CHEMICAL MANURES.

AGRICULTURAL LECTURES

DELIVERED

AT THE EXPERIMENTAL FARM

AT VINCENNES, IN THE YEAR 1867.

BY

GEORGE VILLE.

TRANSLATED BY MISS E. L. HOWARD,

NEAR KINGSTON, BARTOW COUNTY, GA.

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Chemical Manures.

PREFACE.

These admirable lectures of George Ville were originally translated from the French by Miss E. L. Howard for the columns of *The Plantation*, a weekly agricultural paper published in Atlanta, Georgia.

This was, perhaps, the first instance in this country in which an agricultural paper had ventured upon the translation of a foreign scientific work to be published in its columns. It was also, perhaps, the first instance in which a scientific agricultural work had been translated by a Southern—we may add an American—lady. It was a task of much difficulty, requiring not only a thorough knowledge of the French language and familiarity with scientific terms, but a change from French weights, measures and currency to our own. The whole work has been patiently and skillfully executed.

So great was the impression made by this translation that the State Agricultural Society of Georgia, at its recent Convention, held October 8th at Rome in Georgia, took the following complimentary notice of it:

"Mr. Barnett, of Wilkes, offered the following preamble and resolution:

"*Whereas*, The exceedingly interesting work of George Ville, who has done so much to advance the science of Agriculture among mankind, and to promote it almost to the rank of an exact science by his wonderful combination of skill, knowledge and common sense, has been translated by a Southern lady—a native Georgian—in a style of great elegance and perspicuity;

"*Resolved,* That this body, in the event of the publication of the translation, earnestly recommend its circulation, as furnishing the means of enlightenment to the most advanced farmers, both in the knowledge of facts and of the principles of investigation and experiment leading to the further increase of knowledge."

The resolution was adopted by a rising vote of the Convention, "as a mark of respect for the fair translator."

Mr. Fannin, of Troup, offered the following resolution, which was adopted:

"*Resolved,* That we, as representatives of the County Agricultural Societies, will endeavor to promote the circulation of the work of the distinguished agricultural writer and thinker, George Ville, and will recommend to the societies to subscribe liberally, and to take not less than six copies each; that in addition to this, the County Societies, instead of offering cups for premiums, will offer a copy of this work or a year's subscription to some good agricultural periodical."

After this strong endorsement by one of the most numerous, dignified and intelligent assemblages which has ever met in Georgia, it is unnecessary for the writer to add further remark.

H.

CHEMICAL MANURES.

A TRANSLATION OF AGRICULTURAL LECTURES GIVEN BY GEORGE VILLE, IN 1867, AT THE EXPERIMENTAL FARM OF VINCENNES.

LECTURE FIRST.

GENTLEMEN:—Since 1861 I have been in the habit of giving in a series of lectures the results of my studies on the means of husbanding and increasing the fertility of the soil, outside of those traditions consecrated by the experience of the past. My method belongs essentially to science, both in character and origin. From the beginning it has been conceived in the hope of giving a guide to Practice upon which she can safely rely. My efforts have been directed to freeing it as much as possible from all theoretic formulæ which are not imposed by the nature of the subject.

Since commercial liberty has become the economy of nations, we feel with added force the importance of agricultural questions. Under this new rule a nation can have a sound prosperity, but in proportion as it surpasses those nations to whom its interior is thrown open, it must produce more and more cheaply.

By what process can we obtain this end?

We will now seek it together, building upon the facts to which I here bear witness. Entering on my subject under its new aspect carries my thoughts back, and not without emotion, to the time when my labors were first thought worthy of encouragement by his gracious Majesty. Many doubted the results, as my efforts were founded on the studies of the laboratory. The emperor thought differently, and the founding of the experimental farm at Vincennes is an additional proof of the enlightened solicitude of our sovereign for our agricultural interests.

As I have already said, our Agriculture must increase her products if she would reduce their cost. The laws which permit her so to do require me to begin with the most intricate problems of vegetation—in a word, to unveil to you the very elements of which plants are composed, since it is to these she must have recourse if she would increase her returns.

In the composition of plants nothing is permanent. Their elements experience, in different organs, certain movements, veritable migrations, whose order and succession are regulated by fixed laws.

The structure of a plant depends on imponderable agents—light, heat, electricity. Now, to use these as auxiliaries it is absolutely necessary we know the effects of each. This can only be known by basing our deductions and laws upon the theories which precede them.

The first question is: Of what is the substance of plants formed? From whence comes it? How do the combinations of elements which chemists show, operate?

Upon this point Chemistry is as clear as decided.

She answers: Of fourteen invariable elements, which, for convenience, are arranged in two parallel series:

Organic Elements.	*Mineral Elements.*
Carbon,	Phosphorus,
Hydrogen,	Sulphur,
Oxygen,	Chlorine,
Azote.	Silicium,
	Iron,
	Manganese,
	Calcium,
	Magnesia,
	Sodium,
	Potassium.

Why are the first elements called organic and the second mineral? Because the first are found combined only in living beings, and the second belong by their nature to the solid crust of the earth.

But how is it, we ask, that so limited a number of elements suffices for so many dissimilar productions?

The answer is very simple: Because they possess the power of indefinite combination, like the letters of the alphabet—though small in number, yet enough to form all the words of a language.

Another question arises: Is the composition of a plant the same in all its parts? Do its varied organs differ but in form? Are the stem, the bark, the leaves and the fruit but different impressions of the same substance?

Far from that. In a certain degree, each organ has its own composition. But these variations, the result of conditions absolutely necessary to the reproduction of the species, can be reduced to a few simple propositions.

We begin with the mineral elements. In general the leafy parts of a plant contain more minerals than do the tougher parts. This is only because the aqueous parts of the sap evaporate quickest in the first organs.

Evaporation is active in proportion to looseness of tissue and directness of contact with the atmosphere. Thus we find more minerals in grasses than in trees, more in leaves than in bark, and more in bark than sap-wood or in heart-wood.

In the fruit of a leguminose there are two distinct parts—the shell and the pea. The shell, which is in more immediate contact with the atmosphere than the pea, contains most minerals. Following the same order, the leaves of an evergreen hold fewer minerals than do those of a deciduous tree, being renewed at a season least favorable to evaporation.

The following figures show the proportions:

	Dried Vegetable Matter, Containing 100 parts Mineral.
Grasses	7.84
Trees	0.94
Wood	0.55
Sap-wood	2.65
Bark	7.47
Leaves	14.20
Deciduous leaves	6.60
Evergreen "	2.00
Pea-shells	5.50
Peas	3.10

If we make as exact a study of each mineral element as we now do of the whole, we will arrive at an analogous conclusion, to find that by a species of election each of these elements centres by preference in a certain set of organs. Thus we find more silica, lime, oxide of iron, sulphates and chlorides in the stem and leaves than in the fruit and seed, where, on the contrary, sulphuric acid, potash and magnesia become the predominant elements.

Take wheat for example. In the ashes of the seed there is 46 per cent. of phosphoric acid, in the chaff, 2.54, in the straw, 2.26, and only 1.70 in the roots.

What I have just said of phosphoric acid is equally true of magnesia and potash, the proportions of which change from one organ to another, as will be seen by the following table:

	IN 100 PARTS OF ASHES OF		
	Roots.	Straw.	Seed.
Phosphoric acid	1.70	2.20	46.00
Magnesia	1.97	3.92	13.77
Potash	2.87	15.18	32.59
Lime	0.88	3.00	1.19

The differences here found in wheat exist in all plants without exception.

Thus, the distribution of minerals is not left to chance, but is subject to fixed laws; all aid in the general structure of the plant, but each centres in a fixed organ or system of organs. We will now find the cause of this unequal distribution.

In the economy of living beings all the functions, varied as they are, tend to one end—viz., the reproduction of the species for all time. They are ordered with a view to this important result. But to gain this object, the embryo contained in the seed must have within its reach all those minerals necessary to the first acts of vegetable life. Hence, the seed is so abundantly supplied with phosphoric acid, potash and magnesia. It is a kind of reserve laid by for the first movements of the embryo.

If you carefully read the preceding table, you will be struck by the contrast between the potash and phosphoric acid.

Phosphoric acid is pretty uniformly distributed through all the organs, the seed excepted. Not so with potash. The concentration of phosphoric acid in the seed is sudden; the proportions of potash increase by degrees, and, you will observe, in proportion as the organ nears the seed. Why this sudden increase on the one side and gradual progress on the other?

An old remark of Theodore de Saussure informs us:

The phosphates of lime and magnesia are insoluble in water; but there is a double phosphate of potash and lime, and a double phosphate of potash and magnesia, both of which are soluble in water.

Potash—or, to speak more exactly, alkaline phosphates—favors, if it does not determine, the change of terraqueous phosphates into tissues. Now, at the time the seed forms vegetation is retarded and the organs begin to dry. It is evident, then, that the superabundance of alkaline salts must favor the passage of terraqueous phosphates; therefore, the nearer the seed the greater the quantity of potash, and consequent increase of terraqueous phosphates.

Let us look, now, to the distribution of the organic elements. Here a fact strikes us. These elements, four in number, represent at least ninety-five per cent. of vegetable matter. Here let me say that although the minerals do not figure largely, we may not from that conclude they are less important than the organic elements. Wanting them, vegetation would be impossible; it would be languishing and uncertain if the soil were not sufficiently supplied with them. In their distribution through vegetation the organic elements present another contrast to the mineral elements; three of them—carbon, hydrogen and oxygen—are exhibited in almost unvarying proportions. All plants and all organs, without distinction, contain the same quantities of these. Trees, shrubs, simple plants, roots, stems, barks, branches, leaves, fruits and seeds maintain an invariable balance in proportions of carbon, hydrogen and oxygen.

With azote it is different. We may say of that what has already been said of phosphoric acid potash—fruits and seeds contain more of it than the other organs, because during germination the embryo lives on the seed, and within its small circumference it must find azote as well as minerals.

In vegetable matter carbon and oxygen are exhibited, each at 40 to 45 per cent., hydrogen from 5 to 6 per cent., and azote from 1 to 2 per cent.

I have promised to define vegetable composition with *exactness* and *clearness*. It seems to me that the preceding data do so.

But it is not enough to know what composes vegetable matter; we must also know how it is formed, and how those elements combine which shape and increase its organs.

Here the process differs at all points from that proper to minerals. If a solution of marine salt is exposed to the sun, as the liquid evaporates crystals are deposited too fine to be seen but with a magnifying glass. Soon, however, their forms become visible, and we can watch their growth from day to day, which we will soon find is governed by a geometrical regularity not to be thrown off.

Here the growth is made by successive and continued deposits of salt, the first crystals being centres of attraction for the molecules of sugar and salt diffused through the liquid.

The work of vegetable growth is not so simple, though the phases through which a vegetable passes before its full development have a character of fixedness and persistency which excludes all idea of chance and whim. The laws governing it are not less inflexible than those governing minerals, and their principles and details are equally well known.

I have told you that plants owe their formation to fourteen different elements. I now add that some of these elements are in the form of aerial gases, while others, liquid or solid, issue from the soil. The first are absorbed by the leaves, the second by the roots. Thus, plants are formed from many and very different principles, drawn from varied sources. But these principles do not at once build up tissues and organs; they first pass through a stage belonging rather to inorganic than to organic nature.

The formation of a plant is, then, in reality an operation of two degrees.

These compounds of uncertain form are divided into two groups, the one comprehending those compounds into which only carbon, hydrogen and oxygen enter; the other, those in which most azote, sulphur and phosphorus are found.

Here is a list of these products, which I will call *transitory products* of active vegetation, to recall at once their origin, principal character and true distinction.

Transitory Products.

	Hydrocarbonates.	Azotes.
Insoluble in water,	Cellulose, Amidon (starch).	Fibrin.
Semi-solubles,	Gum-dragon, Pectin, Inulin.	Casein.
Solubles	Gum-arabic, Mucilage, Grape sugar, Cane sugar.	Albumen.

We will take first the products of the first group. All these products, to which we will give the name hydrates of carbon, have a common character; their composition is the same. For greater distinctness, we will express them by the common formula, $C_{12}\,(HO)_n$.

In all there are twelve equivalents of carbon, always in combination with hydrogen and oxygen in proportions to form water.

Although unlike in appearance, all these bodies are, in reality, but reproductions of the same type. The proof of this is the impossibility to draw a line of demarkation between them; so, instead of taking them separately in a single plant, we will notice the variations they exhibit in plants in general. A deeper study of these products shows us the point at which it is impossible to make clear and exact distinctions between them.

We have placed the cellulose (so called because it forms the warp of vegetable tissue) at the head of the first group; immediately after comes the starch or amidon, then the gums, and lastly the sugars.

Between the cellulose and the sugar there are great and numerous differences, and if one did not know the other terms of the series—pectin, inulin, gums, etc.—it would not occur to one to see in these two bodies dissimilar forms of an unique type.

Cellulose is insoluble in water—the sugar, on the contrary, melts away in it.

Cellulose is not easily attacked by acids or alkalies slightly diluted. Sugar is easily changed by both. Sugar has a sweet taste, cellulose no taste.

How did we get the idea of assimilating these two bodies, so as to make of them one and the same body?

The identity becomes manifest, and almost forces itself upon us, if we do not confine our observations to the cellulose of woody tissue, but look also at the properties of the other terms in the series, and at the changes to which the cellulose itself is subject.

Cellulose in the form of woody tissue is insoluble in cold water, and even in boiling water. But in Iceland moss cellulose, being less compact, jellies as soon as boiled. Hard as ivory in the kernels of some fruit, it becomes edible in the mushroom. There is no greater difference between the edible part of the mushroom and a piece of the wood of an oak than between the sugar and cellulose of the lichen.

The cellulose in the tubercles of the Irish potato is in isolated grains, formed by concentric layers fitting into each other.

Between the amidon and the cellulose there is little apparent analogy; but if we add that the amidon swells in boiling water to such a degree as to form a true jelly, like Iceland moss, the analogy between the two products becomes incontestable.

Amidon swells in boiling water without dissolving; but inulin, which is found in the tubercles of the Jerusalem artichoke, and which is a species of amidon, dissolves in boiling water, from which it separates itself in independent grains as the water cools.

If we add that gum-dragon forms jelly in cold water without dissolving, and that gum-arabic swells and dissolves in it, and has a slight taste of sugar, the change of the gum into sugar becomes evident, and the analogy which joins the sugar to the cellulose, though at first concealed, can no longer be doubted.

To prove this conclusion, I will add, that the cellulose itself, even when most compact, can be changed into gum and to sugar, and to do this it is only to be treated with sulphuric acid—that it is the same with all the other terms of the series, which can all be turned into sugar by the same means. These transformations are incessant in vegetation; the economy of vegetable nutrition depends upon them, as I will show when I come to speak of albuminous substances. The materials which form the second group of transitory products of vegetable activity are three in number; they are distinguished from the hydrates of carbon by the azote, sulphur and phosphorus they contain, which are wanting in the first.

Their composition is then one more degree complicated. We will observe the same of them as has already been said of the hydrates of carbon: in spite of their dissimilarity, they are in reality the same body under three different conditions. Their composition is the same and is expressed by the same formula, C_{144}, H_{112}, Az_{18}, S_2, O_{44}.

Is it objected that fibrin is insoluble in water while casein and albumen are soluble? But I say, Bring water to the boiling point and these two bodies will be equally insoluble.

But you will say, Heat does not dissolve albumen as it does casein—that albumen coagulates in masses, while casein coagulates but in part, in the form of a skin on the surface of the liquid. To refute this objection, we need only communicate the properties of whichever one of these materials we please to the other two.

Fibrin is insoluble. To make it soluble we have only to pound it in a marble mortar and add a fiftieth part of its weight in caustic soda. The dissolution thus produced possesses all the properties of albumen, and its most characteristic one, that of coagulating in a mass under the action of heat.

If you pour a few drops of caustic soda into a solution of albumen, it will acquire the property of coagulating in parts and forming a skin like casein.

If I add finally, that these bodies, like the hydrates of carbon, are continually changing into each other during the periods of vegetable life, you will agree with what I have already said, that they are varied forms of the same type.

Let us pause a minute at these transformations, which make the very essence of vegetable life.

Wheat, before germinating, contains from ten to fifteen per cent. of fibrin and one or two per cent. of albumen, more or less. As soon as germination begins, the proportion of fibrin diminishes and that of albumen increases. Beans and lentils contain no fibrin, but casein has, like cheese, a very little albumen; now during germination the casein disappears and the albumen takes its place. It is the same with amidon, contained in abundance in seeds: it is changed into gum and sugar, and they in their turn become cellulose in the leaves, branches and roots.

The plant in its first period is but the seed transformed. After germination, when vegetation may properly be said to commence, it receives more and more albumen until the time of flowering, when in wheat the albumen becomes fibrin, and casein in beans and lentils.

Let us return to the hydrates of carbon, taking the beet for example. Before flowering it contains eight or ten per cent. of sugar; after the seed is formed the sugar disappears, amidon having taken its place.

I therefore repeat, vegetable nutrition is a phenomenon of two stages, the first corresponding to the formation of transitory products; the second, to their transformation into vegetable tissues and organs.

Lastly, I add that the mechanism of vegetable nutrition rests entirely on these two orders of phenomena, which are both independent and united.

From the foregoing it results that plants are known to be under the double relation of their composition and manner of formation.

To complete this general view of vegetable production, I must show you the conditions which regulate its movements, and which, in practice, make their cultivation certain or precarious, expensive or remunerative.

These conditions are three in number:

1st. Climate.

2d. The nature of the soil and the choice and quantity of manures.

3d. The choice of seed.

The influence of climates. That is indisputable. Who has not marked the changes of vegetation in passing from the foot of a mountain to its summit? At the distance of a mile or two we distinctly see the bands of verdure on the inclinations of the Alps, contrasting through thickness and coloring as well as by difference in flora.

The same thing takes place on a grander scale in going from the equator to the poles. At the equator, vegetation is marked by an appearance of vigor and majesty which strikes a European traveler with admiration. The number of trees, compared to that of the grasses, is greater than in Europe. The trees are also remarkable for height and the size of trunk, as well as for richness and variety of foliage.

Seventy degrees of latitude from the equator we see only small trees, shrubs and grasses; and near the pole plants are represented by a few brittle byssus and lichens creeping over the surface of the ground.

Climate, therefore, exercises a considerable influence on vegetation, and he would be wanting indeed who ignored it in practice.

Would it not be folly to cultivate the vine at Dunkirk, maize at Valenciennes, and the olive on the plains of Beauce? These are exaggerations, I know, but under them there is a truth it would be well to remember, that in our day agriculture tends to specializations, and we should always have the climate in our favor. With a free commerce and facility of exchange, each region should create a monopoly of its products in which it may defy competition.

The English, an enlightened people, understood this long ago: wherever too great moisture of climate made the cultivation of grain unprofitable, they have substituted grasses and herds.

Among the conditions acting on vegetation we have placed the composition of the soil, and in the same order of ideas the choice of manures in the second rank.

You know that two fields touching each other may often be of unequal fertility. The cause of these differences is in the presence or absence of certain agents. Add to the one the elements wanting, and it will become as fertile as the other. Under this view, by the use of manures man acquires an almost limitless control of nature. It is to the study of this second condition that the teaching of Vincennes is especially devoted.

As to the second condition, that is regulated by the vegetable itself. All species are subject to certain variations, which may become hereditary. Races, varieties of small importance in a botanical point of view, but of great import in agriculture, have often the same origin. Under the same conditions of soil and manures one variety will often yield double the quantity of another. I will show you a remarkable example of this.

For three years I have had blue wheat and English wheat (with red straw) under parallel culture, the soil and manures exactly alike. The blue wheat did not succeed at all; the English wheat grew wonderfully. In autumn the blue wheat has a marked advantage over the English wheat, but in spring, affected by late frosts, it is also violently attacked by rust, while the English wheat, being more backward, escapes both entirely.

There is, then, a means resting entirely upon ourselves, and to which we have perhaps not given sufficient attention. For myself, I believe our vegetables are susceptible of as varied changes as are our domestic animals.

But I repeat, gentlemen, that of the three conditions which rule the activity and the products of vegetation, we should occupy ourselves solely with the second—the choice and the quantities of manures. I have recalled the other two, but to show the subject on all sides, and to leave nothing in obscurity, I promised you an analysis of vegetation, its agents and cause. I think I have fully kept that promise. Are you tempted to reproach me with the too scientific character of my study? Our path was traced out by the light of these ideas. Henceforth there can be no question of empiric results. Besides, if practice is our object, science should be our guide, its methods our auxiliaries, and its principles the foundation of our deductions.

Until the last twenty years it has been asserted that the farmyard was our agent "par excellence" of fertility. We maintain that to be erroneous, and that it is possible to produce better and cheaper artificial manures than can the farmyard.

It has been said: The meadow is the foundation of all good agriculture, because with the meadow we have cattle, and with the cattle, manure. These axioms are now veritable heresies. I hope to show you that agriculture to be remunerative must be founded on artificial manures. With farmyard manures it is now but a question of convenience and cost.

To determine these important views with certainty we must remain faithful to the plan traced out.

In the first place, we must define the degrees of utility of the different elements of which vegetation is composed, seek the forms under which their assimilation is easiest and the useful effects the most certain, and last, form from them rules by which we may associate them to make the most powerful manures.

In our next we will broach the subject under its new view, which will bring us into the domain of practice.

LECTURE SECOND.

GENTLEMEN: In our first meeting I endeavored to show you the nature of the elements composing vegetation. You remember that these elements are very unequally distributed in the different organs, or rather between those forming ephemeral combinations before passing into the state of tissues and organs.

To complete this almost preliminary study, we must now ask in what state we find these elements of nature, the source and cause of fertility of soil, under what form plants absorb them, and to what degree we can, by their aid, act upon the products of vegetation.

I begin with carbon.

The quantity of carbon which enters into the composition of plants is, in round numbers, from 40 to 45 per cent. Carbon, then, plays a prominent part in vegetation. If, however, I add that in agriculture it is not necessary—that it may be entirely excluded from manures without affecting the fertility of the soil—I will appear to contradict myself.

The contradiction is but apparent, and to prove it, permit me to remind you that the carbon of plants has its origin in the carbonic acid of the air, and the atmosphere is an inexhaustible source of it.

I need not, therefore, treat of the assimilation of carbon; in many respects this omission will not be inconvenient; nevertheless, I have determined to stop here and make this the object of a deep study. Why? For two reasons—because the explanation of this phenomenon marks an era in the history of science, but particularly because its study will help us to show clearly the essential characteristics of vegetable productions.

The act which determines the assimilation of carbon is a simple phenomenon. Carbonic acid, formed from carbon and oxygen, is absorbed by the leaves, where it is decomposed. The carbon remains in the plant, while the oxygen, being freed, returns to the atmosphere. Here is produced a truly extraordinary phenomenon, and one which we cannot imitate in our laboratories without calling to our aid the most powerful means of analysis at the disposal of chemistry; this phenomenon the delicate tissue of the leaf performs without affecting its organization.

You will see, farther, that vegetable respiration produces effects opposite to animal respiration. Plants borrow carbonic acid from the air and return oxygen to it, while animals, who borrow oxygen, return carbonic acid. This explains the reason why the composition of the atmosphere is not changed by the incessant drain made on it by plants and animals.

Under this continued though unseen conflict there is an order of phenomena still more profound and mysterious, which I would like to show you, because to my eyes there is nothing more fit to unveil to you the true character of agricultural products, and to show you how this grand act of vegetable life, to which are most intimately joined the most essential conditions of our existence, differs from all other products of human activity.

GENERAL RULE.

All work of production presupposes two equally indispensable things—a first cause and a source of force.

Without these two conditions nothing can be produced.

Whatever we do, the material in use experiences a diminution which we strive to prevent, but cannot entirely avoid. The same in regard to the force expended. We make use of but a part of it—the rest is unavoidably lost. I repeat, then, the product, which is the material representative of the work, is unequal to the first cause and the force employed. Take, for example, any industrial labor you will—metallurgy, weaving, the mechanical arts. The work is always accompanied by a double loss of the first material and vital force, produced by friction of intermediate organs and imperfection of apparatus.

In agriculture the character of the production is different. The earth, through her harvests, returns ten times the value of what we give her by our fertilizers, and every harvest supposes an expenditure of force at least five hundred times greater than the sum of the efforts which produced it.

How can we explain these two opposing facts? The economy of the assimilation of carbon will teach us.

All vegetables, as we have said, contain from 40 to 45 per cent. of their weight in carbon. Now, if the carbon comes from the air and is added to the agents which we give the earth to fertilize it, we immediately perceive why the earth gives more than she has received. It is the same with regard to oxygen and hydrogen, which represent more than 50 per cent. the weight of vegetable matter, and which are given out by water.

From this, then, it follows that 95 per cent. of vegetable matter is provided by sources different from the soil, and that the amount furnished the soil by human industry is but a fraction of the harvest we draw from it. But this fraction is indispensable, for without it the carbon of the atmosphere, the oxygen and hydrogen of water, would remain in their primitive state in the domain of inorganic matter, and could not have entered the current of vegetable life. Here is explained the first characteristic of vegetable life. You know now why the earth gives more than it receives. The excess comes from the air and the rain.

The following table is an undeniable demonstration of the fact. It is understood that what I say of wheat is equally applicable to other plants:

Composition of Wheat (Straw and Grain).

	In 100 parts.	
Carbon	47.69	Here, 93.55 come from the air and the rain.
Hydrogen	5.54	
Oxygen	40.32	
Soda	0.09	Here, 3.386, with which the soil is abundantly supplied, and which we need not give to it.
Magnesia	0.20	
Sulphuric acid	0.31	
Chlorine	0.03	
Oxide of iron	0.006	
Silica	2.75	
Manganese	(?)	
Azote	1.60	Here, 3.00, with which the soil is but poorly provided, and we must give to it by manures.
Phosphoric acid	0.45	
Potash	0.66	
Lime	0.29	
	99.93	

We will now pass to a second characteristic of agricultural production, although of the same order as the preceding, yet more difficult to understand.

Until the last twenty years we believed that the phenomena of nature were due to different causes, because they affected different organs in ourselves.

Under this impression of diversity a more perfect analysis ended by discovering that this multiplicity of causes was but apparent, and that in reality all physical phenomena are the result of a sole cause—motion.

Let us follow the consequences of this fundamental cause. You all know that the combustion of a body is followed by an elevation of temperature. For example, the combustion of 2 pounds of carbon produces heat enough to raise 16,000 pounds of water one degree. If I add that which we call the quantity of heat necessary to raise 2 pounds of water one degree calorie, we may say that the combustion of 2 pounds of carbon produces 16,000 calories.

You know that mechanical force is engendered by heat. There is an immutable correlation between the weight of the body burned, the temperature produced and the force made by it.

We know that one calorie equals a force sufficient to raise a weight of 2 pounds to the height of 1389 feet, and we call the force necessary to raise 2 pounds to the height of 3 feet 3½ inches a kilogrammetre, or a dynamic unity.

It follows, then, that one calorie, or the quantity of heat which will raise 2 pounds of water one degree, is sufficient to raise the same 2 pounds 1389 feet high—or, in other words, 1 calorie is equivalent to 424 kilogrammetres.

Let us follow the results of these facts. The work of a horse in harness is expressed by 540,000 pounds the hour—that is to say, that the efforts he puts forth will raise 540,000 pounds to the height of 3 feet per hour. We estimate the day of a horse at eight hours' effective labor; the day's work is then expressed by 4,320,000 pounds. So, if we concentrate the labor of a horse for a day to one point, we will say he raises 4,320,000 pounds to the height of 3⅓ feet.

But if one calorie equals 424 kilogrammetres or dynamic unities, and if the combustion of 2 pounds of carbon produces 16,000 calories, it results that 2 pounds of carbon correspond to 10,416,000 feet, or, in round numbers, to one and a half day's labor of a horse, the day being fixed at eight hours' effective work.

By the light of these facts, which may seem far-fetched, but which are necessary, the most hidden peculiarities of vegetable life will be unveiled to us.

The combustion of carbon engenders carbonic acid and produces heat, which may be expressed by dynamic unities. If you should attempt to turn back this current, and to undo what combustion has done, to separate the carbon from the oxygen in carbonic acid, you will not succeed, unless you return to the carbon and the oxygen a quantity of heat equal to that born of their combination.

This fact leads us to the following result: that every 2 pounds of carbon which settles itself in vegetable matter requires 16,000 calories, equivalent to 10,416,000 feet, and they equal a day and a half of a horse. Now, as the harvest of 1 acre may be fixed at 8888 pounds of vegetable matter, containing at least, and in round numbers, 4444 pounds of carbon, the settling of which has required 50,000,000 calories, we find that this quantity of heat corresponds to 17 kilogrammetres—that is, 6660 days' work of a horse. The harvest of 1 acre is only obtained at this price.

If, then, the preparation of 1 acre by the plough, the harrow, etc., requires the same of a man as of a horse—viz., 15 days' labor—we see that when man puts forth one mechanical effort, nature adds 444 by the unostentatious means of light and heat.

But what is the source of this enormous consummation of forces always in action and never exhausted? You have already known it: the rays of the sun, in whose absence plants cannot assimilate carbon. If wood and vegetable products give out heat while burning, it is but what they have drawn from the sun, and which passes by combustion from a latent state to a state of liberty. It is, in reality, but an act of restitution.

These explanations are sufficient, it seems to me, to demonstrate the peculiar characteristics of vegetable products.

I repeat that vegetation alone possesses the power of adding to the first material used, which in all other cases is subject to waste, and of giving a relatively enormous yield by the intervention of an unseen force.

Here is shown the marvelous instinct of the people, who, outstripping science, recognize prosperity as durable only when founded on a flourishing agriculture. It is for this reason that certain economists of the last century, Quesney among others, conceived the idea of laying taxes exclusively on the products of the soil, for it is they only which yield an excess in the net produce.

Gentlemen, you perhaps think I have let myself be drawn too far in this train of ideas; I would not retrench my words, for I believe to act intelligently we must have a clear idea of the principles upon which we act. But I hasten to return to the practical in the assimilation of carbon.

The assimilation of carbon is included, as we have said, in two facts: Plants absorb carbonic acid from the air, and decompose it.

To prove that leaves absorb carbonic acid, introduce the leafy branch of a vine into a globe of glass, making a current of air to pass through it.

Before entering the globe, the air will contain from three to four ten-thousandths of its volume in carbonic acid; when it comes out, it will contain but two ten-thousandths, more or less. The leaves have acted like a crucible. All plants and trees effect by their foliage what you see this branch of a vine produce under your own eyes.

But for this three conditions are necessary:

1st. The plants must receive the direct action of the sun.

2d. The temperature of the atmosphere does not descend below ten to twelve degrees above zero.

3d. The plants must be provided with leaves.

The suppression of one of these three conditions is enough to stop the phenomena, and measurably to strike the plant with inertia.

Leaves lose the power of absorbing carbonic acid in the dark. As soon as light fails, the leaves, in direct opposition to what they had done before, absorb oxygen and give off carbonic acid.

In our climate the assimilation of carbon ceases almost entirely below ten to twelve degrees. It would be imprudent to make this an absolute rule, as all plants are not affected in the same degree by the lowering of temperature.

The leaves are essentially the seat of the assimilation of carbon; neither roots, trunk nor branches share in this important office.

We will now proceed to a more practical order of ideas, and one pertaining especially to agriculture.

The quantity of carbon that plants fix during the season the acre reaches as high as 8888 pounds.

Here arises a new question. All plants do not attain this standard. Whence comes the difference? The leaves do not present the same amount of surface.

If, from this point of view, we compare some of the plants in which we are most interested, such as the sweet potato, the beet, the Irish potato and wheat, we find that the sweet potato, which fixes 7111 pounds of carbon the acre, gives a leaf-surface fifteen times that of the soil cultivated; that the beet, which fixes 1776 pounds of carbon, gives a leaf-surface five times that of the soil. The same remarks are applicable to the Irish potato and wheat, which absorb but 1511 and 1244 pounds of carbon, and give a much reduced leaf-surface.

Lastly, to complete the study of the assimilation of carbon, I must add, that if the atmosphere is the principal source from which plants derive it, they, however, draw a certain quantity from the depths of the soil, which the leaves decompose and assimilate. The carbonic acid of the soil is provided by the decomposition of vegetable matter which is wanting. Thus, the economy of the origin of carbon in vegetation is summed up in three facts:

It is always absorbed in the form of carbonic acid.

The leaves digest it.

The sun's rays are necessary to determine it.

Let us proceed to the origin of oxygen and hydrogen. I could tell you the same of these two bodies as I have already said of carbon. Their functions in the economy of vegetation have but a theoretic interest.

Both come from water, and plants, as regards the source of oxygen and hydrogen, receive more through the rain than they can make use of.

Is it certain, you will probably ask, that oxygen and hydrogen are derived from water?

No question easier to determine than this.

Cultivate burnt sand, and let the plant receive oxygen and hydrogen only through distilled water; you will see how the water changes its condition under your eyes, and enters into the composition of the plants.

We come now to azote.

The question changes its character with azote. The origin of this body in plants opens to us a problem of the first order.

Now, this problem may be resolved in two different ways—by science and practice.

I prefer to demonstrate by practice.

I lay down as an axiom that plants can assimilate azote in three different forms:

In the form of ammoniac or salts of ammonia;

In the form of nitrate;

In the form of gaseous azote.

And I add, that each of these three forms adapts itself by preference to certain lists of plants—the ammoniac to wheat, the nitrate to beets, while the legumes absorb azote, especially under the form of elementary gas.

This point admitted, I ask if harvests in general contain more azote than the manures which produce them?

Facts prove this unanimously; there is always an excess of azote in the harvest.

We find, for example, that the excess (and this is the minimum value) in sweet potatoes rises to 38 pounds, and in lucerne to 151 pounds the acre.

Here a new question arises: From whence this excess of azote? From the soil? Evidently not, for it is a permanent and continued phenomenon. This excludes the idea of its coming from the soil, since its resources are limited and it yields yearly, through its harvests, more azote than it receives by manures.

We cannot doubt, then, that the excess of azote comes from the air. But here another difficulty: In what form has the azote been absorbed? Is it in the ammoniac, nitrate or elementary form of azote?

Before pronouncing with certainty with regard to this, we have a question difficult of solution. We must know if the air contains the ammoniac and nitrate forms, and if so, in what proportions.

There is no doubt on these two points. The air contains both the ammoniac and nitrate forms, but so feeble, so weakened, that they belong to the infinitely small.

The proportion of ammonia is comprised between

0.000,000,017 and

0.000,000,032.

This corresponds to nearly one half ounce of ammoniac for 2,000,000 pounds of air. A thimble by the side of the Pantheon! The air, as we have said, contains nitric acid in infinitely reduced proportions, hardly equal to that of ammoniac. In the face of such small quantities it is not possible to attribute to them the enormous mass of azote that plants draw from the air. To escape this difficulty, the nitrates and salts of ammonia being very soluble in water, we admit it is the office of the rain to condense them and bring them in a feeble volume to the plants. But this supposition cannot sustain itself when we examine things a little nearer.

Rain water contains at least 0.0005 ammoniac and the same quantity of nitre to the $2\frac{1}{10}$ pints. Now these quantities correspond to a deposit of 2.66 pounds of azote the acre per year, which is evidently insufficient to explain the excess of 38.03 pounds shown by the sweet potato, and still more so for that of lucerne, which reaches 151 pounds. Neither the ammoniac nor the nitrates of the air can account for the excess of azote which harvests yield.

We are then led to attribute to the elementary azote of the air an excess which would otherwise be inexplicable.

Is this view admitted without dispute? No; and these are the objections raised to it.

It is unanimously agreed that a part of the azote of a crop is drawn from the air, but the assimilation of elementary azote is denied. It is supposed that, before being absorbed by the plant, azote passes into the soil as a nitrate. The soil then becomes the seat of a universal and permanent nitrification.

Thus announced, this opinion does not bear an instant's examination. If azote enters lucerne but in the form of a nitrate, is it not evident that in a crop of it we ought to find the corresponding basis to nitric acid, the supposed source of azote? Now, there is none to be found. Now, in a crop of lucerne gotten here and on the farm of Vincennes, azote surpassed its corresponding basis by 120 pounds the acre; 120 pounds have therefore not entered the plant in the form of a nitrate. This 120 pounds is but one-third the real quantity of azote the acre that lucerne draws from the air, seeing that in the example just cited azote in the form of nitrate of potash and nitrate of soda were intentionally introduced in the fertilizers; and it has been shown me since that equally large returns may be obtained by substituting carbonate of potash for the nitrates—that is to say, alkaline and azotic products by a fertilizer without azote.

I hasten to arguments drawn more directly from practice.

Suppose you enrich peas, clover or lucerne with nitrate of soda. The effect is radically nothing, if it is not decidedly injurious. Now, how bring out in behalf of these plants the good effects of a spontaneous nitrification in the soil?

We may make the argument more general.

Try two parallel experiments: in one let the soil be enriched by a fertilizer composed of phosphate of lime, of potash and lime without azote; in the other, add to these three agents some azotic matter. Under these two conditions different effects will be shown according to the nature of the plants.

The clover, peas and legumes will thrive as well on the ground which has not received the azote as on the other. With the grain, the colza, the beet and tobacco the result will be different. Where the azote is wanting the yield will be more than mediocre, while it will be excellent from the soil supplied with it.

What must we conclude from this contrast? That plants form two distinct groups: the first comprising those which draw azote from the soil; the second, those which take it in preference from the air.

Do you doubt it? Here are other facts in support of this distinction.

Every one knows that culture without fertilizers soon becomes uncertain. The returns are never absolutely nothing, and the quantity of azote corresponds in importance.

According to Messrs. Lawes and Gilbert it reaches—

To 17.9	lbs	the acre	per year	for wheat.
" 24	"	"	"	barley.
" 39.1	"	"	"	the meadow.
" 47.1	"	"	"	beans.

We see by this table that the meadow and beans fix more azote than barley and wheat. Shall we say that the azote of the beans and the meadow comes from the soil? We would thus raise a very embarrassing difficulty. If you sow grain after beans, the return is better and the quantity of azote fixed greater. On the other hand, however, we maintain that the beans contain more azote than the wheat. Is it not evident, then, if they had taken it from the earth the yield from the wheat would show it?

Conclusions:

Azote is absorbed under different forms: for legumes the elementary azote, for wheat and colza the ammoniac, and for beets the nitrates, are the most suitable forms. But we again repeat that all vegetables, without distinction, show an excess of azote for which neither fertilizers nor soil can account, and which can only be explained by attributing it to the elementary azote of the air.

Permit me to sum up the question in indisputable figures, to determine the importance of the quantity of azote plants draw from the air:

	Excess of azote in crop over amount contained in fertilizer.
Wheat	53.33 lbs.
Peas	62.22 "
Colza	115.55 "
Beets	115.55 "
Lucerne	266.66 "

In the preceding examples the fertilizer contains from 44 to 53.33 pounds of azote per acre. As to lucerne, I have taken the excess from a purely mineral fertilizer, and from a yield fixed at 7111 pounds.

You see, then, by these examples, that though all vegetables show an excess of azote, this excess is far from being of the same importance to each.

There is still a distinction to be made with regard to the conditions under which it is produced.

There are plants which contain a great deal of azote, though we do not furnish them by manures: peas, beans, clover and lucerne come under this head. There are others which show a considerable excess of azote, but which must have it given them by fertilizers containing azote; such are in particular beets and colza. Lastly, there is a third list of plants which require a great deal of azote in the soil, and whose crops yield relatively but a small excess, such as wheat.

These differences have a practical signification, which it is of the last importance we should not misunderstand. Who cannot see immediately, and from these simple general facts, that there is an advantage to be gained under the double relation of returns and improvement of soil, by alternating wheat with beets, and above all with legumes; that is to say, the plants which draw their azote from the soil with those which draw it from the air?

Experience confirms this anticipation on all points.

You all know that wheat succeeding clover yields more than when preceding it. Who does not know how favorable it is to the culture of wheat to turn under the leaves of the beet? There is still an important remark to be made concerning those plants (like the beet) which demand large quantities of azote in the soil; that is, that the excess of azote in the crop is somewhat proportional to the quantity the soil has received. It results, then, that those plants are not most beneficial to the soil which require the least azote in their fertilizers, but those which exhibit the greatest excess of azote at the expense of the atmosphere. This relation, this correspondence between the richness of the fertilizer and the benefit to the plant receiving it, of which science now gives us the explanation, has long been confirmed by practice, as the words of Matthew de Dombasle testify. It is a fact generally observed, says he, that the functions by which plants appropriate the nutritive elements contained in the soil and air are *corresponding functions*, so that an increase in the quantity of the principles which they draw from the soil can alone fit them to appropriate a greater quantity of atmospheric food. For this reason plants are most beneficial which draw most from the air, and the more fertile the soil the greater the amount they draw from the air.

This theory of high culture may be explained in a clearer and more scientific manner. Suppose, for example, a plant is cultivated in burnt sand, receiving nourishment only from air and water, and produces 20 leaves in 15 days after germination. If the leaves give nutriment to the plant sufficient to form a new leaf every fifteen days, at the end of three months and a half the plant will have produced 2460 leaves.

On the other hand, suppose another plant cultivated in manured soil, and we admit that the manure determines the formation of only five leaves every fifteen days, besides those that the air and water had supplied in the preceding experiment. After the lapse of the same time the plant will have produced 3475 leaves; that is, nearly twice as many as in the first case, although the manure alone has determined the formation of but 35 leaves. This result you justly think very singular; it is, however, easily explained, when we reflect that the first leaves formed by the manure aid not only in numbers, but by the formation of other leaves, drawing their food from the atmosphere.

I have told you that the quantity of azote must be proportioned to the nature of the plant cultivated.

To show you how necessary it is that nothing be left to chance, I will cite the report of an eminent agriculturist, Monsieur Cavallier, from the farm of Mesnil-Saint-Nicaise.

It is on the beet, cultivated in four different ways by mineral fertilizers without azote, and the same fertilizers with increasing quantities of sulphate of ammonia:

With mineral fertilizers without azote the return was 32,741 pounds the acre.

With the same fertilizer, phos. 71.11 pounds azote, the return was 42,066 pounds.

With the same fertilizer, phos. 88.88 pounds azote, the return was 45,333 pounds.

With the same fertilizer, phos. 106.66 pounds azote, the return was 53,021 pounds.

If we take as a basis 32,741 pounds obtained from fertilizers without azote, we find (the sulphate of ammonia being deducted) the following increase:

With 71 pounds of azote	$5.73
With 88.88 pounds of azote	9.13
With 106.66 pounds of azote	19.30

From this you see that azotic fertilizers play a prominent part in the economy of vegetation. In practice we find the greatest advantage in using the salts of ammonia; the certainty of their action, their ease of assimilation, give them a marked superiority over all other azotic compositions.

I am accustomed to employ from 53 to 80 pounds of azote the acre for wheat; for the colza and the beet you may go as high as 88 to 177 pounds without injury.

The sulphate of ammonia contains in round numbers 20 per cent. of azote, and the nitrate of soda 15 per cent.

As these compositions are very powerful, too much care cannot be taken in spreading them equally. This is easily done by mixing them with four or five times their weight of dry earth. They should be used after the last working, and then harrowed, to mix them well with the surface soil.

From the ideas presented to you, gentlemen, we gather that, in an agricultural point of view, there is a great difference between carbon, oxygen and hydrogen on the one side, and azote on the other; and it is this: that Nature furnishes the first three in superabundance, and we need not occupy ourselves with them, while she gives azote only exceptionally and under certain conditions.

The secret of successful culture consists in alternating those plants which draw azote from the air with those which find it in the soil, and in reserving for these last all the azotic compositions we can procure.

The nitrates and the salts of ammonia are not the only azotic compounds to which we have recourse. We may use animal matter. During putrefaction it acts as salts of ammonia. But I prefer the former, for they admit of direct assimilation, and because of 100 parts of azote which organic matter contains, at least 30 are lost to vegetation. This loss proceeds from the decomposition to which this matter is subject; 30 per cent. of all its azote escapes in the form of elementary azote, under which form the atmosphere already contains more than vegetation can make use of.

I cannot too frequently repeat one of the great secrets of remunerative culture—viz., to draw as much azote as possible from the air by an alternation of crops.

The efforts of all agriculturists should tend to this end, and the most useful aid Science has given them has been to show this truth as clearly as possible.

If Science is a guide which we must sometimes follow with caution—for moneyed questions are involved in agricultural operations—we must not forget that all our useful facts are conformable to her laws, and if we would accomplish a progress superior to all the conquests of the past, it is still to Science we must turn.

In our next lecture we will treat of the office of minerals in the economy of vegetable productions.

LECTURE THIRD.

GENTLEMEN: You know that the minerals entering into the composition of plants are ten in number—namely, phosphorus, sulphur, chlorine, silicium, calcium, magnesium, potassium, sodium, iron and manganese. But you will be surprised to find that we are almost entirely ignorant as to what form these enter into the organization of vegetable tissues. We know that it is in the form of binary or ternary compositions, without being able to exactly determine their nature and composition. The imperfectness of our knowledge on this head will astonish you less if I add that, to acquire the least idea of their presence, we must begin by burning the tissues which contain them. But if science shows a lamentable gap in this respect, we at least know with certainty under what form and what conditions the minerals can be made extremely efficacious agents of fertility. If phosphorus is in question, we employ it in the form of phosphate of lime; potash, in the form of a carbonate, a nitrate or a silicate; and lime, in that of a carbonate or a sulphate. We are, then, perfectly fixed on this second point, which is much more important than the first—namely, the form most favorable to the good effects of minerals as agents of fertility. But here a most unexpected question presents itself.

I have just told you that ten different minerals enter into the composition of plants, and now I am forced to add that three of them, with the aid of some azotic matter, are sufficient to increase and maintain the fertility of the soil, and that the agriculturist need not occupy himself with the seven others.

Does that mean that these last do not affect vegetation? No; they are not less necessary than the first three, and if practice can pass them over, it is only because poor soils are abundantly provided with them.

If the facts which I have just shown are exact, the conclusion is forced: we ought by their aid to obtain from burnt sand, inert of itself, as prosperous a growth as from the most fertile alluvial soil. For that we only need ten minerals and azotic matter. From these fundamental facts it equally results that from a natural soil we should obtain the same growth by the addition of azotic matter and three minerals—phosphate of lime, potash and lime. Experience confirms these two provisions of theory.

We may go still farther in the same train of ideas. If it is true that each mineral fulfills a duty proper to itself, and that the useful effects of the whole be in a measure dependent upon the presence of each of these elements in particular, we ought, by the suppression of one or several of the parts of this fertilizing mixture, to determine a series of gradations running from the most doubtful to the highest yield. Experience again confirms this new anticipation of theory; but as this is touching a very grave question, we will put our conclusions above all dispute by showing the experiments in burnt sand, which contains nothing not well known and defined.

In burnt sand, free from all additions, but moistened with distilled water, wheat acquires but a rudimentary development—the straw hardly attains the dimensions of a knitting-needle. In this condition, however, vegetation follows its usual course; the plant blooms, bears grain, but in each head there are but one or two dwarfed, badly-formed grains. Thus, without soil, the wheat finds in the water it receives and the carbonic acid of air, aided by the substance of its grain, resources sufficient—sorrowfully, it is true, but at last—to run through the entire cycle of its evolution.

From 22 grains of seed, weighing nearly 18 grains, we obtain 108 grains of harvest. Add the ten minerals to the sand, excluding the azotic matter, and the result is but little more.

Under these new conditions the wheat is a little more developed than in the preceding case, but the harvest is still more feeble; it reaches 144 grains. Suppress the minerals and add only azotic matter to the sand; the growth will still be mean and stunted, but the harvest will slightly increase, as it reaches 162 grains. Let us follow the changes. In pure burnt sand, 108 grains; with minerals without azotic matter, 144 grains; with azotic matter alone, 162 grains.

In this last case a new symptom is shown. As long as we operate only with minerals the plants are diseased, the leaves show a yellowish-green color. As soon as we add azotic matter to the sand the leaves change their color, becoming a dark green. It seems as if vegetation would take its usual course, but the appearances are deceitful; the harvest is still feeble.

Until now, you see, we have not gone beyond the most rudimentary returns. Let us attempt a third experiment, which will, in a measure, be a synthesis of the three preceding. Unite azotic matter and the minerals in the burnt sand. This time, gentlemen, you will be tempted to believe in the intervention of a magician, the phenomena so far surpasses those preceding it. Just now the growth was languishing, doubtful, diseased; now the plants shoot up as soon as they break the ground; the leaves are a beautiful green; the straight, firm stalk ends in a head filled with good grain; the harvest reaches from 396 to 450 grains.

You see, gentlemen, relying upon experience, which is our guide by choice, we have succeeded in artificially producing vegetation to the exclusion of manures and all unknown substances.

You will acknowledge that this is an important and fundamental point. No more mystery, no undetermined power; some chemical products of a known purity, distilled water perfectly pure in itself, one seed as a starting-point, and the result, a harvest comparable in all points to the best obtained in good earth.

We are, therefore, justified in saying that the problem of vegetation here receives its solution, for we have not only defined the conditions necessary to the production of vegetation, but the degree of importance of each of the concurring agents.

Thus the azotic matter produces a little more effect than all the ten minerals together, but the harvest does not take the character of a high culture until the two orders of compounds are united.

We may add, that when we pass from burnt sand to the natural soil the number of minerals employed as fertilizers may be reduced from ten to three. If, under these new conditions, we make two parallel experiments, one with azotic matter and the ten minerals that you already know, and the other with azotic matter and but three minerals—phosphate of lime, potash and lime—the returns will be equal.

In the burnt sand this suppression renders vegetation impossible; now, as it does not suffer from it in the natural earth, it is evident that these seven minerals exist in the soil. The most favorable conditions to fertility are found realized in the union of these three terms—azotic matter, phosphate of lime and lime. It is for this reason I have given this mixture the name of a complete fertilizer.

Finally, to assure you of what I have said, permit me to place before you a series of harvests obtained from good earth enriched with chemical manures alone. The great inequalities which they show are caused solely by the suppression of one of the four terms of the complete fertilizer, showing how indispensable is the union of these four to a flourishing vegetation.

Although these ten elements which we have just discussed aid in the production of vegetation, yet to fulfill their duties they imperiously demand the aid of another order of materials, also contained in the soil, and of which I must now speak. These materials, three in number—viz., clay, sand and humus—differ from the preceding by the pure passiveness of their functions. They serve to support plants, but do not of themselves maintain vegetable life. To distinguish them from the first, which have received the name of the "*assimilable elements*" of the soil, we call them the "*mechanical elements.*"

But this is not all; the "assimilable elements" are themselves divided into two groups. The active assimilable elements are the assimilable elements in reserve, so called because they cannot aid in vegetable production but after being submitted to decomposition, which allows plants to absorb them.

I will give you an example to show the necessity of this distinction.

Azotic matters of animal origin produce ammonia and the nitrates in its decomposition, and owe their useful effects to this formation; the skin and offal of animals come particularly under this head, because they are decomposed with unequaled facility and quickness. But if these skins have been tanned, if they have become leather, they decompose slowly and lose a part of their immediate activity.

In the first place, they belong to the group of active assimilable elements, while in the second case they enter the group of assimilable elements in reserve.

Well, there are mineral and organic properties in the soil which only exert a useful action after submitting to a previous decomposition more or less slow.

It was then necessary, you see, to establish a distinction between the two states of the assimilable elements.

The clay has the property of absorbing and retaining much water - an important function, since it maintains a proper degree of humidity in the soil, without which vegetation would become impossible. But you know that at last the clay becomes dry and hardened when exposed to the action of the sun, and then it becomes so compact the roots of the plant cannot penetrate it.

Here the sand, which alone would be improper for vegetation, because it would form a changeable soil and one incapable of retaining water, opportunely intervenes. Formed of isolated grains always independent of each other, the sand by mingling with clay acquires its compactness, and communicates to it its more porous and movable character, making it as permeable to air as to water—qualities absolutely necessary to the exercise of vegetable life.

Clay possesses another quality, which deserves to be noticed—that of fixing in the soil the azotic and mineral compositions which essentially determine fertility. This fixity is not complete and definitive; it is in a measure exterior and transitory, for the clay ends by giving to vegetation the principles of which it seems to be possessed.

To make you better comprehend the character of this function, I will cite an example.

Dilute a piece of clay in the liquor of manure; the liquid is discolored, and analysis shows that at the end of a certain time it has lost a part of the ammonia as well as the salts it contains, and which we will find again in the clay.

Make an inverse experiment: dilute the same clay in distilled water; by degrees it will give out the products it has extracted from the liquor of manure.

Finally, if the active principles of the soil are not washed away by rain, it is due to the clay, which has the property of retaining the fertilizing principles of the soil and of regulating their more tardy dissolution.

Here is the process:

The absorbent power of the clay is greater in proportion as the solutions upon which it acts are more concentrated. In a solution containing four per cent. of potash or ammonia the clay absorbs more of these two alkalies than in a solution containing one to two per cent. of them. It follows, therefore, from this, that if a drought occurs there is no fear that the soluble part of the soil will acquire a degree of concentration dangerous to the plants. The clay prevents it. If the rain is continued, the clay returns to the water the products it has fixed.

It results from this acting and reacting that the clay performs the office of regulator to the assimilable elements of the soil, holding or giving them out according as the earth passes from a state of drought to an excess of moisture.

You see, then, gentlemen, that although clay and sand do not take a part in vegetable life, they fill an office of the highest importance.

Before finishing this point let us say a word on the nature of these two bodies.

Clay is a hydrated silicate of aluminum, the proportion of water in it being very variable, running from ten to twenty-five per cent. of its weight.

Clay has its origin in the silicates of eruptive rocks. You will perhaps find it difficult to believe that granite and porphyry, which are synonymous with resistance and durability, sometimes change with astonishing facility. When the cooling of these rocks is too sudden, they experience a kind of exterior exfoliation from the effects of the weather, consequent upon which their earthy and alkaline bases, potash, soda, lime, etc., are washed off by the rain, while the aluminum remains in combination with a part of the silicate, and forms the clay which we know.

The nature of sand is more simple: it is essentially formed from silicate in the form of quartz; it belongs to the great family of arenaceous rocks, which are themselves but blocks of eruptive or volcanic rocks washed off and divided by the action of water.

Thus, clay owes its origin to the chemical decomposition of these rocks, and sand to the trituration resulting from water, of which the wash of our rivers gives us daily examples.

The soil contains still another product, humus, very different from the preceding, and to which until recently agriculturists have wrongly given a rôle of the first order. You know that the earth of the heath is essentially formed of sand, and contains a black matter besides. This black matter is insoluble in water, but becomes soluble if a small quantity of caustic potash is added to the water. Well, this black matter, which we also find in the liquor of manure and in natural earths in very unequal quantities, is humus.

The following is the composition of humus: C_{24}, H_9, O_9—that is tc say, humus is composed of carbon, hydrogen and oxygen, in the relation to form water, and consequently enters into the frame of the hydrates of carbon: cellulose, sugar, starch represent, as you know, 95 per cent. of the weight of vegetation. Humus has for its origin the same substance with plants, but a species of spontaneous decomposition has caused it to lose a certain quantity of hydrogen and oxygen in the form of water.

The two formulæ following are to show the mode of generation of humus:

Cellulose, C_{24}, H_{20}, O_{20}.
Humus, C_{24}, H_9, O_9.

I tell you, gentlemen, many of the best minds have placed the humus in the first rank as an agent of fertility, but if you ask proofs as a support to this opinion, they can give you none. Vegetable nutrition is an extremely complex phenomenon, of which analysis has shown us very little until the last ten years. When sufficient facts were wanting to define it, they were supplied by hypothesis and words. The word humus has had the happy privilege of serving as an explanation to all which was not understood.

Thanks to this community of expression, we all appeared to agree, when in reality we did not agree at all.

Let us avoid this danger by being faithful to our programme. Let us put words aside to go to the bottom of things, and draw our light and information from experience.

How and in what case does humus show a favorable action?

The first of its good effects come from the property it has like clay of absorbing much water, and thus contributing to maintain the humidity of the soil.

If we remark, however, that earth contains hardly a small per cent. of humus, it is difficult to believe that so small a quantity has the power of modifying the physical condition of the soil.

Humus possesses a more useful property: it is quick at fixing the ammonia in the soil, which it subtracts from the washing of the rains, and which it returns later to vegetation.

Its offices in this respect are analogous to those of clay.

Here is where the importance of its office begins: the humus absorbs the oxygen of the air, and immediately submits it to a slow, inapparent, but real combustion. It thus becomes for the soil the source of a slow but uninterrupted formation of carbonic acid, less useful by the carbon which it furnishes than by the dissolvent action it exercises in respect to certain minerals, and particularly the phosphates and chalks.

We will, if needed, find the proof of this in a very simple experiment: Begin two cultures in burnt sand—one with the aid of humus and the other without this body, both having received equal quantities of chemical manures. In the two cases the returns will be the same, but analysis will show more phosphate of lime in the yield from the sand containing humus than from that without it.

Humus can, in certain cases, produce a more useful effect; it can, in a certain measure, increase the return: this effect takes place when the humus is associated with carbonate of lime.

To prove it let us make four new experiments.

Institute a culture in burnt sand, the soil being provided with azotic matter and all the minerals proper to employ in this condition, excepting the carbonate of lime. If we sow 22 grains we will gather from 360 to 396 grains. Add the humus to the sand, the harvest does not change. Substitute carbonate of lime for the humus, still no change. Add the humus and carbonate of lime together, and the return rises to 558 grains.

These facts are of fundamental importance to practice. Permit me, then, to sum them up in this little table:

Nature of Soil.	Returns.
1. Complete manure, burnt sand...........	396 grains.
2. " " sand with lime......	396 "
3. " " " and humus.....	396 "
4. " " " and lime........	1.3 oz., or 558 grains.

The excess of the return obtained in this last case is due to the combined action of the humus and carbonate of lime. But in what is the favorable action of the humus manifest? Is it because of its absorption under the form of humus? No. Its part is limited to favoring the dissolution of the carbonate of lime; and to prove it, it is sufficient to make a fifth experiment, in which we replace the carbonate of lime and humus by sulphate of lime, or, better still, by nitrate of lime, which is much more soluble, to see another return of 1.3 ounces or 558 grains. It is useless to add that when we employ nitrate of lime, it is with regard to the azote it contains, and that it enters in with the azotic matter. Thus is demonstrated by indisputable experiments that the good effects of the humus are due, in this case, to the dissolvent action upon the lime; and what proves it is the possibility of arriving at the same result by the aid of the salt of lime, which is more soluble than the carbonate. I will even tell you that it is this which has determined me to substitute the sulphate for the carbonate of lime in the composition of the complete manure.

But you will say, These are the experiments of the laboratory, and in matters of agriculture it is often dangerous to abide by such testimony. You ask me for proofs drawn from culture on a large scale. I am happy to be able to give them.

From a field in Champagne, cultivated for the first time with 71,111 pounds of manure to the acre, 19 bushels of wheat were obtained, while by using the complete fertilizer the return was raised to 47 bushels; from an acre of silicious earth in the department of the Aisne, with 36,555.05 pounds of manure, 11.44 bushels of wheat were obtained; with chemical manure, 40.44 bushels; the same earth without any manure produced 3.66 bushels; lastly, in the department of the Drôme, on a pebbly hill broken up for the purpose, the earth without manure yielded 4.33 bushels the acre; with 34,666.06 pounds of manure it gave 11.44 bushels, and with the complete fertilizer the return was 43.11 bushels.

Monsieur Payen, in the department of the Aisne, Monsieur de Matharel, in the department of the Oise, and Monsieur le Chevalier Musra, in Italy, have obtained like results.

Upon land chosen from among the poorest, where large quantities of manure have produced 11.44 to 14.22 bushels, the complete fertilizer has determined a return of from 36 to 43 bushels the acre.

Thus, gentlemen, a few experiments have been sufficient to define the functions of all the agents of fertility that the soil should contain or which we should furnish it by fertilizers.

A priori, one would think that a chemical analysis which has been pushed so far in our day, and whose methods have acquired at the same time so much delicacy and certainty, ought at least to give us a means of estimating with certainty the richness of the soil, and so guiding us in the choice of the manure best suited to its nature. There is none, however, and I defy the most skillful chemist to say in advance what will be the return from earth submitted to him, and what manures are most appropriate.

A few words will explain the reason why chemistry is powerless to furnish us with these indications: you must recall the distinctions we have drawn between the different elements of which the soil is composed.

Let us suppose a soil containing both quartz sand and feldspar sand among its mechanical elements. For vegetation these two sands are equivalent, although the first is from silica and nothing but silica, while the second is a silicate based upon lime, potash and soda, besides containing phosphate of lime in very feeble but very appreciable quantities.

Here, then, are two bodies whose composition, in spite of similitude of exterior, have no analogy, and which, however, are equivalent in an agricultural point of view, because the feldspar being insoluble in water its rôle in regard to vegetation descends to that of the quartz sand; that is to say, to a simple mechanical element. But for the chemist there are no insoluble bodies, so he confounds in one whole the potash, lime and phosphate of lime that the feldspar sand contains, though they are of no use in vegetation, with the products of the same nature which we have ranged under the class of active assimilable elements. Thus is explained the insufficiency of the signs with which chemistry can furnish us.

We have a striking example of the dangers of the confusion into which we are often drawn in the farm at Vincennes. After an analysis which I made with the greatest care of this soil, in 3,555,555.05 pounds—which pretty nearly represents the vegetable layer spread over the surface of an acre—there were:

Phosphoric acid	1596.66 lbs.
Potash	2045.33 lbs.
Lime	34,991.66 lbs.

This constitutes a considerable fund of fertility. Now, if we cultivate wheat on this land for four successive years, employing azotic matter as a fertilizer, at the end of the four years the return will not be more than from 7.11 to 8.44 bushels.

The soil shows a penury of minerals, and these harvests have shown but

Phosphoric acid	74.55 lbs.
Potash	81.77 lbs.
Lime	35.45 lbs.

from the land. Very different quantities from those shown by the chemical analysis.

Was there an error, then, in my analysis? No, gentlemen: the soil contains just what I reported; but this indication cannot be of any practical use, because in the mixture of these minerals we have not distinguished between those which are active in regard to plants and those which are inert.

Doubtless you find this conclusion very unsatisfactory.

To what good giving ourselves the trouble to discover the agents to which plants owe their formation, and to define the conditions of their efficacy, if at last we are not able to recognize their presence in the soil in the especial forms which assure their good effects?

Happily it is not so. The ideas which chemistry cannot furnish on this head we can acquire by other means, and I add, that these processes are not only the door of the agriculturist, but even enter into his daily work.

I have told you that plants are divided into two categories by the relation to the different forms under which they assimilate azote. Some take it from the air in the form of elementary azote, while others draw it by preference from the soil in the form of ammonia and nitrates.

You know the consequence of this distinction. The plants which draw azote from the air flourish in a soil deprived of it if they find the three minerals of the complete fertilizer—viz., phosphate of lime, potash and lime. Plants which borrow azote from the soil, on the contrary, become diseased and give but a poor produce.

It follows from this that by the aid of these two little trials of culture one can always know if the earth contains azotic matter and the minerals.

Cultivate peas and wheat, or peas and beets, alongside each other. If the peas yield much and the wheat very little, you may without hesitation conclude from that that the land, though provided with minerals, is wanting in azotic matter.

At Vincennes, when the earth had not received a fertilizer nothing succeeded, which proved that it was destitute both of azote and the minerals.

These indications, although useful, are not sufficient for the exigencies of practice. It needs more precise facts in regard to the presence or absence of each component of the complete fertilizer; that is to say, the phosphate of lime, the potash, lime and azotic matter.

These new indications are as easy to obtain as the first, in the following manner:

Suppose you institute seven cultures of the same plant—it may be of the beet or wheat; as you will.

To the first give the complete fertilizer; to the second, the same fertilizer excluding azotic matter; to the third, the complete fertilizer deprived of phosphate of lime; to the fourth, the complete fertilizer less the potash; to the fifth, less the lime; to the sixth, less all the minerals—that is to say, reduced to the azotic matter; the seventh not having received any manure.

It is very evident that if in the complete fertilizer the effect proper to each component is manifest but as it is associated with three others, the comparison of the returns obtained from the seven strips of the little field ought to indicate what the soil contains and in what it is wanting.

In this system of investigation the culture with the complete fertilizer becomes, in a measure, the invariable standard of comparison to which are referred the returns of the other strips of ground, and according as they approach or recede we conclude that the earth contains or does not contain the element which has been voluntarily excluded from the fertilizer.

To put the value of this method beyond doubt, I will report the results given under three different conditions.

At the experimental farm at Vincennes were obtained in 1864 the following returns from wheat:

Complete fertilizer	56.44 bu.
" " without lime	53.33 "
" " " potash	40.44 "
" " " phosphate	34.66 "
" " " azotic matter	18.88 "
Without any fertilizer	15.88 "

The conclusion is evident. At Vincennes the complete fertilizer was necessary; the azotic matter was most deficient.

An eminent agriculturist of the department of the Somme furnished me with my second example, which is upon the beet:

Complete fertilizer	45.04 lbs. the acre.
" " without lime	41.03 " "
" " " potash	37.03 " "
" " " phosphate	32.08 " "
" " " azotic matter	32. " "
Without any fertilizer	22.02 " "

You see here, also, the earth is wanting in azotic matter, and to put it under high culture we must have recourse to the complete fertilizer.

This experiment was made at Mesnil-Saint-Nicaise, under the care of M. Cavallier.

I will borrow my third example from a culture of sugar-cane, instituted by the Hon. M. de Zebrun, of Guadaloupe, a former delegate from that colony:

Complete fertilizer	50,666 lbs. the acre.
" " without lime	44,444 " "
" " " potash	32,111 " "
" " " phosphate	13,333 " "
" " " azote	49,777 " "
Without any fertilizer	2,666 " "

If I add that sugar-cane particularly draws its azote from the air, you will conclude that the soil is particularly wanting in potash and phosphate of lime.

Here are, then, two methods of knowing the richness of the land. The first founded on the culture of two different plants without any fertilizer, and the second on the culture of the same plant with five different fertilizers. These two applications of the same principles lead to the same results, and verify and complete each other.

I need not add, that for each of these trials to have its full signification the earth must not be used until the effect of each fertilizer has been spent.

You see, gentlemen, after having defined all the agents which enter into the composition of plants, we have distinguished between those of which nature furnishes an inexhaustible supply to vegetation, and those, on the contrary, which our industry must furnish to the soil. Further, by the aid of our experiments in burnt sand, and with only chemical products, we have realized a theoretic scale of culture whose progressive returns have shown us the laws which regulate vegetable productions. By the light of this collection of ideas we were enabled to conceive and to realize practical processes of analysis accessible to all, whose testimony is of almost absolute certainty, and by means of which we can always say what a land contains, what it needs, and can consequently determine the nature of the agents to which we must have recourse to fertilize it.

In our next lecture we will follow the consequences of these principles, and will occupy ourselves particularly with the returns to be obtained in practice by the aid of chemical fertilizers.

LECTURE FOURTH.

GENTLEMEN: It is true that phosphate of lime, potash and lime united to an azotic matter are the agents, *par excellence*, of vegetable production. Manure, which until now has been the agriculturist's sole means of increasing the fertility of the soil, ought necessarily to contain all the four.

Here are three analyses of manure. They fully justify this provision, for they all show the presence of azote, phosphoric acid, potash and lime:

	100 OF DRY MANURE		
	from farm of Vincennes.	from farm of Bechelbronn.	from farm of Thiergarten.
Organic Elements.			
Carbon			
Hydrogen } Oxygen }	59.65	65.50	64.67
Azote	2.08	2.00	2.56
Mineral Elements.			
Phos. acid	0.88	1.00	1.26
Sulphuric acid	traces.	0.63	0.82
Chlorine	0.70	0.20	0.32
Aluminum per			
Oxide of iron	0.68	2.03	1.51
Lime	5.23	2.83	3.70
Magnesia	0.32	1.20	1.88
Soda	traces.	2.60	0.87
Potash	2.46	2.60	3.87
Soluble silica	1.45	22.13	6.25
Sand	25.66	22.13	10.77

You see, besides the four terms of the complete fertilizer, the manure contains carbon, oxygen and hydrogen.

But after what I have told you of the origin of these three bodies you will not be surprised if I tell you that their presence in the manure does not add to its good effects. The same observation with regard to the chlorate of sodium, of aluminum, of magnesia, of soda, of silica, of the oxide of iron, etc., which manure contains, and which we have excluded from the complete fertilizer, because poor land is always superabundantly provided with them.

Thus, then, the first result is that manure, the incontestable symbol of fertility, contains the four bodies which, according to us, are the regulators, *par excellence*, of production, and the only ones with which agricultural industry need occupy itself. I repeat, this is an incontestable justification of our previous studies; but that this justification may be complete and without appeal to the identity of composition, must be added that of effect. In this respect practice again confirms our teachings. The returns from our complete fertilizer always exceed those obtained from manure.

This conclusion is of more value as it is the result from facts borrowed from a large culture. I owe them to agriculturists who, like you, are seeking truth, and who, at my request, willingly instituted several comparative experiments between the chemical fertilizer and the manure of the farm.

In all these experiments the advantage rests with the chemical fertilizers. The first result I will show you was obtained by M. de Peyrat, sub-director on the school-farm of Beyrie, in Landes.

On a land of ordinary quality three cultures of beet were instituted —the first without any fertilizer, the second with the complete manure, and the third with 71,136 pounds of manure.

	Roots the acre.
On the land without manure the return was	7,264.06
With 71,136 pounds of manure it reached..........................	43,844.07
With the chemical fertilizer it rose to..............................	47,111.24

The chemical manure was used in the quantity of 1511 pounds, which showed itself superior to a manuring of 71,136 pounds of barnyard manure.

With M. le Marquis de Virien, in the Isere, the same result:

	Roots the acre.
From 44,444.04 pounds of barnyard manure the yield was	41,600 lbs.
From 1733 pounds of the complete fertilizer was obtained..	44,444.04 "
With M. Leroy, at Varennes (Oise), from 1243 pounds of chemical fertilizer, the return was.......................	55,440 "
From 44,444.04 pounds of barnyard manure, with the addition of 133.03 pounds of guano, the return only rose to..	35,568 "

At Guadaloupe, on some of the worst land of the colony, barnyard manure produced 28,418.56 pounds of cane the acre.

The chemical fertilizer..................................	51,552.32 lbs.
And the land without any fertilizer............	2,666.24 "

Here are significant facts. I have said they come from distinguished practical men, animated with the desire of progressing, who attack these problems with prejudice, and who are now lending me the most valued help.

With M. Cavallier, at Mesnil-Saint-Nicaise (Somme), from 44,444.14 lbs. of manure (still cultivating the beet), the return was..	30,011.01	lbs. the acre.
From 1733 pounds of the chemical fertilizer it was raised to	53,013.03	" "

The same results from wheat and Irish potatoes.

With MM. Masron and Isarn, at Evreux, the complete fertilizer produced the acre in wheat..............	58	bushels.
While from 26,664.01 pounds of manure the acre were returned but	14.70	"
With M. Bravay, in the department of Drôme, on a pebbly hillock, cleared for the experiment, the yield from the complete fertilizer was..........................	43.50	"
From 25,737 pounds of barnyard manure.................	14.50	"
And from the land without any fertilizer..................	3	"

That is to say, hardly the seed.

But the most remarkable result from wheat is that obtained by M. Pousard from entirely uncultivated land in Champagne, hardly worth $14.35 the acre, and from which he obtained, with 1066 pounds of the chemical fertilizer, 47.50 bushels of wheat; with 1555 cubic feet of manure, 19 bushels. In giving me an account of these results M. Pousard wrote me: "The land upon which I am operating is a land which has never known the plough, and is hardly worth $14.35 the acre. The wheat developed vigorously before the winter of 1865, and in the whole course of its vegetation was always superior to the neighboring grain on manure. To this vigor it owed so quick a maturity that I was able to harvest it before the rains. I could have sold it at a high price as seed-wheat, for the grain was remarkably fine."

At the market prices the acre would have yielded:

Culture with the Chemical Fertilizer.

1119 quintals of wheat, at $6.65........................	$73.88
Cost of fertilizer..	27.02
Profit..	$46.86

Culture with Barnyard Manure.

1555 cubic feet of manure, at 4 per cent...............	$62.20
4.44 quintals of wheat, at $6.08..........................	26.99
Loss..	$35.21

I need not remark that M. Pousard in this *résumé* kept no account of details, but simply set in relief the contrast of the results—a contrast the more significant, as it shows a difference of from $60 to $70 —that is to say, four times the value of the cost.

The harvest obtained by M. Pousard is truly so astonishing one dare hardly believe the facts. We therefore take great interest in affirming them by analogous facts, which make them lose the character of exceptions which we are tempted to attribute to them. With this view I will report the two following results.

On an acre of sand-land of very inferior quality Mr. Leon Payen obtained this year with the chemical fertilizer:

1. 40.44 bushels, at $1.57½, actual price	$63.84
2. 5400 pounds straw	20.52
3. Waste straw	.34
Total	$84.70

35,523.20 pounds of manure only produced from the same earth—

1. 11.55 bushels grain, at $1.57½	$18.2
2. Straw, 1511 pounds	3.72
3. Waste straw	.34
Total	$24.30

As to the same soil without a fertilizer, it only furnished 3.69 bushels.

Is it necessary to support the testimony of M. Payen? The Hon. M. de Matharel, Inspector General of Finances, has given me the means to do it. On the 26th of July he wrote me that upon land which had only produced a coarse bread corn he had this year obtained 36 bushels of wheat.

Let us contrast these four results:

Culture of Wheat—Return per acre.

	M. Pousard (Champagne). bu.	M. Bravay (Drôme). bu.	M. Payen (Aisne). bu.	M. de Matharel (Puy de Dôme). bu.
Chemical fertilizer	47	43	39	36
Manure	18	15	11	36
Without fertilizer	18	4	3.69	36

Here are four results obtained from four different parts of France, always on poor land, whose returns so resemble each other that they are puzzling.

The results obtained from the Irish potato are not the less significant.

With M. le Marquis de Harrincourt the complete fertilizer produced 14,222 pounds of tubers the acre.

From 29,333 pounds of manure only 7111 pounds were obtained.

I have myself exceeded at Vincennes returns of from 22,222 pounds to 26,666 pounds.

With M. Lavaux, at the farm of Choisy-le-Temple, on a piece of 8.44 acres, were obtained—

1st year, wheat	57 bu. the acre.
2d year, colza	47 " "
3d year, wheat	39 " "

The third year the wheat fell down.

In 1867 the returns from beets oscillated between 48,844 and 62,160 pounds of roots the acre, but with 35,520 pounds of manure the returns did not exceed 31,111 pounds.

Shall we speak of the sugar-cane? In 1867 M. de Zebrun obtained at Guadaloupe:

Canes Stripped of Leaves.

Chemical fertilizer	75,316 lbs.	the acre.
Manure	55,428 lbs.	"
Land without fertilizer	23,617 lbs.	"

You know, gentlemen, that practice has proved there is a real advantage in varying crops with manures. But returns are thus obtained otherwise than by always cultivating the same plant. Does the alternation of crops with the chemical fertilizer offer the same advantage? We reply without hesitation, Yes. In these new conditions the chemical fertilizers preserve their superiority. Wheat, succeeding peas, produced 66 bushels; after the beet, 49; after wheat, 47.

The chemical manures act in all points like manure: from this results a new proof that, despite their want of resemblance, the chemical fertilizers and the manure owe their effects to the same cause, and that there is an entire community of nature between them.

We have now arrived at, if possible, a more important point of consideration than the preceding.

The source of profit in agriculture depends particularly on the manuring, and unfortunately, when one produces his own manure, he is not master of as much manure as he would wish.

The quantity of manure disposed of in rural culture depends on its organization, the number of animals raised, or rather fed there—consequently on the surface devoted to the meadow—and finally the rolling capital possessed. A great deal of time, discernment and prudence is necessary in changing a culture; for everything depends on it on an estate where the production of the cereals and of manure is the main object.

With the chemical fertilizer, on the contrary, agriculture acquires an almost absolute liberty of action; the quantity of the fertilizer can be regulated at will. It is only limited by the amount of capital.

By the use of chemical fertilizers one may, in a measure, by to-morrow evening, change a doubtful culture to the order of the highest, and consequently obtain a large instead of a mediocre profit.

You understand, gentlemen, that here is the knot of all future questions in agriculture; I therefore insist on taking things at the beginning.

I say that the profit from agriculture depends on the quantity of fertilizers given to the land. So dependent is it on this that without fertilizers the harvest is weak and the profit nothing, the whole ending in a loss. With abundant manuring the returns are increased and the profit certain, for the excess of expense is but the half or the third of the price of the excess of harvest.

To make this truth plainer, permit me to remind you that the cultivation of the soil involves two kinds of expenses:

Fixed expenses, which are always the same, be the culture good or bad; such are the taxes, the rent that the farmer pays his proprietor, the cost of seed, etc.

Then come the variable expenses, which comprehend transportation, thrashing of the grain, and finally the manures.

Now, I maintain that the agriculturist who uses but little manure loses, while the one who uses much is always benefited. How can it be otherwise? The fertilizer is the foundation of the harvest.

But these are too grave questions to be simply announced. Let us analyze facts, let us decompose the account of the products and expense, to definitely fix our ideas upon this point. To give more generality to our conclusions, I will take as a point of departure the return of 20 bushels, which is the mean return in France. According to Matthieu de Dombasle, the minimum expense for such a return is $24.82 the acre. Reduced to $20.60 the acre by the price of the straw, thus there results from this discount—

Fixed expenses—		
Rent	$3.81	
General expenses	4.39	
Cost of culture	3.63	
Seed	3.86—	$16.60
Variable expenses—		
Manuring	6.24	
Harvest, thrashing, etc	2.87—	9.11
Total expenses		$25.71
From which is deducted the straw		4.22
Remains		$21.49

for 20 bushels, which raises the price of a bushel to $1.03.

Suppose that without changing anything in the régime of the farm of Roville, without reducing the number of animals, without modifying the existing relation between the different cultures and the mode of culture, we had suddenly increased the cost of manuring, by a quantity of the chemical fertilizer, to $10.13 the acre, which would bring it from $6.24 to $16.37 the acre, all the other expenses remaining the same. What has been the consequence? The return would have passed from 20 bushels to 44 bushels! I say 44—I might say 49 bushels, but like best to take a minimum—and from $1.03 the cost of a bushel of wheat would be brought down to $93\frac{9}{10}$ cents.

Let us take up our figures again:

Fixed expenses, like the preceding		$16.60
Variable expenses—Manuring	$16.37	
" " Harvest and thrashing	5.06—	21.43
Total expenses		$38.03
The straw deducted		8.13
Result		$29.90

which will easily change the cost of the bushel from \$1.03 to $93\frac{9}{10}$ cents.

I have always told you, the superiority of a high culture depends upon this circumstance—that the increase of expense from the use of strong manures was always inferior to the value of the excess of harvest.

In the first case, where the return was 20 bushels, and the cost \$1.03, if we fix the price of sale at \$1.16 the bushel, the harvest represents the value of \$23.20, and the net profit \$2.60 the acre.

In the second case, despite the increased expense of \$10.13, which the excess of straw reduced to \$6.22, the harvest was worth \$117.84, and the net profit increased to \$23.20 instead of \$2.60 the acre.

Another consequence resulting from these facts so little known—that it is better to till and manure well than to waste one's efforts and resources over a large surface scantily manured.

Suppose an agriculturist to have \$5700 at his disposal; if he proceeds as at the institute of Roville, where they spend \$57 the acre, he can cultivate 225 acres. What will be the result?—

Straw, at \$4.22 the acre	\$950
Grain—22.22 bu. per acre would be about 4550 bu., at about \$1.17	5320
Total	\$6270

—\$6270 of produce against \$5700; profit, \$570. With the same capital, if we apply the system of strong manuring, one can cultivate but 153.45 acres instead of 225, but these 153.45 acres will produce \$9264.97, instead of \$6270. Thus,

Straw, at, say, \$8.02 the acre	\$1231.08
6865 bu. of grain from 44.74 bu. per acre, selling at \$1.17	8033.96
Total	\$9264.97

which raises the profit from \$570 to \$3564.97.

You will remark, gentlemen, there is no hazardous innovation or revolutionary proceeding, but certain ameliorations of which practice begins to gather the fruits.

I maintain that grain can be raised at 64 to 70 cents per bushel, and I prove it. If it is a revolution, it is at least a revolution of which no one can dispute the benefits, and which will be accomplished, no matter what opposition; for truth always ends by triumphing over resistance and routine.

After having clearly showed the most immediate result attained by employing chemical manures, let us prove by facts the exactitude of these indications.

For example, I will take a continued culture of wheat.

In a period of four years the mean return obtained the acre was 4260 pounds of straw and 44 bushels of grain. I insist upon this result, because I wish to warn you against some dangers in relation to azotic matter.

When, on the faith of my studies in the laboratory, I commenced my experiments here at Vincennes, having nothing to direct me but theoretic views, which I wished to reduce to facts, I first asked, What will be the duration of a good manuring with chemical fertilizers? The manure employed was as follows:

	The acre.
Phosphate of lime	355 lbs.
Potash	118 "
Lime	266 "
Sal ammoniac	577 "

which represents 151 pounds of azote the acre.

The land was given me too late to sow in wheat in autumn; I sowed it in March.

The growth was very pretty; the stalks shot up with so much vigor they fell down, which injured the harvest. However, all things counted, the return showed 44 bushels of grain and 3777 pounds of straw.

The second year the same accident happened, consequent on a still more luxuriant growth. It not falling until late, the return was more affected; it descended to 34 bushels of grain and 6168 pounds of straw.

The third year the grain was sown in autumn instead of March, and things were different. This time the growth was equally splendid, but the stalks did not fall. So the returns were increased to 67 bushels of grain and 6168 pounds of straw.

Lastly, the fourth year I obtained 34 bushels of grain and 4000 pounds of straw.

The total of these four harvests is represented by grain, 179 bushels; straw, 20136 pounds—giving a mean of grain, 44 bushels; straw, 5034 pounds.

What conclusions can we draw from this experience? Two. The first is, that 151 pounds of azote is too much at one time the acre for wheat, because accidents are then almost inevitable: if it does not fall, it rarely escapes rust; and if it avoids both, the straw is so fully developed that the return of grain is diminished. I propose to you the following formulæ, which at present I consider the best:

First Year—Wheat.

Complete fertilizer No. 1, 1066 pounds.

Composition:	The acre. Quantity.	Price.
Phosphate of lime	355 lbs.	$ 5.40
Nitrate of potash	177 "	10.47
Sulphate of ammonia	222 "	9.50
Sulphate of lime	311 "	.59
Cost		$25.96

Second Year—Wheat.

Sulphate of ammonia	266 lbs.	$11.40
Cost		$11.40

Third Year.

Complete fertilizer No. 1, 1066 pounds.

Composition:	The acre. Quantity.	Price.
Acid phosphate of lime	355 lbs.	$ 5.40
Nitrate of potash	177 "	10.47
Sulphate of ammonia	222 "	9.50
Sulphate of lime	311 "	.59
Cost		$25.96
Total		$63.32

Fourth Year—Wheat.

Brought down			$63.32
Sulphate of ammonia	266 lbs.	$11.40	11.40
Expense for 4 years			74.72
Mean expense per year			$18.68

Thus, from an expense each year of $18.68 a mean return of from 43 to 60 bushels of wheat is obtained.

I would advise you to use the following for an alternate culture of wheat and colza:

First Year—Colza.

Complete fertilizer No. 6, 1155 pounds.

Composition:		
Phosphate of lime	355 lbs.	$ 5.40
Nitrate of potash	106 "	6.28
Sulphate of ammonia	355 "	15.20
Sulphate of lime	333 "	.64
Expense		$27.52

Second Year—Wheat.

Sulphate of ammonia	266 lbs.	$11.40
Ashes of straw and husk of colza		
Total expense		$38.92
Total expense per year		$19.46

In this case we open the fallow with the colza, which is a weedy plant, and by cultivating it clear the soil of bad weeds. After the harvest, burn the husk and straw of the colza on the ground, and turn it in with the plough, so as to reduce as much as possible the quantity of potash and phosphate of lime lost by the soil. Spread the sulphate of ammonia broadcast in the spring.

I pass to a succession of four years, much appreciated in practice, and which recommends itself by the facility with which it permits the triennial succession to be replaced by the alternate and continued successions. It comprehends the following succession of harvests:

First year, Irish potatoes.
Second year, wheat.
Third year, clover.
Fourth year, wheat.

These are the fertilizers to be used:

First Year.

Complete fertilizer No. 3, 887 pounds.

Composition:	The acre. Quantity.	Price.
Acid phosphate of lime	355 lbs.	$ 5.57
Nitrate of potash	266 "	15.70
Sulphate of lime	266 "	.50
Expense		$21.77

Second Year—Wheat.

Sulphate of ammonia	266 lbs.	$11.40

Third Year—Clover.

Incomplete fertilizer No. 2, 887 lbs.

Composition:		
Acid phosphate of lime	355 lbs.	$ 5.40
Nitrate of potash	177 "	10.47
Sulphate of lime	355 "	.67
Expense		$16.54

Fourth Year—Wheat.

Sulphate of ammonia	266 lbs.	$11.40
Total expense		$61.11
Annual expense		$15.27

For a succession of four years, comprehending beets, wheat, clover, wheat, the preceding fertilizers must be replaced by the following.

First Year—Beets.

Complete fertilizer No. 2, double, 1154.16 lbs.

Composition:		
Acid phosphate of lime	355 lbs.	$ 5.40
Nitrate of potash	177 "	10.47
Nitrate of soda	355 "	11.82
Sulphate of lime	266 "	.50
Expense		$28.19

Second Year—Wheat.

Sulphate of ammonia	266 lbs.	$11.40
Expense		$11.40

Third Year—Clover.

Incomplete fertilizer No. 2, 877 lbs.

Composition:		
Acid phosphate of lime	355 lbs.	$ 5.40
Nitrate of potash	177 "	10.47
Sulphate of lime	355 "	.67
Expense		$16.54

Fourth Year.—Wheat.

Sulphate of ammonia	266 lbs.	$11.40
Total expense		$67.53
Annual expense		$18.88

I pass to a more complex succession, for it embraces a period of five years, and comprehends Irish potatoes, wheat, clover, colza and wheat Here are the fertilizers to be employed in this case:

First Year—Irish Potatoes.

Complete fertilizer No. 3, 887 lbs.

Composition:	The acre. Quantity.	Price.
Acid phosphate of lime	355 lbs.	$ 5.40
Nitrate of potash	266 "	15.70
Sulphate of lime	266 "	.50
Expense		$21.60

Second Year—Wheat.

Sulphate of ammonia	266 lbs.	$11.40

Third Year—Clover.

Incomplete fertilizer No. 2, 887 lbs.

Composition:		
Acid phosphate of lime	355 lbs.	$ 5.40
Nitrate of potash	175 "	10.47
Sulphate of lime	355 "	.67
Expense		$16.54

Fourth Year—Colza.

Sulphate of ammonia	355 lbs.	$15.27

Fifth Year—Wheat.

Sulphate of ammonia	266 lbs.	$11.40
Ashes of the straw and husks of the colza	—— "	——
Total expense		$76.11
Annual expense		15.22

To show how necessary to regulate the quantity of manure to the nature of the plant, I will show the results of three experiments made by M. Cavallier on the beet, with the progressive quantities of sulphate of ammonia, the manner of passing from 71 pounds of azote to 106 pounds the acre, the proportion of the other terms not being changed:

	Roots the acre.
Without azote	32,741 lbs.
With 355 pounds sulph. ammonia	32,740 "
With 444 " "	42,064 "
With 578 " "	53,012 "

You will remark, gentlemen, the correspondence between the increase of the progressive return and the corresponding increase of the azotic matter. What is the financial result?

The fertilizer without azotic matter, reduced to minerals alone—that is to say, to phosphate of lime, potash and lime—produced 32,740 pounds of roots the acre. Now, if we take this return as a point of departure, we find the excess of harvest, determined by the use of sulphate of ammonia, increases in proportion to the amount of ammonia employed.

With 355 pounds of sulphate of ammonia the profit was $5.47.
With 444 pounds of sulphate of ammonia the profit was $7.13.
With 578 pounds of sulphate of ammonia the profit was $20.57.

These results, which I borrowed from one of the most distinguished departments of the Somme, show—

1st. That the beet requires much azotic matter;

2d. That up to 117 pounds of azote the acre the benefit is proportioned to the amount of sulphate of ammonia employed.

A succession of six years, comprehending flax, beets, wheat, colza, wheat, oats, barley or rye:

First Year—Flax.

Incomplete fertilizer, No. 2, 888 pounds.

Composition:	The acre. Quantity.	Price.
Acid phosphate of lime	355 lbs.	$ 5.40
Nitrate of potash	177 "	10.47
Sulphate of lime	355 "	.67
Expense		$16.54

Second Year—Beets.

Complete fertilizer, 1066 pounds.

Composition:		
Acid phosphate of lime	355 lbs.	$ 5.40
Nitrate of potash	177 "	10.47
Nitrate of soda	266 "	8.86
Sulphate of lime	266 "	.50
Expense		$25.23

Third Year—Wheat.

Sulphate of ammonia	266 lbs.	$11.40
Expense		$11.40

Fourth Year—Colza.

Complete fertilizer, 1152 pounds.

Composition:		
Acid phosphate of lime	355 lbs.	$ 5.40
Nitrate of potash	106 "	6.24
Sulphate of ammonia	355 "	15.27
Sulphate of lime	338 "	.59
Expense		$27.50

Fifth Year—Wheat.

Ashes of the straw and husk of the colza turned in by the plough	266 lbs.	$11.40
Expense		$11.40

Sixth Year—Oats, Rye or Barley.

Sulphate of ammonia	177 lbs.	$ 7.60
Expense		$ 7.60
Total expense		$99.67
Annual expense		$16.60

This succession of cultures, treated as I show, always gives magnificent harvests.

I will end these tables with the two fertilizers which I now consider the best for lucerne and the vine:

Fertilizer for Lucerne for One Year.

	The acre.	
	Quantity.	Price.
Acid phosphate of lime	355 lbs.	$ 5.40
Nitrate of potash	177 "	10.47
Sulphate of lime	355 "	.67
Expense		$16.54

Fertilizer for the Vine for Two Years.

Complete fertilizer, No. 4, 1332 pounds.

Composition:

Acid phosphate of lime	532 lbs.	$ 8.10
Nitrate of potash	444 "	26.17
Sulphate of lime	355 "	.67
Expense		$34.94
Annual expense		$17.47

There is one point, gentlemen, to which I cannot too strictly call your attention: it is the manner of employing the chemical fertilizers.

It is not injurious to spread manure unequally, provided the inequality is not too great.

With the chemical fertilizers, on the contrary, inequality in spreading may compromise the success of the harvest. This part of the work needs particular attention. There is an excellent machine for the purpose. When one has not a machine, the best method is to mix the chemical fertilizer with three times its volume of earth, and spread it broadcast after the last ploughing and before harrowing. The addition of the earth corrects the ill effects of irregularity in spreading. This mode of spreading, it is true, involves some additional expense, but it is fully compensated, for if well spread the yield is increased by two to four bushels the acre—that is to say, $5 increase at a cost of from 40 to 50 cents the acre. Here the care is well repaid.

Another question now presents itself, gentlemen (which I have treated in detail in my discourses of 1864), which need not detain us, but on which I must say a few words, to answer certain fears against which I wish to warn you.

Not able to deny the results which I have just shown you, because too many agriculturists have verified their exactitude, the following objection is made:

"The chemical fertilizers are but a precarious reliance: when their use becomes general the price will become so raised it will be impossible to employ them."

Some few explanations will suffice, I believe, to overthrow this objection.

Let us take the four terms of the complete fertilizer separately, and balance the sources of each which nature offers.

The Phosphate of Lime.—For twenty years no other source was known for phosphate of lime than the bones of animals. It is certain, if we had no other source, its use could not become general. But it is not so. We know that phosphate of lime forms a part of all volcanic rocks, and that in several countries there are sources of inexhaustible richness.

In the environs of Logrosan, in Estremadura, there are eight or ten veins, over an extent of 1000 feet, seventy or eighty-five per cent. rich in real phosphate, and whose full extent is not known. There are others in Canada and Sweden.

Phosphate is found in most marls. Considerable deposits have been found underlying cretaceous earth, which have become the object of a regular working in the departments of Ardennes and Moselle. Although not so rich as that at Estremadura, this deposit contains from sixteen to eighteen per cent. phosphoric acid.

There need be no uneasiness with regard to the phosphates: their price will rather be diminished than increased.

Potash.—The sources from which we can draw potash are three in number:

First. Volcanic rocks, which constitute entire chains of mountains, and which contain fifteen per cent.

Second. The waters of the sea, from which we now extract it with remarkable facility by the admirable method of M. Balerd, and which would be sufficient, in case of need, for all our wants.

The deposits discovered at Strasfürth in Prussia four or five years ago are inexhaustible, and from 2000 to 3000 feet thick, spread over an undetermined extent. These deposits, which are attached to a formation of fossil salt, authorize us in believing that this discovery cannot but become general, since the deposits at Strasfürth are sufficient for several centuries, and after them we will have long chains of mountains and the waters of the sea.

Azotic Matter.—Here, I confess, if we were condemned to employ only ammoniac and nitrate compositions, there would be apparent reason in saying that the actual sources known are insufficient, but new sources are added to these. I will cite, for example, the fabrication of coke, which is done in the open air; it will only be necessary to make it in furnaces to draw considerable quantities of ammonia from it.

But if all three sources failed, we have still the azote of the air. My attention has long been directed to this point.

I have said that some plants draw their azote from the air, while others find it in the soil. From this, consequently, there is the possibility of coming to the aid of the second by the help of the first.

This method is already applied in culture. Green manures are only valuable from this fact. It is then possible to make them general, and to make them more efficacious is to push the yield of plants which draw azote from the air to the utmost limit. I will cite lucerne as an example, which draws from 266 to 355 pounds the acre of azote from the air, which would be sufficient to enrich at least 9.11 acres cultivated in wheat. Thus, if all other sources of azotic matter were exhausted, there would always remain the azote of the air, which is thrown off by the plants themselves.

But this is an extreme supposition. When humanity rests upon a problem, be assured, gentlemen, at the proper moment the problem will be solved.

The air being an inexhaustible source of azote, what remains for us to do to have the nitrate and ammonia in illimitable quantities is to discover the most economical method of combining the azote of the air with oxygen to form nitrates, or with hydrogen to form ammonia. Now this process is discovered, Messrs. Sourdeval and Margueritte having found the means of making the nitrate or ammonia at will with the azote of the air. If the working of it is limited, it is only that, in an economical point, it does not satisfy all the conditions of an easy production. But the principle is known, and the solution may at any moment be complete.

I ask, gentlemen, if, in the face of such facts, azotic matter will ever be wanting? As to lime, I do not speak of it, for we all know there never will be a deficiency of it.

Assured for the future, let us recapitulate the matter of the past lecture.

In our preceding sittings we have been employed in defining, by the aid of experiments more scientific than practical, the conditions which regulate the production of plants.

To-day, entering the domain of the practical, we have asked from the traditions of centuries of experience—that is, from the composition of dung—the choice of agents which, in our eyes, are the symbols of fertility. This test has ended in our favor. Dung contains these agencies, and owes its fertility to them.

To this testimony we have added another. We asked of practical agriculture, If the effects obtained from the chemical fertilizers were not equivalent to those obtained from manure? Experience replies, They were superior. From which we conclude that the principles we hold are incontestable, and there remains for us but to generalize their application.

LECTURE FIFTH.

GENTLEMEN: In practice, we consider 35,555 pounds of manure the acre every two years as a good manuring. Our principal object to-day being to compare manure with the chemical fertilizers, we first ask how much 35,555 pounds of manure contains of the four terms composing our complete fertilizer.

The reply is found in the following table:

Azote	144 lbs.
Phosphoric acid	66 "
Potash	133 "
Lime	283 "

If it is true, as experience demonstrates, that manure owes all its efficacy to these four products, you see that its active part is reduced at least to one-fortieth of the whole mass. Moisture forms eighty per cent. of manure, which reduces the solid part of 35,555 pounds to 7111 pounds, of which the hydro-carbonate matter, whose utility is problematic, forms 3000 to 3552 pounds.

You will not, then, be surprised if I add that with 2053 pounds of chemical products one can compose a fertilizer of equivalent richness to 35,555 pounds of manure.

Here is the proof of it:

Acid phosphate of lime	533 lbs.
Nitrate of potash	286 "
Sulphate of ammonia	497 "
Sulphate of lime	737 "
Total	2053 "

It is evident as regards facility of use, of spreading, economy of transporting, etc., the advantage is with the chemical fertilizers. But this is only a secondary point of view; their true superiority rests on other causes and is justified by other considerations.

The azote of the manure is not immediately assimilable. It is the contrary with the chemical fertilizer. This body in manure is in the form of animal evacuations and partly putrefied litter, which only acts favorably upon vegetation after having submitted to a decomposition which completely changes its form; azote is assimilable only after it is transformed into ammonia or nitrates. Now, this previous decomposition has, as a principal result, the loss of from thirty to forty per cent. of the primitive azote of the manure, which is disengaged in the air in the form of elementary azote. In the chemical fertilizer the azote is, I repeat, immediately and entirely assimilable—its action, for this reason, being the more certain.

Here is another still more important advantage in practice.

You must certainly have remarked, in the formulæ of fertilizers I gave you in my last lecture, that the nature of these agents varied with the nature of the plant. The position which I gave each one in certain categories of plants was not an arbitrary act on my part, or the expression of a fancy; it is the result of an important fact, and one which is absolutely necessary to you, for its application is greatly in favor of the chemical fertilizer.

If it is true that a mixture of phosphate of lime, potash and lime with azotic matter suffices for all the wants of plants, and for the agriculturist is an equivalent for manure, it is also true that each of these four terms fulfills, in regard to the three others, an alternately subordinate or predominant office, according to the nature of the plant cultivated. The azotic matter is the predominant element for wheat, colza, the beet and tobacco; for lucerne, peas and beans the azotic matter is of secondary importance, and the predominance of which we speak passes to the potash. Phosphate of lime predominates for turnips and rutabagas.

For each plant, then, there is an element whose influence predominates over the three others, and for this reason we will call it the dominant of this plant.

As the first application of these ideas, we will suppose the following rotation: Beets—wheat—clover—oats.

It is not possible to divide manure; we may vary the quantity, but not the composition. We have but two methods of procedure—either to put on all the manure the first year, or spread it at different times. In the first case, it is true, we obtain a good yield of beets, but it is to the prejudice of the following cultures. If we divide the manure, the yield of beets is sensibly reduced; and as this culture is expensive from the multiplicity of dressings it requires, it necessarily causes a loss to the producer.

Things are entirely different with the chemical fertilizers. We give each plant the element which has most influence on its harvest; this has the double advantage of reducing the expense and of raising the return to the highest point. As proof of the advantage in practice of this manner of proceeding, I will cite the example of two parallel cultures of Irish potatoes and wheat—one with the complete fertilizer, the other with the same fertilizer divided in the following manner: the first year, the mineral fertilizer alone; the second year, azotic matter. Now, here are the results of these two cultures:

First Case.—The earth receives enough of the complete fertilizer for two years.

	Return the acre.	Price.
First Year—		
Irish potatoes............................	22,522 lbs.	$53.70
Second Year—		
Wheat (straw)............................	4,640 lbs.	17.64
(grain)............................	44 bu.	52.35
Total of products..		$123.69

Second Case.—The earth is enriched the first year with the mineral fertilizer, and the second year with six hundred pounds of sulphate of ammonia.

First Year—	Return the acre.	Price.
Irish potatoes	21,244 lbs.	$12.60
Second Year—		
Wheat (straw)	7,600 lbs.	28.88
(grain)	62 bu.	76.00
Total of products		$117.48

You see by this example to what degree the division of the fertilizer can affect the returns.

Under an economical relation the results are not the less considerable.

With the fertilizer divided the united returns of the Irish potatoes and wheat are $117.48, while with all the fertilizer used at once they are worth $123.69—making a difference of $31.66 in favor of the first method.

The advantages resulting from the division of the fertilizer being thus placed beyond doubt, you will understand why, a succession being given, I do not use the four terms of the fertilizer indifferently, but according to the nature of the plant.

If a succession of beets, wheat, clover and oats is under consideration, we must concentrate azote upon the beets and wheat, and the minerals on the clover, which will leave enough azotic matter in the soil for oats.

If the succession opens with peas or beans, followed by wheat, clover, and wheat again, this time, the minerals being the dominant of beans and clover, and azotic matter that of wheat, we will limit the manuring of the first and third to the minerals, reserving the azotic matter for the wheat—taking care to employ more of it the second year than the fourth, because the clover, which is turned under green at the third cutting, constitutes an azotic manure of a certain efficacy.

You see, gentlemen, what remarkable facility the chemical fertilizers give in practice for obtaining the maximum return with the greatest possible economy. They permit you to concentrate on each culture the agents most suitable to it. In the last sitting I limited myself to indicating these facts, without telling you the reason of them; to-day I complete these first practical indications by the theory, with both their basis and justification.

Let us pass to a new question, not less important than the preceding.

We will ask what manure costs in comparison to the chemical fertilizers.

It is not enough that these latter are superior in useful effects and facility of application; we must still examine the economical question, to see if, all things considered, the financial result is not also in their favor.

The cost of manure is one of the most disputed questions among agriculturists. Each one makes his own price. Some maintain that manure costs nothing; others, on the contrary, that it is very dear.

We must endeavor to ascertain the truth between these two extreme opinions.

I hope to succeed in doing so, building upon documents from agriculturists of the greatest merit, who worked under very different conditions.

It is by such accounts, and detailed accounts, that this question must be settled.

I owe the one which I first lay before you to the Hon. M. Schattenmann, who last year received the first honor in the department of the Lower Rhine, and a large prize at the World's Fair, and who, consequently, is a good judge in matters of culture. I add that M. Schattenmann is moreover a practical man of the first order, and entirely competent to decide a question of this kind, no matter how complicated.

Well, according to the account he has furnished me, the production of 551 tons of manure and 500 tons of liquid manure costs not less than $2869.15, which brings the price of manure to $4.94 the ton if by approximation we fix that of liquid manure at 40 cents.

Thus, according to M. Schattenmann, the manure on a model farm cost in 1866, $4.94 the ton.

You will notice that this price, which we think very high, rests upon exceptional causes, and surpasses the ordinary cost in the culture.

Let us take it, however, as a point of departure:

Cost of Manure at the Farm of Thiergarten (Lower Rhine).

148,142 lbs. of straw for litter	$865.43
984 lbs. of liquid phosphoric acid	31.04
Binding and transporting straw for litter	19.02
4750 lbs. of liquid manure	25.72
Clearing out the sinks	1.90
Wetting of manure	10.21
Loading and transporting manure	187.13
Filling the casks of liquid manure	13.99
Loss on beef	655.04
Loss on cows	897.22
Loss on pork	162.45
Total	$2869.15
500 tons liquid manure, at 40 cts. the ton	200.00
551 " of manure, at $4.91 the ton	2738.47
	$2928.47

The second example is furnished by M. Cavallier, who worked the farm Mesnil-Saint-Nicaise (Somme). Here the conditions are different.

With M. Schattenmann we had to do with a production of manure joined in all its details to a grand culture of which it formed a part, and where the price of manure was influenced by that of the beeves, cows, hogs, etc. The paper now before us relates to a simple case, the fattening of 800 sheep. Here are the details:

Cost of 800 sheep	$3724.00
600,000 lbs. of pulp	684.00
38,160 " cake	513.00
Cost of colza and seeds	256.50
Shepherd workmen	95.00
Interest, cost of commission	47.50
Total of expense	$5320.00
Wool and sheep	4750.00
275 tons of manure, representing	570.00
Total of receipts	$5320.00

This brings the price of manure to $2.03 the ton; let us put it at $2.09.

Observe here, gentlemen, that we have not to do with a general account, in which every detail of the culture is registered. No, I repeat, it is an especial account, the result being independent of all outside operations—a fattening of sheep with the pulp of the beet, which is cheaper than forage. Well, under these conditions the manure still costs $2.09 the ton.

And M. Cavallier observes that if he had used wheat straw, instead of colza and seeds from the ponds of the Somme, the manure would have cost $3.01.

The third account I will take for example relates to the farm of Bechelbronn, in Alsace. I borrow the elements from the *Rural Economy* of M. Boussingault. According to this account, manure costs only 97 cents the ton, which justifies the opinion that manure is the cheapest of fertilizers, and costs almost nothing.

But if we examine things more closely, we will find an objection, which changes all the economy of this account, and changes the price of manure from 97 cents to $2.82.

With the same data, how can we arrive at so different a conclusion?

The explanation is very simple, and I beg you will take note of it, for it furnishes me an opportunity of warning you against an error in matters of accounts into which agriculturists often fall.

By a kind of tacit agreement, founded on the belief that the production of manure is one of the necessities we cannot avoid, we count the consumption of the animal at the price of cost, not at the price of sale. But is it not evident that this manner of proceeding is defective?

When an agriculturist annexes a sugar-boiler or distillery to his farm, does he count the beets fed it at the price they cost? No, he values them at the price for which he could buy them. When he sells an animal, does he deliver it at the price it cost him? No, he takes the mercury of the market for his guide.

To obtain the real cost of manure, expenses should be accurately divided, to define with certainty the origin of its benefits, and to know how much is due to economy and perfection of tools. In a well-directed farm an account should be opened for the stables alone, the creditor of all which is a source of real value—milk, butter, animals sold, increase of weight in animals kept, work done by teams; but, on the contrary, debtor to the expenses of everything which aided in realizing the values put to its credit. In these expenses are comprehended the cost of keeping up teams, the wages of drivers, shepherds, etc., and lastly the market value of food consumed, deducting ten to fifteen per cent. for what would have been the cost of transportation had it been sold. An account established on these facts always shows a loss, but the loss is counterbalanced by the manure. The loss, divided by the number of tons of manure produced, leads to the real price of the ton.

Now if, according to these facts, we look at M. Boussingault's account, the price of manure is no longer 97 cents the ton, but $2.62.

As this is a question of grave import, you will permit me to show you this account as two separate items—one headed the arbitrary price, the other the real price.

Cost of Manure at the Farm of Bechelbronn.

Cr.

	Arbitrary Price.	Real Price.
Living weight gained by the stable at 8.07 per 200 lbs.—135 quintals.	$1092.92	
Milk not consumed by stock, at $2.28 the quintal—282 quintals..	652.96	$2473.48
Weight acquired by hogs, 21 quintals..................................	249.40	
Work of horses, 1200 days' work at 38 cts. per day..................	490.20	
	$2473.48	
Balance to debit of the account,	694.32	1768.36
	$3167.80	$4241.84

Dr.

	Arbitrary Price.	Real Price.	
1627 quintals of hay and aftergrowth, at 68.4 cents...............	$1112.86	at 94.05 cts.,	$1530.19
562 quintals of clover, at 59.85.....	336.35	at 94.05 "	528.56
692 bushels oats, at 26.53 cents......	183.73	at 49.98 "	346.01
244 quintals potatoes, at 40.66 cents	117.83	at 76.95 "	226.23
654 " beets, at 23.18 "	161.59	at 27.36 "	173.23
17⅗ bushels peas, at $1.16...........	20.44	at $1.16 "	20.44
385 quintals straw, at 23.75 cents...	91.45	at 68 "	263.63
	$2014.25		$3088.29
Keeping teams and other expenses	$1153.55		$1153.55
	$3167.80		$4241.84

Cost per ton of above, 710 *tons being produced:*

710 tons cost arbitrary price, $694.32=97.79 cents per ton.
710 " " real price, $1768.36=$2.49.6 " "

It is evident that the arbitrary price is founded upon food given at the price of cost, while the other results from food estimated at price of sale. Between the two accounts there is a difference of $1074.04, which explains why in one case manure is 97 cents and $2.82 in the other.

It is not necessary to add that in the two tables the loss, which varies from $694.32 to $1768.36, represents the value of the manure for the year. Now, the quantity produced being 710 tons, we find, consequently, 97 cents as the arbitrary price, and $2.82 the real price. I told you that the price of $4.94, which we got from M. Schattenmann, was an exception. His farm being new, he was obliged to buy a considerable quantity of straw at a time when it was very dear. This point considered, we may conclude from the preceding facts that the real cost of the manure was between $2.85 and $3.80 the ton. Let us fix it at $2.85.

We will now speak of the price of chemical fertilizers.

In 35,555 pounds of manure there are, as we have already said—

Azote	144 lbs.
Phosphoric acid	66 "
Potash	133 "
Lime	283 "

To obtain the equivalent of this manure under the form of chemical manures, we must have recourse to the following products:

Phosphate of lime	533 lbs.	$ 8.44
Nitrate of potash	284 "	16.57
Sulphate of ammonia	497 "	21.29
Sulphate of lime	377 "	1.43
		$47.73

So $47.73 are the equivalent of 35,555 pounds of manure.

A quantity of chemical fertilizers costing $1.18 can take the place of a ton of manure costing at least $1.25.

Thus, to the advantages already shown in their favor, the chemical fertilizers add that of cheapness. And it is well to remark that the quantity which we consider an equivalent to 35,555 pounds of manure contains, besides, 17 pounds of phosphoric acid.

What an array of proof! The returns from the chemical fertilizers are greater than from manure, and though equal in richness they cost less.

But could not the price ($1.25 the ton) which I have taken for manure be lessened? I do not know; and not being prejudiced, I will thankfully collect all corrections of my estimates which may be given me.

But these are not the limits of the advantages resulting from the use of chemical fertilizers.

We will, for a while, set aside all questions of accounts and expense, and see to what condition an agriculturist is reduced who can only manure his land with the manure it produces. I will take the property of Bechelbronn for an example.

This property is composed of 247 acres, of which 135—that is to say, a little more than the half—are in meadow. According to the traditions of the past, this property is in excellent condition, since the production of manure is made equal with the harvests for sale.

Now, how produce manure there, and how much of it does the land receive the acre?

The production of manure is 710 tons the year, which, spread upon 112 acres of arable land and 22.25 acres of upland meadow, give a mean of 77 pounds the acre per year. But an annual manuring of 77 pounds the acre per year of manure is precarious. You all know, gentlemen, to cultivate under such conditions is to cultivate without gaining anything.

You can judge of it by the returns obtained from Bechelbronn:

	Returns per acre.
Wheat	35 bu.
Oats	75 "
Beets	52,000 lbs.
Meadow	9,090 "

At Bechelbronn the culture is for small returns and little profits; that is true, fixing the rent at 3 per cent., by great trouble a net profit of $627 is obtained.

Thus, here is a domain worth $62,700, which requires a moving capital of $6650, and where, because only manure is used, infinitely precarious results are obtained, in spite of the high intelligence directing it. Is this an industrial situation to be cited as an example, and one which is able to contend against importations from abroad?

Change these conditions, and see what can be made at Bechelbronn by employing chemical fertilizers.

At an expense of $5.67 the acre, $1140 in all, see what will take place.

The returns will pass from 22 bushels to 43, 21 bushels profit—that is to say, against a cost of $5.67, an excess of $20, not counting the straw. Reduce the profit one-third, if you will, and fix it from $15 to $19 the acre, there will always result this important fact—that with an increase of capital of $627, we can increase the profits of the culture of $627 to $1300 or $1500. Will you remark here that I use the lowest estimates?

This ought not to surprise you, gentlemen, since the advantages of high culture are familiar to you.

Once more, at Bechelbronn, without changing anything in the agents or nature of the culture, but by the simple fact of advancing $5.67 of chemical fertilizers the acre, the profit may be tripled.

Here is a convincing demonstration, it seems to me, of the truth of the principle that in agriculture there is no profit without abundant manuring, and in view of the impossibility of producing sufficient manure for high culture, it is necessary to have recourse to chemical fertilizers.

Here is a situation upon the gravity of which we must not close our eyes, for foreign importation will soon have demonstrated the peril of it.

You may say that this proposition is contestable from the example

I have chosen, and there are agriculturists whose industry is more enlightened—those, for example, who have added sugar-boilers or distilleries to their farms, and to whom the importation of fertilizers is not necessary.

Even under these conditions the culture, reduced to its own resources, cannot give manure enough to raise its returns to a point which will make profit certain.

M. Cavallier, whose farm has a sugar-boiler added to it, is only able to produce 1000 tons of manure the year, which is hardly sufficient for 125 acres, at the rate of 44,444 pounds of manure every two years.

Well, under these conditions M. Cavallier obtained but from 31,111 to 35,555 pounds of beets the acre, when, with the complete fertilizer, he last year obtained 52,966 pounds. You will not be surprised if, in the face of these results, M. Cavallier has decided to regulate the economy of his crops on the permanent employment of chemical fertilizers.

The conclusion at which I wish to arrive is this: that in the great generality of cases the most costly of all manures is the manure of the farm.

In the past this proposition has attained the dignity of an axiom: that for successful culture we must have meadow, cattle and manure. Now, I affirm that this proposition is at once an economical and agricultural heresy.

The agriculturist who only uses manure wastes his land. For from whence comes the manure? From its depths. The manure does not, then, in reality, repair the losses in phosphate of lime, potash, lime and azotic matter that the land is submitted to by the exportation of a part of its harvests. When we export meat, the loss is less than when we export grain, though there is always a loss. I repeat, then, this axiom, which, until now, has been made the basis, and, as it were, the palladium, of agricultural art, is in reality but an expedient. It has no right to be so but in the exceptional case where the meadow is watered by a stream of limestone water, which gives the soil the equivalent of what it loses in agents of fertility; but I repeat, this case is so rare it cannot be made a law.

I have said that a culture founded solely on the use of manure is also an economy without judgment.

Suppose the case of mediocre land, yielding from 11 to 14 bushels of wheat the acre; calculate how much time it would take you to bring it with manure to produce 39 to 43 bushels: you would recoil before the sacrifices this would draw you into.

With the chemical fertilizers the change is immediate, the progression sudden, and the benefit immediate also. Now, if you remark that besides the profit, the resources in straw are increased from the first year, is it not evident that, instead of first having meat to have grain, there is a manifest advantage in reversing the preconceived order and commencing by having grain—to gain a profit first, then straw, and lastly manure? I repeat, then, that we only cease to waste our land when we really import manures, and the solution imposed upon us by the force of circumstances is to raise the fertility of the soil by means of artificially-composed fertilizers, with the products existing in the form of mines in nature, and which seem to have been reserved to repair the depredations of the present as of the past, and to preserve us from the disasters of the future.

It is not exact to say that manure, and manure alone, is sufficient for everything. What is true is, that there is but one means of obtaining large returns without delay: it is to have recourse to imported artificial fertilizers and chemical fertilizers in preference to all others, because they are the only ones whose nature can always be exactly defined and identified with itself—the only ones, consequently, in which there can be no fraud, and in my judgment the most economical. Find the real price of products loudly extolled for great virtues by certain merchants of fertilizers, and you will find them burdened with a profit that the most scandalous usury has never attained.

To-day, as the first elements of fertility are known to us, we can no more be imposed upon by absolute rules pertaining to agricultural economy entirely different from the present. To-day, we govern the wants of agriculture, instead of being governed by them. I can but repeat what I have said in another circle.

Agriculturists are no longer under the necessity of producing their own manures; they can become producers of manure if, all things considered, they find an advantage in it; but if they find it more profitable to have recourse to artificial fertilizers, there is nothing to prevent them—it is no longer a question of good culture, but of profit.

When we wish to introduce these new methods on a farm so as to arrive at a maximum product, we must work still another change, of which I have not spoken until now, and with which I must now entertain you, since it will result in giving back to cultivation an important part of the land which has been heretofore given up to forage, without, however, entrenching upon our resources in this respect.

The change in question consists in substituting, as much as possible, lucerne for meadow.

I can call up two testimonies to this, of equal importance—that of M. Boussingault, who recognizes lucerne as more profitable than the meadow, and M. Schattenmann, who has made the substitution I speak of with the greatest advantage.

Who cannot see that if at Bechelbronn the food of the stock were secured, the amount of straw increased, and 33 to 45 acres of meadow more than the 125 now in use were added, there would certainly result a considerable increase of revenue, particularly if that part cultivated was enriched by large quantities of chemical fertilizers? This result is the more important as it can be realized immediately and with a relatively small capital.

You see, gentlemen, there is no way of escaping the conclusion which I must again repeat: the great profit in agriculture is from abundant manuring; what is not well manured is of little value; it is only when we pass from small returns to large returns that benefit is derived. All our efforts should, then, tend to manuring abundantly. I have laid down the principle in this lecture that the chemical fertilizers, whose exclusive use I first studied, can be advantageously associated with barnyard manure, and I have showed you the manner of making this new application. To complete these first indications, it remains for me to take up the questions in detail, and show you the most convenient formulæ for this especial case.

This finishing of our first studies is the more necessary, since the production of manure is, in a certain measure, a necessity we cannot avoid, as it has to do with the working of the land.

This new subject will make the object of our next lecture.

LECTURE SIXTH.

GENTLEMEN: In all clearings of a certain extent the work of animals is indispensable; culture by the hand of man is not possible when we operate on a scale of importance with regard to certain products of large relations, such as the vine, the hop, tobacco, etc. I repeat, then, when we enter the domain of agricultural tillage, properly speaking, the intervention of animals being a necessity born of the force of circumstances, manure is produced, and we are absolutely compelled to take notice of it and learn to regulate the employment of it.

I take up the question, then, from the point where I left it in our last meeting, and to complete the general ideas I gave you on the use of manure and chemical fertilizers mixed, there remains for me but to point out to you the practical rules to be followed in such cases.

Our first example is from a succession of five years, the same practiced at Bechelbronn, comprehending, as you know, the following rotation:

1st year, Irish potatoes.
2d year, wheat.
3d year, clover.
4th year, wheat.
5th year, oats.

At the opening of the fallow the earth received from 35,555 to 44,444 pounds of manure. Now, in 44,444 pounds of manure the four terms of the complete fertilizer are represented by—

Azote	183 lbs.
Potash	156 "
Phosphoric acid	97 "
Lime	355 "

You will remark that at least one-third of the azote of the manure is lost to the soil, on account of the previous decomposition the manure must undergo before it can show its effects. With so small a quantity of manure the returns are doubtful. To change this state of things, and put the land under culture, we must at least double the quantity of agents of fertility by means of the chemical fertilizers, and concentrate upon each plant those terms of the complete fertilizer which fill for it the office of dominants. For the rotation now occupying us I propose to divide the additional fertilizer thus :

Rotation of Five Years, comprehending Irish Potatoes, Wheat, Clover, Wheat, Oats.

First Year—Irish Potatoes.

Manure, 44,444 lbs.
Incomplete fertilizer No. 2, 444 lbs.

Composition:	The acre. Quantity.	Price.
Acid phosphate of lime	177 lbs.	$2.70
Nitrate of potash	88 "	5.23
Sulphate of lime	177 "	.33
Cost		$8.26

Second Year—Wheat.

Sulphate of ammonia	177 lbs.	$7.60

Third Year—Clover.

Incomplete fertilizer No. 2, 887 lbs.

Composition:		
Acid phosphate of lime	355 lbs.	$ 5.40
Nitrate of potash	88 "	10.47
Sulphate of lime	355 "	.67
Cost		$16.54

Fourth Year—Wheat.

Sulphate of ammonia	177 lbs.	$7.60

Fifth Year—Oats.

Sulphate of ammonia	266 lbs.	$11.40
Cost for five years		$51.40

The cost for five years being $51.40, the annual cost is $10.28. With manure alone the Irish potato yields 10,666 pounds of tubers the acre; wheat, 25 bushels; oats, 43 bushels; and clover, 4400 pounds of forage. With the addition of the chemical fertilizer, as just shown, the yield of Irish potatoes is raised to 17,777 pounds at least, that of the wheat to 43 bushels, that of the oats to 65 or 72 bushels, and the clover does not yield less than 7111 pounds of dry forage.

If the Irish potato is to be replaced by the beet, the following fertilizer must be substituted for the fertilizer of the first year:

Complete fertilizer No. 2, 551 lbs.

Composition:	The acre. Quantity.	Price.
Acid phosphate of lime	177 lbs.	$2.70
Nitrate of potash	88 "	5.23
Nitrate of soda	133 "	4.43
Sulphate of lime	133 "	.14
Cost		$12.50

The other fertilizers remaining the same, under this change the expense for five years will be brought from $51.40 to $65.64, which makes the annual expense, in round numbers, $15.10, instead of $10.28.

While with manure alone the yield of beets is with difficulty raised to 23,111 pounds the acre, with the addition of the fertilizer it is raised to 35,000 or 40,000 pounds at least.

In the regions favorable to the culture of colza and the beet, as the department of the Somme, for example, great advantage has been derived by preceding the beet by colza, upon which all available manures are concentrated; under these new conditions the earth is better prepared for the culture of the cereals which follow, and the manure, being in a more advanced stage of decomposition, contributes more effectively to the success of the beets.

If the preceding rotation is changed in this way, the following is the manner of dividing the added fertilizers:

Rotation of Five Years, comprehending Colza, Beets, Wheat, Clover, Wheat.

First Year—Colza.

	The acre. Quantity.	Price.
Manure	44,444 lbs.	
Sulphate of ammonia	266 "	$11.40

Second Year—Beets.

Ashes from the burning of the straw and husks of the colza.

Complete fertilizer, condensed, No. 2, 711 lbs.

Composition:

Acid phosphate of lime	266 lbs.	$ 4.03
Nitrate of potash	177 "	10.47
Nitrate of soda	133 "	4.43
Sulphate of lime	133 "	.14
Cost		$19.07

Third Year—Wheat.

Sulphate of ammonia	177 lbs.	$7.60

Fourth Year—Clover.

Incomplete fertilizer No. 2, 887 lbs.

Composition:

Acid phosphate of lime	355 lbs.	$ 5.40
Nitrate of potash	177 "	10.47
Sulphate of lime	355 "	.67
Cost		$16.54

Fifth Year—Wheat.

Sulphate of ammonia	177 lbs.	$7.60
Cost for five years		$62.21

The cost being this time $62.21 for the five years, the anual expense will be raised to $12.44. The second wheat succeeding the clover may always be replaced by oats. In this case suppress the sulphate of ammonia prescribed for the fifth year, and the total expense will be $54.61, or an annual expense of $10.92.

As a last example, I will report a succession of six years, in which the chemical fertilizers are first used alone, and but partly associated with manure the second year.

The rotation is:

First year, flax.
2d year, beets.
3d year, wheat.
4th year, colza.
5th year, wheat.
6th year, oats, or barley, or rye.

I said the first year only chemical fertilizers ought to be used, because their superiority for flax is now beyond question. Flax may be placed between the wheat (which, as you know, requires manure rich in azote) and the legumes, which use only the mineral part of the fertilizer. It therefore succeeds best with chemical fertilizers, because we can then reduce the proportion of azote without interfering with the minerals. I have cited to you the result obtained with M. Charee, whose harvest was sold in the field at $66.57 the acre.

I return to the formulæ of fertilizers.

Succession of Six Years, comprehending Flax, Beets, Wheat, Colza, Wheat, Oats, Rye or Barley.

First Year—Flax.

Incomplete fertilizer No. 2, 887 pounds.

Composition:	The acre. Quantity.	Price.
Acid phosphate of lime	355 lbs.	$5.40
Nitrate of potash	177 "	10.47
Sulphate of lime	355 "	.67
Cost		$16.54

Second Year—Beets.

Manure spread in autumn, 44,444 pounds.

In the spring:

Complete fertilizer No. 2 again, 577 pounds.

Composition:		
Acid phosphate of lime	177 lbs.	$2.70
Nitrate of potash	88 "	5.23
Nitrate of soda	177 "	5.91
Sulphate of lime	133 "	.25
Cost		$14.09

Third Year—Wheat.

Sulphate of ammonia	266 lbs.	$11.40

Fourth Year—Colza.

Complete fertilizer No. 6, 1044 pounds.

Composition:	The acre. Quantity.	Price.
Acid phosphate of lime	355 lbs.	$5.40
Nitrate of potash	106 "	6.38
Sulphate of ammonia	355 "	15.20
Sulphate of lime	248 "	.64
Cost		$27.62

Fifth Year—Wheat.

Ashes of the straw and husk of the colza, turned under by the plough.		
Sulphate of ammonia	266 lbs.	$11.40

Sixth Year—Oats, Barley or Rye.

Sulphate of ammonia	355 lbs.	7.60
Total expense		$88.75
Annual expense		$14.97

Here the expense is greater, but we must consider the nature and value of the products. Putting things at the lowest, I believe that the harvest in the rough ought not to be estimated over $84 to $92 the acre.

I could multiply these examples by quoting other rotations, but as they come under the same rules, and are deduced from the same principles, it appears to me preferable to recall these rules and principles to you, to enable you to substitute your rotations for mine, and yourself proportion the formulæ and quantities of your fertilizer.

I have already said several times in reviewing, and I must again repeat it, manure owes its good effects to the azote, phosphate of lime, potash and lime which it contains.

For if we operate, side by side, with manure and a mixture of these four bodies in equal richness, we will almost always find the yield from the chemical fertilizer surpass that from the manure.

I have also told you, and must again repeat, that each term of the complete fertilizer fills a dominant or a subordinate office in regard to the others, according to the nature of the plant cultivated. Thus azote, which is the dominant of wheat, descends to a subordinate position in regard to legumes, etc. But here is an essential point, upon which I must insist—the dominants show their action only under the express condition that the soil is in a certain measure provided with the three other terms of the complete fertilizer.

Azotic matter is the dominant of wheat and colza. Azotic matter alone in a soil of pure sand produces hardly any effect, but add the minerals to the soil, and the azotic matter impresses vegetation with an activity approaching the wonderful, and within a certain limit the return corresponds to the proportion of azote employed.

This being so, you will understand the rôle of manure in the system of mixed manures. By its nature and mass it necessarily acts with slowness, while its action is limited by the previous decomposition of its hydro-carbonated parts, which form ,95 of the whole. Large returns are impossible from manure alone, because the sum of its disposable assimilable agents is not great enough. And now, if I remind you that azotic matter is the dominant of wheat, colza and the beet; potash of the legumes; phosphate of lime of the turnip; that the mineral without the azote gives the largest return of lucerne; that the minerals with the addition of a little azote are best for flax and Irish potatoes,—you will not only perceive the rules which guided me in the preceding demonstrations, but you will be able by their aid to form rotations most appropriate to the circumstances in which you are placed.

This is not all. That the solution of the problem of agriculture may be complete, we must not only know the agents which are the source of fertility, but must be also certain that their use is not a cause of decay of soil, and that they do not take more from it than they return to it.

So, to give the examination of this subject a character of severity, precision, and at the same time a generality which makes my conclusions without appeal and applicable in all possible cases, I embody them in these terms: *Can we indefinitely cultivate the same land with chemical fertilizers, and with the same success?* My reply is absolute: *Yes, that is possible, but always under two conditions:*

1st. Give the land, through fertilizers, more phosphate of lime, more potash and more lime than the harvests have taken from it.

2d. Give it about 50 per cent. of azote to the harvest.

I say *about*, because there are some plants requiring less, and others can do without it entirely.

Here the first question presents itself: Why more minerals and less or no azote? Why? But you have already answered. Because a part of the azote of plants comes from the air, and there are even some which draw it entirely from that source. The quantity of azote given the soil varies from 6 to 50 per cent., according to the plant. If we have to do with the legumes, it is 6; if we pass to wheat, it is 50 per cent.

We must return an excess of phosphate of lime, potash and lime over what the land loses, because plants draw them exclusively from the soil, and we must not only compensate the soil for the loss determined by each harvest, but repair that resulting from the action of the rain.

Let us examine if the formula of fertilizers I have prescribed will fill the two conditions I have just pointed out.

I told you in my last lecture that wheat may be cultivated upon the same land indefinitely, provided it is furnished in four years with the following quantities of fertilizers, thus divided:

A Succession of Four Years in Wheat.

First Year—Wheat.

Complete fertilizer No. 1, 1066 lbs.

Composition:	The acre. Quantity.	Price.
Acid phosphate of lime	355 lbs.	$5.40
Nitrate of potash	177 "	10.47
Sulphate of ammonia	222 "	9.50
Sulphate of lime	311 "	.64
Cost		$26.01

Second Year—Wheat.

	The acre. Quantity.	Price.
Sulphate of ammonia	266 lbs.	$11.40

Third Year—Wheat.

Complete fertilizer No. 1, 1066 lbs.

Composition:

Acid phosphate of lime	355 lbs.	$5.40
Nitrate of potash	177 "	10.47
Sulphate of ammonia	222 "	9.50
Sulphate of lime	311 "	.64
Cost		$26.01

Fourth Year—Wheat.

Sulphate of ammonia	266 lbs.	$11.40
Total expense		$65.82

That is to say:

Azote, 241 lbs., equivalent in harvest to	482 lbs.
Phosphoric acid	106 "
Potash	165 "
Lime	256 "

By means of these quantities, renewed every four years, we may easily obtain four harvests of from 44 to 50 bushels, and 4444 lbs. of straw the acre. Now, if we draw a balance between what the fertilizers furnished the earth and what these four harvests took from it, we will find an excess in favor of the soil:

	Fertilizer.	Harvest.	Loss to soil.	Gain to soil.
Azote, 241 lbs., equivalent to	482 lbs.	241	...	241
Phosphoric acid	106 "	87	...	19
Potash	165 "	99	...	66
Lime	256 "	42	...	214

You will see, gentlemen, the balance is closed by a general excess in favor of the fertilizers. In the face of these numbers we may with certainty conclude that we have nothing to fear in the future from the use of these chemical fertilizers.

My experiments in burnt sand—confirmed by the culture of the field at Vincennes—which have continued now more than eight years, seem to me to put this conclusion beyond all contest. In the preceding examples I have intentionally admitted that the whole of the harvest, straw and grain was lost to the domain. I have besides admitted that the land was cultivated by the hand of man. By this double supposition the demonstration is carried to the extreme. It is true that this situation is to be regretted; it is found in France among the small farmers, who are almost entirely without manure, and who, by the extent of the interests they represent, very painfully affect the public fortunes.

I now take up an alternate culture of colza and wheat, and I still suppose the straw and grain are sold. The fertilizer comprehends four years.

Azote, 276 lbs., equivalent in harvest to	552 lbs.
Phosphoric acid	106 "
Potash	99 "
Lime	276 "

The four harvests of colza and wheat contain—

Azote	524 lbs.
Phosphoric acid	108 "
Potash	239 "
Lime	249 "

This time, if we make the balance, a grave fact strikes us. The earth is decidedly the loser in two points, potash and phosphoric acid:

	Fertilizer.	Harvest.	Loss.	Gain.
Azote	552 lbs.	524	...	28 lbs.
Phosphoric acid	106 "	108	2 lbs.	...
Potash	99 "	239	140 "	...
Lime	276 "	249	...	25 "

There is here no illusion; the earth is decidedly in deficit. The fertilizers proposed are insufficient, and their continued use would end in injury to the fertility of the soil. Nevertheless, in reality, these fertilizers are sufficient, and the land is not wasted. These apparently contradictory facts are easy to reconcile. To simplify the discussion, I admit that the preceding culture is done by hand, and that straw and grain are sold. Gentlemen, you are not ignorant of the fact that though the wheat straw may find a ready sale, it is not the same with the straw and husks of the colza, which have no commercial value, and which it is sometimes almost impossible to dispose of. Under these circumstances it is natural to seek a use for them. Suppose we burn them and spread their ashes over the soil. The earth will thus recuperate more in potash and phosphoric acid than is necessary to compensate for the deficit.

This restitution, consequently, immediately shifts the balance. The earth was the loser, and now, on the contrary, receives an excess.

To show you how the remains of the harvest that are without commercial value can acquire an importance as a source of fertility, permit me to show you the composition of two harvests of colza, and to make over our balance, while the straw and husks have been burned on the soil and only the grain exported:

Composition of Two Harvests of Colza.

	Harvests.	Azote.	Phos. acid.	Potash.	Lime.
Straw,	20,656 lbs.	21,480 lbs.	30,980 lbs.	6,628 lbs.	19,924 lbs.
Husks,	9,216 "	10,376 "	1,916 "	29,408 "	28,904 "
Grain,	9,356 "	39,192 "	12,028 "	6,648 "	3,040 "

Balance rectified by burning the straw and husks of colza.

	Fertilizers.	Taken off by harvests.	Gain to soil.
Azote	1244 lbs.	1180 lbs.	64 lbs.
Phosphoric acid	240 "	218 "	22 "
Potash	224 "	178 "	46 "
Lime	624 "	76 "	548 "

This new example shows us, gentlemen, the necessity, in making up the cost of a rotation, to consider as lost to the soil only those products really taken away; the residue, which becomes manure and returns to the earth, ought not to be comprised in this category.

A third case can be shown, always without the use of animals, in which the small producer far from a railroad or a town can sell neither the wheat, colza nor straw. What shall he do with them?

He has a choice of two methods: he can either burn them, or convert them into true manure by rotting them.

If the straw is laid in horizontal beds, and watered with water in which several hundred pounds of little cakes of colza have been dissolved and allowed to stand, this liquid, acting as urine in the preparation of manure, very rapidly determines the decomposition of the whole mass: at the end of fifteen or twenty days the dissolution of the woody parts is complete—the straws have lost their texture and passed into a semi-viscous form, approaching that of manure.

Which of these two processes is the better? By putrefaction we avoid an important loss of azote, but then we have the cost of handling in carrying the straw, preparing the manure and spreading it; by burning we avoid this expense, but we lose the azote, on which we are dependent for an amount of sulphate of ammonia or nitrate of soda.

I repeat, the choice of these two is indifferent to me: they are equivalent in practice; the expense alone need determine us.

If we pass to a more general case, where the work of the field is done by horses, and where the production of manure becomes a necessity, we cannot avoid: the problem remains the same, and the rules which have already guided us are still applicable.

In a word, what is the nature of manure? Its origin has told you. It is vegetable products modified by animal digestion; manure, as the residue of the harvest, draws its value from the azote, phosphate of lime, potash and lime which it contains.

I will now give you the balance of the rotations in which manure is associated with the chemical fertilizers, because the importance of the real loss undergone by the soil depends then upon the exporting of the vegetable products and the raising of stock; but to give you the means of making this estimate for yourself—always necessary in every well-directed labor—I have united in one table the mean composition of manure and that of all the harvests comprised in the rotations shown, so that all the work is reduced to several multiplications. (See Appendix.)

Let us now look at the question of chemical fertilizers under their financial relations, and take as a first example the case of a culture by means of chemical fertilizers alone. Nothing is so variable as an agricultural account; everything affects it—the neighborhood, the plentifulness or scarcity of hands, and the agricultural régime itself. It is impossible to show such an account without exposing one's self to all sorts of objections, which each one draws from his particular situation. To escape this inconvenience, I will limit myself in the following valuations to the price of fertilizer and value of harvest, leaving each one to draw from this parallel the conclusions applicable to his own situation.

The return being 44 bushels of grain and 4444 pounds of straw, if we fix the price of grain at $1.23 the bushel, and that of straw at $6.65 the ton, the harvest represents the value of $151.05.

Thus	$151.05
Against an annual cost of manure of	41.93
Excess of produce	$109.06

You will tell me perhaps that in this valuation I have not counted the cost of transporting the fertilizers. The observation is just. Let us, then, add to this the sum of $5.70; the excess in favor of the harvest will be $103.36, to cover the rent of the soil, taxes, cost of culture and interest on capital engaged.

I am going to examine a second hypothesis, which applies particularly to medium and large cultures—a working directed by the old traditions, but whose returns are small, and which we wish to transfer to the order of high cultures and large returns with little means. To give more precision to what follows, I will again take the farm of Bechelbronn for an example.

There manure alone is used, and of the 247 acres which compose the domain, 135 are devoted to meadow, and only 112 to cultivation, properly speaking. The rough sum of the yearly products is $3919.70, obtained by the aid of a rolling capital of $6650.

Culture with Manure Alone.

		RETURNS.		PRODUCTS.	
	Acres in culture.	The acre.	Total.	The acre.	Total.
Irish potatoes	15¾	10,871 lbs.	171,218 lbs.	$46.44	$731.43
Beets	6¾	23,419 "	158,078 "	80.18	541.21
Wheat (grain)	45	2,672 bu.	1,202 bu.	30.46	1,370.90
Wheat (straw)	45	2,883 lbs.	129,735 lbs.	6.84	307.80
Clover	22½	5,160 "	116,100 "	26.93	605.92
Oats (grain)	22½	45 bu.	1,012 bu.	25.56	575.10
Oats (straw)	22½	1,665 lbs.	37,462 lbs.	3.12	70.20
Total production					$4,202.42

Now, by means of an increase of manure, at $10.13 the acre, the rough sum of the products will be carried from $4202.42 to $5951.96, leaving a profit of $1749.46, instead of $627.

Culture with Manure and Fertilizers Mixed.

		RETURNS.		PRODUCTS.	
	Acres.	The acre.	Total.	The acre.	Total.
Irish potatoes	15¾	17,777 lbs.	124,444 lbs.	$76.00	$1,197.00
Beets	6¾	35,555 "	239,999 "	54.04	364.77
Wheat (grain)	45	43 bu.	1,935 bu.	49.40	2,223.00
Wheat (straw)	45	4,000 lbs.	180,000 lbs.	9.45	425.25
Clover	22½	4,444 "	99,980 "	37.15	835.87
Oats (grain)	22½	65 bu.	1,462½ bu.	36.05	811.12
Oats (straw)	22½	2,222 lbs.	49,995 lbs.	4.22	94.95
Total production					$5,951.96

Rough products by the mixture of manure and chemical fertilizers	$5,951.96
Rough products with manure alone	4,202.42
Difference in favor of first system	$1,749.54

—$1749.54 excess of product against an excess of expense of $1140, the profit is 100 per cent. The rolling fund was originally $6650, increased to $7790, and the profit was threefold. I need not add that the price of sales was the same in both cases. I admit without change those that M. Boussingault took as the basis of his valuations.

Is this result a maximum? Far from it. I have fixed the returns at 20 per cent. below their real value.

Here are the results obtained by M. Lavaux for three years from the farm of Choisy-le-Temple (Seine-et-Marne):

1865, wheat	53 bu.
1866, colza	48 "
1867, March wheat	49 "
1867, beets	53,333 lbs.

The increase of profit realized on fifty acres, which form the culture of Bechelbronn, is not the only advantage to be drawn from the chemical fertilizer.

On the 447½ acres composing the domain, to produce manure 135 acres must be devoted to the meadow, the returns from which hardly exceed 3600 pounds of hay the acre.

By means of an appropriate formula this return can easily be brought to 7111 pounds, which will put, without any diminution of products, 33 to 40 acres at our disposal for other culture.

You know that this result will be more surely attained by replacing the meadow with fields of lucerne.

The use of chemical fertilizers in the case now occupying us produces two equally advantageous results—viz., to increase the return of all the cultures; to reduce the surface devoted to the raising of cattle without diminishing the number of animals; or to increase the number, if we like best, to at least 30 per cent.

When the agriculturist has no fixed idea as to the true agents of fertility with which he should precede the production of manure and cereals, and draws all the fertilizers from his own land, he cannot give the meadow less than the half of the whole surface without wasting the soil and condemning himself to an almost inevitable ruin.

In the economy of this régime the principal use of the meadow is to throw off into the air the azote that the cereals ought to find in the soil; and the animals being the only method of preparing manure, the hay of the meadow and the straw of the cereals are compounded as if of one nature.

With the chemical fertilizers the agricultural problem is simplified, and becomes susceptible of a more independent solution. There can no more be a question of absolute rule. The maxim, Make meadows and raise cattle to have cereals, loses the character of an axiom which has been given it. I will add that now this axiom is agricultural nonsense and an economical heresy, because with the use of manure alone the returns are always poor, and the wheat costs at least $1.05 the bushel, which is not profitable. I say, then, that this axiom has lost its character of a necessity imposed by the culture itself.

And I repeat, what you already know, that from the moment the true agents of fertility are known to us, we make manure only as we find it profitable; for the rest, we will employ chemical fertilizers. It is no longer a question of culture, but simply a question of profit and loss.

The necessity imposed upon the agriculturist is not to make manure, but to manure more abundantly than in the past by whatsoever agents he may have recourse to, manure or chemical fertilizers, employed separately or simultaneously; but in all cases two rules are to be observed: you know them. However, as they sum up the last word of agricultural science, I feel obliged to repeat them to you:

1. Give the earth more phosphate, more potash and lime, than the harvests have taken from it.

2. Give it fifty per cent. of the azote which they contain.

You know now in what the new processes differ from the old.

In the past, you were under the empire of a law which ruled you; you were forced to give the meadow and animals a part destined to maintain the equilibrium.

In the past, the sole origin of azotic matter was the meadow—potash, the phosphates and lime provided by the meadow or manures made irregularly.

In the past, where the meadow was the sole source of manure, the returns were necessarily small, because in this case the sources of fertility were always insufficient. Thus, wheat did not exceed 26 to 30 bushels the acre; Irish potatoes, 8888 to 10,000 pounds; and beets, 26,666 pounds. Now, under these conditions agriculture is become impossible.

Nothing rules us to-day but the necessity of keeping animals for draught and transportation; beyond this necessity we possess a liberty of action without limit: we would make forage and manure only when, all things considered, we found advantage in it.

And if we should raise them, we can, on a relatively restricted surface, produce more food than formerly, because we can increase the returns from the meadow as from other cultures.

We are compelled, it is true, to the necessity of giving the soil more than we take from it, but the observance of this law does not impose upon us the obligation of producing manure beyond what conforms to our interests. We can satisfy it by the aid of foreign manures, whose nature and qualities are clearly defined, and can be regulated with entire certainty.

To whoever reflects, to whoever seeks to comprehend the problems which agitate our century, it is not difficult to perceive the connection which exists between the great interests of our country and the question we are now seeking to solve. At a time when the ways of communication had not the development they have acquired, the interior roads offered certain and easy openings to our agricultural products; but since we have obtained liberty of commerce and facility of means of transport, agriculturists are called upon to contend in our own markets with the entire world. That the contest may be possible and fruitful, it is absolutely necessary that the returns from all cultures be raised to their limit. By the old methods this is impossible, and besides, would exact so formidable a capital that it is not to be thought of.

With the chemical fertilizers the question is different. It is reduced to this simple proposition: To add to $10.13 worth of fertilizers the acre all the manure at disposal, or to pay out $15 to $20 if one has no manure; and the result will be changed by an immediate excess of harvest, representing twice the value of the excess of cost it occasioned. There is neither a doubt nor objection to be raised against this proposition. It is a fact.

May the new methods that the farm of Vincennes is destined to make known receive a more and more general application. I invite the severest criticisms upon them; and if the progress which I expect from this criticism throws my efforts in the shade, I will console myself without too much sadness, persuaded that from the application of these new methods my country must draw an incalculable increase of wealth and prosperity.

APPENDIX.

PRACTICE AND DOCTRINE.

FORMULÆ OF FERTILIZERS.

TO facilitate research and comparison, I unite in this Appendix the formulæ of rotation and fertilizers under consideration in the course of these lectures.

I cannot but repeat, since my experiments have passed from the domain of science to that of practice, that I have found great advantage to be gained by the use of chemical fertilizers in fractional quantities. The division of the fertilizers has, over manuring all at once, the double advantage of causing less expense the first year, and producing larger returns.

The following formulæ have been fixed according to this new method of application.

I have considered here, as in the lectures, two distinct cases—the one where the chemical fertilizers are used alone, to the exclusion of manure, and the other where they are associated with it under the title of supplementary fertilizers, whether we have to do with isolated culture or culture by rotation.

FIRST CASE.

Here the chemical fertilizers are employed alone, to the exclusion of manure.

Isolated Cultures.

Wheat.

Complete fertilizer No. 1, 1066 lbs.

Composition :	The acre. Quantity.		Price.
Acid phosphate of lime..................	355 lbs.		$5.40
Nitrate of potash.........................	177 "		10.47
Sulphate of ammonia......................	222 "		9.50
Sulphate of lime..........................	312 "		.59
Whole.............................	1066 lbs.	Cost...	$25.96

Barley, Oats, Rye—Natural Meadows.

Complete fertilizer No. 1, 533 lbs.

Composition:	Quantity.	The acre.	Price.
Acid phosphate of lime	177 lbs.		$2.70
Nitrate of potash	88 "		5.23
Sulphate of ammonia	112 "		4.75
Sulphate of lime	155 "		.29
Whole	533 lbs.	Cost...	$12.97

The fertilizers may be used on the meadow in two ways—spread it on the soil at once in the autumn; or in two separate times—266 lbs. in the autumn, and 266 lbs. in the spring, after the first method.

Hemp, Colza.

Complete fertilizer No. 1, 1066 lbs.

If the colza is to be followed by wheat:

Complete fertilizer No. 6, 1154 lbs.

Composition:			
Acid phosphate of lime	355 lbs.		$5.40
Nitrate of potash	177 "		7.39
Sulphate of ammonia	355 "		15.20
Sulphate of lime	297 "		.64
Total	1154 lbs.	Cost...	$28.63

Beets, Carrots, Cabbage, Hops, Garden Stuff.

Complete fertilizer No. 2, 1066 lbs.

Composition:			
Acid phosphate of lime	355 lbs.		$5.40
Nitrate of potash	177 "		10.47
Nitrate of soda	266 "		8.86
Sulphate of lime	268 "		.50
Total	1066 lbs.	Cost...	$25.23

For beets, when we can push the returns to their highest limit, we must substitute complete fertilizer No. 2, double, or, better still, intense complete fertilizer No. 2, for complete fertilizer No. 2.

Complete fertilizer No. 2, double, 1155 lbs.

Composition:			
Acid phosphate of lime	355 lbs.		$5.40
Nitrate of potash	189 "		10.47
Nitrate of soda	355 "		11.82
Sulphate of lime	266 "		.50
Total	1155 lbs.	Cost...	$28.19

Complete fertilizer No. 2, 1422 lbs.

Composition:			
Acid phosphate of lime	533 lbs.		$8.21
Nitrate of potash	355 "		20.94
Nitrate of soda	266 "		8.86
Sulphate of lime	268 "		.50
Total	1422 lbs.	Cost...	$38.51

Irish Potatoes.

Complete fertilizer No. 3, 887 lbs.

Composition:	Quantity.	The acre.	Price.
Acid phosphate of lime..................	355 lbs.		$5.40
Nitrate of potash..........................	266 "		15.70
Sulphate of lime...........................	266 "		.50
Total	887 lbs.	Cost...	$21.60

On wasted lands the complete fertilizer No. 2, to the quantity of 1066 pounds, is preferable.

Vines and Small Shrubs.

Complete fertilizer No. 4, 1333 lbs.

Composition:			
Acid phosphate of lime..................	534 lbs.		$8.21
Nitrate of potash..........................	444 "		26.17
Sulphate of lime...........................	355 "		.67
Total..................................	1333 lbs.	Cost...	$35.05

The complete fertilizer No. 2 has also a very good effect upon the vine. I even advise you to begin with it on vineyards whose product is of an ordinary quality.

Turnips, Rutabagas, Artichokes, Sorghum, Sugar-cane, Maize.

Complete fertilizer No. 5, 1066 lbs.

Composition:			
Acid phosphate of lime..................	534 lbs.		$8.21
Nitrate of potash..........................	177 "		10.47
Sulphate of lime...........................	355 "		.67
Total..................................	1066 lbs.	Cost...	$19.35

Beans of all kinds, Clover, Sanfoin, Vetches, Lucerne.

Incomplete fertilizer No. 2, 887 lbs.

Composition:			
Acid phosphate of lime..................	355 lbs.		$5.40
Nitrate of potash..........................	177 "		10.47
Sulphate of lime...........................	355 "		.67
Total..................................	887 lbs.	Cost...	$16.54

Theoretically, this fertilizer ought not to contain azote; potash ought to be exhibited in the form of a carbonate. The nitrate of potash is substituted on account of the price. The quantity of azote introduced in the fertilizer rises to only 24 pounds the acre, and is too small a quantity to be injurious.

I now pass to cultures by rotations.

SUCCESSIONS.

A Culture Exclusively of Wheat.

First Year—Wheat.

Complete fertilizer No. 1, 1066 pounds.

Composition:	Quantity.	The acre.	Price.
Acid phosphate of lime	355 lbs.		$5.40
Nitrate of potash	177 "		10.47
Sulphate of ammonia	222 "		9.50
Sulphate of lime	312 "		.59
Total	1066 lbs.	Cost...	$25.96

Second Year—Wheat.

Sulphate of ammonia	266 lbs.	$11.40

Third Year—Wheat.

Acid phosphate of lime	355 lbs.		$5.40
Nitrate of potash	177 "		5.23
Sulphate of ammonia	222 "		9.50
Sulphate of lime	312 "		.59
Whole	1066 lbs.	Cost...	$20.72

Fourth Year—Wheat.

Sulphate of ammonia	266 lbs.	$11.40
Expense for four years		$69.48
Expense the year		$18.68

The exclusive culture results in favoring the multiplication of bad weeds to such a degree that, to maintain the harvests at a mean level, we must have recourse every year to several workings, which occasions a great deal of expense. To escape this inconvenience, substitute Irish potatoes or clover the third year for wheat. If this is done, employ the following fertilizer:

Acid phosphate of lime	355 lbs.		$5.40
Nitrate of potash	266 "		15.70
Sulphate of lime	266		.50
Whole	887 lbs.	Cost...	$21.60

This change reduces the expenses of the third year to $4.34, and changes the annual expense from $18.68 to $16.48.

If we give the preference to clover, we must reduce the quantity of nitrate of potash by 88, which brings the expenses of the third year down to $11.48.

Alternate Culture of Colza and Wheat.

First Year—Colza.

Complete fertilizer No. 6, 1155 lbs.

Composition:			
Acid phosphate of lime	355 lbs.		$5.40
Nitrate of potash	166 "		7.39
Sulphate of ammonia	355 "		15.20
Sulphate of lime	337 "		.64
Whole	1153 lbs.	Cost...	$28.63

Second Year.—Wheat.

	The acre. Quantity.		Price.
Sulphate of ammonia....................			
Ashes of the straw and husks of the colza,	266 lbs.		$11.40
Total expense..			$40.03
Expense the year.....................................			$19.46

Burn the straw and husks of the colza on the field, and sow the ashes over the surface of the soil after the first working; then spread the sulphate of ammonia when the earth has been worked a second time. Instead of burning the straw and husks of the colza, you may rot them according to the directions given in the Sixth Lecture. The use of the straw and husks of the colza is then confounded with that of the manure.

Rotations of Four Years, comprising Irish Potatoes, Wheat, Clover, Wheat.

First Year—Irish Potatoes.

Complete fertilizer No. 3, 887 lbs.

Composition:

Acid phosphate of lime..................	355 lbs.		$5.40
Nitrate of potash..........................	266 "		15.70
Sulphate of lime............................	266 "		.50
Total..	887 lbs.	Cost...	$21.60

Second Year—Wheat.

Sulphate of ammonia....................	266 lbs.		$11.40

Third Year—Clover.

Incomplete fertilizer No. 2, 887 lbs.

Composition:

Acid phosphate of lime..................	355 lbs.		$5.40
Nitrate of potash..........................	177 "		10.47
Sulphate of lime............................	355 "		.67
Total..	887 lbs.	Cost...	$16.54

Fourth Year—Wheat.

Sulphate of ammonia....................	266 lbs.		$11.40
Total expense..			$62.04
Annual expense.......................................			$15.20

Rotations of Four Years, including Beets, Wheat, Clover, Wheat.

First Year—Beets.

Complete fertilizer No. 2, double, 1155 lbs.

Composition:

Acid phosphate of lime..................	355 lbs.		$5.40
Nitrate of potash..........................	177 "		10.47
Nitrate of soda.............................	355 "		11.82
Sulphate of lime............................	268 "		.50
Total..	1155 lbs.	Cost...	$28.19

Second Year—Wheat.

	Quantity.	The acre.	Price.
Sulphate of ammonia....................	266 lbs.		$11.40

Third Year—Clover.

Incomplete fertilizer No. 2, 887 lbs.

Composition:

Acid phosphate of lime..................	355 lbs.		$5.40
Nitrate of potash.........................	177 "		10.47
Sulphate of lime..........................	355 "		.67
Total..	887 lbs.	Cost...	$16.54

Fourth Year—Wheat.

Sulphate of ammonia....................	266 lbs.		$11.40
Total expense..			$67.53
Annual expense..			$16.99

Rotations of Five Years, including Irish Potatoes, Wheat, Clover, Colza, Wheat.

First Year—Irish Potatoes.

Complete fertilizer No. 3, 887 lbs.

Composition:

Acid phosphate of lime..................	355 lbs.		$5.40
Nitrate of potash.........................	266 "		15.70
Sulphate of lime..........................	266 "		.50
Total..	887 lbs.	Cost...	$21.60

Second Year—Wheat.

Sulphate of ammonia....................	266 lbs.		$11.40

Third Year—Clover.

Incomplete fertilizer No. 2, 887 lbs.

Composition:

Acid phosphate of lime..................	355 lbs.		$5.40
Nitrate of potash.........................	177 "		10.47
Sulphate of lime..........................	355 "		.67
Total..	887 lbs.	Cost...	$16.54

Fourth Year—Colza.

Sulphate of ammonia....................	355 lbs.		$15.20

Fifth Year—Wheat.

Ashes of straw and husks of colza.......			
Sulphate of ammonia....................	266 lbs.		$11.40
Total expense..			$76.14
Annual expense..			$15.20

Succession of Two Years—Maize, Wheat.

First Year—Maize.

Complete fertilizer No. 5, 1066 lbs.

Composition:	The acre. Quantity.		Price.
Acid phosphate of lime	534 lbs.		$8.21
Nitrate of potash	177 "		10.47
Sulphate of lime	355 "		.67
Total	1066 lbs.	Cost...	$19.35

Second Year—Wheat.

Sulphate of ammonia	266 lbs.	$11.40
Total expense		$30.75
Annual expense		$15.32

Rotation of Six Years, including Flax, Beets, Wheat, Colza, Wheat, Oats, Rye or Barley.

First Year—Flax.

Incomplete fertilizer No. 2, 887 lbs.

Composition:			
Acid phosphate of lime	355 lbs.		$5.40
Nitrate of potash	177 "		10.47
Sulphate of lime	355 "		.67
Total	887 lbs.	Cost...	$16.54

Second Year—Beets.

Complete fertilizer No. 2, 1066 lbs.

Composition:			
Acid phosphate of lime	355 lbs.		$5.40
Nitrate of potash	179 "		10.47
Nitrate of soda	266 "		8.97
Sulphate of lime	266 "		.50
Total	1066 lbs.	Cost....	$25.34

Third Year—Wheat.

Sulphate of ammonia	266 lbs.	$11.40

Fourth Year—Colza.

Complete fertilizer No. 6, 1155 lbs.

Composition:			
Acid phosphate of lime	355 lbs.		$5.40
Nitrate of potash	106 "		6.28
Nitrate of soda	355 "		15.20
Sulphate of lime	337 "		.64
Total	1155 lbs.	Cost....	$27.52

Fifth Year—Wheat.

Ashes of straw and husk of the colza turned under by the first ploughing.

Sulphate of ammonia	266 lbs.	$11.40

Sixth Year—Oats, Rye or Barley.

	Quantity.	The acre.	Price.
Sulphate of ammonia........................	177 lbs.		$7.60
Total expense..			$99.80
Annual expense..			$16.54

Rotations for Forage.

First Year—Wheat.

Complete fertilizer No. 1, 1066 lbs.

Composition:

Acid phosphate of lime..................	355 lbs.		$5.40
Nitrate of potash........................	177 "		10.47
Sulphate of ammonia......................	122 "		9.50
Sulphate of lime..........................	312 "		.59
Whole..................................	1066 lbs.	Cost...	$61.11

Second Year—Clover.

Incomplete fertilizer No. 2, 887 lbs.

Composition:

Acid phosphate of lime..................	355 lbs.		$5.40
Nitrate of potash........................	177 "		10.47
Sulphate of lime..........................	355 "		.67
Total..................................	887 lbs.	Cost...	$16.54

Third Year—Wheat.

Sulphate of ammonia........................	266 lbs.		$11.40

Fourth Year—Vetches, Beans, Maize, mixed.

Complete fertilizer No. 2, 887 lbs.

Composition:

Acid phosphate of lime..................	355 lbs.		$5.40
Nitrate of potash........................	177 "		10.47
Sulphate of lime..........................	355 "		.67
Whole..................................	887 lbs.	Cost...	$16.54

Fifth Year—Wheat.

Sulphate of ammonia........................	266 lbs.		$11.40

Sixth Year—Vetches, Beans, Maize, mixed.

Incomplete fertilizer No. 2, 887 lbs.

Composition:

Acid phosphate of lime..................	355 lbs.		$5.4
Nitrate of potash........................	177 "		10.47
Sulphate of lime..........................	355 "		.67
Total..................................	887 lbs.	Cost...	$16.54
Total expense..			$98.73
Expense the year..			$19.75

Fertilizer for Meadow.

First Year.

Incomplete fertilizer No. 2, 887 lbs.

Composition:	Quantity.	The acre.	Price.
Acid phosphate of lime..................	355 lbs.		$5.40
Nitrate of potash........................	177 "		10.47
Sulphate of lime.........................	355 "		.67
Total....................................	887 lbs.	Cost...	$16.54

Second Year.

Sulphate of ammonia......................	266 lbs.		$11.40
Total expense............................			$27.64
Annual expense...........................			$13.82

SECOND CASE.

The chemical fertilizers are employed as auxiliaries of manure.

When we employ the chemical fertilizers in concert with manure, we must consider the latter as equivalent to a fund of richness acquired by the soil, and limit the chemical fertilizer to those of its four terms which are most suitable to the culture in hand.

It follows from this that it is of the utmost importance we should know the dominant of each plant; the following tables are designed to furnish this first indispensable indication:

Nature of Culture.	Dominants.	Corresponding Chemical Products.
Beets. Colza. Wheat. Barley. Oats. Rye. Natural meadow.	Azote.	Sulphate of ammonia. Nitrate of soda. Nitrate of potash.
Peas. Beans. Clover. Sanfoin. Vetches. Lucerne. Flax. Irish potatoes.	Potash.	Nitrate of potash. Purified potash. Silicate of potash.
Turnips. Rutabagas. Artichokes. Maize. Sorghum. Sugar-cane.	Phosphate.	Ashes of bones. Superphosphate.

Supposing 44,444 pounds of manure were used every five years, the following are the chemical fertilizers to which we must have recourse;

Rotations of Five Years, including Irish Potatoes, Wheat, Clover, Oats.

First Year—Irish Potatoes.

Manure, 44,444 pounds.

Complementary chemical fertilizers:

Incomplete fertilizer No. 2, 444 lbs.

Composition:	Quantity.	The acre.	Price.
Acid phosphate of lime	177 lbs.		$2.70
Nitrate of potash	88 "		5.23
Sulphate of lime	179 "		.33
Total	444 lbs.	Cost...	$8.26

Second Year—Wheat.

Sulphate of ammonia	266 lbs.		$11.40

Third Year—Clover.

Incomplete fertilizer No. 2, 887 lbs.

Composition:			
Acid phosphate of lime	355 lbs.		$5.40
Nitrate of potash	177 "		10.47
Sulphate of lime	355 "		.67
Total	887 lbs.	Cost...	$16.54

Fourth Year—Wheat.

Sulphate of ammonia	177 lbs.		$7.60

Fifth Year—Oats.

Sulphate of ammonia	266 lbs.		$11.40
Total expense			$55.20
Annual expense			$11.04

Rotations of Five Years, including Beets, Wheat, Clover, Wheat, Oats.

First Year—Beets.

Manure, 44,444 lbs.

Complementary chemical fertilizers:

Incomplete fertilizer No. 2, 533 lbs.

Composition:			
Acid phosphate of lime	177 lbs.		$2.70
Nitrate of potash	88 "		5.23
Nitrate of soda	133 "		4.40
Sulphate of lime	133 "		.25
Total	531 lbs.	Cost...	$12.58

Second Year—Wheat.

Sulphate of ammonia	177 lbs.		$7.60

Third Year—Clover.

Incomplete fertilizer No. 2, 887 lbs.

Composition:			
Acid phosphate of lime	355 lbs.		$5.40
Nitrate of potash	177 "		10.47
Sulphate of lime	355 "		.67
Total	887 lbs.	Cost...	$16.54

Fourth Year—Wheat.

	Quantity.	The acre. Price.
Sulphate of ammonia................	177 lbs.	$7.60

Fifth Year—Oats.

Sulphate of ammonia......................	266 lbs.	$11.40
Total expense..		$55.72

Rotations of Five Years, including Colza, Beets, Wheat, Clover, Wheat.

First Year—Colza.

Manure, 44,444 lbs.
Complementary chemical fertilizer:

Sulphate of ammonia......................	266 lbs.	$11.40

Second Year—Beets.

Incomplete fertilizer, condensed, No. 2, 711 lbs.
Composition:
Ashes of straw and husks of colza.

Acid phosphate of lime..................	266 lbs.		$4.05
Nitrate of potash..........................	177 "		10.47
Nitrate of soda.............................	133 "		4.40
Sulphate of lime............................	134 "		.25
Total..	710 lbs.	Cost...	$19.17

Third Year—Wheat.

Sulphate of ammonia......................	266 lbs.	$7.60

Fourth Year—Clover.

Incomplete fertilizer No. 2, 887 lbs.
Composition:

Acid phosphate of lime..................	355 lbs.		$5.40
Nitrate of potash..........................	177 "		10.47
Sulphate of lime............................	355 "		.67
Total..	887 lbs.	Cost...	$16.54

Fifth Year—Wheat.

Sulphate of ammonia......................	177 lbs.	$7.60
Total expense..		$62.31
Annual expense..		$12.56

Rotation of Six Years, comprehending Flax, Beets, Wheat, Colza, Wheat, Oats, Rye or Barley.

First Year—Flax.

Incomplete fertilizer No. 2, 887 lbs.
Composition:

Acid phosphate of lime..................	355 lbs.		$5.40
Nitrate of potash..........................	177 "		10.47
Sulphate of lime............................	355 "		.67
Total..	887 lbs.	Cost...	$16.54

Second Year—Beets.

Manure spread in autumn, 44,444 lbs.
In the spring:
Complete fertilizer No. 2, 533 lbs.

Composition:	Quantity.	The acre.	Price.
Acid phosphate of lime	177 lbs.		$2.70
Nitrate of potash	88 "		5.23
Nitrate of soda	133 "		5.91
Sulphate of lime	133 "		.25
Total	533 lbs.	Cost...	$14.09

Third Year—Wheat.

Sulphate of ammonia	266 lbs.		$11.40

Fourth Year—Colza.

Complete fertilizer No. 6, 1155 lbs.

Composition:			
Acid phosphate of lime	355 lbs.		$5.40
Nitrate of potash	106 "		7.39
Sulphate of ammonia	355 "		15.20
Sulphate of lime	339 "		.64
Whole	1155 lbs.	Cost...	$28.63

Fifth Year—Wheat.

Ashes of straw and husks of colza turned under by the first ploughing.

Sulphate of ammonia	266 lbs.		$11.40

Sixth Year.

Sulphate of ammonia	177 lbs.		$7.60
Total expense			$89.66
Annual expense			$14.92

Instead of commencing by a trial on a large scale, I prefer to use the chemical fertilizers on a small field for the experiment, which does not cost more than $1.68 to $2.11, and by means of which we acquire positive facts in regard to the agents of fertility which the soil especially requires, and the extreme limits the harvests can attain on the land on which we wish to operate.

PRESERVATION, PREPARATION AND SPREADING OF CHEMICAL FERTILIZERS.

As a general rule, chemical fertilizers must be kept in a dry place —a granary, for example.

When you prepare the mixture of the products yourself, the operation, without being difficult, requires a certain amount of care. First, the mixing must be as perfect as possible; if this is not done, the little roots of the plant do not find the different agents at once, and their good effects depend on their association.

When you make the mixture yourself, it is necessary to procure the acid phosphate of lime several months in advance. At the time of preparation this product has a pasty consistence which makes it difficult to mix, but at the end of two or three months it becomes powdery.

Here is the rest of the process.

First, spread the phosphate of lime on the ground and then cover it with plaster. In twenty-four hours mix the two products with a shovel, and leave them in a heap for two or three days. Then spread this on the ground and mix in the other products by a vigorous spading, and finish off by mashing the lumps with a pestle, made by fixing a vertical handle in a piece of oak plank 8 or 12 inches in diameter by 4 inches in thickness. The mixture finished, it is absolutely necessary to pass it through a sieve and submit it to a new spreading. It must be well borne in mind, in making this fertilizer, that each thread-like root must be able to absorb all the products of the composition at the same time. Now, this result cannot be obtained if the mixture is not homogeneous.

The spreading of the chemical fertilizers also requires exceptional care. The best, without comparison, is to make use of the admirable machines now made for spreading pulverized fertilizers; with them, the result leaves nothing to be desired. If I add that an intelligent spreading raises the return by two to four bushels of grain the acre, you will see how important it is to be careful.

If you do not possess a machine, and the spreading must be done by hand, the best method is to mix it with its own volume of fine dry earth and sow it broadcast like grain. When we work under these conditions, the fertilizer had best be put in little heaps over the ground on which it is to be spread.

If the culture is one of legumes, peas or beans, the fertilizer must be spread after the first working, and finish the thorough incorporation of it in the superficial soil by an energetic harrowing.

For tap-rooted plants, which go down to a great depth, it is best to spread the fertilizer twice—half after the first working, and the other half after the last working.

The following is the process which has best succeeded with the vine.

Spread half the fertilizer on the surface in tracts 12 inches wide and 8 inches from the rows of vines, and turn it under deeply with the spade; the rest of the fertilizer is spread over the worked surface.

This may also be done by the plough, always 8 inches distant from the vine; open the furrows 12 inches deep, spread half the fertilizer on the bottom of the furrow, cover it with earth, and spread the rest of the fertilizer over the surface.

The vine should be manured in the fall.

I think it best for the meadow to spread half the fertilizer in the fall, and the other half in the spring, after the first cutting. Choose a calm day for spreading broadcast; in case of wind, some may be lost.

I will not go again over what I have said of the advantages the chemical fertilizer has over the manure, by the power it gives of varying the composition of the fertilizer, but I must insist on the resources drawn from their use to overcome the effects of an unfavorable season. When the winter has been severe and prolonged beyond the ordinary limits, grain and seeds of all sorts are often very much injured. With 177 pounds of sulphate of ammonia, or 311 pounds of nitrate of soda, mixed with 177 pounds of plaster, spread as a covering in the beginning of March, in a few days we can change the condition of the crop and be certain of a harvest. The effect of a top-dressing of this manure is truly magical.

But here there are also precautions necessary; you must not wait later than the middle of March. Given in April and May, it throws such extraordinary activity to the plant that the maturing of the grain is retarded, and consequent on the exaggerated development of the straw the grain is malformed—there is but little grain, and that is stunted.

Top-dressing with manures, by the certainty and rapidity of action, offers a resource of inestimable value to the agriculturist.

When the autumn is rainy and the sowing late for want of time, the fertilizers can be used as a top-dressing after the grain is well up. It is certainly the best method to spread the fertilizer before sowing, but when that has been impossible, you should not hesitate—a top-dressing will assure a good harvest. Now with manure this is useless.

In the spring use only sulphate of ammonia or nitrate of soda as a top-dressing. These two products may suffice in extreme cold. I, however, prefer to associate them with 177 pounds of acid phosphate of lime the acre, mixed with 177 pounds of plaster.

EQUALIZATION OF CULTURE.

I have already told you that a judicious agriculturist must take account of what the soil receives and what it loses. He ought every year to make a balance of his cultures, and regulate the quantities of fertilizers to satisfy these two laws:

1. Give the soil more acid phosphate of lime, more potash and more lime than the harvest has taken from it.

2. Give it 50 per cent. of the azote of the harvests.

Finally, to put each one so he can make this balance himself, which is done exactly when done with discrimination, the following table is given, showing the composition of those plants which form the chief rotations. I must remark that all these analyses are from plants harvested from the farm of Vincennes, and all grown under the same conditions—that is to say, with the complete fertilizer, where azote enters at 71 pounds the acre.

Composition of 100 *parts.*

Half-dry Crops.	Water.	Azote.	Phos. acid.	Potash.	Lime.
		Fundamental elements of vegetable production.			
Wheat of March:					
Grain	147.50	23.62	8.93	6.09	0.57
Husk...............	148.00	9.07	2.50	4.19	5.40
Straw...............	150.00	5.43	1.80	4.43	3.50
Winter Wheat:					
Grain	154.00	28.29	6.80	5.02	0.51
Husk...............	105.60	10.12	1.89	1.42	1.95
Straw	103.60	8.19	1.18	3.16	2.10
Barley:					
Grain	154.25	20.59	9.49	7.27	0.77
Husk...............	130.83	10.06	2.70	9.96	9.60
Straw	132.50	7.17	1.48	11.56	6.60
Peas:					
Grain	191.00	42.58	12.55	12.26	0.90
Shells...............	166.50	13.62	5.50	13.79	2.17
Straw	135.50	15.39	4.05	8.24	28.06
Beans:					
Grain	170.01	53.90	12.55	12.26	0.90
Pods...............	185.04	14.80	5.50	13.79	2.17
Straw	203.20	26.60	41.05	8.24	28.06
Colza:					
Grain...............	81.50	41.89	12.86	7.13	3.25
Husks	149.50	11.04	2.08	31.91	31.15
Straw	136.25	10.40	1.54	8.21	9.55
Cabbage:					
Leaves...............	146.00	......	7.52	17.10	54.10
Roots...............	168.00	......	10.60	34.90	12.60
Lucerne...............	123.09	32.33	7.40	31.38	25.10

Composition of 10,000 *parts.*

Green Crops.	Water.	Azote.	Phos. acid.	Potash.	Lime.
		Fundamental elements of vegetable production.			
Leaves............	9265.40	351.17	6.68	16.04	7.45
Roots	8625.00	89.05	11.49	45.84	4.14
Irish Potatoes:					
Tubers............	7873.40	45.20	9.20	33.51	1.90
Tops............	......	......	......	......	......

Composition of 1000 *parts of Moist Manure.*

Manure at	Water.	Azote.	Phos. acid.	Potash.	Lime.
		Fundamental elements of vegetable production.			
Vincennes..........	800.00	4.16	1.76	4.62	10.46
Bechelbronn........	790.00	4.00	2.00	2.60	5.62
Bouxwiller..........	790.00	5.38	2.65	8.12	7.76
In 1000 litres of..	974.00	1.13	0.10	7.00	0.04

Composition of 1000 *Parts of Dry Manure.*

Manure at	Water.	Azote.	Phos. acid.	Potash.	Lime.
		Fundamental elements of vegetable production.			
Vincennes............	......	20.80	8.80	24.60	52.30
Bechelbronn..........	......	20.00	10.00	26.00	28.10
Bouxwiller...........	......	25.67	12.65	38.75	37.06
In 1000 of residue of	......	43.45	3.94	230.97	1.88

EXPERIMENTAL FARMS.

I have repeated several times, and do not hesitate to repeat again, it is by experimental fields that I like to see agriculturists begin the use of chemical fertilizers. First, an attempt upon a scale as reduced as it was unfortunate could never take the proportions of a financial mistake, and that is for me a consideration of very great importance; nothing impresses a practical man like the contrast these fields show him; in face of these contrasts, he instinctively feels that there is a power until now unknown or misapplied.

The reasons of the differences that these returns show are not at first clear to him; he hesitates; but presently the light breaks, and then it is almost with the conviction and fervor of religious sentiment that he speaks of the effects he observes, and of the great loss of which they are at once the proof. You may judge by this letter:

"The harvest of beets around me will be more than mediocre. I alone am fortunate, and I am so by the application of your methods. I bless you, and I gather with happiness the fruits of my immovable faith in your ideas. I say, *my immovable faith.* I say it intentionally; for when it was seen that I was applying your methods, there was a war made upon me, sometimes open, sometimes sullen, and always implacable.

"They sought to warn my tenants of me, telling them my success was ephemeral—that I was preparing bitter regrets for myself by foolishly spending enormous sums, and that in the end I would waste their land.

"They did more. My experimental fields are admirable; they carry with them the most striking proof of the certainty of their methods. That was not noticed by my enemies. They broke down certain sign-posts for guiding the attention and examination of visitors; they overthrew others; they went so far as to change them, and to put, for example, the post indicating a mineral fertilizer in the place of one for complete fertilizer; and then they repeated everywhere that your fertilizers had no real value, and that these experiments proved the contrary of your promises. Fortunately, the fraud is perceived; truth will assert itself, and I hope now that the authors of this inexplicable misdeed will be made known."

We will add that the author of this letter, who first began by one experimental farm, to-day possesses ten of them, and has put 250 acres under the treatment of chemical fertilizers.

You see by this example, to which I could add many others, I am right in insisting you should begin with small experimental fields. M. Lavaux, at the farm of Choisy-le-Temps, where the chemical fertilizers are employed on nearly 675 acres, begun with a modest little experimental field.

After what I have just said, you will not be surprised if I speak in detail and with a kind of partiality of the rules to which you must bind yourself, in order to draw from an experimental field all which can possibly be drawn from it.

A judicious agriculturist, and one animated by the desire to do well, ought to make two kinds of tests here and there over the whole extent of his domain, to know the true wants of the soil; this consists of peas and wheat sowed near each other on squares of 1 to 2 yards.

If the two plants succeed equally well, the indication is certain that the soil is provided both with minerals and azotic matter. If the peas succeed and the wheat gives but a poor return, you may be certain the land is provided with minerals and wanting in azotic matter. Finally, if the return of wheat, without being excellent, is better than that of the peas, it is a sure indication that the soil contains azotic matter, but is wanting in minerals. These are certain and easy means of acquiring positive indications of the differences of composition shown by the different parts of a domain. But these indications, although very useful, are not sufficient; they must be pushed farther to find out what minerals are wanting, both in the superficial and deeper beds of the soil. That is done without difficulty by means of the experimental fields.

In an area of some importance it would be well to establish several of them. One, which I will call the principal field, should comprehend all the plants included in the rotation to be adopted.

The choice of position is a point of great importance. You should choose a part which as much as possible represents, by its exposure, its nature and degree of fertility, the mean quality of the soil of the whole area. The principal field ought to be composed of ten strips of one square each, separated by a path of one yard in width. I have said that the field ought to comprehend all, or at least the principal, plants of the rotation, which would require at least two or three parallel series of culture; among the plants to be preferred, if one cannot try them all, I would name the wheat, colza, or even the beet, and a legume—the pea or bean. By means of the wheat and pea you will be informed of the state of the superficial bed, and by the beet or colza of that of the deeper bed of the soil. Now there are two elements to which you must pay particular attention if you would have large returns with intelligence, certainty and economy.

I have said that each plant ought to be submitted to ten different methods of manuring on ten separate parcels. Here is the exact indication of these manures:

Wheat—No. 1. Manure, 53,333 lbs. the acre.
No. 2. Manure, 26,666 " "
No. 3. Complete fertilizer, condensed.
No. 4. Complete fertilizer.
No. 5. Fertilizer without azotic matter.

No. 6. Fertilizer without phosphate of lime.
No. 7. Fertilizer without potash.
No. 8. Fertilizer without lime.
No. 9. Fertilizer without minerals.
No. 10. Land without any fertilizer.

When you have to do with a very large farm, one field is not sufficient, because of the variation which the composition of the soil shows in the principal divisions of a domain; it will be wise, then, to multiply the test, but on a less scale. One square divided into four parts will be enough for the experiments. They may be reduced to the following terms:

No. 1. Complete fertilizer.
No. 2. Mineral fertilizer without azote.
No. 3. Azotic fertilizer without minerals.
No. 4. Without any fertilizer.

Several corners of the field reserved for this purpose will not interfere with its cultivation, and will show when, for each grand division, to have recourse to azotic or mineral fertilizers.

To those who look with a kind of fright at so large a number of tests, I will reply by an argument of facts. In all the large farms where the chemical fertilizers have been introduced, these experimental squares have been used. The director, proprietor or farmer likes to show them to those who visit him, and after some hesitation he always ends by regulating the quantities of the agents composing his fertilizer by their growth.

Let us now occupy ourselves with the fertilizers most convenient for these experimental farms.

SERIES FOR WHEAT.

(Parcel No. 1.)

Barnyard manure, 53,333 lbs.

(Parcel No. 2.)

Barnyard manure, 26,666 lbs.

Condensed Complete Fertilizer No. 1.

(Parcel No. 3.)

	The acre. Quantity.		Price.
Acid phosphate of lime	533 lbs.		$8.10
Nitrate of potash	355 "		20.94
Sulphate of ammonia	222 "		9.50
Sulphate of lime	312 "		.59
Total	1432 lbs.	Cost...	$39.13

Complete Fertilizer No. 1.

(Parcel No. 4.)

Acid phosphate of lime	355 lbs.		$5.40
Nitrate of potash	177 "		10.47
Sulphate of ammonia	222 "		9.50
Sulphate of lime	312 "		.59
Total	1066 lbs.	Cost...	$25.96

Fertilizer without Azote.

(Parcel No. 5.)

	The acre. Quantity.		Price.
Acid phosphate of lime	355 lbs.		$5.40
Purified potash	123 "		10.13
Sulphate of lime	322 "		.59
Total	800 lbs.	Cost...	$16.12

Fertilizer without Phosphate.

(Parcel No. 6.)

Nitrate of potash	177 lbs.		$10.47
Sulphate of ammonia	222 "		9.50
Sulphate of lime	312 "		.59
Total	711 lbs.	Cost...	$20.56

Fertilizer without Potash.

(Parcel No. 7.)

Acid phosphate of lime	355 lbs.		$5.40
Sulphate of ammonia	355 "		15.20
Sulphate of lime	177 "		.33
Total	887 lbs.	Cost...	$20.93

Fertilizer without Lime.

(Parcel No. 8.)

Phosphate of lime, precipitated	355 lbs.		$5.40
Nitrate of potash	177 "		10.47
Sulphate of ammonia	222 "		9.50
Total	754 lbs.	Cost...	$25.37

Fertilizer without Minerals.

(Parcel No. 9.)

Sulphate of ammonia	355 lbs.		$15.20

SERIES FOR BEETS.

(Parcel No. 1.)

Barnyard manure, 53,333 lbs.

(Parcel No. 2.)

Barnyard manure, 26,666 lbs.

Complete Fertilizer, Condensed, No. 2.

(Parcel No. 3.)

Acid phosphate of lime	533 lbs.		$8.10
Nitrate of potash	355 "		20.94
Nitrate of soda	266 "		8.76
Sulphate of lime	266 "		.50
Total	1420 lbs.	Cost...	$38.30

Complete Fertilizer No. 2.
(Parcel No. 4.)

	The acre. Quantity.		Price.
Acid phosphate of lime	355 lbs.		$5.40
Nitrate of potash	177 "		10.47
Nitrate of soda	266 "		8.76
Sulphate of lime	266 "		.50
Total	1064 lbs.	Cost...	$25.13

Fertilizer without Azotic Matter.
(Parcel No. 5.)

Acid phosphate of lime	355 lbs.		$5.40
Purified potash	123 "		10.13
Sulphate of lime	322 "		.59
Total	800 lbs.	Cost...	$16.12

Fertilizer without Phosphate.
(Parcel No. 6.)

Nitrate of potash	177 lbs.		$10.47
Nitrate of soda	266 "		8.76
Sulphate of lime	266 "		.50
Total	709 lbs.	Cost....	$17.73

Fertilizer without Potash.
(Parcel No. 7.)

Acid phosphate of lime	355 lbs.		$5.40
Nitrate of soda	400 "		13.33
Sulphate of lime	322 "		.59
Total	1077 lbs.	Cost...	$19.31

Fertilizer without Lime.
(Parcel No. 8.)

Phosphate of lime, precipitated	355 lbs.		$5.40
Nitrate of potash	177 "		10.47
Nitrate of soda	266 "		8.76
Total	798 lbs.	Cost....	$24.63

Fertilizer without Minerals.
(Parcel No. 9.)

Nitrate of soda	400 lbs.		$13.33

That an experimental field may furnish truly useful indications of the condition of the soil, it must not have received manure for several years; otherwise, the returns from the different parcels will be so much alike as to be puzzling, and contrasts, such as you see at Vincennes, will only be produced after two or three years of cultivation. But this case is not less instructive than the first; it proves that the soil is provided with all the terms of the complete fertilizer.

In a practical point of view, this indication is of great importance. It teaches us that in such a soil we may have temporary recourse to incomplete fertilizers, and can manure alternately, limiting ourselves to the dominants, which allows us to obtain the maximum product with small expense.

DICTIONARY OF CHEMICAL FERTILIZERS.

Azotic Matters.

We designate under this name products of animal and vegetable origin, of which azote forms a part:

The blood,	Albumen,
Scrapings of horn,	Scraps of wool,
Muscular flesh,	Litter,

Cakes.

These are azotic matter. To act upon vegetation the substances called azotic matter ought to be allowed to decompose in the soil; without this previous decomposition they have no action on plants. When azotic substances are decomposed a part of their azote takes the form of ammonia or nitrate. For this reason we include in the class of azotic substances proper to agriculture—

Sulphate of ammonia.
Nitrate of potash.
Nitrate of soda.

These substances, which are true salts, contain azote to the number of their constituents; in sulphate of ammonia the azote belongs to the ammonia, which is the base of salt; in the nitrate of potash and soda, the azote belongs to the acid of salt.

Sulphate of Ammonia.

This salt is formed of sulphuric acid and ammonia:

Sulphuric acid	60.60
Ammonia	25.76
Water	13.64
	100.00

Now, as the ammonia is in its turn formed of

Azote	14
Hydrogen	3
	17

it results that the sulphate of ammonia contains 21.21 per cent of azote when chemically pure. That of commerce contains at most 20 per cent. Ammonia is drawn from the waters of sewers which have been used for cleaning out cities. It is also obtained from the distillation of coal employed in making coke and gas; but the source which surpasses all others is that offered by volcanoes, when they become so quiet that they only throw off the vapor of water.

In 1866 sulphate of ammonia was worth $6.65 the 200 pounds.

To-day it is worth $8.55, but this price will certainly be lower in the future.

Nitrate of Soda.

Nitrate of soda is formed from nitric acid and soda. Here is the exact composition:

Azotic acid	63.53
Soda	36.47
	100.00

Nitric acid itself being formed of

Azote	14
Oxygen	40
	54

it follows that the nitrate of soda contains 16.4 of azote when chemically pure. That of commerce contains only 14 or 15 per cent. Nitrate of soda is found in Peru, where it exists in the form of compact conglomerates, mixed with sand and marine salt.

The earthquakes on the Peruvian coast this year have affected the importation of this product, the price being raised to $7.60 the 200 pounds, instead of $6.55, at which it could be bought the past year.

Nitrate of Potash.

This salt, also designated under the name of salt of nitre, or nitre, is formed of nitric acid and potash:

Nitric acid	53.41
Potash	46.59
	100.00

By reason of 14 of azote to 54 of nitric acid, it contains 13.8 of azote in its pure form; that of commerce contains only 12 to 13. Nitrate of potash is obtained by decomposing, under vast sheds for this purpose, substances of animal origin, mixed with argilocalcareous earth, which is then washed in ley to extract the nitre. This salt has for a long time been made from rubbish. It is made now by decomposing the chlorine of potassium by means of nitrate of soda. By this we obtain both the chloride of sodium (marine salt) and nitrate of potash, very easy to separate by crystallization. Nitrate of potash is of all substances containing potash the most suitable to agricultural wants.

Nitrate of potash is now worth $5.40 the 200 pounds.

Phosphate of Lime.

Under the name of phosphates of lime are comprehended a great number of different products. For a long time agriculturists only used the phosphate of lime from bones. It was then associated with carbonate of lime. Now, the greater part of the phosphates used as fertilizers are provided by the mineral kingdom, where it is found in inexhaustible veins. All the phosphates are formed from phosphoric acid and lime. Phosphoric acid itself is formed from phosphorus and oxygen:

Phosphorus	31
Oxygen	40
	71

Of the phosphates, phosphoric acid is the active part. Chemists are accustomed to represent phosphoric acid by the symbol,

$$PhO_5.$$

Now, PhO_5, or 71 phosphoric acid, being a fixed term, we know the principal kinds of phosphates of lime:

$$PhO_5 \begin{cases} CaO \\ 2HO, \end{cases}$$

which in hundreds is—

Phosphoric acid	60.68
Lime (CaO)	23.93
Water (HO)	15.39
	100.00

This product has received the name of acid phosphate of lime. It is prepared by treating bones or phosphates of mineral origin with sulphuric acid. The acid phosphate is then mixed with sulphate of lime. Under this form it receives the name of superphosphate of lime.

It contains from 15 to 18 per cent. of phosphoric acid, and is sold at $3.04 the 200 lbs.

The second phosphate is expressed by the symbol,

$$PhO_5 \begin{cases} CaO \\ HO, \end{cases}$$

or in hundreds—

Phosphoric acid	52.20
Lime	41.18
Water	6.62
	100.00

It differs from the first in the proportion of lime, which is greater. This phosphate is not found in commerce. It has remarkable properties, of which it is useless to speak, since we cannot procure it.

The symbol of the last phosphate is,

$$PhO_53CaO.$$

Its composition in 100 parts is—

Phosphoric acid	45.81
Lime	54.19
	100.00

You see the proportion of phosphoric acid in the phosphates is expressed by—

1st	60.68
2d	52.20
3d	45.80

The last, which is least rich in phosphoric acid, is the phosphate of bones; it is found in nature in the form of nodules.

In the form of nodules the phosphate is mixed with 40 per cent. of foreign matter. It is sold in powder at $1.14 the 200 lbs. Calcined bones, reduced to powder, are worth $3.04. By reason of its bulk this phosphate cannot be employed in its natural state. It is used in making acid phosphate of lime.

Sulphate of Lime.

Sulphate of lime is nothing more than plaster, produced by the combination of sulphuric acid with lime.

It is found in great quantities in nature in a hydrated form. Its composition is then—

Sulphuric acid	46.51
Lime	32.56
Water	20.93
	100.00

Exposed to a temperature of 120° to 130°, it loses the form of water and passes to the state better known under the name of plaster. It is under the form of plaster that I advise its use, in preference to sulphate of lime. It is then worth 38 cents the 200 lbs.

JUSTIFICATION BY PRACTICE, SHOWING FACTS AND LAWS.

I will borrow several proofs from the researches of 1867 which merit preservation. Some relate to the conditions of the highest culture, others belong to middle culture. In the latter the land is rented at from $2.50 to $3.50 the acre, and in the former at from $9 to $10 the acre. In all these conditions the use of the chemical fertilizers has been followed, by which, in the most unfavorable cases, the income of the proprietor has been doubled.

The examples cited will have the merit, besides, of showing the advance the ideas we maintain have made in two years.

I borrow the first two documents from *Le Journal des Fabricants de Sucre* (The Sugar-Makers' Journal), an excellent compilation, which recommends itself as much by its independence toward the criticisms of coteries as by the rare merit of its publication.

CULTURE BY MEANS OF CHEMICAL FERTILIZERS.

1. *Wheat.*

My experiments covered the space of three acres, divided into three separate fields of an acre each.

The first received in the spring of 1866—

577 lbs. of sulphate of ammonia, or

120 lbs. of azote.

177 lbs. of real phosphate of lime in the form of acid phosphate.

120 lbs. of purified potash (277 lbs. carbonate of potash).

277 lbs. of lime.

Sown in beets, it produced in 1866, 53,013 lbs. of roots.

The second field had also received the same fertilizer in the spring of 1866, except the quantity of sulphate of ammonia, which had been reduced to 355 pounds, or 71 pounds of azote.

The return from this field in beets was 42,066 pounds of roots.

Lastly, the third field in the autumn of 1866 received—

266 pounds of acid phosphate of lime.

266 pounds of sulphate of ammonia, or

56 pounds of azote.

177 pounds of sulphate of lime.

M. George Ville, consulted by me as to the easiest method of obtaining a maximum return, advised, in case it should be necessary, the addition of a certain quantity of the incomplete fertilizer over the first two acres. After a hesitation provoked by the magnificent appearance of the plants at the end of the winter, I decided to leave the earth to its own forces, fearing the effects of a too luxuriant and herbaceous growth. I was happy in following this inspiration, for it is very probable the abundant rains of spring had determined the fall of the stalks and defeated my hopes if I had used more of the fertilizer.

What returns were obtained from these three fields?—

Field No. 1.

Grain	56 bu., 58 lbs. to 40 lbs. the bushel.
Straw	4888 lbs.

Field No. 2.

Grain	49 bu., 58 lbs. the bushel.
Straw	4857 lbs.

Field No. 3.

Grain	62 bu., 49 lbs. to the bushel.
Straw	4644 lbs.

What is the value in money of these three harvests? The account, reduced one-fifth, leads to the following results:

Field No. 1.

56 bu., from \$5.55 to \$1.46 the bushel	\$84.38
4888 lbs. of straw, at 1¼ cents the pound	61.10
Total	\$145.48

Field No. 2.

49 bu., from \$3.85 to \$1.46 the bushel	\$73.17
4857 lbs. of straw, at 1¼ cents the pound	60.75
Total	\$133.92

Field No. 3.

62 bu., from \$4.73 to \$1.46 the bushel	\$92.48
5532 lbs. of straw, at 1¼ cents the pound	69.16
Total	\$161.64

I ought to stop here, and leave these figures, without comment, to the reflection of practical men; but since it may be said that these results are not superior to the ordinary culture, I remind you that these fields were surrounded by wheat produced by the old method. You have seen them, you have examined them at leisure, you have been able to compare the surprising differences manifest between them. The wheat from the chemical fertilizer carried tall stalks, their heads long and well filled. They were so robust one would involuntarily have taken them for small trees, while those at their side, from manure, doubled over, presenting only stunted spikes. In threshing, this difference was not the less striking, for the latter, from manure, only gave 32 bushels the acre.

I confess the year was extremely unfavorable to the formation of grain. The plants grew too fast; their fall was general, thus destroying the hopes of a harvest which promised better. In a more normal condition perhaps the difference between the two harvests had been less. But it is nevertheless certain the chemical fertilizer is in all circumstances superior. Now, this is what I wished to prove, and what doubles the value of the experiment for me; for is it not evident that such a combination of fertilizing matter is the most precious of all, since we can, by regulating the use of it, increase or diminish the dose according to the exigencies of the season and the appearance of the plant—an impossible thing with manure, and almost impracticable with all other less soluble fertilizers?

But this is not the question. I plead a cause gained, since it is clear to all the world that the chemical fertilizers have an immediate action and an energy greatly superior to all others.

The question for our cultivators is more serious: it is to discover if these exuberant growths are the expression of a real agricultural progress, or whether they are but a kind of ephemeral accident, of which the soil pays the cost and to which the cultivator will be the first victim. You know what I would say: I wish to speak of the impoverishment of the soil. It is pretended that these large returns are due to the dissolvent reaction of the chemical fertilizers upon the fertilizing wealth accumulated in the bed of the soil.

It is said we but half cultivate, and like bad and imprudent workers we burden the future for present profit; we inconsiderately work the earth which has been confided to us, and of which, after all, we are but the tenants, since in reality she belongs as much to future generations as to us; we squander the forces put in reserve by our predecessors, and we have not the right to profit at others' expense.

This is the accusation. We must confess it is very grave, and, I acknowledge, would condemn without hope any system it explained. But I repeat, Has this accusation a foundation? Are not the contradictors of M. George Ville blinded to their interests by a prejudice against everything new that does not emanate from the beliefs of the old school? I am, it is true, somewhat a stranger to the questions of agricultural chemistry—not so much so, perhaps, as would be supposed; besides, this is less a question of science than of arithmetic, and without pretending to the Academy, I pretend to know when I use such and such manures what the soil I cultivate has lost in its elements of fertility.

I will attempt, then, by the aid of facts accepted by all the world, to demonstrate that the system of M. Ville, applied to the culture of the beet and of wheat, with biennial manuring, far from wasting, helps gradually to increase the fertility of the soil.

I will take as the basis of my calculations, field No. 1, which produced in

1866, beets	53,013 lbs.	the acre.
1867, grain	57 bu.	"
" straw	4888 lbs.	"

And I will admit in the beet and wheat,

	Beets.	Wheat.	Straw.
Azote	0.21 per cent.	2.29 per cent.	0.36 per cent.
Phos. lime	0.21 "	2.47 "	0.45 "
Potash	0.29 "	0.72 "	0.65 "

According to this composition, the two harvests represent the following quantities of azote, phosphate of lime and potash:

	Azote.	Phos. lime.	Potash.
53,013 lbs of beets	111 lbs.	111 lbs.	153 lbs.
2,463 lbs. of wheat, less seed	56 "	60 "	16 "
4,888 lbs. of straw	16 "	22 "	32 "

And finally, the balance between the fertilizer and the harvest becomes—

	Harvest.	Fertilizer.
Azote	184	120
Phosphate of lime	183	177
Potash	202	120

At first sight, the earth appears the loser, and the contradictors of M. Ville appear to have reason on their side. But is this balance the expression of what takes place in cultivation? Evidently not. The harvests have not carried off what we said. In reality, the beets go to the sugar-maker, where they become pulp, which, returned to the farm, serves as food for stock and a large production of manure; the straw likewise reaches the same destination.

Let us see what the farm recuperates from different products, and which ought to enter into the deductions of what the soil loses.

	Azote.	Phos. lime.	Potash.
13,333 lbs. of pulp	57 lbs.	24 lbs.	76 lbs.
1,777 " "	10 "	81 "	8 "
4,888 " of straw	17 "	22 "	32 "
Refuse of different kinds	4 "		
Total	88 lbs.	127 lbs.	116 lbs.

This correction made, these quantities of the agents of fertility being added to the corresponding terms of the fertilizer, we are led to the following balance, which is the true expression of the phenomena:

	Fertilizer and products restored.	Harvest.	Excess in favor of soil.
Azote	204 lbs.	184 lbs.	20 lbs.
Potash	238 "	202 "	22 "
Phosphate of lime	308 "	193 "	114 "

This is the truth. It is not just to say that the question of fertilizers is an idle one for us, we being sugar-makers and cultivators, and that the use of them leads to certain ruin, or sooner or later to the impoverishment of our lands. I see the contrary resulting from the so-much decried system, for a source of greater or less profit and an increase of fertility flow naturally from it.

It is easy to give this account without a long train of proofs. Is not the production of beets nearly doubled? Does not the quantity of pulp made follow the same proportions? Is not a richer and more copious nutriment prepared for a greater number of stock, and is not manure consequently more abundant? Then, the chemical fertilizer, instead of excluding the manure of the farm, helps the cultivator to produce it more cheaply and in greater masses. We obtain an immediate increase of profit, thanks to the more soluble and active agents of fertility employed, and a more certain increase of profit in the future from increased resources of manure, consequent upon the increase of first returns. Those who affirm that M. Ville proscribes the use of manure do not perceive that this opinion is in direct opposition to the foundation of his doctrines, since the chemical fertilizers certainly result in developing our resources of straw and food.

Now, I will admit that the two harvests are entirely sent off: is M. Ville's system then dangerous of application? Certainly not; for under these new conditions it is only necessary to give back to the earth the equivalent of what the pulp and the straw helped us to return to it.

If we take away the pulp and the straw, the earth loses, as we have said—

	Quantities.	Price.
Azote	63 lbs.	$11.99
Phosphate of lime	16 "	.21
Potash	81 "	5.85
Total of preserved loss		$18.05

Now, to end this question finally, and to know if, under these new conditions, the methods of M. Ville are advantageous, it is sufficient to inquire if the cost of production, being burdened by $18.05, the result will be less remunerative.

Now, on this new case, what is the result of the operation?

Credit.

53,013 lbs. of beets	$100.73
56 bu. of wheat	84.33
4,888 lbs. of straw	13.93
Total	$198.99

DEBIT.

First Year—Beets.

Expenses of all kinds..	$41.37
Second Year—Wheat.	
Expenses of all kinds..	$34.52
Fertilizer for two years..	38.00
Total expense..	$113.89
Difference..	$85.10

—$85.10, to pay for the additional fertilizer worth $18.05, which compensates for the loss resulting from the exporting of the pulp and straw.

You will remark that in the calculations it is supposed that the whole of the azote came from the soil, and that it must be returned to it, pound for pound. Now, it is a purely gratuitous supposition I have voluntarily made, to add force to my demonstration and put it beyond all dispute.

I know that returns obtained for two years may rightly be considered as maximum returns. I admit the possibility of seeing them sensibly lowered in years unfavorable to the chemical fertilizers. But what a margin, however! and how admit that the profits I have shown can be changed into loss?

You perhaps think it strange, my dear sir, that I enter on these details. If I thought to clear up the question in this manner, it is because I am doubly interested: First, because I feel constrained to say aloud, and without hesitation, what I believe to be the truth, and because we cultivators and a few farmers cannot allow ourselves to be gratuitously accused of wasting the productive forces of a soil confided to our care. Our responsibility, our future, even, are engaged in the question. We cannot allow, without protesting, that we work without judgment. For myself, faithful to the prescriptions of M. Ville, I will continue to apply his teachings, having always present in my mind, as he recommends in such precise terms, the inflexible law of restitution imposed upon us, whose character and signification it is so difficult to define. In acting thus, I have the certainty of increasing the fertility of the lands which form the whole of my farm, while developing the resources of the present. A. CAVALLIER.

November 7, 1867.

SECOND CULTURE OF WHEAT BY MEANS OF CHEMICAL FERTILIZERS.

The land I have operated upon (primitive formation, or, to be more exact, mica-schist) is a poor land, rented at $2.50 to $3 the acre, wasted by a triennial rotation under the worst conditions from time immemorial, and not to my knowledge have the vices of this rotation been corrected—I do not mean by abundant manuring, but by any manure at all. These lands are situated at a considerable height above the farm-buildings, and difficult of access; it is easy, then, to see why the farmers who occupied it preferred to use what little manure was at their disposition in the field, rather than bring any. Now to attempt the cultivation of wheat under such conditions seemed impossible—so impossible that our laborers undertook it with extreme repugnance.

However, by the aid of 888 lbs. of the incomplete fertilizer the acre, I obtained a harvest worth $61.01, of which the following are the elements:

Quantity of grain	37 bu.
Weight of grain	1733 lbs.
Weight per bushel	46 "
Weight of straw	7200 "

Here is a return of products amounting in value to	$61.01
From which must be deducted the whole value of the fertilizer	17.73
Leaving	$43.28

Certainly, gentlemen, this is an enormous return, considering the land in question; but I am convinced that it would have been greater if the ploughing had been deeper, if the fertilizer had been more deeply turned under than it was, and lastly, if the season had been better. Is not 37 bushels the acre an admirable return from the soil where it was realized, when in the neighboring valley, from the alluvial soils, worth $506.66 the acre, the yield was but 23 bushels?

I had so organized my experimental fields as to compare the returns of wheat with those treated with fertilizers and those without them. Unfortunately, the servant charged with spreading them forgot my orders, and threw the fertilizer over the reserved squares. If I had been told of the mistake in time, I could have repaired it, but the servant kept silent, convinced he would not be found out. It was not until later, when the presence of the manure was evident in the growth of the plants, that he acknowledged his fault.

His fault, although it resulted in depriving me of a comparison in the culture of wheat, could not hinder me from comparing the results obtained from the chemical fertilizers with those by the old methods in the culture of rye without fertilizers.

This experimental field was near the field of rye without fertilizers of which I have just spoken, and which had yielded 15 bushels of grain and 1422 lbs. of straw the acre.

Now, in the estimate of the cost of all the fertilizers, which I think excessive, and valuing the grain and straw as here below, we find as the result of the two methods a profit of $30.61 in favor of the harvest with the fertilizer.

Value of harvest of rye without fertilizer	$16.88
Value of harvest of wheat with fertilizer	65.23
Excess in favor of harvest of wheat	$48.35
Deduction of value of fertilizer	$17.74
Net profit in favor of the culture of wheat with the chemical fertilizers	$30.61

Now, you will object that I could have had analogous if not superior results with manure. Certainly, the thing would be possible with time and much manure. But where to get the manure? When with the chemical fertilizer I will have produced much straw, roots, forage, and consequently much stock, I would doubtless be able to do without it. But if I attempt, under the conditions where I am placed, to obtain this straw, roots and forage by the usual methods of culture, you would condemn me for an indefinite length of time, and perhaps for ever, to unremunerative harvests; that is to say, to renewed sacrifices of money, and no compensation.

But you will say, These 37 bushels of wheat, and this great superiority over the ancient methods, are due to *ancient forces* in the soil. This earth you will waste, thus diminishing your property—if not in extent, at least in intrinsic value.

Concerning myself, I am insensible to the objection. Is it because I have furnished the earth with more azote, phosphate of lime and lime than the harvest drew from it? Is it that now—when I expect remunerative harvests from it, and will free it from the weeds which devour it, and the bad water which it retains in excess,—is it because now, thanks to the labors of M. George Ville, I know its language, and can always question it as to preferences and wants? Is it because I can now find out in what it is lacking and what it has in abundance? And from this am I not able to give it at my will, so to speak, those elements of fertility of which it is deprived?

But if well founded, I would not notice the objection. An excess of products to the value of $15, kept up for several years only, would be sufficient to cover the whole value of the soil itself. And if the soil were incapable of producing wheat or rye, I could still, after recovering from it its price, put it to the use I designed before knowing the laws of vegetation revealed by M. Ville, which was to make it a wood or a pasture. But, gentlemen, I am relieved of all uneasiness, not only by the theoretic teachings of M. Ville, but also by the results obtained by him at Vincennes.

I have not limited my experiments to the culture of rye, oats and wheat. I have also employed the chemical fertilizers on artichokes, Irish potatoes and radishes—that is, on plants whose elements are destined to return almost wholly to the soil which has produced them. But these crops are still in the ground, and it would be premature to speak of them. DE MATHAREL.

I particularly call the attention of the reader to this Report, because, the returns having been small, the operation still being profitable, we may consider the conclusions of the author as the least favorable expression of the advantages attending the use of chemical fertilizers:

REPORT MADE TO THE AGRICULTURAL SOCIETY OF ANGOULÊME, BY M. BOURZAC, RECTOR OF THE COLLEGE.

According to the desire expressed to me last year by our honorable president, M. Gellibert de Seguins, I have experimented with the fertilizers of M. George Ville on a property I possess at Charras, canton of Moulbron.

The lands on which the experiments were made were three acres in extent. They were manured, one-half with 1066 pounds of the complete fertilizer No. 2, containing—

Acid phosphate of lime	355 lbs.
Nitrate of potash	179 "
Nitrate of soda	266 "
Sulphate of lime	266 "
Total	1066 lbs.

The other half with 888 pounds of the incomplete fertilizer No. 2, containing—

Acid phosphate of lime	355 lbs.
Sulphate of ammonia	310 "
Sulphate of lime	223 "
Total	888 lbs.

The results obtained from these two kinds of fertilizers showed no difference to the eye before harvest. It was always my intention to separate them, but they were unfortunately mixed by a mistake of my steward.

The harvest was 99 bushels of wheat and 11,127 pounds of straw, which gave 33 bushels of grain and 3709 pounds of straw the acre; while that year the returns from five other farms and reserves forming the same property only rose to 15 bushels of grain and 1829 pounds of straw the acre.

To give a clear idea of the money value of this first trial permit me, gentlemen, to enter into some details.

The total extent of this farm which was sown in wheat was 6 acres; the stable manure to be spread over this surface did not constitute, according to the bad habit of our country, a half manuring. I had it spread over 3 acres—that is, over half the surface for which it was designed. The chemical fertilizers Nos. 1 and 2, to the weight of 3909 pounds, were spread over the remaining 3 acres.

The total harvest was raised to 117 bushels of wheat and 13,452 pounds of straw.

Judging by the five other farms and reserves of this year, the harvests of this farm, without manure, would have been ordinarily 72 bushels of wheat at the most.

The use of the chemical fertilizers increased the harvest by an excess of 117 over 72—equal to 45 bushels of grain and 5191 pounds of straw.

The 45 bu. of wheat, at $1.75 the bu., gave	$78.75
The 5191 lbs. of straw, at .004¾ per lb	24.65
Total	$103.40
The fertilizers and all expenses included	75.42
The net profit is, the first year	$27.98

In the preceding account I stand in the position of a proprietor furnishing the fertilizers made use of by his farmer.

Under these circumstances, the price of manure being put down entirely to the first harvest, the rent of the 6 acres increased to $27.98, about $4.65 the acre.

If we value the products of the 3 acres treated with chemical fertilizers, the net profit, all expense of manuring paid, will be $10.97 the acre.

If the owner worked it himself, would the result be equally to his advantage? It appears to me very interesting to look at the question in this light.

Fixing, as M. George Ville has done in his lecture at the Sorbonne, and according to Matthieu de Dombasle, the cost of the culture of one acre at $18.57 is thus divided:

Rent of soil	$3.80
General expenses	4.39
Work of culture	3.63
Seeds	3.88
Harvesting and threshing	2.87
Total	$18.57

Putting the manure by itself, there is always for the 3 acres—

99 bu. of wheat, at $1.75 the bu		$173.25
11,127 lbs. of straw, at .004¾ per lb		52.85
Total		$226.10
Deducting cost of culture	$67.80	
Manure	106.14—	$172.94
Net profit		$42.16
Net profit the acre		$14.05

In an account like the preceding the total cost of the manure has been put down to the first harvest. This is an extreme supposition, according to M. George Ville, for the price of the annual manuring, deducted from his formulæ for four years, is but $15.20 the acre, instead of $29.03. Looking at the question in this point of view, the results to which we are led, for the 3 acres on which I experimented, are—

99 bu. of grain, at $1.75 the bu		$173.25
11,127 lbs. of straw, at .004¾ per lb		52.85
Total		$226.10
Deducting cost of culture	$26.01	
Manure	60.78—	$86.79
Net profit		$139.21
Net profit the acre		$25.65

From whatever point of view we look at it, and with the actual price of wheat much superior, I must say, to its mean price, the use of chemical fertilizers in the experiment I have just made is attended with profit. Would it be the same in an abundant year? I do not know; it always seems natural to me to suppose that the abundance of products obtained by the chemical fertilizers will compensate in this sense, at least in part, for the lowering of the price of wheat.

We may say that the first returns from the chemical fertilizers will not be maintained in the future; experience must decide that.

For myself, I have made known the facts produced under my own eyes; I have fixed their economic signification with the greatest severity, and I have abstained with the greatest care from all personal prejudice.

I will continue next year to give an account of all new results I may obtain—am determined to keep account of facts alone, and to respect their testimony, whatever it may be. BOURZAC.