GEORGE E. WARING

THE ELEMENTS OF AGRICULTURE

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The Elements of Agriculture

A Book for Young Farmers, with Questions Prepared for the Use of Schools

EAN 8596547250012

DigiCat, 2022
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THE PLANT.

CHAPTER I.

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INTRODUCTION.

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What is the object of cultivating the soil?

What is necessary in order to cultivate with economy?

Are plants created from nothing?

The object of cultivating the soil is to raise from it a crop of *plants*. In order to cultivate with economy, we must *raise the largest possible quantity with the least expense, and without permanent injury to the soil*.

Before this can be done we must study the character of plants, and learn their exact composition. They are not *created* by a mysterious power, they are merely made up of matters already in existence. They take up water containing food and other matters, and discharge from their roots those substances that are not required for their growth. It is necessary for us to know what kind of matter is required as food for the plant, and where this is to be obtained, which we can learn only through such means as shall separate the elements of which plants are composed; in other words, we must *take them apart*, and examine the different pieces of which they are formed.

What must we do to learn the

If we burn any vegetable substance it disappears, except a small quantity of earthy matter, which we call *ashes*. In this way we make an important division in the constituents of plants. One portion dissipates into the atmosphere, and the other remains as ashes.

composition of plants?

That part which burns away during combustion is called *organic matter*; the ashes are called *inorganic matter*. The organic matter has become air, and hence we conclude that it was originally obtained from air. The inorganic matter has become earth, and was obtained from the soil.

What takes place when vegetable matter is burned?

What do we call the two divisions produced by burning?

This knowledge can do us no good except by the assistance of chemistry, which explains the properties of each part, and teaches us where it is to be found. It is not necessary for farmers to become chemists. All that is required is, that they should know enough of chemistry to understand the nature of the materials of which their crops are composed, and how those materials are to be used to the best advantage.

Where does organic matter originate? Inorganic?

How much of chemistry should farmers know?

This amount of knowledge may be easily acquired, and should be possessed by every person, old or young, whether actually engaged in the cultivation of the soil or not. All are dependent on vegetable productions, not only for food, but for every comfort and convenience of life. It is the object of this book to teach children the first principles of agriculture: and it contains all that is absolutely necessary to an understanding of the practical operations of cultivation, etc.

Is organic matter lost after combustion?

We will first examine the *organic* part of plants, or that which is driven away during combustion or burning. This matter, though apparently lost, is only changed in form.

Of what does it consist?

How large a part of plants is carbon?

It consists of one solid substance, *carbon* (or charcoal), and three gases, *oxygen*, *hydrogen* and *nitrogen*. These four kinds of matter constitute nearly the whole of most plants, the ashes forming often less than one part in one hundred of their dry weight.

What do we mean by gas?

Does oxygen unite with other substances?

Give some instances of its combinations

When wood is burned in a close vessel, or otherwise protected from the air, its carbon becomes charcoal. All plants contain this substance, it forming usually about one half of their dry weight. The remainder of their organic part consists of the three gases named above. By the word gas, we mean *air*. Oxygen, hydrogen and nitrogen, when pure, are always in the form of air. Oxygen has the power of uniting with many substances, forming compounds which are different from either of their constituents alone. Thus: oxygen unites with *iron* and forms oxide of iron or *iron-rust*, which does not resemble the gray metallic iron nor the gas oxygen; oxygen unites with carbon and forms carbonic acid, which is an invisible gas, but not at all like pure oxygen; oxygen combines with hydrogen and forms water. All of the water, ice, steam, etc., are composed of these two gases. We know this because we can artificially decompose, or separate, all water, and obtain as a result simply oxygen and hydrogen, or we can combine these two gases and thus form pure water; oxygen combines with nitrogen and forms nitric acid. These chemical changes and combinations take place only under certain circumstances, which, so far as they affect agriculture, will be considered in the following pages.

As the organic elements of plants are obtained from matters existing in the atmosphere which surrounds our globe, we will examine its constitution.

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ATMOSPHERE.

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Atmospheric air is composed of oxygen and nitrogen. Their proportions are, one part of oxygen to four parts of nitrogen. Oxygen is the active agent in the combustion, decay, and decomposition of organized bodies (those which have possessed animal or vegetable life, that is, organic matter), and others also, in the breathing of animals. Experiments have proved that if the atmosphere consisted of pure oxygen every thing would be speedily destroyed, as the processes of combustion and decay would be greatly accelerated, and animals would be so stimulated that death would soon ensue. The use of the nitrogen in the air is to *dilute* the oxygen, and thus reduce the intensity of its effect.

What is atmospheric air composed of?

In what proportions?

What is the use of nitrogen in air?

Does the atmosphere contain other matters useful to vegetation?

What are they?

Besides these two great elements, the atmosphere contains certain impurities which are of great importance to vegetable growth; these are, *carbonic acid, water, ammonia, etc.*

CARBONIC ACID.

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Carbonic acid is in all probability the only source of the carbon of plants, and consequently is of more importance to vegetation than any other single sort of food. It is a gas, and is not, under natural circumstances, perceptible to our senses. It constitutes about $\frac{1}{2500}$ of the atmosphere, and is found in combination with many substances in nature. Marble, limestone and chalk, are carbonate of lime, or carbonic acid and lime in combination; and carbonate of magnesia is a compound of carbonic acid and magnesia. This gas exists in combination with many other mineral substances, and is contained in all water not recently boiled. Its supply, though small, is sufficient for the purposes of vegetation. It enters the plant in two ways—through the roots in the water which goes to form the sap, and at the leaves, which absorb it from the air in the form of gas. The leaf of the plant seems to have three offices: that of absorbing carbonic acid from the atmosphere—that of assisting in the chemical preparation of the sap—and that of evaporating its water. If we examine leaves with a microscope we shall find that some have as many as 170,000 openings, or mouths, in a square inch; others have a much less number. Usually, the pores on the under side of the leaf absorb the carbonic acid. This absorptive power is illustrated when we apply the lower side of a cabbage leaf

What is the source of the carbon of plants?

What is carbonic acid?

What is its proportion in the atmosphere?

Where else is it found?

How does it enter the plant?

What are the offices of leaves?

to a wound, as it draws strongly—the other side of the leaf has no such action. Young sprouts may have the power of absorbing and decomposing carbonic acid.

What parts of roots absorb food?

How much of their carbon may plants receive through their roots?

The roots of plants terminate at their ends in minute spongioles, or mouths for the absorption of fluids containing nutriment. In these fluids there exist greater or less quantities of carbonic acid, and a considerable amount of this gas enters into the circulation of the plants and is carried to those parts where it is required for decomposition. Plants, under favorable circumstances, may thus obtain about one-third of their carbon.

What change does carbonic acid undergo after entering the plant?

In what parts of the plant, and under what influence, is carbonic acid decomposed?

Carbonic acid, it will be recollected, consists of *carbon and oxygen*, while it supplies only *carbon* to the plant. It is therefore necessary that it be divided, or decomposed, and that the carbon be retained while the oxygen is sent off again into the atmosphere, to reperform its office of uniting with carbon. This decomposition takes place in the *green* parts of plants and only under the influence of daylight. It is not necessary that the sun shine directly on the leaf or green shoot, but this causes a *more rapid* decomposition of carbonic acid, and consequently we find that plants which are well exposed to the sun's rays make the most rapid growth.

The fact that light is essential to vegetation explains the conditions of different latitudes, which, so far as the assimilation of carbon is concerned, are much the same. At the Equator the days are but about twelve hours long. Still, as the growth of plants is extended over eight or nine months of the year, the duration of daylight is sufficient for the requirements of a luxuriant vegetation. At the Poles, on the contrary, the summer is but two or three months long; here, however, it is daylight all summer, and plants from continual growth develop themselves in that short time.

Explain the condition of different latitudes.

Does the proportion of carbonic acid in the atmosphere remain about the same?

It will be recollected that carbonic acid constitutes but about $^1/_{2500}$ of the air, yet, although about one half of all the vegetable matter in the world is derived from this source, as well as all of the carbon required by the growth of plants, its proportion in the atmosphere is constantly about the same. In order that we may understated this, it becomes necessary for us to consider the means by which it is formed. Carbon, by the aid of fire, is made to unite with oxygen, and always when bodies containing carbon are burnt *with the presence of atmospheric air*, the oxygen of that air unites with the carbon, and forms carbonic acid. The same occurs when bodies containing carbon *decay*, as this is simply a slower *burning* and produces the same results. The respiration (or breathing) of animals is simply the union of the carbon of the blood with the oxygen of the air drawn into the lungs, and their breath, when thrown out, always contains carbonic acid. From this we see that the reproduction of this gas is the direct effect of the destruction of all organized bodies, whether by fire, decay, or consumption by animals.

Explain some of the operations in which this reproduction takes place.

How is it reproduced?

Furnaces are its wholesale manufactories. Every cottage fire is continually producing a new supply, and the blue smoke issuing from the cottage-chimney, as described by so many poets, possesses a new beauty, when we reflect that besides indicating a cheerful fire on the hearth, it contains materials for making food for the cottager's tables and new faggots for his fire. The wick of every burning lamp draws up the carbon of the oil to be made into carbonic acid at the flame. All matters in process of combustion, decay, fermentation, or putrefaction, are returning to the atmosphere those constituents, which they obtained from it. Every living animal, even to the smallest insect, by respiration, spends its life in the production of this material necessary to the growth of plants, and at death gives up its body in part for such formation by decay.

Thus we see that there is a continual change from the carbon of plants to air, and from air back to plants, or through them to animals. As each dollar in gold that is received into a country permanently increases its amount of circulating medium, and each dollar sent out permanently decreases it until returned, so the carbonic acid sent into the atmosphere by burning, decay, or respiration, becomes a permanent stock of constantly changeable material, until it shall be locked up for a time, as in a house which may last for centuries, or in an oak tree which may stand for thousands of years. Still, at the decay of either of these, the carbon which they contain must be again resolved into carbonic acid.

What are the coal-beds of Pennsylvania?

What are often found in them?

The coal-beds of Pennsylvania are mines of carbon once abstracted from the atmosphere by plants. In these coal-beds are often found fern leaves, toads, whole trees, and in short all forms of organized matter. These all existed as living things before the great floods, and at the breaking away of the barriers of the immense lakes, of which our present lakes were merely the deep holes in their beds, they were washed away and deposited in masses so great as to take fire from their chemical changes. It is by many supposed that this fire acting throughout the entire mass (without the presence of air *to supply oxygen* except on the surface) caused it to become melted carbon, and to flow around those bodies which still retained their shapes, changing them to coal without destroying their structures. This coal, so long as it retains its present form, is lost to the vegetable kingdom, and each ton that is burned, by being changed into carbonic acid, adds to the ability of the atmosphere to support an increased amount of vegetation.

Explain the manner in which they become coal.

Thus we see that, in the provisions of nature, carbon, the grand basis, on which all organized matter is founded, is never permanent in any of its forms. Oxygen is the carrier which enables it to change its condition. For instance, let us suppose that we have a certain quantity of charcoal; this is nearly pure carbon. We ignite it, and it unites with the oxygen of the air, becomes carbonic acid, and floats away into the atmosphere. The wind carries it through a forest, and the leaves of the trees with their millions of mouths drink it in. By the assistance of light it is decomposed, the oxygen is sent off to make more carbonic acid, and the carbon is retained to form a part of the tree. So long as that tree exists in the form of wood, the carbon will remain unaltered, but when the wood decays, or is burned, it immediately takes the form of carbonic acid, and mingles with the atmosphere ready to be again taken up by plants, and have its carbon deposited in the form of vegetable matter.

How does the burning of coal benefit vegetation?

Is carbon ever permanent in any of its forms?

What enables it to change its condition?

The blood of animals contains carbon derived from their food. This unites with the oxygen of the air drawn into the lungs and forms carbonic acid. Without this process, animals could not live. Thus, while by the natural operation of breathing, they make carbonic acid for the uses of the vegetable world, plants, in taking up carbon, throw off oxygen to keep up the life of animals. There is perhaps no way in which we can better illustrate the

Give an instance of such change.

How do plants and animals benefit each other?

Describe the experiment with the glass tube.

changes of form in carbon than by describing a simple experiment.

Take a glass tube filled with oxygen gas, and put in it a lump of charcoal, cork the ends of the tube tightly, and pass through the corks the wires of an electrical battery. By passing a stream of electrical fluid over the charcoal it may be ignited, when it will burn with great brilliancy. In burning it is dissolved in the oxygen forming carbonic acid, and disappears. It is no more lost, however, than is the carbon of wood which is burned in a stove; although invisible, it is still in the tube, and may be detected by careful weighing. A more satisfactory proof of its presence may be obtained by *decomposing* the carbonic acid by drawing the wires a short distance apart, and giving a *spark* of electricity. This immediately separates the oxygen from the carbon which forms a dense black smoke in the tube. By pushing the corks together we may obtain a wafer of charcoal of the same weight as the piece introduced. In this experiment we have changed carbon from its solid form to an invisible gas and back again to a solid, thus fully representing the continual changes of this substance in the destruction of organic matter and the growth of plants.

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HYDROGEN, OXYGEN AND NITROGEN.

HYDROGEN AND OXYGEN.

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What is water composed of?

If analyzed, what does it yield?

How do plants obtain their hydrogen and oxygen?

Let us now consider the three gases, *hydrogen*, *oxygen* and *nitrogen*, which constitute the remainder of the organic part of plants.

Hydrogen and oxygen compose *water*, which, if analyzed, yields simply these two gases. Plants perform such analysis, and in this way are able to obtain a sufficient supply of these materials, as their sap is composed chiefly of water. Whenever vegetable matter is destroyed by burning, decay, or otherwise, its hydrogen and oxygen unite and form water, which is parted with usually in the form of an invisible vapor. The atmosphere of course contains greater or less quantities of watery vapor arising from this cause and from the evaporation of liquid water. This vapor condenses, forming rains, etc.

Hydrogen and oxygen are never taken into consideration in manuring lands, as they are so readily obtained from the water constituting the sap of the plant, and consequently should not occupy our attention in this book.

NITROGEN.

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Nitrogen, the only remaining *organic* constituent of vegetable matter, is for many reasons worthy of close attention.

If vegetable matter be destroyed, what becomes of these constituents?

What is the remaining organic constituent?

1. It is necessary to the growth and perfection of all cultivated plants.

2. It is necessary to the formation of animal muscle.

3. It is often deficient in the soil.

4. It is liable to be easily lost from manures.

Why is it worthy of close attention?

Although about four fifths of atmospheric air are pure nitrogen, it is almost certain that plants get no nutriment at all from this source. It is all obtained from some of its compounds, chiefly from the one called ammonia. Nitric acid is also a source from which plants may obtain nitrogen, though to the farmer of less importance than ammonia.

Do plants appropriate the nitrogen of the atmosphere?

AMMONIA.

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What is the principal source from which they obtain nitrogen?

Ammonia is composed of nitrogen and hydrogen. It has a pungent smell and is familiarly known as *hartshorn*. The same odor is perceptible around stables and other places where animal matter is decomposing. All animal muscle, certain parts of plants, and other organized substances, consist of compounds containing nitrogen. When these compounds undergo combustion, or are in any manner decomposed, the nitrogen which they contain usually unites with hydrogen, and forms ammonia. In consequence of this the atmosphere always contains more or less of this gas, arising from the decay, etc., which is continually going on all over the world.

What is ammonia?

How is it formed?

Where does it always exist?

How do plants take up ammonia?

This ammonia in the atmosphere is the capital stock to which all plants, not artificially manured, must look for their supply of nitrogen. As they can take up ammonia only through their roots, we must discover some means by which it may be conveyed from the atmosphere to the soil.

Water may be made to absorb many times its bulk of this gas, and water with which it comes in contact will immediately take it up. Spirits of hartshorn is merely water through which ammonia has been passed until it is saturated.[A] This power of water has a direct application to agriculture, because the water constituting rains, dews, &c., absorbs the ammonia which the decomposition of nitrogenous matter had sent into the atmosphere, and we find that all rain, snow and dew, contain ammonia. This fact may be

Does water absorb it?

What is spirits of hartshorn?

Why is this power of water important in agriculture?

What instance may be cited to prove this?

chemically proved in various ways, and is perceptible in the common operations of nature. Every person must have noticed that when a summer's shower falls on the plants in a flower garden, they commence their growth with fresh vigor while the blossoms become larger and more richly colored. This effect cannot be produced by watering with spring water, unless it be previously mixed with ammonia, in which case the result will be the same.

Although ammonia is a gas and pervades the atmosphere, few, if any, plants can take it up, as they do carbonic acid, through their leaves. It must all enter through the roots in solution in the water which goes to form the sap. Although the amount received from the atmosphere is of great importance, there are few cases where artificial applications are not beneficial. The value of farm-yard and other animal manures, depends chiefly on the ammonia which they yield on decomposition. This subject, also the means for retaining in the soil the ammoniacal parts of fertilizing matters, will be fully considered in the section on manures.

Can plants use more ammonia than is received from the atmosphere?

On what does the value of animal

After ammonia has entered the plant it may be decomposed, its hydrogen sent off, and its nitrogen retained to answer the purposes of growth. The changes which nitrogen undergoes, from plants to animals, or, by decomposition, to the form of ammonia in the atmosphere, are as varied as those of carbon and the constituents of water. The same little atom of nitrogen may one year form a part of a plant, and the next become a constituent of an animal, or, with the decomposed dead animal, may form a part of the soil. If the animal should fall into the sea he may become food for fishes, and our atom of nitrogen may form a part of a fish. That fish may be eaten by a larger one, or at death may become food for the whale, through the marine insect, on which it feeds. After the abstraction of the oil from the whale, the nitrogen may, by the putrefaction of his remains, be united to hydrogen, form ammonia, and escape into the atmosphere. From here it may be brought to the soil by rains, and enter into the composition of a plant, from which, could its parts speak as it lies on our table, it could tell us a wonderful tale of travels, and assure us that, after wandering about in all sorts of places, it had returned to us the same little atom of nitrogen which we had owned twenty years before, and which for thousands of years had been continually going through its changes.

manure chiefly depend?

What changes take place after ammonia enters the plant?

May the same atom of nitrogen perform many different offices?

Is the same true of the other constituents of plants?

Is any atom of matter ever lost?

The same is true of any of the organic or inorganic constituents of plants. They are performing their natural offices, or are lying in the earth, or floating in the atmosphere, ready to be lent to *any* of their legitimate uses, sure again to be returned to their starting point.

Thus no atom of matter is ever lost. It may change its place, but it remains for ever as a part of the capital of nature.

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[A] By *saturated*, we mean that it contains all that it is capable of holding.