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CHEMISTRY AND CANADIAN AGRICULTURE¹

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To me has been accorded the honor of participating in the welcome which is being offered to the members of this society at this, their first, meeting on Canadian soil. At any time and under ordinary circumstances it would have afforded me—as indeed any citizen of Canada—very great pleasure to give you a hearty greeting. Your presence here is evidence of the goodwill and friendly feeling that exist between the chemists of the United States and those of Canada, and we are proud to have gathered here in convention representatives of that great chemical body that includes in its membership men from all parts of the North American continent. Chemists, I have always believed, are to be numbered among the men whose work makes for the welfare of their country and they know no political boundary lines in the giving out of the results of their labors. I know that we in Canada have benefited largely by the work of the chemists of the experiment stations in the United States.

But the pleasure of having you here and in some small way reciprocating the favors you have so often showered upon us is enhanced in the great satisfaction we feel that you should visit the Dominion at a time when our country is so prosperous. At no previous stage in its history has there been the same substantial, steady progress and

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¹ Address of the chairman of the Section of Agricultural Chemistry at the Toronto meeting of the American Chemical Society, June 27, 1907.

development that has marked the past five years. In agriculture, in all industries and manufactures, in mining, in exports and we may say in all those things which we believe conduce to a country's prosperity, we are to-day in an enviable condition. Nor have we as yet reached the high-water mark. We believe that we have only entered upon an era of "good times." The prospects for the future are bright and the signs of the times indicate that for some years there will be a steady advance—an ever-increasing development of the many great natural resources we possess. In all this I know you will rejoice with us.

And having said this, the question will naturally arise in your minds: What is the secret, the reason for this phenomenal development? My answer is that it is due, chiefly, to a better, more thorough realization by ourselves and those of other countries, of the great agricultural possibilities of this Dominion. We have in our north-western provinces alone unmeasured, almost illimitable, areas of the most fertile soil, yet awaiting the plough—soil rich and deep, a veritable mine of plant food, chemically and physically perfect and specially adapted, so far as we can judge under the climatic conditions that prevail, for the production of the finest quality of the most important, the most valuable of all food-stuffs—wheat. While we recognize the value of all her other natural resources, Canada is, and will probably always remain, essentially an agricultural—a food-producing—country, capable, as the years go by, of sustaining an immense population and giving a large surplus of food-stuffs for export.

It is not my purpose to make this address a statistical record, but in order to give you proof that I have not spoken in exaggerated terms regarding this truly astounding development I must give you a few figures kindly furnished to me by the Dominion

Census Office. They refer to the north-western provinces, Manitoba, Saskatchewan and Alberta.

	Population	Cereals	
		Acres	Bushels
1900	419,512 ²	3,491,414	43,251,662
1905	808,863 ³	6,025,190	162,244,929
1906		7,894,666	239,841,001

These data need little comment. They furnish evidence of the most satisfactory character respecting our growth as a whole and of the rapid extension of agriculture in the Northwest, particularly. May I quote in this connection the concluding sentence of the Report of the Select Committee on Agriculture and Colonization of the House of Commons, 1906-7?

A careful survey of the entire field demonstrates that agriculture, the cornerstone of national wealth and power, is in a more prosperous condition at present in Canada than in any other country of the world, while the yet unmeasured territory of rich virgin lands awaits settlement ready to respond bounteously to the industry and intelligence of many millions of willing hands. In a word, Canada is the world's greatest bread field of the day.

If time permitted I should have liked to tell you something of the agriculture, the various soils and climatic conditions characterizing the different provinces as we travel across the Dominion from the Atlantic to the Pacific. There would be much of interest to the agricultural chemist in such a study. But such a recount, even in the briefest form, is now impossible. Every province has its own advantages, but it also has its own peculiar problems to solve. No doubt you already know something of the farming conditions in eastern Canada, which was first to be settled; of the Garden of the Gulf, Prince Edward Island, that has recently been brought to realize the

² Population on April 1, 1901.

³ Population on June 24, 1906.

extent to which she has impoverished her soils by continued cropping with potatoes and oats and who now is endeavoring to restore lost fertility by the development of dairying and the more extensive growth of clover; of Nova Scotia and her world-famous orchards in the valleys of the Annapolis and Cornwallis, her dyked lands which she shares with her sister province, New Brunswick, and from which hay has been cut for many a decade without apparent deterioration of the soil; of the picturesque province of Quebec, on either side of the St. Lawrence, peopled for the most part by the thrifty "habitant" who has tilled faithfully, if at times not over-wisely, the land that has descended from father to son for many a generation; of the banner province of Canada, Ontario, with her strong, productive soils, her immense wealth in live stock, her splendidly developed dairying industry, her cereals and fruits.

Again, in the West there is the province of the Pacific coast, British Columbia, as yet but sparsely settled, where mining and lumbering are more important industries to-day than agriculture, but which nevertheless is daily gaining prominence from the great success that has attended fruit growing within her confines. This industry is still in its infancy, but already the Okanagan, the Kootenay and other similarly situated districts in the semi-arid belt of the interior are exporting large amounts of fruits of the finest quality to the settlers of the northwest provinces.

It is to these latter, comprising Manitoba, Saskatchewan and Alberta, that we now turn our attention, though I can only give you the merest outline of them and their possibilities. The cry for some years past, and still is to-day, "Westward, ho!" People are going in, one might say rushing in, to possess and to till these vast, fertile western plains. The first to enter in and to possess

this great lone country were farmers from Ontario and eastern Canada. Of late years, however, while the exodus from the east has continued, these provinces have received thousands from Great Britain, northern Europe and lastly we have welcomed from the great republic south of us, and more particularly from the northwestern states, large numbers of experienced farmers. This area in the west, containing probably more than 170,000,000 acres of arable land, is being fast occupied by an industrious, intelligent, law-abiding people—a progressive, ambitious people, imbued with the spirit of the west, who are not content merely with the methods that satisfied a past generation, but who are anxious, as far as may be possible, to farm their land according to the principles of modern, economic agriculture. Our room for expansion will be evident from the consideration of the following estimates collated from official sources by Dr. Wm. Saunders, director of the Dominion Experimental Farms, and given by him in a paper on "Wheat Growing in Canada," in 1904. Dr. Saunders, I may add, has always been considered as a well-informed and most conservative authority in his statements regarding agricultural matters:

Land fit for settlement in western Canada (Manitoba, Saskatchewan and Alberta): 171,000,000 acres, of which there is now under cultivation 5,000,000 acres.

Present production of wheat and other grains, about 125,000,000 bushels.

Possible wheat production (one fourth under crop annually), 800,000,000 bushels.

With these facts before you it will not be surprising to learn that the past two decades have witnessed great activity on the part of our governments, both federal and provincial, in providing means and establishing machinery for education in farming matters, for the solution of such agricultural problems as require scientific re-

search, and for giving assistance in such ways as may be practicable to the individual farmer in his every-day work. The Ontario Agricultural College at Guelph, instituted in the seventies, has earned a continental reputation for the excellence of the training given her students, now to be found on farms and in technical positions all over the land. A large amount of very valuable experimental work has also been done at Guelph and, through the cooperative society of her graduates, in various parts of the province of Ontario. The system of farmers' institutes has been a further means of disseminating the principles of modern agriculture in the various provinces, chiefly by lectures and addresses, and also to some extent by practical demonstrations in the field. Manitoba and the maritime provinces within the past three years have established agricultural colleges which, besides doing strictly collegiate work, are fast becoming active centers for the propagation of agricultural knowledge.

It is just twenty years ago since the federal government established the Experimental Farm system, comprising at that time a central institution at Ottawa with a scientific staff and laboratories, and four branch farms, located, respectively, at Nappan (Nova Scotia), Brandon (Manitoba), Indian Head (N. W. T.) and Agassiz (British Columbia). Quite recently two others have been added to this list, at Lethbridge, southern Alberta, and Lacombe, northern Alberta. The immediate establishment of others, both in the east and in the west is under contemplation by the government.

It would be altogether too long a story to tell you, even in outline, of the experimental work done in the various branches of agriculture during these years by the experimental farms, in stock-feeding, in dairying, in soil management, in the growth of crops, in the use of manures, in the

originating and distributing new and improved cereals and roots, in orchard work, in disseminating information relating to the prevention of insect and fungous pests. But is it not all recorded in the reports and bulletins of the farm, no doubt to be found on the shelves of your libraries?

I must not, however, omit to say that there is a very large amount of work done which finds but little permanent record. The experimental farms are not only for research and experimentation, but for the dissemination of information on agricultural matters generally. We have endeavored to make each farm, and especially the central farm at Ottawa, a bureau to which all engaged in farming should feel themselves at liberty to apply for advice and instruction. To this end the privilege of sending letters to the central farm, Ottawa, free of postage was extended by the government and has been largely used. The experimental farm undoubtedly exerts an influence of great practical value through this correspondence, the magnitude of which will be apparent when I tell you that from the central farm alone in the neighborhood of 35,000 letters are sent out annually in addition to reports, bulletins and other printed matter. This branch of the work has served to keep the farm officers in touch with the farmers in all parts of the Dominion. Further, it has brought to our notice many difficulties which have subsequently furnished most interesting subjects for research and we can point to many valuable results to the country at large that have arisen in the first place from a farmer's inquiry.

But it is of the chemical work more particularly that I am to speak to-day. Agriculture is not a branch of chemistry, but it is, nevertheless, to-day a vocation which calls for the intelligent application of principles based on chemical truths. Physics and

biology are sciences that also supply fundamentals, but all must agree that of these three, chemistry takes the first place, furnishing, as it does, the very foundation and framework of modern agriculture. It seems to be the science which above all others we fall back upon for an explanation of all agricultural operations, whether performed by nature or by man. We have not tried to make our farmers chemists, but in the presentation of chemical information relating to farm work (put as far as possible into language understandable to the layman) we have endeavored to make it clear that profitable agriculture to-day means putting into practise the teachings of the laboratory and the experimental plot; and I am happy to say that in this our labors have not altogether been in vain. Looking over the country as a whole and comparing the sentiment of our farming community of twenty years ago with that of to-day, I am well satisfied that good progress has been made in establishing a confidence in, and in awakening an appreciative attitude towards, scientific research and teaching.

Since among the factors that conduce to profitable farming, a productive soil is perhaps the one of greatest importance, it was only natural that from the outset we should have made the matter of the economic maintenance and increase of soil fertility our special study. As I have already told you, we have in certain parts of the older districts of the Dominion soils which have been partially exhausted by irrational and wasteful methods; and again, as you know, we have vast areas in the west, as yet practically untouched, of virgin soil of the finest quality, capable of producing magnificent crops. For the former we have endeavored to devise practical methods that would restore fertility—and this in a large measure without recourse to commercial

fertilizers; for the latter we are trying to construct a plan or system of farming that would materially lessen the deterioration consequent upon exclusive grain farming.

In the course of this work during the past twenty years we have examined chemically several hundreds of surface soils representative of cultivated and virgin areas, and collected in every province of the Dominion. Many of these have been submitted to what we might term complete soil analysis, including the determination of available plant food by the Dyer method. Physical determinations, in a large number of instances, have been obtained to supplement the chemical data. With these results at hand and with conclusions we have been able to draw during this period from personal observation and inspection of soils in various parts of Canada, it might naturally be expected that we should be in a position to make some pronouncement regarding fundamental differences that might exist between fertile virgin soils and unproductive, worn soils, respecting the factors that go to make up what we might term fertility, and their relative importance. With regard to these factors, we may say that our work, in accordance with that of many others, has shown that, apart from climatic conditions (temperatures, rainfall, sunshine, etc.) soil-productiveness results from a happy assembling of the chemical constituents of plant food in more or less assimilable forms, of physical properties allowing of soil aeration, the retention of moisture, and the providing of freedom for root extension, and, lastly, the presence of an abundance of those microorganisms which, living on the organic matter of the soil, prepare the nourishment of our farm crops. It is thus seen that, according to our present views, the three sciences, chemistry, physics and biology, must all contribute

their share of work towards a complete and correct soil diagnosis. We can not stay now to consider how far our methods to-day are satisfactory towards that end; we all admit they are far from perfect. Nevertheless, there has been a marked advance during the past ten years, and there are at the present time earnest and skilful workers engaged in this research whose labors are yearly adding to our store of knowledge on this important but exceedingly difficult and complicated subject.

Our own work in this matter has been more particularly in tracing the relation of organic matter and its concomitant, nitrogen, to crop-producing power.

1. Very early in our soil studies I was impressed by the fact that our virgin soils of great productiveness were invariably characterized by large percentages of organic matter and nitrogen, and that, on the other hand, worn soils resulting from continuous grain growing or other irrational systems, and soils from naturally poor areas, showed meagre amounts of these constituents. If we except soils from the semi-arid districts of the west, and the muck soils of the east, these statements will apply, more or less strictly, to all types of soils, from heavy clays to light sandy loams.

2. We found, further, that in those soils from humid districts there was a relationship between the organic matter and the nitrogen—that what affected or destroyed the former dissipated the latter; while, on the other hand, the methods that led to an increase of the organic matter also raised the nitrogen content. Undoubtedly these two constituents stand and fall together.

3. Another feature of importance was that accompanying a fair organic content there was usually a goodly proportion of available phosphoric acid, potash and lime:

that is, according to the Dyer method of determination.

4. Lastly, it was evident that the proportion of organic matter present influenced in a marked degree the capacity of the soil for holding moisture, and in several other important particulars affected the mechanical condition.

We have not been able to study the effect of the organic matter and nitrogen content on bacterial life, but I believe it will be shown that, other conditions being equal, there is a distinct relationship between these important factors, the latter being determined by the former. Further, that fertility will be found largely dependent upon the rate of nitrification during the growing season, which, though largely regulated by temperature and moisture, must be materially affected by the amount of the food supply that the microorganisms find in the form of partially decomposed nitrogenous organic matter.

Another matter closely connected with nitrification is the liberation in available forms of mineral plant food. Is it not more than probable that the two processes are coexistent and interdependent—possibly identical?

As the years went by and our data increased it became ever more and more plain that in the semi-decomposed organic matter and its nitrogen we had factors of primary importance and of the greatest diagnostic value—that from them we could obtain a fairly clear insight into the character of the soil—chemical, physical and biological.

Since, then, we have reason to believe that the percentage of nitrogen is directly and indirectly a measure of the soil's fertility, and that this percentage is largely influenced by the treatment the soil receives, we may consider the data from one or two series of experiments to show the rate of

depletion of soil nitrogen under certain conditions of farming, on the one hand, and, on the other, the extent to which nitrogen enrichment may take place when nitrogenous organic matter is allowed to decay in the soil.

To procure figures that would illustrate the injurious effect on soils by continued grain growing interspersed with fallowing, we obtained from our Experimental Farm at Indian Head, Sask., in 1905, a sample collected from an area that had been broken in 1882 and that had between that date and 1905 borne six crops of wheat, four of barley, and three of oats, with a fallow between each crop since 1887, nine fallows in all. No manure or fertilizer had ever been applied.

HISTORY OF CULTIVATED SOIL

1883, wheat.	1890, fallow.	1898, fallow.
1884, wheat.	1891, barley.	1899, wheat.
1885, wheat.	1892, fallow.	1900, fallow.
1886, barley.	1893, wheat.	1901, oats.
1887, wheat.	1894, fallow.	1902, fallow.
1888, fallow.	1895, oats.	1903, barley.
1889, oats.	1896, fallow.	1904, fallow.
	1897, barley.	

For comparison, a sample of soil was taken from an adjacent area that had never been cultivated, the point of collection being about 120 feet away from where the cultivated soil samples were taken. Each sample was, of course, of a composite nature. There is every reason to believe that the soil over the whole area was originally of an extremely uniform nature and with a similar nitrogen content throughout.

Samples were taken representative of the first four and eight inches, respectively, and the nitrogen results, calculated to the water-free soil, are as follows:

In this comparison I am obliged to assume that the virgin soil is no richer to-day in nitrogen than it was twenty-two

DEPLETION OF SOIL NITROGEN

Nitrogen Content of Virgin and Cultivated Soils, Indian Head, Sask.

	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	3824	.371	6936
Cultivated soil.	.257	2402	.253	4730
Difference or loss due to removal in crops and to cultural methods.	.152	1422	.118	2206

years ago. This is not, of course, strictly correct, for we must suppose that this prairie soil with its annual crop of grass would year by year increase its nitrogen content. The increase, however, we think, could not be such as to materially affect the significance of the above figures.

The loss of nitrogen consequent upon this style of farming is seen to be enormous. It presents an aspect of western farming of a most serious character. Yet there has not been, so far as we can judge, any marked diminution in the yield during this period; provided climatic conditions are favorable, it is held that this cultivated soil will give as fine a crop as it did twenty years ago. The reason is that there is in this soil to-day in spite of its losses a nitrogen content about twice that considered necessary to the production of a maximum crop—it was one of the richest soils; it still is one of exceptional fertility. In such a matter as this chemistry is as a watchman upon the tower warning us of trouble that is yet afar off and which we still have time to avert; interrogating the soil by pot culture, so much favored by some, would be of no value in announcing the fact that most disastrous losses are taking place.

The next enquiry in this soil study is, what proportion of this loss may be due to removal by crops, what proportion to cultural operations? To answer this we

have calculated the nitrogen contained in the various grain crops produced, and find that from this cause there has been removed during this period, approximately, 694 pounds per acre. If we subtract this amount from the total loss, calculated to a depth of eight inches of soil, we shall see that more than twice as much nitrogen has been dissipated by our methods of cultivation than is removed in the crops. The loss ordinarily in the grain growing districts of the west would not in all probability be as great as that here recorded, because as a rule the land is fallowed every third year only, and not every other year, as with the soil under discussion. Nevertheless, the deterioration must be marked and I fear unless checked the experience of the extreme east may be at no very distant date that of the west. It seems to me incumbent upon us at once to seek for methods that are less wasteful—we must introduce a crop for the west as we already have for the east, occasionally, or better still systematically, as in a rotation, that will keep up the store of organic matter and nitrogen.

The natural means for replenishing the soil with these organic constituents is of course farm manures, but unfortunately in the districts where such are most required the supply is frequently inadequate. We, therefore, at once fall back upon the leguminosæ—the nitrogen gatherers. These are nature's soil enrichers. We know of no other family of plants that can be used on the farm possessing the unique and valuable property of appropriating the free nitrogen of the air—nitrogen which may be subsequently made available for succeeding crops. Not that the fertilizing value of the legumes lies simply and solely in the nitrogen they contain, though therein is their chief merit; the large quantity of humus-forming material they furnish, the

mineral matter—potash, phosphoric acid, and lime—set free in their decomposition, are features the significance of which, I think, has been somewhat overlooked. It is, however, simply from the standpoint of nitrogen that I shall present certain data at the present time. They will serve to illustrate the three methods we have employed to demonstrate the manurial value of clover and other legumes, viz.: by analysis of the legumes, by estimation of the nitrogen in the soil before sowing the legume and after its decomposition, and by determining the yields of various farm crops following this use of the legumes.

NITROGEN CONTENT OF VARIOUS LEGUMES

There are presented in the following table data showing the weight of crop and nitrogen per acre furnished by eight of the more common legumes, the determinations being made on the foliage (stems and leaves) and roots (collected to a depth of nine inches), respectively.

Of course, no attempt will be made to say what proportion of this nitrogen was obtained through the agency of the nitrogen-fixing bacteria, but of the strong probability that the greater part was from the atmosphere we have, I think, good evidence in the fact that all these legumes were well provided with nodules on their roots, and also that there is, all things considered, a remarkable agreement between these figures and the increase in soil nitrogen due to the decomposition of the legume crop.

Further, I wish you to consider these results as merely indicative—the amount of nitrogen appropriated and available for manurial purpose would undoubtedly be influenced, within certain limits, by the character of the soil, the prevalence of the nitrogen-fixing bacteria and the nature of the season. In this matter I have been in the

NITROGEN IN VARIOUS LEGUMES

Legumes: One Season's Growth	Weight of Crop per Acre		Per Cent. of Moisture	Nitrogen	
	Tons	Lbs.		Per Cent.	Pounds per Acre
Clover:					
Common red, stems and leaves.	4	1,779	76.24	.920	90
Roots.	2	1,445	71.22	.881	48
Total.	7	1,224			138
Clover:					
Mammoth red, stems and leaves.	6	1,310	79.13	.616	82
Roots.	3	1,260	77.57	.661	48
Total.	10	2,570			130
Clover:					
Crimson, stems and leaves.	11	234	83.32	.382	85
Roots.	3	201	83.87	.304	19
Total.	14	435			104
Alfalfa:					
Stems and leaves.	5	1,192	71.63	.670	75
Roots.	5	558	64.74	.577	61
Total.	10	1,750			136
Hairy Vetch:					
Stems and leaves.	11	1,895	82.78	.544	129
Roots.	2	345	86.35	.414	18
Total.	14	240			147
Soja Beans:					
Stems and leaves.	7	350	74.69	.571	82
Roots.	1	900	80.12	.448	13
Total.	8	1,250			95
Horse Beans:					
Stems and leaves.	7	733	84.04	.429	63
Roots.	2	852	86.72	.308	15
Total.	9	1,585			78
Pease:					
Stems and leaves.	12	1,013	86.56	.476	119
Roots.	1	1,132	84.94	.328	10
Total.	14	145			129

habit of telling our farmers that in the growth of red clover which takes place after the harvesting of the cereal crop and before the season closes (in eastern Canada we advocate sowing eight to ten pounds of red clover seed with all classes of cereals) there should be in the neighborhood of one hun-

dred pounds nitrogen per acre—that is, provided growth has not been retarded by a period of drought. The ploughing under of this crop, either in the late autumn or the following spring, according to the nature of the next crop to be planted, is now a system widely adopted with excellent results.

Though we have shown conclusively that clover can be successfully grown at many points in Manitoba and Saskatchewan, there is not in many parts of these provinces a sufficiency of moisture during the growing season for both clover and grain crops. Further, the severity of the winter is such as to render doubtful the survival of the clover. Therefore, while advocating clover wherever its growth is possible, we have looked about for a legume that would better fulfill the requirements of the case, that would allow the fallowing of the land, say, till the middle of June, to get rid of weeds, and then, being sown, would in two months give such a growth for turning under as to make it of practical value. We think we have such a legume in pease, data regarding which from two months' growth are given in the table. Though the root system is not extensive, it will be seen that by plowing under the whole crop we can enrich the soil by, approximately, two tons of humus-forming material per acre containing in the neighborhood of 130 pounds of nitrogen.

INCREASE OF SOIL NITROGEN DUE TO GROWTH OF LEGUMES

For a number of years we have been endeavoring to determine directly, that is, by analysis of the soil, the amount of nitrogen derived from the growth of a leguminous crop. I may very briefly describe one of the experiments in this series and which, begun in 1902, is still in progress. A plot 16 feet by 4 feet was staked off and the sides protected by boards sunk to a depth of eight inches. The surface soil to this depth

was then removed and in its place a strictly homogeneous but very poor sandy loam substituted—the nitrogen content of which was .0437 per cent. This was dressed with the following chemical fertilizer:

Superphosphate at the rate of . . . 400 lbs. per acre.

Muriate of potash at the rate of 200 lbs. per acre.

It was then sown with red clover, May 13, 1902. During each succeeding season the growth has been cut twice, and the material allowed to decay on the soil. At the end of every second season the crop has been turned under, the soil being stirred to a depth of approximately four inches, and the plot resown the following spring. From the subjoined table, it will be seen, four collections and analyses of this soil have been made since the experiment began, and each successive collection has shown a marked increase in nitrogen—an increase which I think very satisfactory for such an open, sandy soil.

NITROGEN-ENRICHMENT OF SOILS DUE TO GROWTH OF CLOVER

	Date of Collection	Nitrogen	
		Percentage in Water-free Soil	Pounds Per Acre to a Depth of 4 Inches
Before experiment.	13-5-02	.0437	533
After two years.	14-5-04	.0580	708
After four years. ⁴	15-5-06	.0608	742
After five years.	30-5-07	.0689	841
Increase in nitrogen due to five years' growth of clover.		.0252	308

In two seasons we enriched this soil in nitrogen to the amount of 175 pounds per acre; in five years, despite losses, the land is richer by 308 pounds per acre.

EVIDENCE OF SOIL ENRICHMENT FROM SUBSEQUENT CROP YIELDS

To conduct experiments in the field to

⁴The season of 1905 was an exceedingly poor one for clover and the growth on the plot was consequently very meager.

prove that the growth of clover has a beneficial influence upon succeeding crops might seem to some as superfluous and unnecessary. The knowledge of the value of clover in this particular is truly a matter of ancient history. Nevertheless, to bring home in a very practical way to the Canadian farmer the fact that he could find in clover and other legumes the very cheapest and best of manures, and to show that our laboratory results would receive confirmatory evidence in the field, we instituted several series of experiments on the Dominion Experimental Farms in the growing of various crops after clover. I shall only present data from two series, but they are typical and may, therefore, very well serve to illustrate the results we have obtained regarding the after-effect of the legume. Each series consisting of two plots, one with and one without clover, was continued for three seasons after the growth of the clover and it will be noticed that there was an increased yield from the plots that had carried the clover—right to the end of the experiment period. The increases are truly phenomenal. All our results have been of an equally convincing nature and it seems almost impossible to comment upon the data without appearing to use extravagant language regarding this method of green manuring. I will, therefore, let the figures tell their own story.

This table requires but a word of explanation. The plots in each series are contiguous, the soil uniform in character with the same history and of an open, sandy nature. In series I. the clover was sown without any nurse crop, one cutting made and removed; in series II. oats were sown with the clover and no cutting of the latter made. In each case the clover was turned under in the following spring.

Perhaps I may have already overstepped the bounds set me and encroached on the valuable time of this convention. I am

INCREASE OF CROP DUE TO GROWTH OF CLOVER

1900	1901			1902			1903		
		Tons	Lbs.		Bush.	Lbs.		Tons	Lbs.
<i>Series I: Plot A: Clover.</i>	Corn	27	1760	Oats	75	10	Sugar beats	22	600
<i>Plot B: Wheat.</i>	"	19	1280	"	51	26	" "	8	1,260
Increase due to clover.	Corn	8	480	Oats	23	18	Sugar beats	13	1,400
1901	1902			1903			1904		
								Bush.	Lbs.
<i>Series II: Plot A:</i>	Corn	20	600	Pota-	202	40	Barley	45	
<i>Oats with clover.</i>				atoes					
<i>Plot B: Oats.</i>	"	15		"	154		"	38	16
Increase due to clover.	Corn	5	600	"	47	20	Barley	6	20

anxious not to sin in such a serious matter and, therefore, I will ask you to take this chapter as giving an example of the way in which we have approached some of the fundamental problems in Canadian agriculture. To review, even in a similarly sketchy manner, our work during the past twenty years for the various branches—stock feeding, dairying, fruit growing, etc.—would be now quite impossible. Investigations that occupy several years, such as, for instance, the one undertaken to learn the effect of different feeding stuffs on the quality of the pork produced and in which the fat from more than 300 pigs was analyzed, can not be summarized in a sentence or two. Of a similarly protracted character have been the experiments to ascertain the losses that take place in the preservation of barnyard manure, in winter and summer; of experiments with various cultures or preparations of nitrogen-fixing bacteria—a matter that has engaged our attention since 1897 owing to its relationship to the maintenance of soil fertility through the leguminosæ; of experimental work carried on in different parts of the Dominion to determine how far soil moisture can be controlled by various systems of soil managements, more particularly in orchards; of reclamation work on swamp muck soils, of which there are large areas in eastern Canada as well as in British

Columbia. Then, again, chemical work has been brought into requisition for determining the relative value of Canadian forage crops—grasses, Indian corn, rape, etc., and the period in their growth at which they are most nutritious; for the examination of sugar beets in connection with the establishment in Canada of the beet sugar industry; for tracing the effect of environment and cross-breeding on the composition of wheats, with a view to assisting in the discrimination between the many wheats produced by hybridization—a work that has largely received the attention of the experimental farms. And so I might continue, for our field of operations has been a wide one and we have endeavored to make the chemical work useful to as large a number as possible. Perhaps a thought that has been uppermost in my mind, and in the minds of others engaged in this work from the beginning, is that while all our investigations should be conducted with the spirit of true scientific research they should be undertaken as far as possible with a definite, practical purpose in view. So that while our work, I hope, rings true, judged from the chemical standpoint, it may also be accounted of some practical worth to that national industry for the assistance of which our institutions were established. The motto of the Royal Agricultural Society of England, "Practise with Science," always

had a certain charm for me. The principle here expressed applied to our work might be interpreted, "Utility with Research." We have not, so far as I am aware, made any discoveries that will revolutionize the agricultural world, nor have we been looking for such; we have endeavored to do the work that came to our hands faithfully and with such skill as we possessed. Our results may not have been made the subjects of magazine articles, nor heralded in the public press under sensational head-lines, but we have the greater satisfaction of knowing that they have been helpful to the Canadian farmer. There is so much work to be done that one feels at times as if a beginning had not yet been made; nevertheless, on looking back it is not difficult to see wherein chemical research has played its part in the development of Canadian agriculture.

May I, in conclusion, say that our work in agricultural chemistry has been very greatly assisted by help in various ways from those in charge of the chemical investigations at the experiment stations in the United States? Many of our problems have been yours. You were the pioneers in the field; we have profited much by your work and experience. We acknowledge with gratitude our indebtedness, and trust that the friendly relations that have so far existed between us may always continue; and that we may always be able to work together, recognizing that our object is one and the same—the progress of agriculture on the North American continent.

FRANK T. SHUTT

DOMINION EXPERIMENT FARM,
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conferred by the universities of the United States. The total number of doctorates conferred was 327, almost exactly the same as in 1905 and 1906, when the numbers were, respectively, 325 and 326. The average number for the past ten years has been 271. There has thus been an increase, though probably not so large as in the number of positions to be filled. It must also be remembered that the number of American students receiving degrees from foreign universities is probably less now than it was ten years ago.

TABLE I.
DOCTORATES CONFERRED

	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	Total
Chicago.....	36	24	37	36	27	32	36	44	31	53	356
Harvard.....	26	24	36	29	31	28	46	38	46	34	338
Columbia.....	22	33	21	25	32	39	29	38	42	41	322
Yale.....	34	30	26	39	29	36	39	34	29	22	318
Johns Hopkins.....	33	38	33	30	17	23	31	35	32	33	305
Pennsylvania.....	24	20	15	25	14	29	18	26	28	26	225
Cornell.....	19	7	19	21	23	20	13	21	19	19	181
Clark.....	12	5	9	7	1	4	10	18	13	8	87
Wisconsin.....	5	6	5	6	11	4	12	9	9	19	86
Michigan.....	7	4	5	3	10	10	8	7	8	7	69
New York.....	5	9	7	6	4	4	9	7	9	7	67
Boston.....	0	0	0	0	0	4	7	14	10	9	44
California.....	1	3	2	2	1	3	3	4	9	5	33
Virginia.....	0	2	2	3	6	3	1	1	0	5	28
George Washington.....	1	0	5	3	2	4	3	3	2	5	28
Princeton.....	0	3	3	3	1	1	2	5	2	3	26
Minnesota.....	1	2	3	2	3	3	3	3	2	2	24
Brown.....	1	3	3	1	2	5	0	2	1	4	23
Bryn Mawr.....	3	3	1	2	2	0	5	2	2	1	21
Nebraska.....	2	1	1	1	0	0	2	3	7	3	20
Catholic.....	1	0	0	0	2	2	5	1	5	4	20
Stanford.....	2	0	2	2	2	1	1	1	2	1	14
Iowa.....	0	0	0	0	0	2	0	2	5	2	11
Georgetown.....	0	0	0	0	0	3	1	2	0	4	10
Washington.....	0	2	0	1	0	1	1	0	2	0	7
Vanderbilt.....	0	0	3	1	0	0	0	0	1	1	6
Colorado.....	0	1	0	0	0	0	2	0	2	0	5
Illinois.....	0	0	0	0	0	0	0	1	3	1	5
North Carolina.....	0	0	0	0	2	1	0	1	0	1	5
Missouri.....	0	1	0	0	0	0	0	2	0	1	4
Northwestern.....	1	1	0	1	0	0	0	0	0	1	4
Wash. and Lee.....	0	0	0	0	1	0	1	0	1	1	4
Cincinnati.....	0	0	0	0	0	1	1	1	0	0	3
Kansas.....	0	1	0	0	0	2	0	0	0	0	3
Lafayette.....	0	0	0	0	0	3	0	0	0	0	3
Massachusetts Inst.....	0	0	0	0	0	0	0	0	0	3	3
Lehigh.....	0	0	0	0	0	2	0	0	0	0	2
Syracuse.....	0	1	0	0	1	0	0	0	0	0	2
Dartmouth.....	0	0	0	0	0	0	0	0	1	0	1
Tulane.....	0	0	1	0	0	0	0	0	0	0	1
Western of Pa.....	0	0	0	0	0	0	0	0	1	1	1
	236	224	239	255	224	270	289	325	326	327	2,715

DOCTORATES CONFERRED BY AMERICAN
UNIVERSITIES

For the tenth consecutive year we publish statistics in regard to the degrees of doctor of philosophy and doctor of science

Chicago awarded last year 53 degrees, which is the largest number conferred so far by a single institution. This makes the total number of degrees conferred by Chi-