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THE DUTY OF CHEMISTRY TO AGRICULTURE[1]

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Chemistry is commonly looked upon as an exact science, and we will all agree that exactness is the ideal standard which every chemist worthy of the name sets for himself.

Agriculture is an art, a business, an industry. In passing, we may remind ourselves that agriculture is the greatest, the most necessary, and the most honored industry of civilization.

Agricultural chemistry is the servant of agriculture, and it is the highest aim and the most laudable purpose of the agricultural chemist to render the most trustworthy and the most enduring service to agriculture.

The Association of Official Agricultural Chemists is organized to discover and advance the truth and to point out and discard error, relating to agricultural chemical questions. It is as truly the duty of science to protect agriculture from error as it is to afford new truth.

It would be a pleasure for me to dwell upon the history of agricultural chemistry, especially upon the achievements of this

(1) Address of the President of the Association of Official Agricultural Chemists, delivered at the Annual Convention, November 8, 1906, at Washington, D. C.

The publication and wide dissemination of this address was requested by vote of the Association of Official Agricultural Chemists.

association, for they are many, and of great importance, but I feel that it may be of greater profit to the association, and more nearly in the line of duty at this time to discuss in the frankest manner some important sources of error and to point out possible methods of increasing the value of our service to American agriculture.

It has well been said that an experiment is a question put to Nature and that Nature always answers every question truthfully, but the question that Nature answers and that the experimenter asks is not always the question that he thinks he asks.

To illustrate, I call to mind that a few years ago a young lady student came into the private laboratory of Professor James H. Shepard, and said triumphantly: "Professor, I've got that unknown now. I found it was silver." The professor asked how she had made the test for silver and she stated that when the substance was put in solution with nitric acid and hydrochloric acid was added a white precipitate was obtained. "But how do you know," asked Professor Shepard, "that this test was not given by lead or mercury?" Whereupon she promptly replied: "Just because I was not testing for lead or mercury at all."

In order to determine with certainty the definite cause of a given effect, we must first eliminate other causes or influences which might contribute to that effect. This applies not only to simple qualitative analysis, but also to the application of chemistry to the development of agricultural science and the control of agricultural practice. Chemistry already controls in large measure many industries. Iron and aluminum, zinc and copper, silver and gold and other metals are extracted and refined by methods largely developed and controlled by chemistry, the preparation and mixing of materials being based upon chemical analysis. Soap, starch, sugar, paper, gunpowder and fertilizers are only examples of products now manufactured under chemical control.

Progress in agriculture demands that to the greatest possible extent practice shall be controlled by science. not by chemistry alone but by every science that deals with principles fundamental to agriculture. Every science that can contribute to agricultural development is a necessary, and should be a loyal, servant to agriculture, the industry upon whose success rests all industries and all civilizations.

It is only the ignorant who says agriculture is simple. To analyze an unknown substance, to operate a mine or a factory, to manage a bank or a bank failure, to drive a railway locomotive, to erect a cathedral, or to bridge Niagara,—these are simple compared to raising on an acre of land the largest crop of corn possible with maximum profit.

Who has sufficient knowledge to select the best seed? What should have been its breeding? What kind of land shall be chosen? How and when shall it be fertilized? What crop rotation should have preceded? Who knows how best to prepare the seedbed? At what time shall the corn be planted? What should be the temperature and the moisture content of the soil? What distance between and how many kernels in the hills? No man today can answer any one of these questions with certainty or with satisfaction, and the seed is not yet germinated in the soil, where the bacteria, the fungi, and the insect enemies await the young plant.

The factors and influences are many, but every effect has its cause. Many can contribute to the science of agriculture by gathering facts, but few can interpret the meaning of the facts gathered.

While it is easy to accumulate exact chemical facts, it is easier still to promulgate erroneous agricultural conclusions; and not only the science but the practice of agriculture has suffered, and is suffering today, from an insufficient accumulation of facts and data and from an over-production of theories and conclusions.

About three hundred years ago Van Helmont, a Flemish alchemist, planted a five-pound willow tree in 200 pounds of dry soil. He watered it with rain water for five years, and then found that the tree had gained 164 pounds and that the soil had lost only two ounces, in weight. Therefore, he concluded, water is the source of plant food. While it seemed to him that his evidence was strong and positive, we all know that his conclusion was wrong, and that the air, the water, and the soil are all essential sources of plant food.

In 1822 William Corbett, in his compilation of the writings of Jethro Tull, made the following statements:

"Mr Tull's main principle is this, that tillage will supply the place of manure; and his own experience shows that a good crop of wheat, for any number of years, may be grown every year upon the same land without any manure from first to last."

"Mr. Tull continued his wheat crops to the harvesting of the twelfth upon the same land without manure; and when he concluded his work, ... he had the thirteenth crop coming on, likely to be very good."

It is now known that the conclusion drawn by Tull and Corbett was wrong, although, as will be shown later, a theory recently promulgated by the United States Bureau of Soils, "that practically all soils contain sufficient plant food for good crop yields," and "that this supply will be indefinitely maintained," is in accord with the teaching of Jethro Tull. Indeed Tull's data are perhaps as trustworthy and conclusive as any thus far reported in favor of this theory.

The Minnesota Experiment Station has recently reported the yields of twelve crops of wheat grown continuously upon the same land, with results shown in Table 1.

TABLE 1. MINNESOTA SOIL INVESTIGATIONS

(a) Crop Yields per Acre in Bushels or Tons

Year.	Plot No. 1 without manure wheat grown continuously.		Plot No. 2 8 loads of manure in five-year rotation.	Plot No. 3 8 loads of manure in four-year rotation.
1893	12.3	Av. 14.7	Wheat 13.7 bu.	Oats 46.1 bu.
1894	8.9		Clover 2.16 tons	Clover 1.18 tons
1895	17.3		Wheat 22.0 bu.	Barley 42.5 bu.
1896	14.1		Oats 31.4 bu.	Corn 66.7 bu.
1897	10.2		Wheat 14.2 bu.	Corn 33.7 bu.
1898	25.2		Clover 1.41 tons	Oats 76.4 bu
1899	17.6	Av. 17.2	Wheat 19.5 bu.	Clover 1.86 tons
1900	18.8		Wheat 24.4 bu.	Barley 28.3 bu.
1901	16.2		Oats 58.7 bu.	Corn 40.6 bu.
1902	18.3		Corn (?)	Oats 80.0 bu.
1903	18.6		Wheat 30.0 bu.	Clover 4.70 tons
1904	13.7		Clover 3.98 tons	Barley 40.0 bu.
Total clover in 12 years....			Clover 7.55 tons	Clover 7.74 tons

(b) Nitrogen in Soil per Acre 12 inches deep

	Total, lb.	Loss, lb.	Total, lb.	Loss, lb.	Total, lb.	Loss, lb.
1892	7735 (?)		7735 (?)		7385 (?)	
1896	6755	(?)	8085	(?)	7630	(?)
1900	6055	700	6930	1155	6930	700
1904	5661	394	6720	210	7805	(875) gain
Total loss in 8 yrs.		1094		1365		(175) gain

It will be observed from the yields of Plot No. 1 that the Minnesota Station has not only confirmed the results of Jethro Tull, in growing good crops of wheat continuously on unmanured land for 12 years, but these crops have been grown without the special tillage that Tull considered so essential. Indeed, the Minnesota results show that the yields are increasing, the average of the first six years being 14.7 bushels per acre, while 17.2 bushels were produced as the average of the last six years reported. A theory based upon these yields, which cover 12 years, would show that under continuous wheat culture the average yield will be increased by more than 10 bushels per acre with every passing quarter century.

While these experiments are being carried on primarily to determine the effect upon wheat yields of continuous wheat culture upon the same land, the information secured only shows that some factor or factors, other than the continuous growing of wheat, have thus far exerted predominating influence upon the production of wheat.

The Minnesota Station has undertaken by another method to determine the effect produced upon the soil by different systems of cropping; namely, by analyzing the soil chemically at intervals of four years. The results obtained are given in the lower part of Table 1, including data secured from Plot No. 1 where wheat is grown continuously, and also from Plots Nos. 2 and 3 upon which crop rotations are practiced which include clover about once in four years. (The crops and yields are shown in Table 1.) It is assumed from statements made in the Minnesota bulletins that farm manure is applied at the rate of eight loads (8 tons approximately) per acre once in five years to Plot No. 2 and once in four years to Plot No. 3.

On page 254 of Minnesota Bulletin No. 70 occurs the following statement:

"Plots Nos. 1 and 2 contained, at the beginning of the experiment in 1892, .221 percent of nitrogen, while plots Nos. 3, 4, 5 and 6 contained .211 percent."

It is apparent from this statement that the nitrogen content of the soil from the two plots, Nos. 1 and 2, was determined either by the analysis of one composite sample or by the average of two or more analyses, while the identical nitrogen content of the soil from the four plots, Nos. 3, 4, 5 and 6, was evidently determined in a similar manner. If this is the case, of course the nitrogen content of the individual plots in 1892 is an unknown quantity. It is also questionable whether these original soil samples were collected to the same depth as those taken in subsequent years, the earlier data being reported for nine-inch depths while the later bulletins report all data for 12-inch depths.

Because of these discrepancies and uncertainties I feel obliged to discard the data given for 1892.

If we assume with the Minnesota Station that an acre-foot of the soil weighs 3,500,000 pounds, we find from the published data that during the eight years, from 1896 to 1904, Plot No. 1 lost 1094 pounds of nitrogen per acre under continuous wheat growing. During the same period Plot No, 2 lost 1365 pounds of nitrogen per acre with a rotation including two crops of clover and a moderate use of farm manure, while Plot No. 3 with a system of cropping and manuring quite similar to that of No. 2 lost 700 pounds of nitrogen per acre from 1896 to 1900 and then gained 875 pounds of nitrogen per acre from 1900 to 1904, making the net gain, for the eight years, 175 pounds, compared with a net loss of 1365 pounds on Plot No. 2, the difference between these two plots being 1540 pounds of nitrogen per acre in favor of Plot No. 2, to be attributed to the effects of eight years cropping and manuring under very similar systems. Thus, during the eight years, Plot No. 2 produced five crops of small grain and one of corn, while Plot No. 3 produced four crops of small grain and two of corn, two crops of clover having been produced on each.

Even these enormous gains and losses of nitrogen do not represent the extremes shown by the analytical data. If we compare the loss of 1155 pounds of nitrogen from Plot No. 2, from 1896 to 1900, with the gain of 875 pounds of nitrogen on Plot No. 3 during the next four year period, we find a total difference of 2030 pounds of nitrogen per acre as the measure of difference in the effect produced by comparatively similar treatment during equal periods of time.

A five-ton crop of clover would leave in the roots and stubble about 100 pounds of nitrogen per acre, and eight tons of average farm manure would contain about 80 pounds of nitrogen. The 40-bushel crops of corn and barley and the 80-bushel crop of oats would require about 180 pounds of nitrogen. It is apparent that this system of cropping and manuring would barely maintain the nitrogen content of the soil, even if all of the nitrogen used by the clover was taken from the air and if the loss of nitrogen by leaching was no greater than that supplied by the rain water, neither of which is probable. What then is the source of the 875 pounds per acre increase in the nitrogen on Plot No. 3 during the last four-year period?

It is an easy matter to determine with great accuracy the nitrogen content of a sample of soil. But it is exceedingly difficult to collect a sample of soil that shall accurately represent a field or plot. This year we sample a soil to a depth of 12 inches, but next year under different conditions of tillage and compactness, that

12-inch stratum occupies only 10 or 11 inches and our sample taken then may contain 10 or 20 percent of subsoil not represented in the first sample. Moderately sloping land plowed or cultivated in different directions during different years may receive or lose easily one-half inch of surface wash during a season of heavy rainfall.

In 1896, at the end of the first four-year period in these Minnesota experiments, Professor Snyder evidently had confidence in the data then at hand, and his early conclusions have passed into wide circulation in the agricultural press and even in text books; but at the present time he will no doubt agree that the chief value of the accumulated data from these special plots is to emphasize the fact that unknown or uncontrolled factors greatly predominate as an influence in the analytical chemical results, even more markedly than in the crop yields with continuous wheat culture.

While the general average of the Minnesota investigations, not only upon the special plots referred to, but also upon other fields in different parts of the state, clearly demonstrate the well-known fact that the nitrogen content of the soil is rapidly reduced under continuous grain cropping, they are by no means conclusive regarding the permanent maintenance in the soil of sufficient nitrogen and humus for satisfactory crop yields by the suggested systems of cropping and manuring. Aside from market gardens and permanent pastures, probably there are few if any agricultural soils in America whose nitrogen content is being maintained.

Notwithstanding the tremendous importance of nitrogen, as an element of plant food, and of humus, for its power to absorb and retain moisture, to prevent surface washing and running together of the soil, and for its power, as it decays, to liberate, from insoluble compounds, applied to or contained in the soil, the valuable mineral elements of plant food, as phosphorus and potassium,—notwithstanding these facts, even the corn and wheat soils in the Central West are being rapidly depleted of their humus and nitrogen under the prevailing systems of agricultural practice, and there is great need that investigations such as Professor Snyder has had in mind shall be so enlarged and extended and controlled that positive and complete information shall ultimately be secured regarding the maintenance of soil nitrogen and humus.

Another series of soil investigations extending over more than twelve years to this date has been conducted by the Ohio Experiment Station. These experiments include the application of the different commercial elements of plant food, singly and in various combinations. Probably no plot experiments have ever been planned and carried on with greater care than has been given to these by Director Thorne and his associates; and some very definite and valuable results have already been secured.

Recently the Bureau of Soils of the United States Department of Agriculture conducted a series of culture tests with the Bureau's paraffin pot and soil extract methods upon soil taken from these experiment plots of the Ohio Station, the purpose being to acertain whether the information secured by the Ohio Station from the field experiments extending over many years could not be essentially duplicated by 20-day cultures in paraffin pots and in soil extracts. The results obtained from the soil at Wooster, Ohio, have been prepared for publication by the Bureau of Soils and published without modification by the Ohio Station as Ohio Bulletin No. 167.

Because of the damaging influence upon agricultural science and practice that is sure to result from the continued publication of bulletins such as this and others issued directly by the Bureau of Soils, a frank and somewhat complete discussion of the data reported and of the conclusions drawn becomes an imperative duty.

The following direct quotation is from the conclusions of the Bureau of Soils given on page 119 of Ohio Bulletin 167.

"The experiments carried on at the Ohio Agricultural Experiment Station during eleven years by the plot method and those carried on during the last six months by the culture methods of soil in wire baskets and of soil extracts in bottles agree in showing that the best results which have been obtained are those following the application of nitrate of soda in combination with acid phosphate, the application of lime or the application of manure. Being submitted to a five crop rotation, this soil soon responds markedly to applications of phosphoric acid, and the effect of the continued application of this fertilizer is undoubtedly cumulative. This point being brought out equally well by both field and culture methods."

It is to be regretted that some of these specific conclusions are by no means in accord with the reported data. There is one well-known fact that stands out prominently in these pot culture results; namely, that the vegetative growth of young plants is increased on most soils by readily available nitrogen, unless applied in excessive amount or in injurious form. This increase in growth is usually obtained whether the nitrogen is applied in chemical salts, in organic commercial fertilizers, or in farm manure, especially in liquid manure, and it may be produced by an application of lime, which usually hastens the liberation of nitrogen from the soil.

In Table 1 of Ohio Bulletin 167 the Bureau of Soils gives data showing a somewhat systematic, though incomplete, effort to study by the paraffin pot culture method the soil fertility problems which the Ohio Station has been investigating for many years by field experiments. Because of the incomplete system of pot cultures a full comparison is not possible, but, so far as it is possible, I give in Table 2 a comparison of the results obtained by the Bureau's twenty-day tests in pot cultures, with nine year's field results reported by the Ohio Station in Bulletin 71. It should be understood that this is the fullest comparison afforded by the data as to the effect of applications of the different elements of plant food singly or in combination.

TABLE 2. EXPERIMENTS ON WOOSTER (OHIO) SOIL

Comparison of Ohio Field Experiments with Bureau of Soils Pot Cultures for determining needed elements of Plant Food

(a) Ohio Station Nine Years' test in Field

(Average increase in yield per acre)

Effect produced by	Corn, bu.	Oats, bu.	Wheat, bu.	Hay,* lb.
Nitrogen (NP over P)	6.53	6.52	4.17	881
Phosphorus (alone)	6.59	7.46	6.96	490
Potassium(KP over P)	4.11	2.34	2.02	333
Nitrogen (NPK over PK)	4.48	8.18	5.44	737
Phosphorus (PNK over NK)	11.05	14.52	12.45	1077
Potassium (KNP over NP)	2.06	4.00	3.29	289

(b) Bureau of Soils twenty-day test in Pots

(Wheat, weight of green tops, increase only in grams)

Effect produced by	Ordinary soil.	With lime.	With manure.	With lime and manure.
Nitrogen (NP over P)	2.71	4.20	1.90	2.50
Phosphorus (alone)	-.01	.10	-.70	-1.20
Potassium (KP over P)	.81	.50	.00	- .30
Nitrogen (NPK over PK)	2.80	2.60	2.90	-2.80
Phosphorus (PNK over NK)	.95	-.10	-.40	-4.80
Potassium (KNP over NP)	.90	-1.10	1.00	-5.60

(N=nitrogen; P=phosphorus; K=potassium).

* Increase in clover and timothy hay.

When we inspect the average of nine years' results from the Ohio field experiments, we find that phosphorus always produces a marked gain. In seven cases out of eight the gain by phosphorus exceeded that by nitrogen, and, when the single element was applied in addition to the two others, the gains produced by phosphorus were practically double those produced by nitrogen.

The pot culture results on the other hand show that phosphorus produced an actual loss in six cases out of eight, these losses ranging from .10 to 4.80 grams; whereas nitrogen produced a marked increase in seven cases out of eight, the gains ranging from 1.90 to 4.20 grams, in the weight of the green tops of the wheat seedlings.

In the one case where a decrease is indicated from the use of nitrogen, the data show that this exception is not real, but is accounted for by an error in obtaining the weight of green tops in series 25, as is plainly apparent from a study of the Bureau's data in the bulletin referred to.*

On page 119 of Ohio Bulletin 167, the Bureau of Soils states that the field experiments and pot cultures "agree in showing that the best results which have been obtained are those following the application of nitrate of soda in combination with acid phosphate—," and that the cumulative effect of the phosphoric acid is "brought out equally well by both field and culture methods", notwithstanding the fact that the Bureau's results show an average loss and no cumulative effect from the use of phosphorus, and that sodium nitrate without acid phosphate produced better average results than in combination with it.

On page 115 of Ohio Bulletin 167, the Bureau of Soils gives a table showing the "order of effectiveness of treatments," in which the Ohio nine-year field averages are supposed to be compared with results obtained by the Bureau of Soils with wheat seedlings grown in water extracts treated with different fertilizers corresponding to the Ohio system of field experiments.

In the tabular statement prepared by the Bureau of Soils, the test with nitrogen alone is omitted without explanation.

* The increased yield from treatment as determined by the weight of green tops in all other cases is essentially equal to or much greater than the increase as determined by the weight of water transpired, while in the case of series 25 the percentage increase shows less than one-third as much in weight of green tops as in water transpired, indicating that the tops from series 25 had lost some water and were not strictly fresh when weighed. To illustrate, series 19 shows an increase of 42.8 percent measured by transpiration and 89.6 percent, measured by weight of green tops, and this is about the usual relation between the two methods, but a striking exception to this rule is series 25, which shows an increase of 43.9 percent (greater than No. 19) when measured by transpiration, and an increase of only 12.1 percent (less than one-seventh of No. 19) by weight of green tops. (See Table 1, page 95, Ohio Bulletin 167.)

In Table 3 is given an exact copy of the Bureau's tabular statement and below it a completed table, showing the actual effectiveness of treatments as well as the order of effectiveness.

TABLE 3. EXPERIMENTS ON WOOSTER (OHIO) SOIL

(a) Bureau of Soils. "Parallel arrangements of treatments numbered according to efficiency, as obtained from the field methods for nine years and from bottled cultures. (Table X.*)"

Plot Number.	Treatment	Order of effectiveness of treatments. In field method 1894-1902		In bottle cultures (See Table X*)
		Grain	Straw	
2	Phosphate	3	3	2
3	Potash	1	1	1
6	Phosphate and nitrogen	5	5	5
8	Phosphate and potash	4	4	3
9	Potash and nitrogen	2	2	4
12	Phosphate, potash, and nitrogen	6	6	6

(b) Complete statement showing actual increase and order of effectiveness.

Plot Number.	Treatment	Ohio Station 9-years' field test with wheat Av. bu. per acre (Increase only).		Bureau of Soils soil extract cultures. Water transpired by wheat seedlings (Increase only).	
		Bushels.	Order.	Gram.	Order.
5	Nitrogen	1.41	1	216	4
3	Potassium	1.48	2	-4	1
9	Nitrogen, potassium	1.97	3	241	5
2	Phosphorus	6.96	4	78	2
8	Phosphorus, potassium	8.98	5	121	3
6	Nitrogen, phosphorus	11.13	6	268	6
11†	Nitrogen, phosphorus, potassium	14.42	7	279	7

* These references should be to Table XII, Ohio Bul. 167.

† Plot 11 is strictly comparable in this series, while plot 12 is not. (See Ohio Bul. 141, page 68).

It is difficult to imagine a more discordant comparison than is here exhibited. The wheat seedlings plainly respond to nitrogen, but whether the effect of the other elements is real or accidental is questionable. The field results show that the soil needs phosphorus first, nitrogen second, and potassium third. The increase produced by the combination of the three elements, including phosphorus above that produced by nitrogen and potassium without phosphorus, was less than 16 percent by the Bureau's cultures, and more than 600 percent by the Ohio field tests.

Of course where both nitrogen and phosphorus are present there is some apparent agreement, because the seedlings respond to the nitrogen, while the phosphorus is needed by the soil for the production of wheat; but the order of effectiveness, 1, 2, 3, 4, 5, in the field results, is not in harmony with 4, 1, 5, 2, 3, in the extract cultures.

Nevertheless, the following conclusion is drawn by the Bureau of Soils (Ohio Bulletin 167, page 116):

"This is very good agreement considering the nature of the work. The only considerable discrepancy is shown in the case of the treatment with potash and nitrogen. It is impossible to explain this difference from any data at hand. On the whole, however, the agreement of the two methods is as perfect as is usually obtained with growing plants, the growth of which is greatly influenced by many factors which we are not yet able to measure and control."

Table 4 shows the degree of agreement between the Bureau of Soils water cultures from soil extracts (see Ohio Bulletin 167, page 112) and the nine years' average of Ohio field experiments with wheat in rotation (see Ohio Bulletin 141, page 71), as measured by the effects produced by the plant food elements, nitrogen, phosphorus, and potassium, when applied alone and when one is added to the others.

Attention is called to the fact that this form of tabular statement is not only entirely fair and trustworthy, but it is the only method by which the effect produced by each element can be ascertained for the different conditions. Suppose, for example, that a farmer is using potassium alone upon his land for increasing his crop yields, which, as a matter of fact, hundreds of Illinois farmers are doing on peaty swamp lands. The question may naturally arise: Will it pay to apply nitrogen also to the soil? According to the Bureau's results, such an addition would produce a greater increase than any other addition of a single element; while, according to nine years' actual field trials by the Ohio Station,

TABLE 4. EXPERIMENTS ON WOOSTER (OHIO) SOIL

Comparison of Ohio field experiments with Bureau of Soils water cultures for determining needed elements of plant food.

Effect produced by	Ohio wheat yields in field tests. Average of 9 years. Bushels per acre. (Increase only).	Bureau of Soils. Extract cultures. Water transpired by wheat seedlings. (Increase, grams).
Nitrogen (NK over K)	.49	245
Nitrogen (alone)	1.41	216
Nitrogen (NP over P)	4.17	190
Nitrogen (NPK over PK)	5.44	158
Phosphorus (PK over K)	7.50	125
Phosphorus (alone)	6.96	78
Phosphorus (PN over N)	9.72	52
Phosphorus (PNK over NK)	12.45	38
Potassium (KP over P)	2.02	43
Potassium (KN over N)	.56	25
Potassium (KNP over NP)	3.29	11
Potassium (alone)	1.48	-4

such an addition produces a smaller increase than any other. In other words, that which is greatest by the Bureau's method is least in Ohio's nine year's experience.

Again, suppose the farmer is adding nitrogen to his soil, as most farmers are doing by growing legumes, if not in commercial form. There is no more sensible or appropriate question than, will it pay to add phosphorus also? The Ohio Station reports that such an addition of phosphorus will increase the yield of wheat 9.72 bushels per acre annually, which is almost seven times the increase produced by the nitrogen alone; but according to the Bureau of Soils the increase by phosphorus added in this way would be less than one-fourth of that produced by the nitrogen.

So far as nitrogen and phosphorus are concerned, the perfect disagreement between the water culture method and the actual field results is indeed remarkable.

The addition of potassium produces some increases in the field experiments, but they are not in accordance with the results obtained with the soil extract cultures, the lowest positive increase by potassium in the water cultures being produced where its effect should have been greatest, as, indeed, was the case in the field trials, namely when applied in addition to both phosphorus and nitrogen.

Considering this almost absolute disagreement between the Bureau of Soils 20-day tests with wheat seedlings and the Ohio Station's nine years' field work, it is with wonder that we read the following statement from the Bureau of Soils:

"The general conclusions from the field experiments, both at the beginning in 1894 and in their more advanced stages, are in agreement with those from the experiments carried on by the methods of basket cultures and cultures in soil extract." (See page 116, Ohio Bulletin 167). And again:

"The results of the two investigations at Wooster and Strongsville leave no reasonable doubt that the paraffin pot method does give results in harmony with the average results obtained by the much longer timed experiments in the field. It thus has an unquestionable value as a practical method for investigating the manurial requirements of the soil." (See page 122, Ohio Bulletin 168).

It is appropriate to state that the pot culture tests on the Strongsville (Ohio) soil were conducted by the Bureau of Soils along lines suggested by Director Thorne, but no conclusions were drawn by him from the data furnished regarding the fertilizer requirements of the soil.

Another publication has recently been issued, as Farmers' Bulletin No. 257, entitled "Soil Fertility", by Milton Whitney, Chief of the Bureau of Soils. This bulletin deserves some special consideration. Indeed, it is the publication of this bulletin that compels a public discussion of some of the methods, conclusions, and teachings of the Bureau of Soils that might otherwise remain buried in so-called technical literature unnoticed by the general public interested in agricultural progress.

The "Farmers' Bulletins" are undoubtedly the most widely distributed and the most extensively read, especially by actual farmers, of all the publications issued by the United States Department of Agriculture; and the injury to American agriculture that may result from the wide dissemination and adoption into agricultural practice of erroneous teaching from one occupying a national position of high authority is too vast to justify agricultural scientists and investigators in the easier and more agreeable policy of ignoring these teachings; and we must not forget that the responsibility to the American farmer for correct teachings relating to the principles of soil fertility rests most heavily upon the association of Official Agricultural Chemists.

Two points should be mentioned in order that it may be clearly understood that there is no misinterpretation of Professor Whitney's teachings, in Farmers' Bulletin 257. First, Professor Whitney recognizes that plants must have food; and, second, he admits that the addition of fertilizers to the soil frequently increases the yield of crops.

The following direct quotations fairly illustrate the theories and teachings of the Bureau of Soils relating to soil fertility. Professor Whitney says (Farmers' Bulletin No. 257, pages 10, 11, 12, 13, 20, and 21):

"In all soils there are rock particles or minerals containing phosphoric acid and potash, and in all the soil solutions that we have ever examined—and we have examined hundreds of them from all parts of the country—you will be astonished to learn that the composition and concentration of the soil moisture, which is the nutrient solution spread throughout the surface soil of the earth for plants to grow in and to gather their food from—you will be astonished to learn that the concentration of this soil moisture is sensibly the same whether we examine your sandy truck soils on your river necks, your sandy clay wheat soils on the uplands, the Hagerstown clay in the valley of the Shenandoah, or the black prairie soils of the West. These minerals are contributing to the solution in which the plant feeds. As I have said, these minerals are difficultly soluble, but they are appreciably soluble. They are soluble enough to maintain a solution which is amply sufficient for the plants to gather their food from. All soils having, broadly speaking, all of these minerals in them, have approximately the same composition in their soil moisture.

"This is a very astonishing fact, but looked upon in the light of our experiments it is an actual fact, that all soils contain sufficient plant food for the support of plants. Further, when the plant takes into its substance some of the mineral matter from the solution, the solid minerals in contact with the solution immediately dissolve and the solution is restored to its former concentration. The exhaustion of the soil, therefore, is merely a relative phrase and resolves itself into the question of the rate at which the solution can recover itself. I may state to you that the rate is as fast on an acre planted in our ordinary crops as the demand made upon it by the plant...."

"If the concentration of the soil solution is constantly maintained by the dissolving of these minerals, a plant can get along with much less than the concentration of our soil moistures...."

"If we take a plant and grow it in a water culture, the plant does better if we have a solution containing several times more phosphorus and potash than it actually needs to feed on. Why it is we do not know, but granting that the plant does better in a solution stronger than it actually needs as a food, we still have a solution in the soil apparently strong enough for any need the plant may have."

"Now we come to a very interesting thing to the farmer. If soils have sufficient food for the needs of plants and if this supply is constantly maintained, as I say, by the solution of these minerals in the soil, then what is the function of fertilizers and what do we mean by worn out lands or exhausted soils? It is just along this line that the Bureau is working and it is just along this line that we are getting most interesting results, results even now apparently of practical application; and this brings me to my fourth heading:

"PLANTS MUST HAVE A PROPER SANITARY ENVIRONMENT"

"Plants must have a healthful home to live in. Plants, like animals, throw off excreta, which must be disposed of—we must clean out the soils as we do the stalls in our stables. If we do not, the substances given off by the plants, or the substances that are formed from those substances by the action of bacteria, will produce acid substances, will produce what we call toxic or poisonous matters, that will themselves seriously affect if not kill the crop . . . ."

"These toxic substances, like the ptomaines or the tox-albumens in decaying meat, that are so poisonous to the human system, are difficult to separate and study. These substances are all more or less easily changed, easily broken down, easily destroyed, and it is our belief that fertilizer applications in many cases act in much the same way that manure and cowpeas do in changing these toxic substances, namely, in affecting them in some way so as to purify the soil. . . . . Apparently, these small amounts of fertilizers we add to the soil have their effect upon these toxic substances and render the soil sweet and more healthful for growing plants. We believe it is through this means that our fertilizers act rather than through the supplying of food to the plant . . . "

"I have attempted to show you the way I believe fertilizers act and the reason we use them. They are in a great many cases a ready means of purifying the soil. I think that is the way stable manure and green manures act. I think that is the principal office of nitrate of soda, potash, and phosphoric acid. . . . "

"These principles I have laid down give a plausible reason for the rotation of crops. If there are toxic substances thrown off by plants which the soil is not in a condition to change at once, we try to hasten it by cultivation, by aeration, by oxidation. In many of our systems of rotation, especially in Europe, the need of fallowing or resting the soil is recognized. When the soil is allowed to lie fallow almost invariably beneficial results are seen. The benefits may not be sufficiently great, as we believe in this country, to justify loss of the crop, but fallowing is generally beneficial to the soil. There is another way in which the fertility of the soil can be maintained, viz., by arranging a system of rotation and growing each year a crop that is not injured by the excreta of the preceding crop; then, when the time comes round for the first crop to be planted again the soil has had ample time to dispose of the sewage resulting from the growth of the plant two or three years before."

These quotations which I have taken from Farmer's Bulletin No. 257 present in very satisfactory form the present teachings of the Bureau of Soils. In the introductory remarks of the address which has been published as Farmers' Bulletin 257, Professor Whitney said: "You need not necessarily believe everything I say (because I cannot say truly that I *believe* everything myself, but only that our opinions seem reasonable deductions)." On another page he says: "I believe that through the results of our investigations during the last twelve years we are beginning to understand clearly the chemistry of the soil." And again he says: "I hope before long we shall have very strong proof of what I am about to say."

We may summarize the Bureau's soil fertility theories as follows:

1. All ordinary soils, including so-called exhausted soils, contain sufficient plant food for good crop yields, and this supply will be indefinitely maintained, without the addition of any of the plant food elements.

2. Most agricultural plants, and probably all of them, excrete substances that are poisonous to the plant furnishing the excreta. Weeds are poisonous or excrete substances that are poisonous to agricultural plants. So-called exhausted soils contain substances that are poisonous to all agricultural plants.

3. The fertilizers we add to the soil have their effect upon these toxic substances and render the soil sweet and more healthful for growing plants. It is through this means that our fertilizers act rather than through the supplying of plant food to the plant. This is the way stable manure and green manures act. This is the principal office of nitrate of soda, potash, and phosphoric acid.

These are the plain teachings of Farmers' Bulletin 257. Professor Whitney believes that there are cases in which fertilizers do act as plant food, although he states that among all the hundreds of soil samples examined by the Bureau of Soils, from nearly all sections of the United States, none has been found that is deficient in plant food.

I beg to offer a theory which shall be truly comparable with Professor Whitney's soil fertility theory.

Hundreds of determinations have shown that grass contains water, in fact that it consists largely of water. In good pasture each cow is usually allowed at least one acre of grass. The green grass in a good pasture will weigh at least one ton to the acre and the water in this grass will weigh more than the cow. The common practice of watering cows is not justified. Even if the cow demands more water than she needs the grass to which she has access will supply even her unreasonable demands. Indeed, this theory goes even beyond providing for the needs and for the unnecessary and unreasonable demands of the cow. Altogether aside from the water in the grass is the water supplied as dew. Determinations have shown that good grass pasture contains ten spears of grass to the square inch and that each spear carries a globule of water weighing, as an average, one-sixth of a grain. In other words about 42,000 of these globules make one pound of water. There are 43,560 square feet in an acre, and if one globule from each square foot makes one pound, then 144 times 10 globules from each square foot would make 1440 pounds of water, which again is more than the weight of the cow. It may be argued that there is dew on the grass only twelve hours out of the twenty-four and that cows should have water during the day; but the fallacy of this argument is easily shown from the fact that cows regularly do without water for twelve hours during the night and the day without dew does not exceed twelve hours.

A second chapter could be added to this theory by which it could be proven that the food which a cow eats serves not as a food but rather as a medicine to counteract the poisons contained in the stomach, at least one of which is not merely theoretically present, but actually known to exist in the form of hydrochloric acid. There may be cases in which a calf needs food, but not so with a cow. Indeed, the proof of this theory is practically self-evident for it is common knowledge that even if cows eat food they do not grow or gain in weight.

Let it be understood that I do not offer this theory as a farce or burlesque, but rather as the simplest and fairest comparison with the Bureau's theory of soil fertility.

The application of science to agriculture is only beginning. We have not yet learned everything, but we have learned something. We do not know the exact minimum requirement of every agriculture plant for each of the different essential elements of plant food, but we do know that our largest crops of corn and clover are removing annually from the soil more than twenty pounds of phosphorus per acre, and that phosphorus is an important and essential constituent of the grain of plants and of the bone of animals. We know also for example that the average total phosphorus content of the two most prevalent normal types of soil in Illinois does not exceed 1000 pounds of phosphorus per acre to a depth of seven inches, and that the subsoil is no richer in that element. We know that if such crops as we are now growing on our richest and best treated land had been removed annually from a soil representing an average of these two extensive types, from the time Columbus discovered America until the present day, every pound of phosphorus would have been required of the soil to a depth of five feet. We know that if the people of Holland had removed such crops from their lands, with no plant food returned, from the Conquests of Charlemagne until the Peace Conference at The Hague, they would need now to place their country twelve feet farther below the level of the sea in order to unload more than 20,000 tons per acre of phosphorus free soil, if originally as rich as ours.

We know that by the chemical analyses of the crops harvested and of the soils under experiment, the Rothamsted Station has shown that the phosphorus actually removed from one of the best yielding plots on Braudbalk field in fifty years is equivalent to 49 percent of the total phosphorus originally contained in the soil to a depth of 7 inches. The later soil analyses also show that these Rothamsted soils are losing phosphorus even in somewhat larger amount than that removed in the crops alone. While Dyer assumes that this excess loss of phosphorus from the surface soil is by descent into the subsoil, such assumption is not justified by the subsoil analyses, and it seems much more likely that the excess loss should be attributed in large part at least to surface washing, a factor evidently overlooked by Dyer.

The Bureau of Soils' theory of plant nutrition rests upon the assumption that so long as there is as much total plant food within the depth of soil to which plants feed as is needed for a maximum crop, the soil solution will be constant and the maximum crop should be produced. From the scientific and practical standpoint this assumption is no less ridiculous than that the cow's need for water should be satisfied so long as the acre of grass carries an amount equal to her capacity. It is indeed possible to so increase the moisture content of animal foods that cows will require no water in addition to that taken with the food, and it is now thought by entomologists that insects which take their food in the form of plant juices sometimes even die of starvation because their capacity for every watery juice is not sufficient to afford the nourishment required.

While Professor Whitney teaches that the movement of moisture in soil in fair moisture condition as regards the needs of plants is so slow as to be negligible, and consequently that the plant roots must themselves seek the moisture and plant food, and furthermore, that plant roots are incapable of absorbing water and plant food except at or near the tip of the root, that it is only about one-tenth of an inch of the root that actually absorbs water and food, and that the part that was absorbent yesterday ceases to be absorbent today, nevertheless he assumes that plants can secure abundance of plant food to meet their needs and demands even from the poorest soils ever examined by the Bureau.

We do not know what percentage of the water in an acre of grass can be utilized by a cow, nor do we know what percentage of the plant food in the soil is accessible to a growing crop, but there is good reason to believe that the percentage is not large in either case.

Under ordinary Illinois conditions some of our crops remove from our common soils the equivalent of, say, one-fourth percent of the total potassium and from one to two percent of the total nitrogen and total phosphorus contained in the surface seven inches of the soil. Of course these percentages vary with the feeding power of the plant, with the feeding range afforded by soils of different physical characteristics, and with the climatic or seasonal influences. If, under normal conditions, with suitable crop rotations, and by practical agricultural methods, the phosphorus accessible to the corn plant is equivalent to one percent of the total phosphorus content of the surface seven inches, then for a hundred-bushel crop of corn, requiring 23 pounds of phosphorus, the phosphorus content of the soil should be 2300 pounds, even if 23 pounds are sufficient to maintain a solution saturated with reference to the difficultly soluble forms of phosphorus naturally contained in the soil. If it is more profitable to practice methods that will increase the percentage of phosphorus liberated or rendered accessible to the plant, than it is to increase the available supply by applying phosphorus to the soil, we should be governed accordingly, having in mind always the future as well as the present productive capacity of the soil.

There is one other point that I feel compelled to mention:

After pointing out the benefits of fallow cultivation, Professor Whitney says:

"There is another way in which the fertility of the soil can be maintained, viz., by arranging a system of rotation and growing each year a crop that is not injured by the excreta of the preceding crop."

Exactly the opposite of this is true. The rotation of crops is a means for the depletion of soil fertility even more rapidly than can be accomplished by a one-crop system. Nitrogen is the only plant food element that can thus be added to the soil (an unnecessary addition according to the Bureau's theory), and this only in rotations that include legume crops; and the only soil whose productiveness can thus bé maintained (and this usually at low yielding power) is on sloping land whose surface soil is washed away in proportion to the exhaustion of the plant food elements and whose subsoil is as rich or richer than the surface. I have found some places where soils of this topography, with subsoils rich in mineral plant food, have been cropped for centuries with the production of two or three grain crops every ten or twelve years, the intervening years providing for the accumulation of nitrogen by legumes while the land is kept in pasture. It is highly probable, however, that a better system of farming even with such subsoils (and certainly with subsoils deficient in plant food) would provide measures to prevent surface washing and then enrich the surface soil to a higher productive capacity.

On page 22 of Farmers' Bulletin No. 257, there appears an erroneous and very misleading statement concerning the rotation experiments at Rothamsted, in the following words:

"In other experiments of Lawes and Gilbert they have maintained for fifty years a yield of about 30 bushels of wheat continuously on the same soil where a complete fertilizer has been used. ......With a rotation of crops without fertilizers they have also maintained their yield for fifty years at 30 bushels, so that the effect of rotation has in such case been identical with that of fertilization."

It is embarassing to offer comment upon these statements. Instead of 30 bushels with the unfertilized rotation wheat, the average yield is only 27 bushels per acre; and, instead of 30 bushels with the best fertilized continuous wheat, the average yield is 37 bushels per acre. In other words, the statement "that the effect of rotation has in such case been identical with that of fertilization" is far from the truth, the average difference being 10 bushels a year for half a century in favor of the fertilized wheat, even though grown continuously. This means that during the fifty years one fertilized acre in wheat every year has produced 500 bushels more wheat than four unfertilized acres in a four-year rotation.

But this is not all. Professor Whitney's statement is misleading because he ignores the fact that the barley in this unfertilized rotation yielded only 25 bushels, while the best fertilized continuous barley yielded 44 bushels per acre. The applications of plant food have increased the yield of continuous wheat by 36 percent, and the yield of continuous barley by 76 percent, above the yields in unfertilized crop rotations.

But this is not all. Professor Whitney also ignores the almost complete failure of the root crop on the unfertilized rotation plots. Doctor Bernard Dyer, speaking for the Rothamsted Experiment Station, regarding this rotation says:

"As far as the unmanured plots are concerned, the growth of roots was for the greater part of the time so small that it may be said that, practically speaking, there was no crop of roots."

It was my good fortune to visit Rothamsted in the summer of 1900, and to walk with Sir John Lawes, only a month before his death, over the different experiment fields while he talked of the investigations whose progress he had watched personally and almost daily for more than half a century. As we reached Agdell field Sir John said:

"Well, here are the turnips in the four-year rotation, and every time I come here the turnip says to me, 'If you won't feed me, I will not grow'."

These quaint but striking words were based upon the fact that as an average of all plots the unfertilized turnips, even when grown on the same land only once in four years, had produced less than one ton per acre of fresh roots as an average of fifty years, while on the fertilized plots in the same rotation the average yield had been 17 tons per acre.

With an average for fifty years of 10 bushels difference in yield of wheat, and 19 bushels difference in yield of barley, and 16 tons difference in yield of turnips, how can it be said to the American farmer "that the effect of rotation has in such case been identical with that of fertilization?"

There are fifty-six years of exact comparison reported from these Rothamsted four-year rotation experiments. Even this period of time is not to be considered sufficient to furnish absolutely conclusive data as to the effect of the rotation upon the productive capacity of the land, especially when but one of the four crops is represented each year. While Lawes and Gilbert's four-year rotations were not planned with four similar fields so that every crop could be represented every year, as is the case with most modern plans, nevertheless there are four divisions of the Rothamsted rotation field which are paired in one way to study the effect of fallow cultivation compared with growing a legume crop, and paired in the other way to study the effect of removing the root crop compared with returning to the land either the entire root crop or the manure made from it. By making an average of the yields produced during the first 28-year period and another average of the yields of the second 28-year period, we secure the best obtainable information relating to the effect of the farming system upon the producing power of the soil.

In each of the four divisions in the Rothamsted unfertilized rotation experiments the average yield of wheat is less during the second 28-year period than during the first. This difference, or reduction in productiveness, as an average of the four series, amounts to 4.0 bushels of wheat per acre in twenty-eight years, or 7.1 bushels in fifty years, by computation from these data.

With the unfertilized continuous wheat the average yield of the second 30 years was only 3.4 bushels less than the average of the first 30 years, showing a reduction in productive power amounting to 3.4 bushels per acre in thirty years, or 5.7 bushels in fifty years. If we consider the average of the first ten years ending 1853, and the average of the last ten years reported, ending 1903, we find that the yield has been reduced 3.4 bushels during fifty years. If we consider the yields only for the identical years when wheat was grown on the rotation plots, then we find the reduction in yield on the unfertilized continuous wheat plot to be only 2.7 bushels in 28 years, or, by computation, 4.7 bushels in fifty years. Knowing that the yield of continuous wheat has decreased about five bushels in fifty years, it is impossible to justify Professor Whitney's statement (page 22, Farmers' Bulletin 257) that Lawes and Gilbert "have seen their yield go down where wheat followed wheat without fertilizers for fifty years in succession from 30 bushels to 12 bushels." In other words, he states that the yield has been reduced 18 bushels, while the data show the reduction to be about five bushels. The unfertilized continuous wheat plot never produced 30 bushels per acre. The first recorded yield, in 1844, was only 15 bushels, and the highest yield ever reported is only 23¼ bushels; and it is interesting to know that last year, in 1905, a yield of 18 bushels was produced as the sixty-second successive crop of wheat on the unfertilized land.

In the case of unfertilized barley there has been a reduction in yield during 28 years of 14.5 bushels when grown in rotation and a reduction of only 7.5 bushels with continuous barley.

If any conclusion can be drawn from the Rothamsted data, it is that crop rotation is a means, not of maintaining soil fertility, but of depleting it, even more rapidly than can be accomplished by a continuous one-crop system. Indeed, this result is to be expected. Any method by which larger crops are produced without the addition of plant food must result in a larger removal of plant food and consequently in a more rapid depletion of the fertility of the soil, whether it be accomplished by crop rotation, by better cultivation, or by the use of better seed. While the adoption of good crop rotations, and of improved methods of cultivation and of seed selection is always to be encouraged, it should not be forgotten that larger crops grown by these better methods remove larger amounts of plant food, and whenever any plant food element becomes so depleted as to limit the crop yields, even under these better methods of farming, then that element should be returned if it can be done with profit.

A one-crop system followed year after year upon the same land tends to the breeding of insect enemies and to the development of fungous diseases peculiar to that crop, such as "flax sickness", investigated by the North Dakota Station, and perhaps "clover sickness," which has long been thought to be an actual fact in practical agriculture, and which the Tennessee Station is now investigating. A similar development of bacterial diseases seems probable. While it is possible that inanimate toxic substances may also be formed in the soil from plant excreta, or less improbably from the decomposition of the crop residues, there is no knowledge or evidence sufficient to justify a theory that fertilizers act primarily as antitoxins. It should be remembered that well fed plants are usually better able to resist or overcome the attacks of insects and disease.

Alkaline slag phosphate, acidulated rock phosphate, or neutral steamed bone are very different chemical substances, but they all contain phosphorus and in soils deficient in available phosphorus they are beneficial essentially in proportion to their phosphorus content, except where continued use influences appreciably the acidity of the soil. Sodium nitrate, ammonium sulfate, and dried blood are exceedingly different substances, but they all contain nitrogen and where nitrogen is deficient in the soil they are almost equally valuable in proportion to their nitrogen content.

To assume that the beneficial effect of these different plant food carriers is due to the correction of toxic substances assumed to exist is an absurdity and without foundation in known fact.

In this connection it is noteworthy that with legume plants essentially the same results are secured whether nitrogen is supplied in dried blood or provided by the nitrogen-fixing bacteria without fertilizer application; and it is also noteworthy that fre. quently two and sometimes three different elements of plant food must be applied to insure maximum crop yields, and yet two of the elements may produce little or no effect if the other one is omitted. Thus, in the nine years' results with wheat at the Ohio Station (See Tables 3 and 4), the combined effect of nitrogen and potassium was less that 2 bushels increase when applied without phosphorus, while the three elements produced an increase of more than 14 bushels, although phosphorus alone produced less than 7 bushels increase. Wheat must have these plant food elements for its growth and development; but under the Bureau's theory we must assume that this Ohio soil contains three different kinds of toxic substances, of which one is destroyed by nitrogen, another by phosphorus, and a third by potassium.

If it were possible I would emphasize in the thought of this association the fact that American agriculture is the fundamental support of the American nation and that soil fertility is the absolute support of American agriculture. The United States Department of Agriculture and the State Agricultural Experiment Stations are not founded and fostered by our Government in order to instruct the American farmer how more rapidly to deplete the soil of its fertility and rob American posterity of a rightful heritage.

I need not remind you that there are abandoned agricultural lands in this new country. Indeed, among all the nations of the earth, the United States stands first in rapidity of soil exhaustion. The improvement of seed, the use of tile drainage, the invention and immediate adoption of labor-saving agricultural machinery, the wonderful development of cheap and rapid means of transportation, and the opening of the world's markets to the American farmer have all combined to make possible the rapid depletion of American soil.

If we are ever to adopt systems of soil improvement it must be done while we are prosperous. Of what advantage is it to say to a poor man with accumulated debts and depleted land: If you will invest two dollars an acre in the improvement of your soil, it will bring you three dollars in return? He will answer you and say: I have not the two dollars to invest. I need every dollar I can obtain from this old farm to pay my debts and taxes and to provide support for my family. Ultimately this man's farm will be sold for taxes. Indeed, hundreds of farms in the older parts of our country have been sold, or reverted to the commonwealth, because of unpaid taxes.

It is common knowledge in my own rich state of Illinois that the lands that have been under cultivation for half or three-quarters of a century are less productive than they once were. By means of soil stimulants, including better drainage and more thorough cultivation, green manuring and crop rotation, all of which are truly soil stimulants, because they aid in taking from the soil and add nothing in return of which crops are made (save nitrogen in legumes), by these means, supplemented perhaps by the more destructive action of caustic lime and land-plaster, these lands may be made to produce fair crops for another generation or half-century. But what is a generation or half-century in the life of a nation?

If America is to live and support her people the crop yields for next year should be as large or larger than for this year, for the next generation as large or larger than for this generation, and for the next century, and for centuries upon centuries, the crop yields of America should be as large or larger than for this century.

If the theory which is being widely promulgated by the National Bureau of Soils, to the effect "that practically all soils contain sufficient plant food for good crop yields, that this supply will be indefinitely maintained," and that "the fertility of the soil can be maintained,—by arranging a system of rotation and growing each year a crop that is not injured by the excreta of the preceding crop," if this theory is forced upon, and accepted by, the farmers of the United States during the next quarter of a century, it would doubtless require another quarter-century to eradicate it from the mind and practice of the masses. Who shall try to estimate the possible damage to American agriculture if this teaching shall be allowed without contradiction to pass from the place of highest national authority into general acceptation?

Who shall estimate what proportion of the farms that are now prosperous and capable of inaugurating and supporting a system of profitable improvement leading to permanent prosperity, would, under fifty years' struggle to practice the Bureau's theory, become too poor ever to redeem themselves from ultimate ruin?

In closing, I desire to state plainly and in deep sincerity that to say these things is far from pleasure, and they are said only because the ultimate prosperity of American agriculture is at stake, and public duty must always rise above personal preference.

Of all the sciences that deal with matter, chemistry is the most fundamental. Chemistry controls oftentimes the investigation of other sciences, for chemistry deals with the ultimate substance,—the chemical element. Analysis of matter does not go beyond the chemical element. We may ask what it is or why it is, but the only answer is, it is because it is.

Chemistry is, and is to be, the mainstay of truly scientific agriculture. It is the staff or chief support upon which agriculture must lean, and should lean, with confidence, in order that agricultural practice may be controlled more and more completely by agricultural science.

As members of the Association of Official Agricultural Chemists, let us press forward with earnest desire and sincere devotion, with tireless energy and enduring patience, and with the highest standards of absolute fairness and honesty, toward the accumulation of facts, duplicated and multiplied, until are solved with certainty the foundation problems of a permanent and prosperous American agriculture.