas.

(4) Soil management practices that result in earlier germination or earlier maturity such as (a) packing the land, (b) less frequent fallowing, (c) shallow plowing of the fallow, (d) later plowing of the fallow, and (e) the use of manure to warm up cold soils.

(5) Thicker seeding—No combination of practices will result in preventing damage to grain crops from summer frosts, but a few days earlier maturity may lessen the probability of injury from fall frosts. Thick seeding results in somewhat earlier maturity of the crop.

CHAPTER XVI

LESSONS FROM EXPERIENCE

The Great Plains Region of North America includes a large part of the Prairie Provinces of Canada and most of the United States lying between the Mississippi Valley and the Rocky Mountains. This large area includes many soils and climatic conditions and its problems therefore, are not the same in all parts. They are, however, sufficiently similar to justify the inclusion under one cover of the experiences of the settlers in its different parts. It has therefore been thought wise to ask some of the leading agronomists in this large area to summarize the experience of the best farmers and the results of experiment station work in their respective states and provinces. These summaries, for which the author is very much indebted to the writers, are as follows:—

Dry Farming in the Great Plains Region of the United States, E. C. Chilcott, Agriculturist in Charge of Dry Land Investigations, Washington, D.C.

Dry Farming Practices in Kansas, L. E. Call, Professor of Agronomy, Manhattan, Kansas.

Dry Farming in Nebraska, W. W. Burr, Professor of Agronomy, Lincoln, Neb.

Dry Farming Practices in North Dakota, Manley Champlin, formerly Associate Professor of Agronomy, Brookings, S.D.

Dry Farming Practices in North Dakota, W. R. Porter, Superintendent of Demonstration Farms for North Dakota.

Dry Farming Practices in Montana, Alfred Atkinson, President Montana State College of Agriculture.

Dry Farming in the Red River Valley, T. J. Harrison, Professor of Field Husbandry, Manitoba Agricultural College, Winnipeg.

Dry Farming in Western Manitoba, W. C. McKillican, Superintendent Experimental Farm, Brandon, Man.

Dry Farming Practices in the Park Belt of Alberta, G. H. Hutton, Superintendent of Agriculture and Animal Industry, C. P. R., Calgary.

Summer Fallow In Southern Alberta, James Murray, Superintendent of Farms, Noble Foundation Ltd., Nobleford, Alberta.

DRY FARMING IN THE GREAT PLAINS REGION OF THE UNITED STATES

A Summary of Some of the Conclusions Drawn From the Investigations Conducted by the Office of Dry Land Agriculture, United States Department of Agriculture, Into the Best Method of Managing Land in the Great Plains Area.*

By E. C. Chilcott, Agriculturist in Charge.

240. Summer Tillage.—

Spring Wheat:—Summer tillage without crop has given the highest average yields of any method under

*The references in parenthesis refer to the U. S. D. A. Bulletins in which may be found the evidence upon which the conclusions herewith reproduced are based.

trial at 12 of the 14 stations. However, on account of its high cost due to extra labor and alternate year cropping, it has not been the most profitable practice. (Bul. 214, —p. 43-11).

Winter Wheat:—Summer tillage has given the highest average yields of any method under trial at 11 of the 13 stations. However, on account of its high cost due to extra labor and alternate year cropping it has not netted the largest returns except at Huntley (Montana). (Bul. 595, —p. 35-10).

Oats:—Oats following summer tillage produced the highest average yields at all stations except Hettinger (N.D.) where the yield was exceeded only by that on disked corn ground. While the expense of the method has prevented its being the most profitable the degree of insurance which it affords against failure of the feed crop might justify its practice in oat production in at least some sections of the Great Plains. (Bul. 218 —p. 42-9).

Barley:—The highest average yields at 11 of the 14 stations have been by summer tillage. On the average it increased the yields nearly one-half over those produced on land cropped in the preceding year. On account of its cost, it has not been the most profitable method of production. (Bul. 222—p. 32-3).

Corn:—Summer tillage has slightly increased the grain yields at all except three stations and has materially increased fodder yields at the three southern stations. The increased yields, however, have not been sufficient to make it the most profitable method at any station except Scottsbluff (Nebraska). (Bul. 219—p. 31-3).

241. Corn or Sorghums vs. the Fallow.—

Spring Wheat:—Disked corn ground has given consistently high yields. This, together with the low cost of preparation, has resulted in its showing the highest average profit or lowest average loss of any of the methods tried at all fourteen of the stations except one. These profits are based on the assumption that the corn crop was so utilized as to pay for the cost of its production. (Bul. 214—p. 43-7).

Oats:—At Garden City (Kansas) and all stations north of North Platte (Nebraska) disking corn ground has been productive of higher average yields of oats than either fall or spring plowing. At North Platte (Nebraska), Hays (Kansas), Dalhart and Amarillo (Texas), it yielded either the same as one of them or its place was intermediate between the two. (Bul. 218—p. 41-5).

Barley:—At ten of the fourteen stations under study, disked corn ground produced higher yields than from either the fall plowing or the spring plowing of barley stubble. It has been the most profitable method under trial at all the stations except Hettinger (N.D.). (Bul. 222—p. 32).

Winter Wheat:—Disked corn ground has given consistently high yields. This, together with the low cost of production, has resulted in this method showing the highest average yields of any of the methods at all of the 11 stations where it has been tried, except at Huntley (Montana) and Amarillo (Texas). These profits are based on the assumption that the corn crop was so utilized as to pay for the cost of producing it. (Bul. 595—p. 35-p).

242. When Disking May Be Substituted for Plowing—These investigations have shown that when the corn crop has been grown on properly prepared land and kept free from weeds, the land does not require plowing in preparation for a following crop of small grain. Wheat, oats and barley have usually given better yields on disked corn land than upon land that has been plowed. This, together with the fact that disking is cheaper than plowing, makes disking corn land generally the most profitable method of preparation for small grain. Discing potato land is probably as good a preparation for small grain as disking corn land, and there are undoubtedly other intertilled crops such as peas, beans and peanuts that will serve the same purpose. The sorghums, however, do not leave the ground in as favorable a condition for the crop that is to follow as the other crops mentioned. (Bul. 268—p. 22).

243. The Use of the Lister in the Fall.—The practice of ridging with a lister as a substitute for fall plowing, and cultivating down level without the use of a plow in the spring has been tested at most of the stations as a preparation for all of the small grain crops considered in this bulletin except winter wheat. It has usually produced as good or better yields than fall plowing. Its lower cost has made it in many instances nearly or quite as profitable a method as disking corn stubble. In addition to its low cost it has the advantage of catching and holding the snow and checking soil blowing during the winter and of arresting run-off.

When the lister is used in preparing land for winter wheat, the listing is done immediately after the harvest of the preceding crop. The soil is worked down level, usually with a disc, in late summer or early fall and then seeded with an ordinary grain drill. Very little difference in average yields between listing and plowing have been noted except at Hays (Kansas), where the advantage is in favor of listing. (Bul. 268—p. 22).

244. How and When to Plow.—The comparative average yields from fall and from spring plowing at each station for corn, spring wheat, oats, barley, milo and kafir have shown but small differences. As the land requires plowing for all annual crops except in those cases above noted, and as plowing is an expensive operation, it is a question of great economic importance as to how and

Fig. 98.—Harvesting Winter Wheat with a Header in Kansas.

when this plowing should be done. Much has been written upon this subject and many theories have been developed and advocated, but the investigations conducted in the Great Plains by the Office of Dry Land Agriculture seem to show conclusively that no set rule can safely be followed. The best practice seems to be to do a good clean-cut workmanlike job of plowing to a depth of from 4 to 8 inches when the soil is in proper condition and the work can be done to the best advantage, taking into consideration the most economical distribution of labor throughout the year. (Bul. 268—p. 23).

245. The Purpose of Plowing.—It is mistaking or failing to recognize the purpose of plowing that leads to the belief that its efficiency increases with its depth, even though that depth be extended below all practical limits of cost and effort. Plowing does not increase the water-holding capacity of the soil, nor the area in which roots may develop, or from which the plants may obtain food. Plowing removes from the surface either green or dry material that may encumber it, provides a surface in which planting implements may cover the seed, and removes or delays the competition of weeds or plants other than those intended to grow, and in some cases, by loosening and roughening the immediate surface checks the run-off of rain water. All these objects are accomplished as well by plowing to ordinary depths as by subsoiling, dynamiting, or deep tilling by any other method. There is little basis, therefore, for the expectation of increased yields from these practices, and the results of these experiments show that they have been generally ineffective. (Journal of Agricultural Research, Vol. XIV, No. 11—p. 484).

The quite general popular belief in the efficiency of deep tillage as a means of overcoming drouth or of increasing yields has little foundation in fact, but is based on misconceptions and lack of knowledge of the form and extent of the root systems of plants and of the behaviour and movement of water in the soil. (*loc. cit.*—p. 521).

245a. Green Manuring.—Green manuring has not usually given as high yields of spring wheat, winter wheat, oats or barley as has summer tillage. It has yielded but little if any higher than disked corn ground with any of these crops. It is much more expensive even than summer tillage. There is not yet any apparent cumulative effect of the addition of humus to the soil, although it has been practised at some of the stations for twelve years. The evidence so far as to its practicability is negative.

246. Destruction of Weeds.—The destruction of weeds is nearly always desirable, as under dry-farming conditions weeds are one of the most serious obstacles to successful crop production. When summer tillage is practised on a bare fallow during the entire season, cultivation should be frequent and thorough enough to destroy all weeds before they attain sufficient size to transpire appreciable quantities of water or to reseed themselves. This tillage will also keep the surface in a condition sufficiently loose and open to allow the rain that falls to penetrate it. When the soil becomes well filled with water early in the season and additional rains can reasonably be expected, it may sometimes be desirable to allow the weeds to attain a larger growth and then plow them under in order to provide additional organic matter in the soil, but it must be borne in mind that this gain in organic matter is made at the expense of the soil moisture.

Our investigations show that summer tillage is, with the exception of green manuring, the most expensive and least profitable method under trial. Exceptions are to be noted in the case of kafir and milo at Dalhart, corn at Scottsbuff, and winter wheat at North Platte and Huntley.

The purpose of summer tillage is accomplished by the prevention of vegetative growth rather than by the maintenance of a mulch. Numerous experiments made in connection with this work have furnished an abundance of evidence that when vegetative growth is restrained the loss of water from a mulched surface is practically the same as from an unmulched one.

The cheapest and most efficient methods of weed destruction necessarily form a soil mulch. The results accruing from the prevention of weed growth have been very generally attributed to the mulch itself when the mulch is, in fact, only accidental.

Tillage for the purpose of destroying weeds after harvest is warranted only in those exceptional cases when sufficient water remains in the soil to start weed growth after harvest or when heavy rains come soon after. In such cases early fall plowing is the most effective method of destroying the weeds and thus saving the moisture that would be used by them if allowed to grow. The same object may be accomplished by disking soon after the weeds have started. This method has the advantage of being more rapid than plowing, thus making it possible to cover more ground with the same number of teams and men. But as the land will have to be plowed before another crop is sown, the labor of disking is mostly lost, although the labor of plowing the disked land may be somewhat less than if it were not disked and a better job of plowing may sometimes be done on the disked land. The cost of early fall plowing or disking, when the weather is hot and the men and teams are needed for stacking, threshing, and hauling grain, is greater than later in the fall, when the weather is cooler and there is less other work for men and teams. All of these facts should be taken into consideration before going to the extra expense of tillage to kill weeds immediately after harvest.

Spring plowing or disking, as soon as the weed seeds have germinated, is usually a profitable practice. Where small grain is to be sown, the sowing should be done soon after plowing; but where corn, potatoes, or the sorghums are to be grown there is often a period of several weeks between the time of the germination of the weed seeds and the time when the season is sufficiently advanced to plant the crop. This period should be utilized as far as possible for the destruction of weeds before the crop is planted. Much labor in keeping the crop free from weeds during its growing period can thus be saved.

Harrowing small grain for the destruction of weeds after the grain is sown and until it has reached a height of 3 or 4 inches may sometimes be practised to advantage. Experimental evidence does not show it to be generally profitable. Harrowing corn and potatoes after planting and until the young plants have attained a height of 2 or 3 inches is quite generally practised to advantage.

It is absolutely essential for the most profitable growth of corn, potatoes, the sorghums, and, in fact, all the intertilled crops, that sufficient tillage be given to keep the growing crop free from weeds until the plants have attained such growth that they will be seriously injured by the cultivators or the horses. (Bul. 268—p. 24-25).

247. The Application of the Capillary Theory to Dry Farming Practices.—The capillary theory is undoubtedly responsible for more false reasoning about dry land agriculture than any other one thing. It is a convenient theory to explain certain well-known phenomena such as the rise of oil in a lamp wick, but it must be taken in its entirety. It will not do to eliminate the one most important factor in the theory and then expect it to work. This one factor is *the presence of a constantly replenished supply of free-moving water at the base of the system.* In other words, a permanent water table within a few feet of the surface of the soil, a condition that is never met under true dry land conditions. Therefore, any system of dry land farm practice that is dependent upon the assumption that there is a continuous upward movement of soil water by capillarity of sufficient magnitude to materially affect crop growth will prove disappointing when put to the test of actual field practice, as has been done in the extensive investigations conducted during the past fourteen years in the Great Plains by the Office of Dry Land Agriculture.

A careful study of hundreds of thousands of soil moisture determinations fails to show any such movement. The soils of the semi-arid regions undoubtedly do lose large quantities of soil water, but this loss is undoubtedly due almost entirely to some one, or to a combination of two or more, of three factors, utilization by the growing crop, transpiration from growing weeds, or loss from internal evaporation and escape from the soil to the atmosphere in the form of water vapor. Only such methods of moisture conservation as will prevent loss from these sources are worth considering, so far as the water which has actually entered the soil is concerned. Excessive runoff may be retarded and the absorption of water by the surface soil may be facilitated to a limited extent by proper methods of surface tillage. But any method of tillage calculated to prevent capillary rise and surface evaporation of soil water in semi-arid regions will be useless except in so far as it stimulates the growth of crop plants, destroys weeds or retards their growth, or checks the escape of water vapor from cracks or other openings in the soil.

248. Farm Organization and Crop Rotations.—As forage crops of some kind can profitably be grown at all stations, they must occupy an important place in any system of farming adapted to the Great Plains. Sufficient live stock must be kept to convert these crops into finished products on the farm and sufficient forage must be produced and stored during the favorable seasons to carry the live stock through specially unfavorable seasons.

Good farming is an essential to success in the Great Plains area as elsewhere. Good farming means practicing the best method of producing the largest crops at the lowest relative cost of production and leaving the soil in the best condition for the production of subsequent crops. Good farming may involve methods either intensive or extensive, either expensive or inexpensive; and it must be practical and economical as well as scientific and thorough in order to be good farming. It is just as poor farming to go to too much expense as it is to go to too little expense to accomplish a given result. These investigations show that the largest net profits have usually been obtained from crops raised by cultural methods involving a low cost of production rather than from high yields obtained under methods involving a high cost of production. Lessening the cost of production without proportionately lessening yields should therefore be given first consideration. In other words, extensive rather than intensive systems, of farming should be followed.

Different types of soil and different combinations of climatic conditions require different cultural methods and different combinations of crops to produce the most profitable results.

The personality of the farmer and his family; the size, location, soil and environment of the farm; market facilities and prices; the available capital, in cash, labor, or equipment, may any or all be determining factors in the problem of profitable dry farming in the Great Plains area.

Dry farming in the Great Plains area, in common with all farming, to be successful must be systematized, and in order to accomplish this, some definite rotation of crops should be established. In planning such a rotation, due consideration should be given to all the factors here enumerated, as they apply to each particular farm and farmer. With these considerations clearly in mind, it is believed that no intelligent farmer will experience any great difficulty in adopting a system of crop rotation and farm organization that will be better adapted to his conditions than any that could be proposed by anyone less familiar with these conditions than is the farmer himself. (Bul. 268—p. 27-28).

DRY FARMING PRACTICES IN KANSAS

By L. E. Call, Professor of Agronomy, Agricultural College, Manhattan, Kansas.

The average annual rainfall of Kansas varies from less than sixteen to over forty-five inches. In the eastern two-thirds of the state, it exceeds twenty-two inches while in the western third, it is less than this amount. The average annual rainfall is ample for all crops in the eastern two-thirds of the State, but irregular distribution and very rapid evaporation during the growing season often makes it necessary to conserve moisture with care if profitable crops are to be produced. It is only in the western third of Kansas that moisture is so deficient that it is necessary to use the bare summer fallow in the cropping system. In this section, fallowing is not necessary more often than once in three to five years, and even then may not be necessary if the fallow season should prove unusually favorable.

249. The Place of Summer Tillage.—The sorghum crops and winter wheat are the most dependable dry farming crops for Kansas. These crops must be grown in rotation for best results. It is advisable in western Kansas to summerfallow sorghum ground in changing from sorghum to wheat unless conditions are unusually favorable. In an unusually wet fall, wheat may be sown on disked sorghum ground, and in an unusually wet spring, barley may be sown on disked sorghum ground in the spring. At all other times, it is best to summerfallow sorghum ground for wheat.

The best method of preparing sorghum ground for wheat is to disk the ground in the spring after the first weeds start. This kills the first crop of weeds and starts other weed seeds germinating. The ground is then plowed before the second growth of weeds becomes too large and in time to finish plowing before harvest. The fallow is usually plowed in late May or early June. It is left without work until after wheat harvest which occurs in July. In August and early September, it is worked down and the wheat seeded in late September. Care must be exercised not to work the fallow ground more than necessary to kill weeds and to prepare a good seedbed for wheat, otherwise, the surface of the field may be left too smooth and the wheat injured by soil drifting during the winter. When stubble ground is summerfallowed, it is handled in the same manner. It is the usual practice to grow wheat at least three years after fallowing before changing the ground to sorghum. The first year the wheat is on fallowed ground. The second year the crop is drilled in the stubble and the third season, the ground is plowed after harvest and the crop seeded the same fall.

The next year the field is changed to a sorghum crop. After growing sorghum from one to three years the land is fallowed and returned to wheat. Corn frequently replaces sorghum in this rotation, or corn may be planted

Fig. 99.—Black Amber Sorghum in Kansas.

This is one of the leading types of drought-resistant forage crops in the South.

after the sorghum crop in place of the fallow. It is only under the most favorable conditions that corn should be used in this way.

250. Kansas Dry Farm Crops.—The best dry farming crops in Kansas are of two distinct kinds. First, those that are able to withstand extremely hot summer weather and take advantage of moisture whenever rain may occur and second, those that mature early enough in the spring to escape the hot dry summer weather.

The sorghums are the best example of the first class of crops. They have the ability to withstand high temperatures and to remain in an uninjured condition for a long period of time without rain. There are varieties of sorghums adapted to many different uses. Kafir, milo, feterita and kaoliang are especially valued for the production of grain; the sweet sorghums such as black amber red amber, orange and sumac are very large growing, leafy plants and are especially valuable for fodder and silage; while Sudan grass is more grass-like in character and is especially valuable for hay and pasture. Kansas is fortunate in having this valuable sorghum family of crops so well adapted to the dry farming sections of the State.

251. Crops That Mature Early.—Winter wheat is the best example of those crops that mature early. It matures in late June or early July and thus escapes the hot summer months. The best winter wheat varieties are those that mature early and at the same time are winter hardy. Varieties of the Turkey Red type have given best results. Of these, Kanred, a variety developed at the Kansas Experiment Station, is the best. It matures somewhat earlier than other varieties of Turkey, is more winter hardy, less susceptible to most diseases and is somewhat more productive. Spring wheat always matures later than winter wheat and consequently is more often injured by hot weather. It cannot be successfully grown in Kansas except in the northwestern part where the elevation is higher and the summers cooler than in the rest of the State. Barley is the best dry land spring grain for Kansas. It matures earlier than oats and consequently produces more grain. When oats are sown only very early varieties such as Burt and Red Texas should be used.

252. The Amount of Seed to Sow.—Where moisture is limited it is not advisable to sow grain too thick, otherwise the supply of moisture may be exhausted before the crop is matured. The quantity to sow will depend upon the character of the soil, and the time of seeding. On well prepared summerfallowed ground, one-half bushel of winter wheat is sufficient seed to sow in western Kansas. On ground less well prepared, a bushel of seed is often necessary. When wheat is sown very late in the season, more seed should be used for it will tiller less and therefore, should be sown thicker.

DRY FARMING IN NEBRASKA

By W. W. Burr, Professor of Agronomy,
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Lincoln, Neb.

A large portion of the cultivated land west of the hundredth meridian in Nebraska is under what is commonly called dry farming. The conditions that determine dry farming are a dry subsoil and a limited rainfall. Within the area mentioned in western Nebraska are sub-irrigated areas where sheet water comes close to the surface, and there we could not say that dry farming is practised. Obviously, where water is applied by irrigation, it is not dry farming.

The early experiences of farmers in western Nebraska were far from satisfactory, and many failures resulted. There were several causes for this, aside from the uncertainty of the weather,—lack of experience in dry regions, poorly adapted crops, and lack of working capital probably being the main ones. The conditions have changed considerably in the last 15 years. Out of the experiences of the farmers have crystallized some very sound and definite information. To this have been added results of agricultural investigations, all of which has brought about a much better understanding of the situation. More adapted crops, more suitable machinery, and, what is per haps even more important, the farmers have accumulated

Fig. 100.—Disking Behind the Binder to Conserve Moisture in Nebraska.

a working capital or a credit, sufficient to tide them over adverse seasons.

The dry farming area of Nebraska contains many types of soil. Considerable areas are so sandy as to be unfitted for grain production, and the farming operations are confined largely to supplementing the native feed for live stock. In other areas the soil is heavier. It is fertile, and with sufficient moisture responds abundantly to grain cropping. No very distinct methods are employed in dry farming. The amount and kind of tillage is usually determined by the seasonal conditions and the available supply of man and team labor.

253. Summer Tillage is not extensively practised in

Nebraska. It is occasionally practised on limited areas in preparation for winter wheat or in preparation for a grass crop or alfalfa. The farmers have found that wheat is quite as certain after corn as it is after summer tillage, though the yield may be somewhat less. The cultivation of the corn costs practically no more than the summer tillage, and by growing the corn they obtain a considerable amount of roughage and usually a grain crop. The roughage is an important factor, since in almost all of our dry farming sections considerable live stock is carried. Where summer tillage is practised, the land is usually left uncultivated until after corn planting, when it is plowed; and after plowing, sufficient cultivation is given with a disc or harrow to keep down weed growth.

254. Crop Rotation.—There is no very definite system of rotation in the dry farming area. The most nearly definite is corn and winter wheat alternating. The winter wheat is usually drilled with a one-horse drill into the standing corn. Later the corn is harvested, usually by husking from the standing stalks and then turning the stock in to get what rough feed they can. Where the corn has been kept fairly clean, this is a very satisfactory way of growing winter wheat. The wheat goes into a firm seed bed and has the stalks and stubble to catch snow and serve as a protection from blowing during the winter. Ordinarily the wheat stubble is prepared for corn simply by disking it early in the spring and then putting in the corn with the lister.

255. Crop Adaptation.—This is a very important factor in the development of any section. Obviously no amount or kind of tillage will make profitable the production of a poorly adapted crop. All of the ordinary grain crops suitable to this section are grown in the western part of our State. Winter wheat is tending to replace spring wheat. Turkey Red winter wheat is most commonly grown and is well adapted. Both common and Macaroni spring wheats are grown, and no one variety has proved markedly superior to several others. In most of the area the early type of oats has proved superior to the later types. Kherson is most commonly grown. Ordinary six-rowed barley has proved superior to any of the two- or four-rowed variety. The comparatively small types of corn are grown, the size varying with the section and the probable amount of available water. Under the most extreme conditions a rather flinty type of corn with a 5- or 6-inch ear is grown, while under more favorable conditions they grow an 8 to 10-inch ear decidedly more dent in type. Alfalfa grows abundantly in the bottom lands where sheet water is within reach of the deep roots. It is grown, but with less certainty of production, on the uplands. For seed purposes it is sometimes grown in rows. Millets and Sudan grass are successfully grown throughout the entire area. Sorghum for forage is probably the predominant annual forage crop. Grain sorghums are not extensively grown.

256. Cultural Practices.—Small grain is almost universally planted with a grain drill in preference to broadcast seeding. Corn is usually planted with a lister. Early planting is advisable for all small grain crops, as it tends to get them ahead of the usual dry, hot weather of midsummer. Corn is planted early in the frost-free period.

The usual rates of seeding are much less than under more humid conditions. The following are the common rates per acre: Winter wheat, 40 to 50 pounds; spring wheat, 4 pecks; oats, 6 pecks; barley, 6 pecks; corn, one stalk to 18 to 24 inches in the row.

Harrowing small grain is not extensively practised. On the average it has not proved beneficial. Under certain conditions, where ground cracks or where there are many young weeds that may be killed, harrowing might be advisable. The harrow is often used to break down standing cornstalks where grain has been sown in the corn.

Deep plowing, or in fact stirring the soil in any manner to a greater depth than ordinary 6- to 8-inch plowing, has not given average increased yields nor shown any particular advantage in overcoming drought. It has greatly increased the labor cost and lessened the acreage that a man with a given equipment can handle. After plowing, the furrow slice is usually worked down with a disc or harrow. The subsurface packer is not in general use but may have an important place, especially where small seeded crops such as grass or alfalfa are to be sown. Getting the soil firm is an important factor, since the loose soil will dry out much more quickly than the more firmly packed soil.

257. The Farming Unit.—In the dry farming section the farming unit is comparatively large. Intensive cultivation is not generally practised. Broadly speaking, climatic conditions are more important than tillage methods in determining yields. Naturally when the differences of yield that come from climatic causes are greater than differences due to other factors, cost of production becomes the most important factor and the system of farming tends to become increasingly extensive.

258. Live Stock.—In order to equalize income, live stock is almost essential to farming under our dry land conditions. Where strict grain farming is followed, a crop failure is apt to be very serious; but where both grain and live stock are raised, there is the chance, if the necessity arises, of selling off some of the live stock in order to get through the period of stress. Animals are also important in that they furnish a profitable market for the roughage produced on the farm. Without stock, this roughage would have little value and probably would be wasted.

259. The Possibilities for Dry Farming.—Even under the climatic limitations, the possibilities for dry farming are good for the man who will work in accord with nature. He needs a reasonable amount of capital and a clear understanding of conditions. He should not allow himself to be hampered by false hopes and theories, nor try to farm by hard and fast rules. Under the erratic climatic conditions of that section, any system of farming to be successful must be sufficiently elastic to meet conditions as they arise. By studying the conditions as they exist on his own farm and carefully considering the various factors that influence crop production, he can determine the kind and amount of labor that should be expended. By doing each operation in the most advantageous way and as nearly as possible at the right time, the labor required can be materially decreased, more land gotten over with a given amount of equipment, and the cost of production lowered.

DRY FARMING PRACTICES IN SOUTH DAKOTA

By Manley Champlin, Formerly Associate Professor of Agronomy, Brookings, S. D.

The average rainfall in South Dakota varies from 25 inches in the southeast to about 14 or 15 inches in the northwest section. Most of the rain comes during the spring and summer months. There is usually a light snow-fall and comparatively little rain in the autumn. The months of April, May and June are generally well provided with moisture and occasionally good rains occur in July and August, but there are short periods of drouth

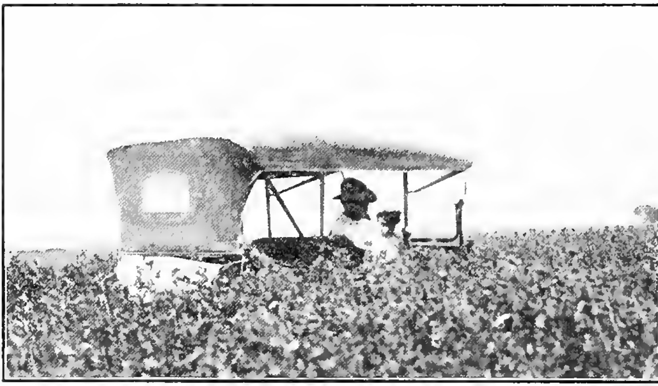

Fig. 101.—Sweet Clover.

A crop that is coming into popular use in parts of Nebraska and South Dakota.

in some parts of the state nearly every season and successful farming or crop production depends to a very great extent upon the success which one has in overcoming these short periods of drouth. There are occasional seasons such as the year 1911 when certain crops are failures in spite of good tillage and crop rotation methods, but there has not been any season since the State was settled that has not been favorable to some crops. It therefore is excellent policy to diversify as much as is practicable in order to avoid total loss in any one season.

260. Summerfallowing.—Summerfallowing is practised very little. Successful crops are frequently produced on summerfallow, but on account of the loss of the income from the land for a season incident to this practice, it has never become a common one in the state. When summerfallowing is practised the land is plowed 5 or 6 inches deep in June, disked three or four times during the summer to keep the weeds down and usually sown to winter rye during the latter part of August. This practice gives good results and could be more generally adopted in the western two-thirds of the state.

261. Crop Rotation.—Crop rotation is a very important factor, not only in insuring safe crop production, but also in increasing the yield and improving the quality of the crops. Fortunately, it is possible for the farmer here to rotate his crops to the best advantage of the land and at the same time produce crops that are profitable. Among the cultivated crops corn is easily first. In fact it is the most important cereal crop of the state. Potatoes, amber sorghum, navy beans and soy beans may also be grown as cultivated crops. Oats, barley, spring wheat, emmer, spring rye and winter rye as well as proso and millet furnish wide choice among the small grain crops. Sweet clover is the leading biennial legume. It is hardy so far as we know in all parts of the state and it is easier to secure a stand of sweet clover than any of the other small seeded legume crops. Red clover can be grown in the southeastern and eastern sections, but it is very difficult to obtain a stand in the drier parts of the state with this kind of clover. Canadian field peas and oats are sometimes grown together as hog pastures or as a temporary hay crop. Soy beans are occasionally mixed with corn for silage. Alfalfa succeeds in nearly all parts of the state and may be used as a permanent meadow or may be treated as if it were a short-lived crop and used in the rotation. Experiments conducted at the State Agricultural College experiment farms in various parts of the state indicate that a three-year rotation of corn, small grain and sweet clover is very satisfactory. This rotation is easy to take care of and is satisfactory from the economic or business standpoint. It is also a good rotation for maintaining the soil in good condition. It is handled about as follows: the land is divided into three parts approximately equal, the first field is plowed 6 or 8 inches deep in the fall. In the spring this field is harrowed to break up the lumps and level the ground. About the first of May or a little later, it is double disked to further pulverize the seed bed and kill weeds. It is then harrowed again and planted to corn, potatoes or whatever cultivated crop may be desired. This crop receives thorough cultivation, usually from three to five cultivations during the season to keep it as free from weeds as possible. The following year this land is double disked and dragged in the spring without plowing and is sown to an early maturing variety of grain with 10 or 15 pounds of sweet clover per acre. If alfalfa is preferred, it may be substituted for the sweet clover. The grain crop is harvested leaving the stubble to protect the clover or alfalfa plants during the second winter. The third year this field will be producing sweet clover or alfalfa. A crop of sweet clover hay will be ready to cut by the 10th to the 15th of June. A seed crop will be ready late in August or early in September. If in alfalfa the crop will be cut from one to three times according to the abundance of moisture during the season. It is not best to cut it after the first of September as the alfalfa is more likely to winter in good shape with a liberal aftermath. After the rotation is in full swing there will be one field in corn or other cultivated crop, one field in small grain and one field in legume, either sweet clover or alfalfa. Variations in this plan of rotation are easily made and work out very nicely. In fact the rotation is so adaptable that it can be made to fit almost any requirement. It can be changed to a four-course rotation by growing two crops of corn in sucession, followed by the grain and sweet clover or to a five-course rotation by growing corn in one field for silage, following it with winter rye, following the rye with corn for grain and the corn in turn with spring grain and sweet clover or alfalfa. The principle involved in sucessful crop rotation in South Dakota consists in providing for a cultivated crop preceding the grain crop in order to conserve moisture and render the seed bed firm and in good tilth for the seeding of the grain and the hay crop. Yields in favorable seasons are often doubled by this practice and in unfavorable seasons yields are secured that are very satisfactory while the crop on land put into grain continuously may prove a total failure.

262. Drought-Resistant Crops.—In the early years of South Dakota's development great difficulty was experienced because the crops which the settlers attempted to grow were not of the proper variety. Through the efforts of the United States Department of Agriculture and the State College of Agriculture crops have been introduced from south-central Russia and other countries where conditions are somewhat similar and thoroughly tested in comparison with varieties from other sources, until the ones which were best for South Dakota conditions were determined. After introduction and testing, these varieties have been distributed through the efforts of the South Dakota Experiment Association until at the present time nearly all of the crops grown in the state are of adapted varieties. Odessa, S.D. 182 barley can be grown successfully throughout the state. Manchuria, Minnesota 105 is well adapted to the eastern section. Among the oat varieties, Sixty Day S.D. 165 and its selections have proved best and are generally grown. Two medium late varieties are fairly popular, namely, the Swedish Select S.D. 112 and the Silvermine. Durum wheat is represented by Kubanka S.D. 75 and a pedigreed variety selected from the Kubanka, Acme S.D. 284. Common spring wheat is almost exclusively Marquis or Preston procured from Canada. Swedish S.D. 348 and Dean S.D 177 and a selection from Dean, the Advance S.D. 1030 are hardy varieties of winter rye. Grimm S.D. 162 and common alfalfa grown in South Dakota for a long time are the most commonly grown and best adapted varieties of alfalfa. There is some Turkestan grown, but its popularity has not increased with that of the Grimm and the South Dakota Common. Cossack, a new variety, is proving hardy and becoming popular in some localities. White Spring emmer is the only variety of emmer grown. Tambov S.D. 80 is the best proso and Kursk S.D. 79 or a selection from Kursk known as Shelley S.D. 348 are the best adapted millets. Corn varieties have been introduced and developed by corn growers in nearly every section of the state. In the southeastern section A. J. Wimple has developed the Wimple's Yellow Dent, in the northwestern section the late Logan Slaughter has carried on the work of selecting and increasing the large strain of Squaw corn known as Slaughter's Squaw corn. The Northwestern Dent variety has given a good account of itself in the entire northern section. In the central section the Minnesota 13 Yellow Dent and the Dakota White Dent are quite generally grown.

Conclusions

As a result of the introduction of hardy adapted crops and the increasing practice of crop rotation and diversified farming in conection with the production of registered and high grade live stock, the agriculture of South Dakota is rapidly getting upon a permanent basis and the prosperity of the state which depends entirely upon its agriculture has constantly increased. The state is growing rapidly in population. If a proper proportion of this population interests itself in farming so that the farm labor problem gradually becomes less acute, there is every reason to hope for a continuation of this prosperity, due to increased farm production which can be attained by the better farm practice that will be possible with more help available.

In making these statements, we have tried to make it clear that successful crop production in this state does not depend upon any one minor practice, such as harrowing the growing crop, harrowing fall plowing, excessively deep plowing, packing or sub-soiling, but depends upon a continuation and combination of all good farm practices in connection with the use of good crop rotations and good seed of adapted varieties with requisite attention given to keeping up the fertility of the soil and improving its physical condition by the addition of barnyard manure and the inclusion of clovers, alfalfas and similar crops in the rotation system.

DRY FARMING PRACTICE IN NORTH DAKOTA

By W. R. Porter, Superintendent of Demonstration Farms for North Dakota.

The term dry farming is usually considered to include those types of farming that are practised in areas having less than twenty inches of annual rainfall. If this definition is correct parts of the Red River Valley in North Dakota and all the region west of the Red River Valley come within the dry farming area.

The ability of the soil to hold moisture is probably a more important factor in the success or failure of a farmer than the amount of rainfall annually received. Thirty inches of rainfall on a loam soil with a sand or gravel subsoil will probably not be as effective in producing crops as fifteen inches of rain on a loam soil having a clay subsoil. The place for summer tillage under North Dakota conditions is where the farms are too big to use all the corn or handle all the potatoes that might be produced if these crops were grown or where perennial weeds such as the sow thistle, and quack grass, have got a hold on the land. Summer tillage is the only method we have of combating these weeds.

263. Summer Tillage.—Land which is to be summer tilled, particularly if infested with the above named weeds, should be plowed about 3 inches deep the latter part of October. This has two effects, it saves moisture and exposes the weed roots to more or less winter killing. The latter part of May or early in June this land should be plowed five to six inches deep and after that it should be cultivated at frequent intervals with the Spring Tooth Duck Foot Cultivator.

The bare fallow has no place in a good system of crop rotation in North Dakota. The climate of North Dakota is a little too cold to grow sorghum. Corn, however, does well and as a feed crop it should always be used in preference to summer tillage as it gives a good return in feed and the land is in just as good shape to produce a small grain crop the following year.

Potatoes are a profitable crop and they leave the land in excellent condition for small grains. One acre of potatoes requires approximately as much labor as five acres of small grain and will probably give more than five times the return per acre.

264. Stubble Land.—In the heavy soil areas stubble land should be plowed as soon after harvest as possible. This land should be packed with a subsurface packer or with a disc run straight, the day it is plowed. The next spring such land may either be disced or harrowed or both in order to make a compact fine seed bed. The important thing is to have the seed bed compact with a rather coarse mulch on the surface and not too smooth. Light soils should be left for spring plowing. They should be subsurface packed and seeded the day they are plowed, if possible. Only rarely should the harrow be used on lighter, sandy soils in the spring.

265. Grass Land.—One of the best ways of utilizing grass land is to break in the spring, pack down level with a weighted disc or roller and disc until a fine mulch is on the surface and seed to flax. The other method is to break in the summer time and double-disc early the next spring, harrow until the seed bed is fine and seed to wheat.

266. Rotations.—Profitable rotations require small grains, legumes and cultivated crops. The simplest profitable rotation of this character for North Dakota is potatoes or corn, seeded to wheat without plowing and with the wheat sow sweet clover. This would be a three-year rotation consisting of wheat, sweet clover, and corn or potatoes. A longer and more practical rotation would be to have a field in each of corn, wheat, sweet clover, potatoes, wheat, oats or barley, flax and one field seeded permanently to alfalfa.

In the dry region it is very important to maintain the organic matter of the soil as this constituent has great ability to hold moisture and prevent the soil from drifting. Legumes are necessary to keep up the nitrogen content of the soil and at the same time they furnish the best kind of feed for live stock which in turn helps to keep up the fertility of the soil and at the same time give a permanent income.

267. The Best Crops.—The best varieties of wheat for the dry region are Marquis and the two Durums, Acme and Kubanka. Early varieties of oats should be used, such as the "Sixty-day", Early Mountain, and Swedish Select. Of the mid-season varieties the Siberian White and the Lincoln are the best. One of the wilt-resistant varieties of flax should be used such as N.D. 114, 52 or 155. The two-rowed barleys, such as Swan Neck and Hannschen are the most productive. The yellow variety of sweet clover (Melilotus officinalis) is probably a little superior to the white (Melilotus alba) variety. The Grimm is the only variety of alfalfa hardy enough for our conditions. Brome grass is the hardiest and most palatable grass. Western rye grass is also very good. Sunflowers may be used as an intertilled crop or as a substitute for corn as a silage crop.

268. The Rate of Seeding.—In the drier parts the rate of seeding should always be less than in humid sections. In western North Dakota three-fourths of a bushel of wheat is sufficient on most farms. One and one-fourth bushels of oats and barley are plenty to seed.

269. Weeds are a great nuisance throughout the dry farming section. Wild oats is probably the worst of our annual weeds. The seed will not grow in the fall but readily grows and matures in fields of small grain. A good system of crop rotation is necessary to keep this weed in control. The Russian thistle is present everywhere in the dry regions. In the wetter years it causes but little harm but in the dry seasons it often grows up and smothers crops and makes their harvesting difficult. It may be used for hay or silage and if fed with other feeds it has been found fairly nutritious. A good system of crop rotation is also very beneficial in holding this weed in check.

270. Soil Drifting.—This sometimes causes the total destruction of crops. It is usually the result of the continuous growing of small grains, particularly if alternated with summerfallow or summer tillage. Prevention of soil drifting is preferable to curing it after it starts. The growing of grass crops in the rotation and the return of all the organic matter such as straw to the soil, in the form of manure and the leaving of the surface soil rough will prevent soil drifting. Where the soil is light and so deficient in organic matter that it drifts badly it should be spring plowed only. Strips of straw should be scattered over it at intervals and the surface of the soil should be left rough and the land seeded the same day it is plowed.

Great care must be used in harrowing the growing crop. This practice usually makes the crop somewhat later but it is effective in thinning out weeds, particularly those starting from small seeds such as mustard, buckwheat and pig weed. Harrowing should only be done with a light harrow on a firm soil after the crop is 5 or 6 inches high and on a warm sunshiny day. Heavy soils should be harrowed immediately following the plow as this breaks up all the lumps and leaves a good surface mulch.

Packing is best accomplished by using a disc set straight and going over the soil the day the land is plowed. The subsurface packer is also a good implement to use. Early after harvest disking probably is beneficial but it comes at a time when the labor supply on the farm is in great demand for other necessary operations. Plowing deeper than 6 inches probably does not pay.

A farmer in the dry region should aim to get one-half of his income from live stock and live stock products. In the good years when he has an abundance of feed and straw, this should be carried over for the years of excessive drouth. This together with what he can produce by good cultivation will assure him a steady income even through the most adverse seasons.

DRY FARMING IN MONTANA

By Alfred Atkinson, President Montana State College of Agriculture. (Formerly Professor of Agronomy).

Dry farming in Montana has been practised in sections of the state for a long period of years and is now thoroughly established. In the light of the experiences gained, the following stand out as the essential requisites which must be met if success is to be gained.

271. Limited Supply of Moisture.—The conditions for crop growth in the dry farm sections are most favorable with one exception. The soils are rich in plant food and the temperatures are favorable, but the supply of moisture is below the amount commonly considered necessary. A system must, therefore, be adjusted to make the most efficient use of the moisture present. The chief ways of doing this are conserving moisture by careful tillage and the selection of crops and the use of crop management methods that make the most economical use of moisture.

The saving of a maximum amount of valuable moisture is important to insure plant growth and also to make available the plant food in the soil. Continuous cropping results in low yields, chiefly because the valuable plant food in the soil becomes used up. It is, therefore, necessary to make light moisture demand occasionally in the summer time in order that there may be heat, air and moisture present to bring the plant food into condition to be used by growing crops. The common method of establishing these conditions is by means of the summer-fallow. In many sections, the tendency has been to substitute cultivated crops, such as corn or sunflowers, in place of the fallow. Where careful tillage is followed, moisture may be conserved about as effectively in a corn field as in a bare fallow and the feed produced is most valuable in maintaining and adding to the number of live stock kept. It, therefore, seems essential that the dry farm field should be fallowed or planted to an intertilled crop not less than two years in five.

272. Early Maturing Crops.—In many dry farm sections of the West, the heavy precipitation falls between the first of April and the 15th of July. Under this condition, it seems wise to plant crops that will make most of their growth during this period and be far enough along to fill in good shape before the hot, dry weather starts in. Fall-sown wheat commonly matures early and the heads fill before the dry period. Such early maturing strains as the Marquis Wheat, the Sixty-Day Oats and the White Hulless Barley are rapidly growing spring strains and they should be used on the dry farm. The late maturing strains, which produce the heavy straw returns, commonly exhaust the moisture in the soil before the grains are developed and this means a light grain return.

273. Light Seeding.—To economize the moisture present, light seeding should be practised. Under humid or irrigated conditions, two bushels of seed is a fair rate of planting, while on the dry farms, from three to four pecks has given better returns. The light seeding limits the straw production and carries more moisture over foi the maturing of the grain.

The dry farmer, who would play safe, must have more than one source of income. Where land returns on the year's effort are all tied up in one grain crop, a dry season has a very disastrous effect. Every dry farm should carry some live stock, so that the risk of the dry period is not so great. Even if forage may not be produced during the dry spell, the live stock may be sold to some extent and this will insure some income. Corn or Mammoth Russian sunflowers, if carefully cultivated, give large silage returns, and with the winter and also the summer silo, the pasture shortage may be supplemented. Many successful dry farmers are filling one or more silos and carrying them over to feed during the following summer. This, as a pasture supplement, is most valuable.

Dry farming is not gambling on a wet season. It is so conducting the operations of the farm that there is fair prospect of returns every year.

DRY FARMING PRACTICES IN THE RED RIVER VALLEY

By T. J. Harrison, Professor of Field Husbandry, Manitoba Agricultural College, Winnipeg.

The Province of Manitoba may be divided into three agronomic zones, i.e., Eastern, Southwestern and Northwestern. It is not possible at this time to state definitely the boundaries of these districts because no detailed climatic and soil survey has been made. The Eastern section or the Red River Valley may, however, be described as that portion occupying the basin of the old glacial lake Agassiz. It is approximately that part of the Province which lies between the 96th and 98th meridians, and south of the 51st degree of latitude. The Southwestern and Northwestern sections are west of the 98th meridian and are separated approximately by the 50th degree of latitude.

The fundamental differences in farming methods in these districts may be summarized as follows:—

Southwestern: Except for the lack of moisture the climate in this district is favorable to the production of any of the small grain crops. The average annual precipitation is only about 15 inches. The farm practices are, therefore, adapted to the conservation of moisture.

Northwestern: In this portion of the province there are many variations in climate due to the mountains and lakes. The annual precipitation is about 18 inches. This with the cool climate and low evaporation is usually sufficient moisture to produce good crops. The early fall frosts influence the type of farming more than moisture conservation; therefore, the growing of early ripening varieties and the use of methods of soil management that will induce early maturity are the general farm practices.

Eastern or Red River Valley: The climate of this district is more favorable to crop production than that of any other portion of the Province. The annual precipitation is about 20 inches. A large amount of this moisture comes during the growing season and if not wasted is more than sufficient to produce maximum crops. With the standard varieties now in use on most farms there is practically no danger from fall frosts. The methods of farming are based as much upon the control of such factors as weeds, plant diseases and insects as they are upon the conservation of moisture. Fortunately, however, methods that control weeds and insects are usually the same as methods that conserve moisture.

274. The Place of the Bare Summerfallow in the Red River Valley.—Since the pioneer days when grain growing became prevalent the summerfallow has been the popular method of preparing stubble land for crop. The purpose of summerfallow is to prepare, during the slack season, a large acreage of land for crop and to conserve moisture. Before the advent of the perennial sow thistle the summerfallow was introduced into the rotation every fourth year. Since the control of this weed has become important it is now necessary in most instances to fallow every third year. Where this practice is followed profitable crops are ensured.

275. Methods of Fallowing.—The methods of fallowing are determined quite as much by weeds and other factors as by the need of moisture. There are three methods practised although each has many modifications under different conditions.

1st. Using cultivator only.

2nd. Plowing in the fall and cultivating the following season.

3rd. Plowing in the spring and cultivating the balance of the season.

In the first method cultivation is done by the use of the stiff-shank wide duck-foot cultivator. From five to eight cultivations are required during the season to eradicate perennial weeds. The work is started the last of May or the beginning of June and is repeated as frequently as necessary to keep the land black until freeze-up. The first stroke is necessarily shallow but the depth is increased each time until the final cultivation is five or six inches deep. This ensures the shares cleaning and thoroughly cutting off the roots of the perennial weeds.

The second method consists of plowing the land five inches deep in the fall, and in the following year cultivating with a duck-foot cultivator. Six cultivations are usually necessary to control the weeds.

The third method with some modifications is the one that is in general use throughout the district. The land is plowed in June about six inches deep, and is cultivated three to six times afterwards to keep down the weeds. This method is often improved upon by either skim plowing or disking in the previous fall as soon as the crop is off the ground. This practice induces the germination of the annual weed seeds in the fall and early spring. For fields infested with wild oats this method is to be commended.

276. Substitutes for Summerfallow.—Intertilled crops, such as corn, sunflowers and roots, can be grown in the Red River Valley for fodder every year with a fair degree of success. They leave the soil in a better condition for the succeeding crop of wheat than summerfallow. The wheat crop has shorter straw and is, therefore, less subject to rust. Sow thistle cannot be successfully controlled by intertilling and the average farmer cannot utilize the crop from 80 to 100 acres of corn, sunflower or roots. While this method may be profitably practised on a limited acreage, it will never fully displace summerfallowing as long as the present system of grain farming is practised.

277. Preparation of Stubble Land for Crop.—In preparing stubble land for crop it is conceded in the Red River Valley that fall plowing is necessary. It requires the mellowing effect of frost and moisture to put the heavy clay soil in condition for spring seeding. Spring plowing leaves the land so hard and rough that a seed bed cannot be made; so if the land has not been plowed in the fall, cultivation in the spring will give better results than plowing. This method of preparing stubble land for crop without the use of the plow will give fair results if the land is clean, but as the average farm contains several kinds of noxious weeds this method cannot be recommended.

278. Preparation of Grass Land for Crop.—In the preparation of grass land for crop the best results are obtained by breaking two or three inches deep in June or even later and back-setting five inches deep in September. After the land is backset it should be packed and disked sufficient to keep down the weeds. Although this means the land is idle for the first year the succeeding crops will more than compensate for the loss.

279. Rotations.—The question of the most profitable rotation is one that has not been conclusively answered, but is one that is now under close observation by many practical farmers and by the experiment stations. From the information on hand the following would seem to be the most profitable where straight grain growing is followed:—

1st Year—Summerfallow.

2nd Year—Wheat.

3rd Year—Oats and barley.

Where mixed farming is followed the following rotation has given good results and with modifications to suit the needs of individual farmers is being adopted:—

1st Year—Fallow, corn, sunflowers and roots.

2nd Year—Wheat seeded down to grass.

3rd Year—Hay.

4th Year—Pasture until after haying, then break and backset.

5th Year—Wheat.

6th ear—Oats and barley.

280. Importance of Organic Matter in Soil.—The maintenance of organic matter in the soil is essential to keep it friable and prevent baking. After a heavy rain the fibre-depleted soil bakes and cracks and much moisture is lost. In this district, with the exception of some of the lighter soils here and there, soil-drifting is not a problem. Within the last few years farmers throughout the valley have been making more use of farmyard manure and grass and clover crops for the purpose of maintaining the soil fibre and returning some plant food to the older soils.

281. Crops.—In this district, wheat, oats, barley, rye, flax, grass, clover, corn and sunflowers are the crops that may be considered to give the best results.

Wheat: This crop has been the main source of wealth in this district in the past. It will also continue to be the principal cash crop in the future unless the ravages

Fig. 102.—Sunflowers for Silage, Agricultural College, Winnipeg.

of rust make its production unprofitable. At the present time 95% of the wheat grown is of the Marquis variety. The remainder is made up of Red Fife and other less-known strains, such as Red Bobs and Kitchener. Durum Wheat, of which Kubanka is the chief variety, is also being grown. The Red Fife is later maturing than the Marquis, and, therefore, is more subject to rust. The Red Bobs is somewhat earlier but does not yield nearly so well. The Kitchener matures about the same time as Marquis but on the heavy clay soils gives a poorer yield. The Durum wheats are of more recent introduction. If a ready market can be found for this type and if they prove to be rust-resistant they may become more popular.

Oats: This crop does not thrive so well in this district as in the Northwestern. For that reason it is not considered one of the important cash crops. It is, however, largely grown for feed purposes; part of the crop is threshed and part used for cured fodder in the sheaf. Less attention has been paid to the varieties of this crop, and in nearly every municipality there will be found as many as ten to fifteen different sorts. The results at the experiment station, however, indicate that the three best varieties are Banner, Gold Rain and Victory.

Barley: The soil of the Red River Valley seems well adapted for the production of this crop. This, coupled with the fact, that it can be used for weed control, because of its early maturing habit, makes it one of the cash crops that is receiving more and more attention each year. Its main use, however, as yet is for hog and cattle feed. The three best varieties are O. A. C. 21, Manchurian and Mensury.

Flax: Where conditions are favorable excellent flax crops are produced. Flax, however, is considered one of the new land crops, and as a large percentage of the land has been brought under cultivation, this crop is not being grown to as great an extent as in the past. The average farmer has paid very little attention to varieties of flax. The most common variety grown is Premost, while some of the wilt resistant strains from the North Dakota Experiment Station are also on the market.

Rye: A limited amount of winter and spring rye is produced. The difficulty with winter killing has prevented the winter sort becoming more common. Spring rye has given such a small average yield that it has not displaced any of the three foregoing cereals. Because of the small amount of this crop grown there are no varieties being recognized by the farmers.

Grasses: With the introduction of weeds and the need for diversification of crops more attention has been given each year to grasses. Timothy remains the most popular, largely because of the cheapness of the seed and its popularity in the Eastern Provinces and the States. Western Rye, Meadow Fescue and Brome are grown in limited quantities.

Legumes: Little attention has been paid to legumes, but where they have been tried out Alfalfa and Sweet Clover seem to give best results, while in most years the common Red Clover and Alsike can be grown with a fair degree of success. This is especially true east of the Red River.

Intertilled Crops: As mentioned previously, fodder corn, sunflowers and roots are the intertilled crops that are grown in this district. The root crops have never come into favor because of the expense in handling and the amount of hand labor necessary. A five- to ten-acre patch of fodder corn is quite common on the farms throughout the district; where there is a silo a greater acreage is grown. The success with sunflowers as silage has displaced corn on some of the larger farms. The varieties of corn usually grown are Northwestern Dent and Minnesota No. 13. So far Mammoth Russian is the sunflower that is being used.

282. Rate of Seeding.—The rate of seeding with practically all crops is much heavier in this section than in most of the Great Plains Area. This is due to the comparatively heavy precipitation and the need to crowd out all other plants. Wheat is sown at the rate of a bushel and three-quarters per acre, oats—two and one-half to three bushels per acre, barley—two to two and a half bushels per acre, and all other crops at an equally heavy rate.

283. Dates of Seeding.—Experience has shown, other things being equal, that the earlier the crop, the heavier the yield as it is less liable to insect damage and plant diseases. Wheat should be sown as soon as the land can be worked; oats and barley about the first week after the land is fit for cultivation. Grasses and clovers are usually sown sometime between the 15th of May and the 15th of June; sunflowers during the month of May, and corn between May 20th and June 10th.

284. Weeds, Plant Diseases and Insects.—These are the three factors that cause the greatest loss throughout the district. Among the most pernicious weeds are perennial sow thistle, wild oats, Canada thistle, French weed and wild mustard. The plant diseases that have taken the greatest toll from the farmers are rust, smut and wilt. The insects are cut-worms, western saw-fly and grasshoppers.

Conclusion

The successful farmers of the Eastern zone are those who have selected suitable crops and varieties and have adapted their farming practices to the control of weeds, plant diseases and insects. Incidentally these practices conserve moisture but this has not been the primary consideration. The use of the bare fallow and other farming practices mentioned above have produced profitable crops practically every year in the Red River Valley.

DRY FARMING IN WESTERN MANITOBA

By W. C. McKillican, Superintendent Experimental Farm, Brandon, Man.

The average precipitation for the ten years, 1911-1919, at Brandon, Manitoba, was 16.33 inches. The area which this represents is therefore of a semi-arid character and farm practices which conserve soil moisture and utilize it to the greatest degree are necessary for success in agriculture.

Summerfallow.

285. Importance of the Fallow.—The corner stone of dry farming in Western Manitoba is the summerfallow and so is it likely to continue for many years. Grain crops have enjoyed almost a monopoly of crop raising, and the summerfallow has served to clean the land, to conserve the moisture from one year to another and indeed has made grain growing possible in the pioneer and exploration stages of the country's development.

286. Methods of Fallowing.—The main features of a good summerfallow as practised in this region are early plowing and thoroughness of after-cultivation. Both of these derive their importance from their efficacy in preventing the loss of moisture through weed growth. By early plowing we mean the first half of the month of June. May plowing has given no advantage over June but June has a very decided advantage over July. Depth of plowing is also generally believed to be an important feature of good summerfallowing. I believe this is usually correct, though our experimental results at

Brandon have not corroborated this opinion. In the control of annual weeds one plowing followed by bare cultivation is better than two, but where couch grass or other persistent perennials are to be fought two plowings are justified.

The best implement for the cultivation of summerfallows is the stiff-tooth, duck-foot cultivator. Disc harrows and drag harrows should be used very sparingly if at all. Only in exceptionally loose, soddy or lumpy land is the use of the packer justified. A very full set of experiments at Brandon show no returns from its use.

287. Dangers of Fallowing.—The dangers of summer fallowing are soil exhaustion and soil drifting. It makes no provision for the return of plant food. This result (loss of fertility) has not been felt as yet in Manitoba, but it is something that plans for the future must take cognizance of. Soil drifting is here and is perhaps the biggest difficulty in Western Manitoba farming today. The grain and summerfallow system of the past must be modified to control it.

288. Substitutes for Summerfallow.—Corn is the best substitute for the summerfallow. It should not be used in very dirty fields as the cost of cleaning is too great. The crop of grain produced on a well cultivated corn field will usually equal and often exceed that on summerfallow.

Other intertilled crops such as mangels, turnips, potatoes or sunflowers, may also be used in the same way as corn, but none are so satisfactory as corn so far as effectiveness as a substitute for fallow is concerned.

A pastured fallow is sometimes substituted for bare cultivation. It is not satisfactory in the real farming districts; the pasture crop uses too much moisture, and if there are perennial weeds, persistent cultivation is necessary to kill them.

Hay crops may be used as a partial substitute for summerfallow. For this method to be successful the sod must be plowed early so as to be well rotted and to provide for the accumulation of moisture. At the best there will not be as much moisture conserved as in a bare fallow but practical results have been satisfactory and it is only by the use of sod-forming crops that the soil drifting menace can be overcome.

ROTATIONS.

289. Rotations now in Use.—The standard rotation generally in use in the western part of Manitoba is sum-

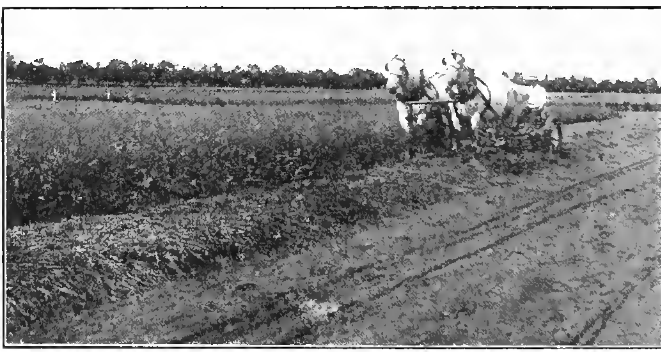

Fig. 103.—Cutting Western Rye Grass and Alfalfa at Branden Experimental Farm.

merfallow and three crops of grain. Wheat practically always follows the summerfallow, the second year after fallow being sometimes wheat and sometimes oats and the third year oats or barley. In the early grain growing years on a fertile soil this was found to be very satisfactory. The summerfallow once in four years was found to be sufficient to conserve moisture and keep the weeds at least partly in check. This rotation with modifications represents most of the farming in this region. However as has already been indicated soil drifting is proving its inadequacy for a permanent system, and the great increase in weeds also indicates the need of a change.

290. Improvements in Rotation.—These have been indicated generally in discussing substitutes for summerfallow. Greater diversity of crop is needed, including, first a sod-forming hay crop to return fibre to the soil and make feed for live stock which will result in manure. Second, the use of corn or other inter-tilled crop to provide additional live stock fodder and to cheapen the cost of production of wheat. Third, fall rye may be needed to control soil drifting where it is so bad that grasses could not be started. A practical rotation which combines these features is as follows:

1st Year—Wheat.

2nd Year—Oats.

3rd Year—Summerfallow and partly corn.

4th Year—Wheat or, if necessary, Fall Rye, seeded down with grasses and clovers.

5th Year—Hay.

6th Year—Hay or pasture plowed up in midsummer or earlier, and prepared for wheat.

This rotation has one half the land in grain crops, one sixth in hay, one sixth in hay or pasture for the early part of the season and afterwards fallow, and one sixth in summerfallow and corn. The seeding down to grasses is on summerfallow or corn land which is the only place to insure a catch. The wheat which is our main crop is given the two most advantageous years in the six.

This rotation is offered as a practical suggestion, which may be altered to suit varying conditions.

290a. Dry Farming Crops.—

Wheat:—The effect of shortage of moisture on a crop is to make it sacrifice leaf and stem for the development of the seed. Dry areas are consequently best fitted for the production of seed-bearing crops. Wheat is the great seed-bearing crop of Manitoba. Wheat made Manitoba, and will continue to be its chief support for many years to come. The object of diversification of crops, introduction of new crops and live stock raising is not to replace wheat, but rather to make the continuation of profitable wheat growing possibile, where an attempt to grow nothing but wheat is suicide for wheat growing.

Marquis is at the time of writing (1920) the best variety of wheat for Manitoba. Red Fife has been entirely replaced and rightly so. Red Bobs has had a somewhat sensational period of advertising but is proving distinctly inferior. Kubanka, a durum variety, is being introduced to some extent on account of drought resistance and supposed immunity from rust. Its low milling value makes it distinctly undesirable unless rust should become so bad as to make the growing of Marquis or other white-flour-producing wheats impossible. Ruby is a new variety somewhat earlier than Marquis and of similar quality which has not been fully tried out, but may be of importance for northern districts.

Oats.—Oats fill an important place in Manitoba farming. The Banner and Victory varieties are the leading favorites.

Barley.—Manchurian and O. A. C. No. 21 both six-rowed varieties, are the best in use at present.

Fall Rye.—Fall Rye has been used to some extent as a means of controlling soil-drifting and combating wild oats and is proving very valuable for these purposes.

Corn.—The great value of corn in a crop rotation has already been mentioned. Northwestern Dent and Minnesota No. 13, are good varieties for this territory.

Sunflowers.—Sunflowers have been proven to be a good silage crop and can fill the place of corn where it does not succeed.

Mangels and Turnips.—Are not extensively grown but can be grown successfully.

Grasses.—Brome grass is our most drouth-resistant grass and is used to quite a degree for permanent hay and pasture. Its persistence makes it undesirable where more easily handled grasses will succeed. Western Rye grass is probably the most generally useful grass for this territory. It stands drought well, yields almost as well as brome grass and being easily plowed up is a better rotation grass. Timothy is too dependent on moisture and the same is true of all grasses commonly grown in humid countries.

Leguminous Hay Crops.—Alfalfa is the most valuable of these. It is grown with great success at Brandon Experimental Farm and by some few private farmers but is generally considered throughout this region as impossible to grow successfully. I believe the future will see it grown very much more generally, and that it will contribute very largely to the solution of farming problems. Sweet clover is being introduced to a considerable degree and has a great value where alfalfa cannot be grown. Its productiveness, hardiness, free seeding and adaptability give it a great value as a pioneer leguminous crop, but its coarseness and short life lessen its value. Red clover is only grown successfully in limited areas and can hardly be recommended for general use; the same is true of Alsike. Neither of these are really dry farming crops.

DRY FARMING PRACTICES IN THE PARK BELT OF ALBERTA

By G. H. Hutton, B.S.A., Superintendent of Agriculture and Animal Industry, C.P.R., Calgary.

291. The Place of the Summerfallow.—As a general proposition it is not necessary to summerfallow in Central Alberta. The average precipitation during the year is in the neighbourhood of seventeen inches, sixty per cent. of which falls during the growing months. Other conditions than the amount of rainfall influence crops, such as the kind of soil on which the rain falls, its depth, and character of subsoil, velocity of prevailing wind, and amount of protection against such winds afforded by trees. The soil in the Park Belt of Alberta is a heavy black loam as much as three or four feet deep in many places, resting on a clay subsoil; there is therefore, practically no loss of moisture below, while the rate of evaporation is slow because of the fact that wind is not a serious factor to be reckoned with, also the large amount of humus in the soil holds the moisture tenaciously. Under such conditions a summerfallow stores such a large amount of moisture and liberates such a high percentage of nitrogen that the following crop lodges ninety per cent. of the time, fails to fill well, and is difficult to harvest.

292. Suitable Rotation for the Park Belt.—A rotation which has given excellent results is as follows:—

1st Year.—Hay; manure during winter, 12 tons per acre.

2nd Year.—Pasture.

3rd Year.—Pasture to July or early August, plowed 6 inches deep and cultivated.

Fig. 104.—Alsike Clover and Timothy, Lacombe, Alta.

4th Year.—Wheat or oats.

5th Year.—Oats.

6th Year.—Barley seeded down.

As a rule a first-class stand of timothy and alsike or red clover combinations can be obtained when seeded down with a nurse crop of barley. The land is cleaned to some extent by means of the cultivation given after the sod is plowed in the third year of the rotation, while the manure applied in the winter of the first year to the surface of the sod maintains fertility, and the weed seeds contained therein are largely destroyed prior to the plowing of the land in the third year of the rotation. On account of the liberal rainfall in May or June weed seeds germinate near the surface and in the manure, but lack sufficient roothold to come to maturity, and are thus destroyed. Such a rotation has resulted in the freeing of land from weeds to a remarkable extent, and has also built the land up as to fertility to a noticeable degree.

293. Corn vs. the Fallow.—Corn has been tested for some years in Central Alberta with rather indifferent success. During only about half of the years, has it given a crop which could be called profitable, and the risk thus indicated is too great to warrant the general use of this crop in that part of the country. It is admitted that an intertilled crop would be an advantage if it were practical in a large way, and economical use could be made of the fodders grown. The sunflower may prove to be a plant which can be utilized in this section of the country to good advantage because it resists frost better than corn, and from the data at hand would appear to be superior to corn. When the size of farms reaches a better balance in relation to the amount of labor available this intertilled crop will command much more attention, and can be used to splendid advantage in conjunction with silos. Such use of crops suitable for ensilage and of silos will result in doubling the stock-carrying capacity of land.

294. The Preparation of Stubble Land for the Crop Following.—If time permits, stubble land should be plowed six inches deep in the fall and plowing operations should be followed immediately by the use of a soil packer, or if this implement is not available, by the drag harrow or disc. Such practice closes the air space in the land, and prevents the loss of moisture through the circulation of air. The use of a packer immediately following the plow also permits of fall germination of weed seeds by firming the soil near the freshly turned surface, thus permitting the movement of moisture to these seeds. Packing promptly after the plow is an effective cultivation in preparing the land for work the next spring, as it levels as well as firms the soil. Such land, well plowed and double-disked after the packer, is in good condition for the grain drill in the black loam soil of this section of the West.

295. Preparation of Grass Land for the Crop Following.—As indicated in the previous paragraph the plowing of grass land in July or early August is advised. The depth should be six inches and the plow should be followed by the packer or by the disc harrow operated in the same direction as the plow. As soon as convenient after the packer the land should be given a double disking, after which it may remain for some time without further cultivation. It is advisable, however, to give such land the necessary work in the fall so that it will not require much more than drag harrowing, or a double disking and drag harrowing at most, the following spring, in order to insure a good seed-bed.

296. Organic Matter, Legumes and Soil.—The importance of organic matter in the soil is shown by the wonderful crops which it is possible to grow when the virgin prairie is first broken. Such fertility is the result of the decayed organic matter of generations of plant growth, and its presence insures yields of as much as seventy bushels of wheat to the acre and one hundred and forty bushels of oats. Such rich soils will produce profitable crops with light rainfall, as compared with the possibilities of poorer land with the same precipitation. No permanent system of agriculture can be maintained which disregards the maintenance of soil fertility through the use of barnyard manure and leguminous crops. It is quite possible to exhaust the fertility and to make barren, lands which, with ordinary good farming practice could be maintained in a splendidly high state of fertility. The ease with which alsike clover, red clover and other clovers can be grown with a nurse crop in Central Alberta, and the natural adaptability of the country for live stock should insure for this district perpetual resources of fertility in the land if any semblance of sane agriculture is followed.

297. Best Dry Farm Crops.—Cereals, legumes and grasses thrive. As to varieties, Marquis wheat, Banner or Victory oats; Mensury, O.A.C. 21 and Barks barley; alsike, red clover, alfalfa in some districts, sweet clover in some districts, and Giant Russian Sunflowers; timothy Western rye, and brome grass, are all suitable for different parts of the country.

298. Rates of Seeding in Central Alberta.—As a general practice rather heavy seeding is advisable for the Park Belt in Alberta. The proper rate to sow, of course, depends upon the variety of grain, which involves size of kernel and the kind and condition of the land on which the grain is to be sown. Breaking and summerfallow well supplied with moisture will carry from one-half to one bushel more seed per acre than stubble land equally well cultivated. It has been found advisable to sow from two to three bushels of spring wheat per acre on well-cultivated breaking or summerfallow, depending upon the character of the land and its location, reducing the amount of seed on stubble land by half a bushel to a bushel, again depending upon condition. Oats should be seeded at the rate of from two and a half to three bushels per acre; barley at about two bushels per acre; sunflowers about ten pounds, and grasses and legumes at various rates according to the combinations used. As a rule it is advisable to sow from twelve to fifteen pounds of Western Rye grass to the acre when this is the only variety being used, and this may be used as the basis for determining other mixtures.

299. Weeds.—The eradication of weeds, while a serious problem, is not as acute a question in Central Alberta as in districts where wind has more sweep, and where the varieties of weeds have adjusted themselves to these conditions and spread over the whole territory by means of wind. The disking of stubble land following the binder, the following of the plow with the packer to encourage germination of seed; giving the land a stroke with the drag harrow as early in the spring as it is possible to work the soil, and the drag harrowing of the growing crop, together with the fall cultivation of July plowed sod, will gradually reduce the weed population of a foul farm, and will keep a clean farm clean.

300. Soil Drifting.—The drifting of soil will never be a serious problem in Central Alberta provided methods outlined in the paragraphs immediately preceding are followed. The use of barnyard manure, the seeding down of land to grass, and the growing of such big-rooted plants as a number of the legumes are, will all assist in solving this problem before it arises, and it might be said in passing that this is the time to solve such a problem. The reclaiming of all soil which has been allowed to reach the drifting stage is a serious matter, and the said condition should be avoided by every serious-minded, thinking farmer as he would avoid a plague. The following of the practice which will lead to the avoidance of the difficulty will also prove more profitable than those farming practices which lead to the soil-drifting condition.

301. Plowing.—Good plowing is one of the most, if not the most important cultural operation on the farm. If this work is well done the battle is half won. Deep plowing is advisable in most cases, and in my judgment should never be less than six inches. Deep plowing of breaking is important, not only to permit of a good seed-bed being worked after breaking without the necessity of backsetting, which is not feasible in the Park Belt, but is also necessary in areas where there is much willow or other growth of tree roots to be turned down. The breaking plow must cut under these roots. Where the ground is very rich it is advisable to disc in the second crop on the stubble allowing more time for roots to rot. The deep plowing of stubble land provides a greater reservoir for the storing of moisture, and a better opportunity for plants to develop roots. The importance of taking pride in the various operations in connection with farm work cannot be overstated. The doing of work well is the only thing which will lift farm work from being a mere job to an interesting home-building occupation.

THE SUMMERFALLOW IN SOUTHERN ALBERTA

By James Murray, B.S.A., Superintendent of Farms, Noble Foundation Limited, Nobleford, Alberta.

302. Climate.—The climate of Southern Alberta is characterized by light rainfall,—about fifteen inches,—and the prevalence of chinook winds which blow intermittently throughout the year. The chinook frequently attains the proportions of a gale; in winter it carries away a heavy snowfall in a few hours, and in spring and summer, and also frequently in winter, it not only dries out the surface soil very rapidly, but carries away in dust storms any soil in condition to blow readily. On account of these conditions—light precipitation and heavy winds,—the Southern Alberta farmer on dry land must keep always before him the need of conserving as much as possible of the moisture and of so working his land that it does not readily blow.

303. A Fallow Considered Necessary.—The general practice on the farms of the Noble Foundation Limited is to summerfallow one half of the land each year. This is departed from more or less every year, as feed oats is frequently grown on land that was in crop the previous year; but only in very favorable seasons does the yield approach that from summerfallow. In dry seasons the yield from such land is very low. Over a series of years the further we depart from the method of fallowing one half each year the less satisfactory are the results. With most of the crop grown on summerfallow a fair return is secured even in a poor year, and an excellent crop in a good year.

304. Summerfallow to Control Weeds.—The method followed in summerfallowing is planned to control weeds since most of the moisture lost during a fallow season is by the growth of weeds. The land to be summerfallowed is sometimes double-disked in the fall after the crop is removed, but more frequently, on account of lack of time in the fall, this operation is delayed until spring when it is done either during the progress of seeding or immediately after. This disking covers weed seeds and grain so that they grow readily. It kills millions of small weeds just starting and it breaks up the crust and leaves a light mulch on the surface. Such a surface makes a much better connection with the bottom of the furrow when the land is plowed than one that is hard, cracked and lumpy. In some seasons it may be advisable in order to control weeds to disc a second time any land that is not plowed reasonably early, but usually one double-disking is sufficient.

305. Plow Summerfallow Early.—The plowing of the summerfallow is started immediately after seeding and an effort made to have it completed before July. No single operation in summerfallowing is so important as plowing, so that care is taken to do the work well, turning a furrow of from six to eight inches deep depending upon how deep the land was plowed previously. Only a little subsoil is brought to the surface at each plowing. Immediately after plowing the land is packed by using either a subsurface packer or a disc run straight or one notch back. The packing is more perfectly done when the land is fresh-plowed, so that an effort is made to have the packing done the same day as the plowing.

306. Controlling Weeds After Plowing.—After the plowing and packing of the fallow is done little more attention will need to be given for three weeks or a month when weeds begin to appear. A start must be made at

Fig. 105.—Banner Oats on the Noble Farms in Southern Alberta in 1915.
This crop yielded 130 bushels per acre in 1915.

destroying the weeds when they are very small, else many of them will be large and have made a heavy draft on the moisture before they have been all killed. The implement used almost exclusively during the first two seasons as a weed destroyer in the fallow is the Rotary Rod Weeder. For several years previously a stationary rod weeder was used, but since the weeder with the revolving rod has been tried, the other one has been discarded. The Rotary Rod Weeder destroys all the weeds if it is used before they are too large, and leaves the land with a rough surface, not likely to blow. In some seasons it will be necessary to go over the fallow twice with the weeder to control weed growth, but the amount of work given is governed entirely by conditions. If weeds make their appearance and are likely to attain any size they should be destroyed.

307. Fall Treatment of Fallow.—The final operation on the fallow in the fall should be such as will leave it in a condition to best withstand heavy winds during the winter. Ridging with either a cultivator or a spring tooth harrow across the direction of the general winds is a good practice. The ridges not only serve to catch any soil that starts to shift, but they catch and hold light snowfalls that are frequently swept off fields that have a smooth surface. By removing two-thirds of the teeth from the spring tooth harrow so that the ridges are one foot wide the draft is lightened and the work more effectively done at the same time.

308. Hoe Drill Preferred.—The hoe drill has been given a fairly good trial during the past two years and since it leaves the land much rougher than the other types of drills, it will probably come into fairly general use in districts where soil-drifting is particularly troublesome.

When the hoe drill has been used on land not likely to drift, harrowing is advisable after sowing, but if drifting is feared the harrow had best be dispensed with.

309. Two Important Points About Fallowing.—In all the work on the summerfallow it is particularly important that two points be borne in mind,—the killing of weeds when they are small and the use of implements that will not pulverize the surface. The only safe time to use the disc harrow is before the land is plowed,—at other times it tends to pulverize too much. The drag harrow must, for the same reason, be used with great caution and drags of any kind that grind the surface should not be used on any account.

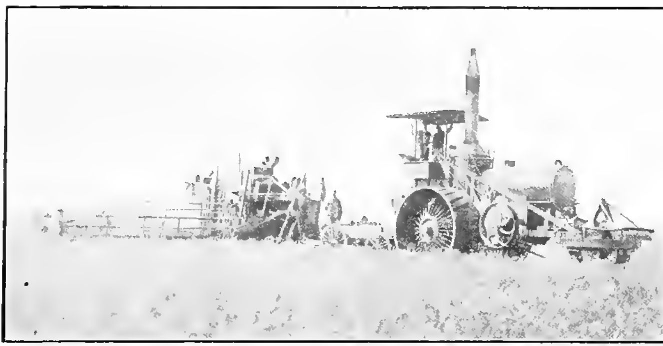

Fig. 105a.—Combined Harvester and Thresher.
Used in the Inter Mountain States, but very little in the Great Plains and almost never seen in the Canadian Wheat Fields.

CHAPTER XVII

THE PROBLEM OF CROP PRODUCTION

The control of crop yields and the maintenance of soil productiveness are problems that directly affect the prosperity of both the individual and the state.

An increase in net return equal in value to one bushel of wheat per acre on the land at present under cultivation in Western Canada would, at $1.00 per bushel, pay the whole cost of the general expenditure for purposes of government of the three Prairie Provinces. The same increase per acre per year for six years would more than pay Western Canada's share of the Great War debt.

An increase in net return equal to one bushel of wheat per acre would mean that approximately $35,000,000 additional cash would be available for that section of the community engaged in supplying the needs of the farmer and in distributing his products—the commercial and industrial interests; while a decrease of one bushel per acre would mean that an equally large amount of mortgages, loans and notes would remain unpaid for at least an additional year.

310. The Problem in a Nutshell.—If one bushel per acre or more of an increase is to be obtained or even if one bushel or more decrease is to be prevented, the men who control our great resource, viz., the soil, must know:

(1) The factors that are essential to the growth of crops;

(2) The factors that affect the profit of crop production; and

(3) The factors that affect the permanence of a profitable agriculture.

And they must not only know, but they must also put into practice, the means at their disposal for controlling or influencing the factors of growth, profit and permanence.

A statement and brief discussion of the fundamental principles underlying crop production, has seemed to us essential to a proper appreciation of the subject, both by the producer and the student of agricultural affairs. In this chapter we have, therefore endeavored to bring together the various phases of the question in such a way that the reader may get a general view, even though a brief one, of the relationship of its different parts to each other and to the problem as a whole.

311. The First Part of the Problem—That of Growing Crops.—As previously mentioned* the factors that must be provided before plants can grow are:

(1) The seed—which contains the life principle, the reproductive part.

(2) Plant food materials—the chemical elements of soil, water and air that are available to plants and that are necessary for growth.

(3) Water—a plant food itself and also a carrier of elements of plant food from the soil to the plant.

(4) Heat—without which the life process of the plant, germination and growth, cannot go on.

*In Chapter III.

(5) Light—for the synthesis or building up, in the leaves, of organic compounds from the inorganic elements of plant food.

(6) Air—which not only supplies a large part of the food of plants, but which in small quantity in the soil

Fig. 106.—Cattle on the Range in Northern Saskatchewan.

provides a desirable environment for plant roots and at the same time plays a large part in the development of "available" plant food.

Fortunately for us nature provides most of these requirements with a lavish hand. It remains for man to increase, or at least maintain the supply of those that under his own climatic and soil conditions have been either wasted or but sparingly supplied.

312. Light and Air Essential, but of Little Practical Importance.—Light and air are as important to the plant as plant food, water or heat, yet neither is as important to the crop grower for the reason that he finds both provided in very great abundance. More light than reaches the earth in most climates where agriculture is practised, is seldom needed, and even if it were, the amount could not be increased profitably.

Nature supplies plenty of air above ground and in all except humid climates, low lying soils, or very heavy lands sufficient in the soil as well. It is our business only to regulate the supply so that the soil will contain neither too much nor too little, but just the right amount for good tilth.

313. Frost Limits the Yield in Northern Climates.—The average number of days between spring and fall frosts for a period of twelve years in the Central West varies from 73 in the north to 133 in parts of the south. The shortest period between frosts during the same length of time was 33 days for the north and 101 for the south while the longest frost-free period in each of these districts was 112 and 163 days respectively. These figures probably represent the extremes in length of frost-free period for most of the present settled area of Western Canada.

It is apparent from these data as well as from actual experience that in northern climates nature sometimes fails to provide enough heat to mature crops without injury from low temperature, and that, therefore, man must either add to the supply or take such steps as will offset the danger from frost. This is one of the two chief difficulties facing the crop grower in Western Canada. There is need for developing a system of "Northern Farming" for northern regions just as there is a need for a system of "Dry Farming" for dry regions or one of "Humid Farming" for wet ones.

314. Water in the Soil Determines the Yield in Dry Climates.—Water is generally the limiting factor in crop production here. In other words, it is the chief cause of low yields. From 250 to 1,000 pounds of moisture are extracted from the soil and transpired by the plant into the air in the process of forming one pound of dry organic matter in the plants' tissues. In Western Canada we receive from 12 to 22 inches of water from the clouds annually. The precipitation in most agricultural countries ranges between 10 inches and 150 inches per year. Our supply is small and our need is great. Man must make the best use of what nature supplies or furnish artificially the shortage, otherwise he must be content with low yields.

In humid regions the supply of moisture from the clouds is generally sufficient to produce large returns. In arid and semi-arid climates there is insufficient rainfall to produce large crops every year with the result that the supply of water must be increased by irrigation or steps must be taken to store a portion of one season's moisture in the soil for the use of the next season's crop, as by summerfallowing, or the use of intertilled crops.

The efficient utilization of our precipitation for the development of the latent wealth that is in our soil is the biggest material problem Western Canada has to face. She has made some progress towards its solution, but much work still remains to be done.

315. Plant Food Materials, the Limiting Factor on Poor Soils.—Of the eighty odd chemical elements known to science, fifteen may be used by plants, but only ten are essential to growth, and of these ten, all but four—nitrogen, phosphorus, potassium and calcium—are provided in liberal quantity in the soil. The available supply of one or more of these essential elements of plant food is sometimes so small in humid climates that large yields on poor soils are an impossibility. Under these conditions the terms "manure" and "fertilizer" are therefore almost synonymous with soil fertility, and the chief problem of the crop grower is to maintain the supply of available plant food in the soil.

In Western Canada our normal soils are rich. The total supply of the chemical elements essential to plant growth is relatively large—so large in fact that on many soil types we are permitting ourselves to neglect almost wholly the question of its conservation. Our immediate problem is one of development rather than conservation. Nevertheless, it should be possible for us to do what older agricultural countries have done, viz., conserve our soil resources while still developing them. The maintenance of soil productiveness is likely ultimately to become one of our most serious problems and it would therefore seem to be the part of wisdom to direct more of our energies and resources toward the early solution of this difficult question.

316. The Importance of Good Seed.—The seed we sow may be good or poor. Its vitality may be lessened by frost or other injury, its vigor of germination lowered by disease and exposure, while the health and purity of the resulting crop may be seriously affected by the presence of disease spores and weed seeds in the sample sown.

It is man's privilege to see that the seed he uses will germinate and germinate vigorously, that it is free from disease and admixture, and that it is a sort that is suited to the climate and soil where it is to be planted. These are fundamental requirements. They constitute the primary elements of successful crop growing. They are the only things essential in good seed, and fortunately for us it is absolutely within our power to see that the seed we sow meets all these requirements.

317. Some Fundamental Facts.—The seed, plant food materials, moisture, heat, light and air are all absolutely essential to growth. When each is provided in suitable quantity and in available form, the soil produces abundantly. If any one is lacking, no growth whatever will take place. And it is important to note that the factor that is present in smallest quantity in relation to the

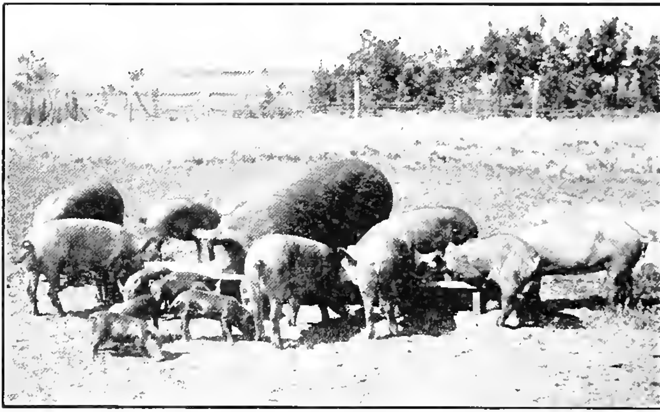

Fig. 107.—Bacon Hogs in the Making.

need of the crop will determine the yield. A chain is as strong as its weakest link. The yield of a crop will be as high and no higher than the supply of the limiting factor will permit.

318. The Vital Part of the Problem—That of Profit.—It is not enough that man should know the factors that are essential to plant growth nor that he should provide them. The intelligent farmer does not farm for his health alone. For him there must be some profit after the various items in the cost of production have been paid.

It is not difficult to grow crops. It is not very difficult to produce large yields. But it is a difficult matter to grow crops at a profit whether the yields be small or large.

319. Factors Affecting Profit.—Suitable crops planted in productive soil according to up-to-date methods do not necessarily yield profitable returns. In order that a profit may be assured, not only must all the essential conditions of growth be provided, but (1) the crop must be protected from weeds, insects, plant diseases and storms, and (2) either the cost of production or the selling price must be controlled.

320. The Cost of Weeds.—Weeds rob the crop of its plant food and moisture and increase the cost of production. It has been estimated by the Department of Agriculture that the weed crop of Saskatchewan costs her farmers $25,000,000 a year, and probably this item does not cost the average farmer in Saskatchewan more than it does the average one in either of the other Prairie Provinces.

321. The Cost of Insects.—Insect, animal or bird pests may lessen the yield or quality of the crop either before or after maturity. The Dominion Department of Agriculture places the loss through destruction of crops by cutworms in one district in a single season at 35,000 acres. And the cutworm is only one of dozens of insects that take an annual toll from the farmer's crops.

322. The Loss from Rust.—Plant diseases nourish themselves on the tissues of plants and thus lessen the yield or quality or both. The loss to Western Canada from rust alone in the year 1916 has been estimated to average six bushels per acre. This at the October price of $1.50 per bushel on an area of aproximately 12,000,000 acres, reaches the enormous sum of over $100,000,000. In other years wheat smut, flax wilt, potato blight and other fungous or bacterial enemies have contributed to the large annual loss from plant diseases.

323. The Amount Hail Takes from the Profits.—Severe storms may injure the soil and damage the crop by soil "drifting" or by stunting, lodging or breaking down the plants, or by shattering the grain. The loss from hail is variously estimated at from one-half to two and one-half per cent. of the total acreage, or on the basis of the present acreage a loss of 125,000 to 600,000 acres. The damage done by hail in the year 1916 was considerably greater than the highest of these percentages. These storms come as the insurance men say "by act of Providence". It is fortunate that provision for carrying this risk has been provided by hail insurance companies.

324. The Moral.—And yet these losses may occur even after the soil has been made productive. It is apparent that one of three things must result:—(1) those factors that affect cost must be controlled, or (2) the price must be regulated by the producer, or (3) the business of growing crops profitably cannot be controlled, and is therefore more or less of a gamble.

325. The Cost of Production and the Selling Price.—A farmer, like any other business man, is legitimately concerned with obtaining the largest possible return for his labor and for the capital invested. This being the case he is concerned with the profits of his business rather than with his total output. Society in general is greatly concerned with the desirability of increasing the quantity of foodstuffs produced, since cost of living is thereby reduced. Herein lies the reason for the cry "Back to the Land" and the slogan "Greater Production" raised by those not living on the land.

The farmer from a purely business point of view is concerned with the problem of greater production only in so far as it tends to increase his own net profits. He has been forced to recognize that larger crops do not necessarily mean larger net returns, partly because the larger crop usually costs more to produce, and partly because a bountiful crop tends to reduce the selling price. Profit is measured by the difference between the cost of production and the selling price and farmers are concerned with maintaining, if possible, a reasonable and constant spread between the two.

Intelligent and timely cultural practices, hard work, good management and frugal habits will lower the unit cost of production and increase the unit value. But the cost of the farmer's machinery and other equipment, the cost of his money and, to a considerable extent, the cost of his living are all fixed by conditions and institutions over which he individually has no control. It is coming to be realized, however, that those factors which cannot be controlled by individual effort may be very considerably modified by collective and co-operative effort. Farmers' organizations seem to be in a fair way toward having tariff schedules, particularly those on implements of production, reduced, thereby reducing cost of production. Farmers' business organizations in the handling of agricultural implements and supplies in general have had considerable to do with keeping down the costs of these supplies. The cost of money to the farmer has also been reduced by organizations, such as rural credits societies and farm loan associations designed to meet the needs of the agriculturist. In general the cost of production seems to have been materially reduced wherever farmers' organizations have made a determined effort to compete in the handling of farmers' business.

The price a farmer gets for his products is fixed by the law of supply and demand, the tariff schedules, the cost of transportation and the cost of handling by middlemen. Here even more than in the cost of production the factors that determine the selling price are beyond the influence

Fig. 108.—Manitoba Farm Yard Scene, in Winter.

of the individual producer. Individually a farmer can influence the price of wheat about as much as he can the state of the weather. If he is ever to get a larger proportion of the consumer's price it seems apparent that it must be through co-operative effort.

The price of crops in the future as in the past will in a large measure be controlled by the law of supply and demand. The world's demand is relatively constant. May not the supply be made more uniform? By a better knowledge of the probable market requirements may it not be possible to avoid over-production of one crop and under-production of another with consequent loss in net returns? May it not also be possible to arrive at a valuation of the services of transportation companies and middlemen, with fairness to all concerned? These are problems that farmers, transportation companies, middlemen and consumers must solve collectively. In this way only will the interests of society as a whole, rather than that of any class or section of it, be equitably served.

326. The State's Third of the Problem—That of a Permanent Agriculture.—The conditions that affect growth and the factors that affect profit are and will continue to be the chief considerations of the individual farmer. Yet a third set of conditions of vastly greater importance to the future of the state, viz., those that affect the permanence of our agriculture, remain to be considered.

We are hearing much to-day on the one hand about the "depletion" of the land, the loss of "fertility" and the "exhaustion" of plant food from the soil; and from another quarter about our soil being "the richest in the world", and about its supply of plant food being "inexhaustible".

We hear of some land that after continuous cropping and no return of plant food, is producing as much as, or more than it did a generation ago, and we are led to ask ourselves, "Do soils wear out?" "Can they become depleted?" "Are they being exhausted?" These are questions upon our solution of which the future material success of Western Canada very largely depends.

What is fertility? In its narrowest sense it is plant food materials in the soil, — the chemical substances plants use in growing. In its broadest sense it is ability to produce crops, and includes (1) "available" plant food, (2) tilth, or a favorable condition of the soil with relation to water and heat and air; (3) health, or freedom of the soil from disease, and (4) purity, or its relative freedom from weeds and weed seeds. In its broadest sense "fertility" means productiveness, which is not necessarily synonymous with, although generally closely related to, the content of plant food materials in the soil.

Soils do not become literally "depleted" or "exhausted" of the plant food elements they contain, although the amount may be seriously lessened, but the land may become depleted or exhausted of its "productiveness". These so-called "depleted' soils may at any time be made productive, but the trouble is they cannot be made to produce a profit until such time as the pressure of population or some other economic condition increases the price of soil products or lowers the cost of production. And if this does not happen, such soils remain unprofitable and unproductive. In any case they seldom redeem themselves. They generally have to be built up by capital brought from some other source. Such soils become not only a source of loss to the man who operates them but also a burden to the state which indirectly has to bear, not only the loss from their inefficient use, but also the cost of their redemption.

327. Factors that Affect Permanence.—The chief factors that affect the maintenance of productiveness in any community have already been mentioned, but will bear repeating. They are:

1. The maintenance of soil tilth, which in practice generally means the maintenance of organic matter.
2. The maintenance of soil health, or the prevention or control of plant diseases that live in the soil.
3. The maintenance of soil purity, or weed control, and last but by far the most important in the long run
4. The maintenance of a sufficient amount of available plant food.

In addition to being productive, a permanent agriculture must also be a profitable agriculture.

And now, having considered this many-sided problem the farmer has to solve, let us examine the nature and effectiveness of the instruments he has been given with which to achieve his purpose.

328. The Means at Man's Disposal for Controlling or Influencing the Factors of Growth, Profit and Permanence.— The instruments now available for controlling or influencing the factors of growth, profit and permanence are:

1. The choice of suitable crops.
2. Suitable crop management practices.
3. The improvement of crops by selection and breeding.
4. Irrigation or drainage, or both.
5. Tillage.
6. Suitable crop rotations.
7. The use of live stock.
8. The application of business principles to the management of the whole farm—the land, the stock, the labor, the finances and the machinery and other equipment.
9. The use of legumes and nitrogen fixing bacteria.
10. The utilization of manures.

329. The Choice of Suitable Crops.—Nature has given us some plants that resist disease, some that resist frost, some that resist drought, and some that avoid these conditions. A great number of crops suited to different systems of farming are available to choose from, and the experience of farmers and the records of our experiment stations are fast teaching us the ones that are best suited to our climate and soil. The value of some new and untried crops has yet to be determined, and the suitability of different classes and types of crops for peculiar local soil and climatic conditions is a line of work that needs greater attention. But our present knowledge, if utilized, is sufficient for our present need, and we have faith that new plant forms will be developed or discovered that will meet any pressing requirements of the future.

Some doubt exists concerning the relative value of different varieties for some local climatic and soil conditions, but these are being quickly dispelled. One needs but

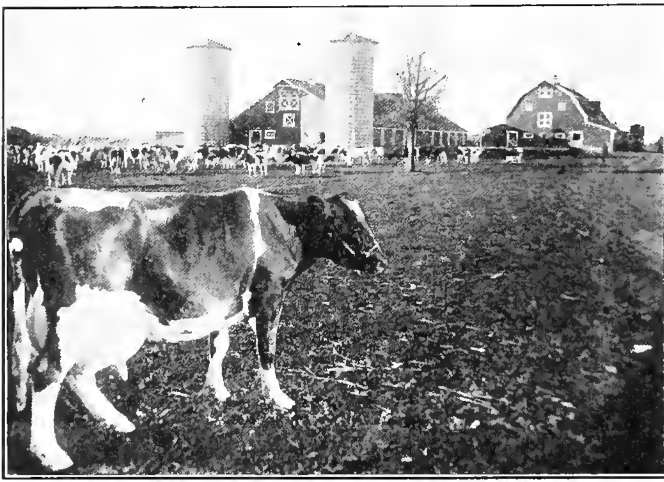

Fig. 109.—Dairy Herd in Red River Valley.

refer to the nearest experiment station for the results of comparative tests. If these are not conclusive, co-operative trials on one's own farm can easily be made. It is sufficient here to refer the reader to the reports of the different experiment stations, and to urge him to keep informed on the results of official tests.

330. Suitable Crop Management Practices.—The cleaning of the seed, its treatment for disease, the time, rate and depth of planting, and the time and method of harvesting and curing of crops, offer many opportunities for error. In new countries, and particularly where the settlers are unfamiliar with farming, the best practices have to be learned by experience, and in the early days of such settlements this experience is often gained at a very great cost. But even now there is a considerable fund of information, sufficient at least to make a safe working guide to the successful prosecution of each of these, even under the diverse climatic conditions the different parts of the West present. The experimental farms have been given the responsibility for getting more accurate information on this subject and their results are being made available to all in their annual reports and periodical bulletins. No one need long remain in the dark concerning the "crop management" practices now recognized as suitable in different portions of Western Canada.

331. The Improvement of Crops.—Men are improving crops by doing two things: (1) by the negative process of preventing them from deteriorating, and (2) by increasing their hereditary power with respect to yield, quality, or some other economic character. The first is the business of the farmer, the responsibility for the second lies with our experiment stations.

Our crops have in many instances deteriorated sadly by admixture with weeds and seeds of other crops, by attacks of disease, by drought and frost and by improper care of the seed. The prevention of each of these in so far as it is possible is necessary in order to maintain productiveness and quality. It is not always within the farmer's power to wholly prevent these conditions, but ordinarily he can do much to lessen their ill effects.

The hereditary power of our crops has been and is being improved by selection and by artificial crossing, followed by selection. It is true generally that "like produces like", but it is not always so. Variations occur in all our crops. It is necessary then that the undesirable variants be eliminated and that the favorable ones be isolated and tested out, and if better than the parent, increased and made available to the crop grower. This is accomplished by the selection of individual plants, the propagation of the seed in a "pure culture", the testing of its yield and constancy for a number of years, and then increasing it as quickly as possible and making it available to the crop grower.

"Crossing" is resorted to, first, in order to produce variation so as to give greater opportunity for selection, and second, to engraft on a race some desirable character possessed by another. Crossing or breeding, the intermixture of the blood of two parents results in many new combinations of characters, some one of which may be the very one desired by the breeder. This favorable plant must be found, isolated, tested out, the seed increased, and then distributed. Practically all of the common crops now grown have felt the influence of the breeders' touch. Marquis wheat, Victory oats, O.A.C. No. 21 barley and N.D. No. 959 winter rye are familiar examples of improvement by selection and breeding.

332. Irrigation and Drainage.—In warm, dry climates, moisture is the limiting factor in crop production. Where water can be secured by artificial means, a profitable agriculture generally results. We practise irrigation in parts of Western of Canada, but over most of our country, it is not possible to do so, because water is not available.

In wet climates and low lying soils moisture may also limit the yield, not because there is too little, but because there is too much in the soil. Under such conditions the removal of the surplus by artificial surface or underground drainage is just as necessary as the addition of of water to dry lands. Outside a few local areas and on low, flat lands and alkaline soils, land drainage is not a serious problem in the Prairie Provinces.

333. Tillage.—Tillage is the greatest means at man's disposal for controlling the conditions that at the present time are causing low yields on the farms of Western Canada. It is also by far the largest single item on the cost side of the crop account. Tillage is a universal practice, but on account of the great variation in soil, temperature and moisture conditions in different countries and in different parts of the same country, the various methods employed art still fruitful of debate and somewhat difficult to determine satisfactorily. At the present time in the West, tillage is one of the most important subjects connected with crop growing, yet it is one upon which conclusive data concerning the relative value of different practices is not available for more than a few sections of the country. In the dry year of 1914 the yields of Marquis wheat at Saskatoon ranged from six bushels per acre to thirty-two. In the wet year of 1915 they ranged from seventeen to forty-seven. The range in yield in each of these seasons was due entirely to the different tillage practices followed. This subject is discussed at some length in chapters VII to X.

334. Crop Rotations.—The most reliable information the world affords on the value of crop rotations shows that land in England when cropped continuously to wheat for sixty years produced an average of fourteen bushels per acre, and when grown in a rotation of turnips barley, clover and wheat it produced twenty-five bushels per acre every fourth year for the same length of time. The most reliable information that America affords shows that corn in Illinois when grown continuously for twenty-nine years produced twenty-seven bushels per acre, while in a rotation of corn and oats it produced forty-six bushels, and in a rotation of corn, oats and clover, fifty-eight bushels per acre.

But we are not living either in England or in Illinois. Their rotations do not suit the conditions found here. Yet our rotations of the future must include, as do those of older regions, a legume crop, an intertilled or fallow crop and a money crop. Until recently in Western Canada, neither legumes nor intertilled crops suitable for use in a large way were available, or if so were either not well suited to all conditions or did not lend themselves satisfactorily to practicable changes in our present system of farming. Some difficulties have yet to be surmounted before paying crop rotations are discovered and firmly established, but at least we are fast becoming familiar with the crops we must depend upon not only as nitrogen gatherers and as intertilled crops but also as money crops.

In the meantime the spread of weeds, the "drifting" of soil and the loss of organic matter are in many places lowering the profit from grain farming so materially that resort to hay crops occasionally is being practised. In other places corn is coming to be a partial substitute for the fallow. It is possible that these crops, together with alfalfa, or some other legume such as sweet clover, may be the stepping stones to more desirable crop rotations.

335. Crop Rotations and Live Stock.—The introduction of a large acreage of forage crops on the farms of Western Canada will require an enormous initial outlay of capital for stock and for fencing and buildings. The greater part of this money must be made on our farms. The problem then will be solved but slowly. It is largely a rotation, a farm management and an economic problem. The purely agronomic or crop and soil phases of it are the least difficult to answer.

In our opinion we shall not control weeds and drifting soil permanently until we adapt our systems of farming to meet those conditions which have caused and are now causing low yields and poor quality in our crops. That adaptation will include a rotation of crops designed chiefly for controlling weeds and drifting soil, for lessening the cost of production and for building up a more permanent agriculture. It will necessarily include live stock, (1) to make use of the forage crops that must be grown, (2) to lessen the amount, and thereby the cost of the tillage necessary to control weeds, (3) to lessen the risk of our one-crop system and (4) to turn the wastage and by-products of the farm into a realizable asset.

336. Business Farming.—It is not long since the farmer did not need to be a business man. He produced his own food, he grew and manufactured his own clothing and built his own house. He lived unto himself largely. He needed little business training.

The modern farmer cannot live unto himself. He does not produce his own clothing nor the material to build his house, nor does he grind his own wheat into flour. To-day he must spend, even for the necessities of life. Therefore he must have something to sell. In other words, the modern farmer must be a business man.

It does not take long to learn the art of farming, but unfortunately it takes some of us a long time to learn the art of successful farm business. It would seem that we as individuals might with profit give more attention to mathematics in relation to our business. Our profits are determined by the difference between our receipts and our expenditures, and not by our gross incomes. Let us know, if possible, the essentials of our own business enterprises. It would seem also that we as a class must practise greater co-operation. Our co-operative enterprises have accomplished much in the interest of the farmer, chiefly in the marketing end of his business, and they have still much opportunity for service. At the same time let us not forget that as individuals we can still do much to lower the cost of production and to lessen the risk in farming, both of which are directly related to profit.

337. Legumes and Inoculation.—The air over every acre of land contains seventy million pounds of nitrogen, the most costly of fertilizing elements. This amount is sufficient to supply the nitrogen of fifty bushel crops of wheat every year for a million years, yet farmers in some countries are paying twenty cents a pound for nitrogen to put on the land. Nitrogen in the air can be secured at no cost to the farmer if he will but grow some legume crop at intervals. This kind of crop when inoculated with nitrogen-fixing bacteria, has the power of drawing upon the immense store of nitrogen in the air.

In such of our virgin soils as are rich in nitrogen it is possible that the use of legume crops may not now result in large increases in yield. Investigations at present under way will soon answer that question. In the meantime the fundamental fact regarding legumes should not be forgotten. Neither should it be forgotten that all our soils are not virgin, nor are all rich in nitrogen.

338. The Use of Manures.—Land cropped continuously to wheat for fifty-five years in England produced an average yield of 12.9 bushels per acre, while in a nearby field the wheat in a rotation that was heavily fertilized gave an average of 35.5 bushels.

In Illinois, as was stated previously, land continuously cropped to corn for twenty-nine years produced an average of 27 bushels per acre, in a rotation of corn and oats, 46 bushels and in a rotation of corn, oats and clover, 58 bushels per acre. In the latter rotation when the land was manured the yield was 81 bushels, and when manured and given commercial fertilizers as well, the yield was 96 bushels of shelled corn per acre.

At the present time we cannot get such large increases from the use of either manures or commercial fertilizers, although we can and do get good returns from the intelligent use of manure, even on our new soils.

In this connection a definite statement regarding the amount of the more important food elements in western soils and the actual results of the application of manures and fertilizers to them may not be out of place.

In the surface 6 2/3 inches of the normal Saskatchewan soils so far analyzed by the Department of Chemistry of the Provincial University, the nitrogen supply ranges from 3,000 to 14,000 pounds, the phosphorous from 1,000 to 3,000 pounds, and the potassium supply from 14,000 to 45,000 pounds. Assuming that the straw were all returned to the land, the amount of these elements removed from the soil in the production of one bushel of wheat would be 1 2-5 pounds of nitrogen, 1-5 pound of phosphorus and about 1-5 of a pound of potassium.

It is, therefore, apparent that if all of this plant food could be utilized by crops without loss, there is enough nitrogen to produce from 2,000 to 10,000 bushels of wheat, enough phosphorus to produce 5,000 to 15,000 bushels and enough potassium to produce from 70,000 to 225,000 bushels in the surface 6 2-3 inches of one acre.

Man would take out all this wheat in a year if he could, and leave none for future generations, but Providence has wisely provided that only about 2 per cent. of the content of certain elements, 1 per cent. of others and 1-4 of 1 per cent. of still others can be annually released from the soil and taken up by growing plants, so that we cannot literally deplete our soils of their potential wealth by cropping even if we would; but we can and are depleting even the best of our soils of their surplus wealth and their productiveness. We must not let the supply of total plant food get so low that the small percentage that becomes available to plants annually will be insufficient for a large crop.

It may be asked, why add manure or other fertilizer to soil containing so much plant food? The answer is to be found in the proportion of the plant food in the soil that is available to plants. The elements added in decayed manure are quickly available to the plant, while much of that found in the soil is not. And in addition, decaying organic manures not only improve the physical condition of the soil, lessen its tendency to blow, and improve its moisture holding power, but also liberate or make available other more or less insoluble plant food elements. Of course it costs money to handle manure and there are some minor objections to its use under certain conditions. Nevertheless at many different places in the West it has increased the yield of every crop tested, even on rich land.

If a system of permanent agriculture is to be established on our western prairies—and our future welfare depends upon its establishment—we must not carry our wheat system too far. We cannot waste the fertility of our soil and still have it. To-day we are selling our soil fertility at the rate of 25 cents for each bushel of wheat sold. We individually can afford to do that for some time, but the State cannot afford to permit us to do it indefinitely.

339. In Conclusion.—It is the moral duty of the crop grower to produce as large crops as can be profitably grown. It is the double function of society to see (1) that the farmer is not hampered in this purpose by economic disadvantages and (2) that agriculture receives such co-operation and encouragement from the State as will enable it to establish a more permanent system of farming.

Intelligent tillage, the choice of suitable crops, and suitable cultural practices, will enable us to develop the resources of our soil. Business methods and in some places a rotation of crops and the introduction of live stock will enable us to produce crops more profitably, but only the use of legume crops, the practice of a crop rotation and the return to the soil of some of the plant food we remove in crops and in fallowing will enable us to build up a permanent agriculture, and a permanent agriculture is absolutely essential to the future well-being of the State.

In the final analysis our ultimate success as a nation depends not only upon our ability to produce profitable crops now, but upon our ability to keep on producing profitable crops.

APPENDIX

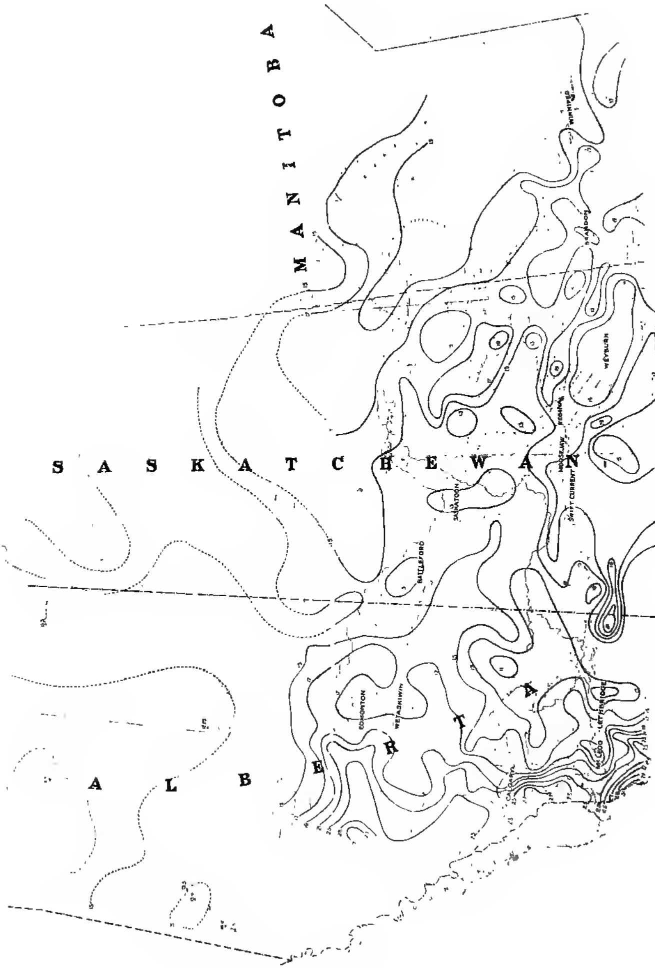

Fig. 110.—Precipitation Zones of the Three Prairie Provinces.
From most recent Meteorological Service Map.

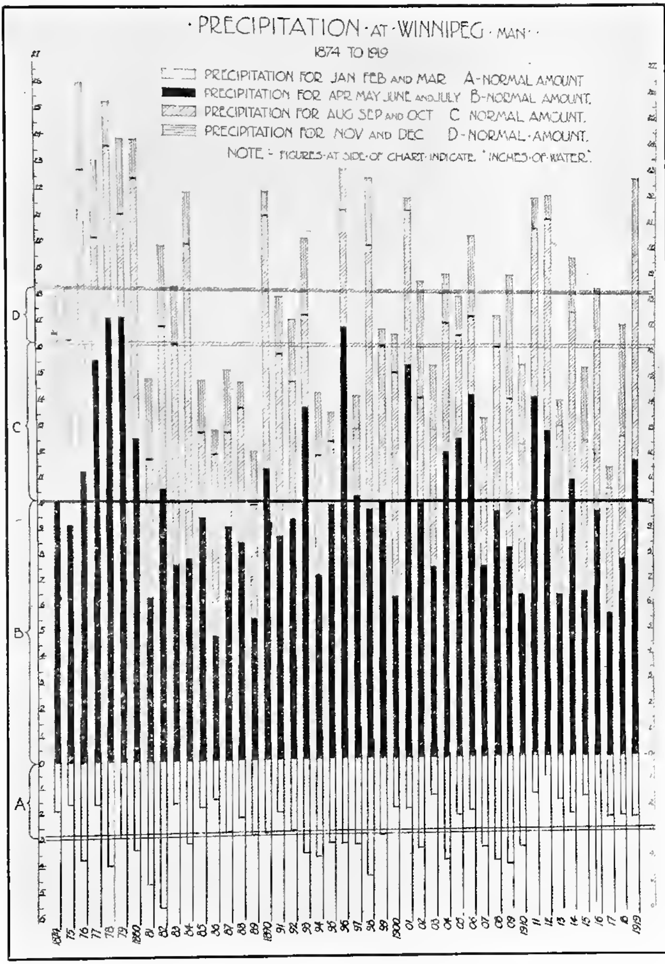

Fig. 111.—Precipitation Record—Winnipeg, Man.

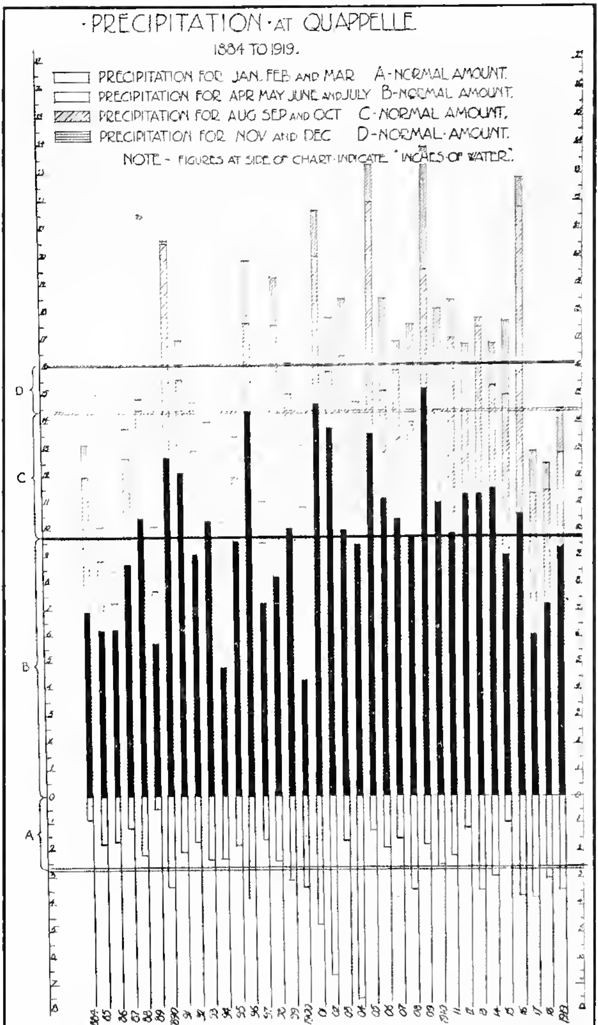

Fig. 112.—Precipitation Record—Qu'Appelle, Sask.

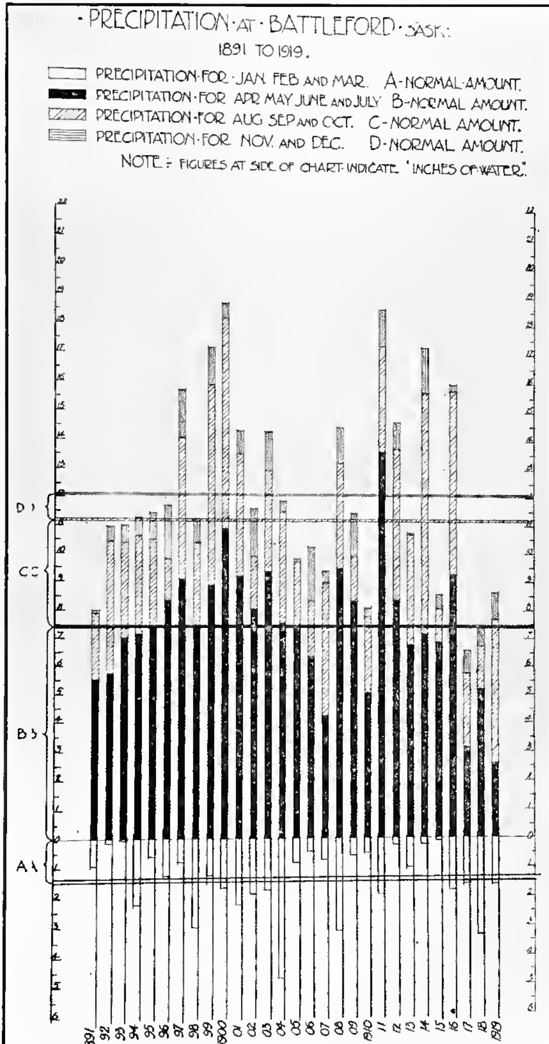

Fig. 113.—Precipitation Record—Battleford, Sask.

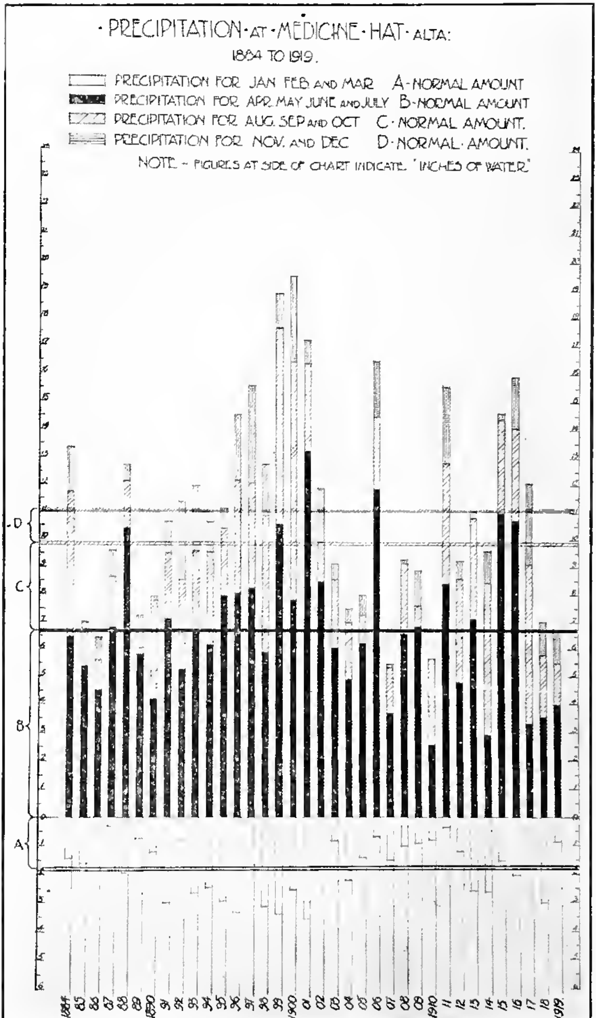

Fig. 114.—Precipitation Record—Medicine Hat, Alberta.

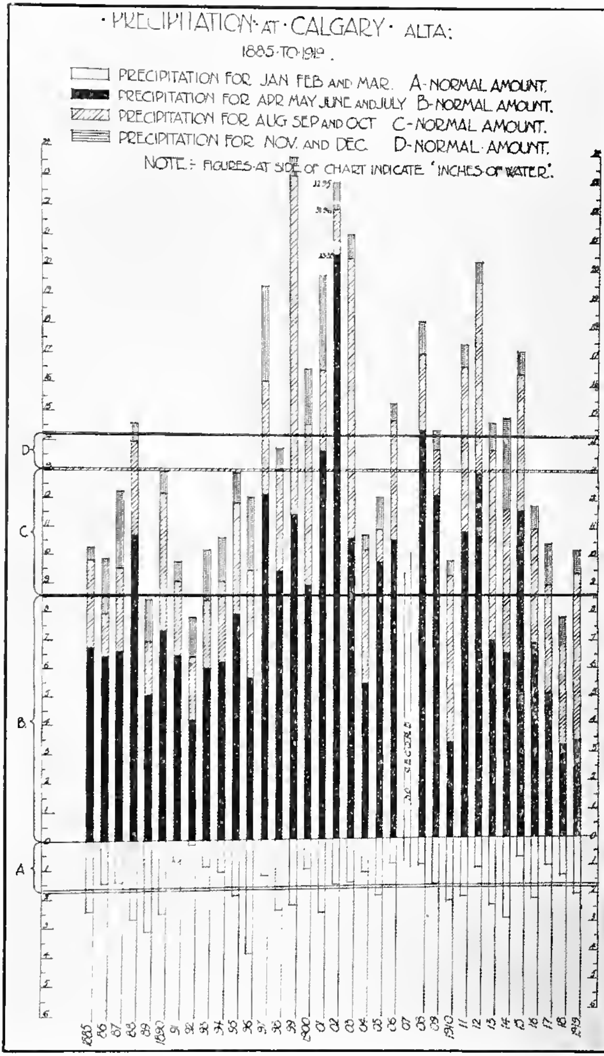

Fig. 115.—Precipitation Record—Calgary, Alberta.

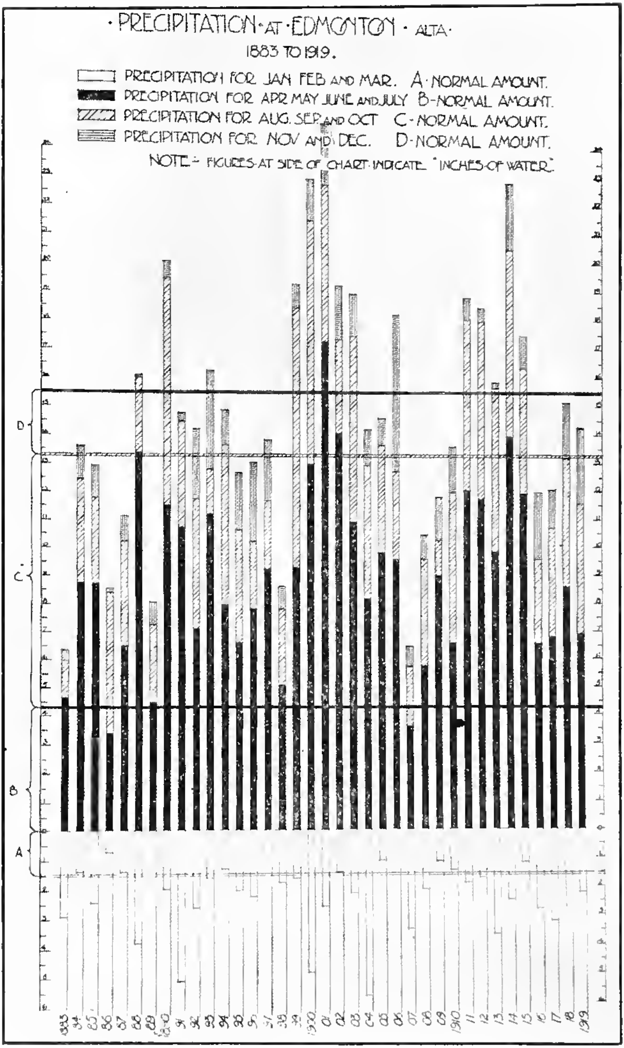

Fig. 116.—Precipitation Record—Edmonton, Alberta.