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THE CULTURE
OF
FARM CROPS.

A Manual
OF THE
SCIENCE OF AGRICULTURE,
AND A
HAND-BOOK OF PRACTICE
FOR
AMERICAN FARMERS.

BY HENRY STEWART,

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"The Shepherd's Manual," "Irrigation for the Farm, Orchard and Garden,"

Civil Mining and Agricultural Engineer.

Member of the Western Society of Engineers.

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The Culture of Farm Crops.

PART FIRST.

CHAPTER I.

THE ART OF AGRICULTURE.—IMPORTANCE OF A KNOWLEDGE OF ITS PRINCIPLES.

No farmer can be successful in the pursuit of his industry without a knowledge of the principles upon which the practice of it is founded. Every work of the farm has more or less of mystery attached to it. No other art, among all the industries of the human race is so intricate or has so many varying conditions and circumstances environing and affecting it. The soil, the season, the character of the plants grown, the time and manner of their cultivation; the air, water and mineral matters which furnish them with food; and many other things related to these; are all involved in an inextricable maze and mystery to the farmer who knows nothing of them or their relations to and reactions upon each other. But these mysteries are unfolded in the most beautiful and interesting manner, and the laws which relate to the growth of plants are seen to form a system which gradually develops—as the farmer progresses in this study—into form and method from which rules may be laid down for his guidance; or from which he may form his own rules and practice as any emergency may arise.

When principles are known and understood, one may form his own practice. Otherwise he is the slave and the victim to the innumerable accidents which befall him in the various operations of the farm, which are controlled in

a great measure by the qualities and characters of different soils; by temperature, moisture, the action of the various manures and fertilizers—not only upon the soil and the crops, but upon each other—the habits of the plants, and the vicissitudes of the season. But when the farmer has a sufficient knowledge of these and of the laws which control their action, he is able to guide himself through the labyrinth, just as the sailor steers his ship safely among the rocks and shoals which environ his desired port, by the aid of the chart which lies before him, and his knowledge of the currents which sweep about them. For a farmer to succeed, and grow large crops, without this knowledge of his art, is as impossible as for the sailor to reach his port in darkness, without a compass or a chart, and wholly ignorant of his bearings, and the obstacles in his way. That so few farmers wholly fail in their business is a proof not to the contrary of this, but to the rich rewards which the prolific soil offers to man's labor and industry, and of which a moderate share only is sufficient for all his needs; but the whole of which brings competence and wealth to the most skillful and studious farmers.

It is about forty years since agricultural knowledge took a scientific turn, and students began to search for the causes of the results which they reached by the slow process of a life long practical service in the field. Then a young man had to learn slowly, day by day, and year by year, often waiting many years to verify, through repeated contradictions, any facts which he learned by the closest observation. All the gathered lore of the most successful farmers was then comprised in a very few books, and some popular beliefs, current only verbally, and handed from one to another amid dispute and contradiction. The old writers upon agricultural topics merely repeat what they learned from the results of their practice; they wrote of manures from what they had seen of the results of their use; but they had no conception of the fact that manures supplied the crops with certain elements which were absorbed into their substance and became a part of them.

Not a farmer of that day, nor a chemist, knew that bones furnished phosphoric acid to plants; or that guano provided in its ammonia the materials from which their gluten and other nitrogenous substances were derived. Indeed the renowned father of agricultural science: Liebig—when he propounded his mineral theory, which was that the ashes of plants contained everything which they drew from the soil, and that if the mineral substances contained in the ashes, were supplied in sufficient quantity to the crops, there would be scarcely a limit to the product, excepting the space in which they were contained—knew nothing about the invaluable nitrogen which we now know to be wholly indispensable to plant growth. But light has gradually dawned upon us, and by slow and sometimes faltering progress, there has been built up a system of agricultural science which explains the laws of plant growth and affords the most important information to the cultivator of the soil.

Science is based upon fact. Philosophy is based upon speculation. Science is the outgrowth of philosophy, because before we can reach a true knowledge of any fact we must approach the study of it by a well devised theory, changed as may be necessary, and tested patiently and slowly until the knowledge sought is found. This knowledge, when verified by practice, sufficiently proved and classified, becomes science. Science then is nothing for the farmer to fear, or cast doubt and suspicion upon. Theory as has been said, has no part or lot in it; it is a summary of known facts, and is therefore of the most valuable use to the farmer as it gives him a sound basis upon which to build up such conclusions in regard to his practice as will enable him to meet the various difficulties which are always arising in his work.

Nor need the farmer be afraid of science because of any difficulty in comprehending it. Truth is very simple, and is so plain that he who runs may read. And there is nothing in agricultural science, and nothing will be offered in the pages to follow, that would give any difficulty to any

farmer's boy, or girl to understand and comprehend, to its full extent.

Nothing need be said of the importance of the farmers vocation further than as it relates to his own interest. While he feeds and clothes the world, he is most interested in feeding and clothing himself, and in advancing his own condition as far as possible. Society exists now upon a much higher base than it did a score of years ago. Education and intelligence have made necessary a much higher civilization, and a more luxurious and less laborious living. All this calls for increased income. Scientific skill in any art necessarily increases the value of the labor expended and enhances the profits of it. This is true of agriculture as of all other arts. Hence the farmer is compelled by the general advance of other industries to advance his own. He can only do this by increasing the products of his labor by means of more skillful work, and the help of every appliance. Better culture, better manuring, better mechanical aids in the form of improved implements and machinery, and an economical division of labor, are all indispensable to him. The culture of farm crops, then becomes a most important subject for study and critical examination and whatever in the study can be turned to practical use should be adopted into practice. The age is advancing in every way; but agriculture lingers behind, perhaps because of its vastness and the unavoidable inertia and slow movement of vast interests. But it must advance with the world. Mechanical ingenuity has given it a wonderful impetus and from the far better hoes of the present time, to the gigantic twelve-wheeled locomotives and the great ocean steam ships which are at his service, the farmer is helped in a thousand ways. Then he must improve his own work consistently and stand in the front as becomes the feeder of the world and the importance of his vocation.

In every other country than ours, the vast importance of agriculture is recognized by the general governments, and the investigation of the principles upon which the rational practice of the art is founded, is made a prominent care of

the state and commands the principal attention of the leading men. Here the citizen is less closely involved in the affairs of government, and looks after his own class interests himself. An American citizen glories in his independence, but in this case he suffers considerably as compared with farmers in other countries. There is then all the more need of private and personal enterprise among farmers. American farmers are better educated, read more and are better able to advance their own interests by skillful industry and untiring energy than any others. Hence, technical literature of the highest class abounds, and agriculture is well represented in it. And these pages are offered as a modest contribution of a farmer and student to this literature, and to his brother farmers and students.

CHAPTER II.

KINDS^o AND CONDITIONS OF MATTER.—THE ELEMENTARY CONSTITUENTS OF PLANTS.

All matter in existence, presents itself to our view in two forms only. The solid rock, the water of the ocean, the atmosphere, the plants which clothe the earth's surface and the animals which move over it; are all formed of two kinds of matter which are called organic and inorganic. Of all these everything which is and has been devoid of life, is classed under the head of inorganic substances; while living bodies whether plants or animals or the remains of these, are classed as organic matter. There are cases in which the two classes seem to approach very closely if not to mingle; but this is only apparently and not in fact, for the distinction between them is broad and marked and must appear on a close examination. This distinction is life. Anything which has lived, which has performed any of the various functions of life however simple and low in character these may have been, is organic matter; and all else is inorganic. Thus while the rocks and the soil are classed among inorganic substances, yet the coal which we find imbedded deep in the bowels of the earth, or the soft porous sand or fine clay which is known as infusorial earth, or the limestone which is made up of an infinite number of the skeletons and shells of microscopic animals, are organic substances; because the coal has been formed from various mosses and ferns, with the larger plants and great trees, which have lived and died and fallen and have in time been buried under the soil brought by vast floods, and have formed the beds of coal now lying under thousands of feet in thickness of rocks. And the minute insects which have lived and died in the primeval oceans have all been endowed with life; although they appear to the casual obser-

ver as mere stony or earthy matter. All organic matter, shows on examination, a certain structure or form which is visible to the eye or can be made so. This structure is either cellular or fibrous, as may be seen in the pores of wood or the fibers of various plants, and of muscular tissue; and it serves to distinguish between these two classes of matter.

But there are many substances of organic origin which do not exhibit any observable trace of organized structure; as sugar, starch, gum, and yet these are formed in plants in great abundance. They do not possess any cellular or fibrous tissue and have never possessed any organs; nevertheless as they are the productions of living organized bodies, they are included in the general term of organized matter. So the ash of plants which consists of mineral matter only; and the decomposed dust of plants and animals are recognized as organic matter, and as such, have a specially favorable effect in the soil upon the growth of plants. So all the ultimate products of organic matter; the charcoal made from wood, the vinegar, spirit, and tar, also derived from wood by distillation; and the vinegar and alcohol which are produced by the fermentation of sugar; are all included in the general term as organized matter.

The cells and fibers of organic matter are in fact the organs or instruments of life by which the vital functions are performed and growth effected. Thus the pores of wood or the cells of a potato are centers of life, and as will be hereafter explained, are able to effect a distinct reproductive action; absorb nutriment, grow and produce organs like themselves, and so increase the substance of the plants of which they form a part.

If we take any one of these forms of matter of either class, excepting comparatively a few, and subject it to certain chemical processes we shall find that it is resolved or separated into more than one, or several substances, as the case may be. Thus a piece of limestone subjected to heat—which is a chemical process—undergoes a very considerable change by the separation of its component parts;

carbonic acid and lime; and these by further process, but much more difficult, can be separated into carbon and oxygen and the metal calcium and oxygen. If an attempt is made to separate or resolve these further, it is fruitless and we find these substances remain unchangeable under every known chemical process; and they remain, carbon and oxygen and calcium. These ultimate unchangeable substances, are called elementary bodies; and those which are formed by the union of two or more of them are called compound bodies. There are now in existence sixty-five known and recognized elementary substances; but the compound bodies which exist and are formed by combinations of the elementary bodies, are infinite in their variety. The rocky and earthy crust of the globe, the ocean which bathes it, the atmosphere which envelopes it, the plants which grow upon it, and the animals which cover the face of it; are all made up of diversified forms of matter which are absolutely innumerable. A man can no more count them than he can number the sand upon the sea shore. It is one of those wonders of nature, which appeal so strongly and in a manner so full of interest to the farmer as he goes about his daily labors, with observant eye and thoughtful mind, that these infinitely varied forms of matter, which are—so to speak—the raw materials from which he is enabled to elaborate by his skillful use of nature's forces, all the vegetable and animal products of his farm; are made up of a few only of the sixty-five elementary substances, by a most intricate system of combinations. This is sufficiently surprising, yet it is far more amazing that nearly the entire mass of these vegetable and animal products consists of, and may be resolved into one or more of only four of these simple substances.

When any vegetable or animal substance is destroyed—as is commonly said—but more correctly decomposed, or resolved into its elements by intense heat and combustion, it either entirely disappears, or leaves behind it a very small quantity of ash. Oils, fats, gum, sugar, starch, cotton fiber, wool, horn, hair, when burned, either disappear en-

entirely or leave an insignificant remnant behind; while wood or flesh leaves but little more of earthy matter or ash unconsumed. All that has disappeared of these substances consist generally of three of the elementary bodies, and rarely of four; while of all agricultural products the greater part, inclusive of the combustible and incombustible portions together, is made up of no more than twelve. The four bodies referred to are carbon, oxygen, hydrogen, and nitrogen. The twelve consist of these four, and calcium, chlorine, magnesium, phosphorous, potassium, silicon, sodium and sulphur.

An acquaintance then with the most important four elements mentioned is indispensable to the farmer; for it is quite impossible for him to comprehend the laws which govern the operations of nature in the growth of plants, or the reasons why he adopts certain processes in his farm work to aid and facilitate these natural operations, without a previous knowledge of the nature of these elements and their reactions upon each other. And at the same time it is of the greatest interest to him that he should have some knowledge at least of the nature of the other eight elementary substances which enter more or less into the ash or incombustible mineral portion of the plants which he cultivates.

A brief consideration of the properties of these four elements which make up the organic constituents of plants and of the eight which go to make up their inorganic substance, will lead the way for a study of the means whereby, and the manner in which, they enter into the circulation of plants and form their substance.

CHAPTER III.

CARBON.—ITS PROPERTIES AND RELATIONS TO VEGETABLE LIFE.

Carbon, a word derived from the latin *carbo*, coal, is the name given to a mineral substance which occurs in an inorganic condition in the diamond, in graphite or plumbago (commonly called black lead) in bitumen, petroleura, amber and a number of mineral resins, and in an organic condition as charcoal, mineral coal, lampblack, soot, etc. Its three best marked forms are the diamond which is pure carbon; graphite; which is found sometimes nearly pure, but mostly mixed with more or less iron; and charcoal which contains a small proportion of mineral matters which form the ash of the wood of which the charcoal is made. An interesting form of vegetable carbon is the fiber of the cotton plant which is almost pure.

Carbon forms a large proportion of the substance of vegetable matter when it is freed from water; amounting to from forty to fifty per cent. by weight of all the parts of plants grown as farm crops. It therefore performs an important part in the growth of plants and becomes an interesting subject of study for the farmer.

The diamond is the hardest substance known, and resists a high degree of heat, but is combustible at a very high temperature. When made red hot, and placed in a vessel of pure oxygen, it burns with a brilliant steady glow, combining with the oxygen and forming carbonic acid. It has been artificially, but accidentally produced, in iron furnaces in which charcoal has been used as fuel; but in every other way it has resisted all the efforts of the chemists to produce it. Sir Isaac Newton predicted that the diamond would prove to be of organic origin and this has some show of probability from the fact that on burning

the crystals a residue of ash has remained in the form of a cellular net work.

Graphite is a well known and useful mineral which although seemingly very soft, its particles are so hard as to wear out with great rapidity the steel saws with which it is cut. It is produced artificially in charcoal iron furnaces and in the manufacture of coal gas.

Charcoal is the form in which carbon appears of the most interest to the farmer, because it is derived from vegetable matter, chiefly from wood, although it is made from peat, by charring it in heaps covered with earth and thus protected from the oxygen of the atmosphere which would change it into carbonic acid. It is brittle, black, tasteless, and inodorous; and perfectly insoluble. Its perfect insolubility disproves the common impression that it can be used as a fertilizer or as plant food in any manner; but its peculiar behavior with other substances does give it an indirect agency in this way. It resists the action of the air as well as of moisture, hence it is almost indestructible.

The charred remains of timber, and of wheat and rye grains which have been found in the ruins of Herculaneum where they have remained unchanged for eighteen hundred years proves its unchangeable character. This property of charcoal has been made use of in preparing posts to be set in the ground by charring them, by which they are made exceedingly durable. When pure and dry, charcoal burns without any flame; the light blue flame sometimes seen when it is burned, is caused by the combustion of water of which it absorbs, in the form of vapor from the atmosphere, from ten to twenty per cent. in a single week's exposure.

Having the porous structure of the wood or peat from which it may be prepared, charcoal possesses a remarkable power of absorbing gases and of condensing them in its pores; hence it becomes at times of much value in the soil, and it is to this fact that its notable effect upon vegetation is due. This effect is the dark green color of the herbage

and the luxuriance of the vegetation in its vicinity; caused doubtless by its absorption of ammonia. It will absorb ninety times its bulk of this gas, thirty-five times its bulk of carbonic acid, and nine times its bulk of oxygen. Charcoal made from the hard and dense woods exerts this absorbing power in the greatest degree; having as much as one hundred square feet of surface in its exceedingly fine pores, in every cubic inch. This power to condense gases gives it a very great importance in agriculture in various ways. It absorbs noxious gases and offensive odors, and when crushed so as to expose its greatest absorbing surface will filter water and purify it from foul matter, and restore tainted meat to its former sweetness. It will absorb the deadly carbonic acid which accumulates in wells and pits, and thus remove the danger of loss of life in entering such places. It will purify and remove the dark color from cider, syrups, wines and vinegars, and is thus used to a large extent.

Charcoal is thus a powerful disinfectant as well as a deodorizer; for by condensing in its pores noxious vapors and gases, it removes poisonous substances from the air and avoids the danger of fatal diseases. It however does not act as an antiseptic and prevent decomposition, but hastens it, by absorbing oxygen, which is the most active agent of decomposition; and which rapidly destroys organic matter; but while thus accelerating the decay of substances which are brought into contact with it, it prevents all offensive results by continually seizing upon these products and causing their immediate oxidation. This process goes on continually and thus a small quantity of powdered charcoal may have a surprisingly disproportionate effect. It is turned into valuable use in this way by surgeons for poultices to corrode and decompose sloughing and gangrenous flesh, in malignant sores and in serious wounds. It changes ammonia into nitric acid and thus serves a most useful purpose as an ingredient of manure heaps and composts; preventing the loss of valuable ammonia and changing it into the stable forms of nitric acid

and nitrates. It also changes the disgustingly offensive sulphuretted hydrogen of decaying manure and other organic matter, into sulphuric acid, and thus removes a sometimes intolerable nuisance of barn yards and hog pens to uninitiated passers on the road.

Humus is another form of carbon, although an impure one, which deserves notice. It is the decomposed remains of vegetable matter which has undergone the slow process of decay—a kind of combustion and oxidation—in the open air. It exists in swamps in the form of peat and black porous soil; in woods as a dark spongy mass on the surface, covering the lower soil, and wherever a mass of vegetation has slowly decayed. The leaf mold so much prized by gardeners is chiefly humus.

When the woody matter of plants, large and small alike, is exposed to moisture and air, it undergoes a slow decomposition, in which oxygen is absorbed. It is in fact precisely similar in its operation and effects to a slow combustion or charring, although accompanied by so small a quantity of heat as to be almost imperceptible. With the absorption of oxygen and its combination with a portion of the carbon, carbonic acid is formed. Some of the oxygen also combines with hydrogen and forms water; but as the hydrogen is taken first, a large portion of carbon remains and the mass gradually assumes a dark brown or black color and becomes what is termed: "vegetable mold." To this crumbled porous substance the term humus is applied. It contains various acids, as geic, ulmic and humic acids. This class of substances is of great importance in agriculture, as by their decomposition they yield up carbonic acid to plants, and have the power of absorbing and retaining ammonia to be yielded up for the same purpose.

Carbonaceous matter gradually accumulates in soils that are always covered with vegetation, as in forests, pastures and prairies. This is a conclusive proof that the carbon of it is derived from the atmosphere, and that growth is more rapid than decay. When land is brought under cultivation this carbonaceous matter is consumed by the crops

and unless it is restored by a course of good culture, by plowing under green crops, or by furnishing manure to the soil, or by cultivating such crops as clover and grass which leave a large amount of vegetable matter behind them in their roots, the land is gradually exhausted and becomes unable to produce profitable crops. A crop of clover has been found to leave in the soil more than three tons weight of roots, while the roots left by wheat do not amount to one-fifth of this quantity. Hence we have the explanation of the deep rich soils of newly cleared forest land, of drained swamps, and of the western prairies, as well as of the valuable effects of clover upon the land.

CHAPTER IV.

OXYGEN.—ITS PROPERTIES AND RELATIONS TO LIFE.

Oxygen is the most remarkable and important of all the elementary substances. It is a gas. This term gas was first used in the seventeenth century and is a reminder not only of the origin of a great part of our present chemical knowledge, but of the superstitions of the early periods of chemical investigation; and of the recent emancipation of chemistry from those superstitions. The early chemists, known as alchemists, who believed in such notions, as the existence of an "elixir" or fluid, which would make man immortal; and of a substance which could transmute all the base metals to gold, and which they termed the "philosophers stone," were surprised and alarmed by the sudden explosions of their retorts, often accompanied by the violent death of the experimenters, or of the sulphurous exhalation and fumes which produced suffocation. They were led to believe in their ignorance that these disasters were due to the agency of spirits which refused to be imprisoned and brought under the power of their tormentors, and burst the vessels and slew the operators in revenge. The alchemists therefore began their work with prayers and marked their vessels with the holy cross from which we have had brought down to us the word "crucible;" a vessel in which substances are subjected to great heat for the purpose of procuring their decomposition. Hence we have the origin of the terms spirits; as spirits of wine, spirits of nitre, etc., and also the term gas; which was derived from the German *gahst*, a ghost or spirit.

Oxygen is a recent discovery, having been first discovered in 1774 by Dr. Priestly. Its discovery was claimed by the French chemist Lavoisier; but the honor is generally accorded to Priestly. Its discovery, like all others of that and

previous periods, was the result of an accidental submission of the red oxide of mercury to the rays of the sun concentrated by a lens or burning glass. It is an interesting coincidence that the sun, the central focus of the chemical action of the universe, should be the agent by which the most potent of chemical agencies should have been brought to the knowledge of mankind.

This discovery may well be classed as the most important in the history of human knowledge, rivaling the great discovery of gravitation by Newton in the preceding century, and throwing floods of light upon the investigations of the mysteries of what we call nature. Of the discovery of this potent substance, Prof. Liebig has observed that "it has produced a revolution in the manners and customs of mankind. With it are linked, as results, our knowledge of the composition of the atmosphere, of water, of the solid crust of the earth, and of the influence of these upon the existence and life of plants and animals. Every human industry has been affected by it; all trades and manufactures and by no means least agriculture, have been aided and advanced immeasurably by our knowledge of it." The study of its properties may be made a profitable and most interesting pursuit in the farmers household, in the leisure hours which may be devoted to the acquisition of all useful knowledge connected with his vocation, and no better subject could be selected for the most pleasing and instructive experiments. It is easily procured and managed by means of simple and cheap apparatus.

Oxygen is a transparent, colorless, tasteless, inodorous gas, one-tenth heavier than the atmosphere of which it forms 23 per cent. of its weight. It has never been condensed into a liquid. It exerts a weak magnetic force which is supposed to cause, or to be concerned in, the daily fluctuations of the magnetic needle; and this property varies with its temperature. It is slightly soluble in water, $4\frac{1}{2}$ parts of it being absorbed by 100 parts of water.

It is neutral, possessing neither acid nor alkaline qualities, and although mild and bland, it exerts the most amazing

power in its combinations. It combines with every other substance and produces the most diverse and opposite compounds. With some substances it forms gases, with others liquids or solids; with some it forms acids of the most corrosive quality; with others it forms alkalies equally corrosive; while a union of two of these—an acid and an alkali—often forms neutral compounds perfectly bland and innoxious. An instance may be given. With sulphur, oxygen forms sulphuric acid, the intensely burning and destructive “oil of vitriol” as it is commonly called. With calcium—a metal—it forms caustic lime, an intensely acrid and destructive alkali, which corrodes and destroys all vegetable and animal substance. These two combined form sulphate of lime, the well known gypsum, an inoffensive and useful compound well known as “plaster” to every farmer.

The oxygen of the air is equally diffused through it in the form of a mixture, and not combined. If this oxygen were to become combined with the other element of the air, all life, of whatever kind it might be, would be destroyed in an instant; for the product of the combination would be that most corrosive substance nitric acid; but as it is only mixed it exerts only a beneficent action in supporting life. All combustion is the result of the action of oxygen, it has a powerful affinity for carbon and the other elements of which fuel is composed and unites with them so violently as to produce the heat and light of our fires and lamps. Combustible substances burn with greatly increased heat and brilliance in pure oxygen, and the reason why a furnace that is supplied with a blast is so intensely hot, is because a large volume of oxygen is forced into it with the increased supply of air. Iron and steel burn with wonderful brilliancy in a jar of oxygen, if tipped with sulphur, and ignited to start the combustion. This combustion is called oxidation and it goes on slowly in the absence of heat; but is always accompanied by some slight rise of temperature. A piece of iron which slowly oxidizes, or rusts away, to a brown powder—which is oxide of iron—is subjected to precisely the same amount of heat in the aggregate, as if burn-

ed in a jar of oxygen or consumed in an intensely heated furnace. The heat and time, in both instances, multiplied together, would produce precisely the same sum. Vegetable matter decomposes or is consumed by the action of oxygen in a similar way. The oxygen breaks up the organic substance into simpler compounds; separating the other elements previously mentioned (see chap. II) and uniting with them; forming carbonic acid with the carbon, water with the hydrogen, nitric acid with the nitrogen, potash with the potassium, soda with the sodium, lime with the calcium, magnesia with the magnesium, phosphoric acid with the phosphorus, silica with the silicon, and sulphuric acid with the sulphur. All of these constituents of plants are thus seen to be composed in part of this common element, which pervades all nature.

Oxygen is the universal supporter of respiration; and plants perform this function in much the same manner as animals. That is, they imbibe air through the pores in their leaves and separate oxygen from it and utilize this in their vital functions. Animals draw it into their lungs where it comes in contact with the blood, then and there loaded with impure matter brought through the veins from the extremities of the system, and oxidizing it changes these impurities, frees the blood from them, and sends the vital fluid back through the arteries, bright, clear and fitted to reinforce and build up the muscular tissue. And this oxidizing effect of this "vital air" as it has been called, is accompanied by a certain elevation of temperature for it is accompanied by a chemical process closely akin to combustion.

The air over every square inch of the earth's surface weighs 15 pounds. Three pounds of this is oxygen. A man consumes by respiration about 2 pounds of oxygen daily. One pound of coal in burning consumes $2\frac{2}{3}$ pounds of oxygen, so that the heat produced in a man's system by the process of respiration is equal to that produced by the combustion of one pound of coal.

Oxygen not only contributes the vital element to the at-

mosphere but it also comprises 8 ninths of the water we drink; water consisting of 8 pounds of oxygen and 1 pound of hydrogen combined. It also forms the larger portion of all the rocks which form the solid crust of the earth. Of these the three chief minerals are lime, silica and alumina, and of these about one-half of the mass consists of oxygen. Thus about one-half of all the mass of the earth and everything upon its surface is made up of this simple element, which no man has ever seen or will probably see; and when this great fact is considered along with the vast force of this all pervading gas, it seems to call to the mind of man a type of eternal existence and resistless power. It is an omnipresent, all powerful spirit, benevolent and destructive at the same time; which holds all nature in its embrace; evolves life and action, and yet revels in consuming fire and is able to reduce all things to death and ashes.

But the vast force of this grand element is controlled and reduced to order and system by the beams of the sun. These are the grand antagonists of oxygen. The solar rays with their genial vivifying warmth bring the dormant forces of vegetable life into action. They start the vital germ into active life. The spire appears and soon brings forth the green leaves. These leaves absorb carbonic acid from the air, rescue the carbon from the grasp of the all devouring oxygen and store it into their cellular tissue. The roots supported by the leaves, extract nutriment from the matter which has been reduced from organized substance by the destroying influence of oxygen and form it again into living organism. What oxygen has decomposed the plants reconstruct; and if this element is the main spring of destruction and decomposition, the solar ray which starts vegetable life into action and gives it vitality, is the still more powerful controlling and counteracting agent and brings life and beauty from death and desolation. An ancient fable tells that Prometheus stole a spark of celestial fire and with it warmed into life an earthly body which he had formed. This is no fable; it is but a poetical fancy which contains in pleasing picturesque form a great truth. Perhaps the

ancient poet realized through some inspiration this fact as yet then unknown, and put it into a form of life and personality. The spark is the sunbeam; which indeed starts dead matter into life and fills the earth with vitality; causing the luxuriant vegetation which in turn supports directly and indirectly every form of animal life. The sunbeam is then the master spirit of the universe; controlling the great agent of destruction and building up again the structures which oxygen reduces to dust.

OZONE.

This subject is too important to leave without a reference to a form of oxygen which plays a most important part in nature and is believed to have some effect upon vegetation. This is called ozone. When an electrical spark is passed through dry air a peculiar odor is perceived. The cause of this was not understood until recently when Prof. Schonbien proved that it was a form of oxygen greatly increased in intensity. It is believed by some chemists that ozone (as it was termed by its discoverer because of its peculiar odor) is formed by the combination of two atoms of oxygen with each other; or in other words, an oxide of oxygen. This substance is therefore of great intensity, equal in force to that of oxygen multiplied by itself. It has an extraordinary energy and produces changes which oxygen is unable to do. It corrodes silver, bleaches colors untouched by oxygen, destroys the odor of tainted flesh instantly, by decomposing the gases which escape from it, and causes the decay of woody fiber with excessive rapidity. It is believed to be the cause of the mysterious souring of milk in dairies which so often occurs after thunder storms, when the peculiar odor of ozone pervades the air. The vivid greenness of the herbage of the meadows after thunder showers is also supposed to be due to the effects of the ozone produced and washed into the soil by the rain.

This substance is readily detected by means of slips of test paper made by soaking them in a mixture of iodide of potassium dissolved in water, and starch. The ozone frees

the iodine from its combination with the potassium and the iodine then instantly acts upon the starch in its usual manner and turns the paper blue. At present very little is known of this substance, its manner of production or its economy in nature, yet its connection with oxygen gives it an importance which calls for its recognition in this treatise.

CHAPTER V.

HYDROGEN AND NITROGEN AND THEIR COMPOUNDS.
THEIR RELATION TO VEGETABLE GROWTH.

Hydrogen, like oxygen, is a colorless, tasteless gas without any odor; slightly soluble in water and exceedingly inflammable. It is never found free, but always in combination, forming one-ninth by weight of water, and a considerable proportion of all organized matter. When combined with nitrogen in the proportion of three parts to one of the latter it forms ammonia, and this compound is always formed during the decomposition of organic matter. Its part in the formation of water by the union of one part with eight parts of oxygen gives to it, its greatest importance in the economy of nature; and its name hydro-gen or "generator of water" is derived from this, its chief property. But it is no more entitled to this name than oxygen is, but received it because it was discovered and became known a few years before oxygen. The English chemist, Cavendish, first discovered it as an element in 1766. The only important solid mineral into whose composition it enters is coal.

This gas is the lightest of all known substances being $14\frac{1}{2}$ times lighter than air, and hence is employed to inflate balloons. It will not support life, but is not noxious; an animal immersed in it dies simply for want of oxygen. When mixed with oxygen and ignited, the gases explode violently and water is formed. It burns when pure with a light blue flame, giving out intense heat, but very little light and also forms water. When mixed with carbon, it forms the common marsh gas, and the fatal fire-damp of coal mines. This gas is produced by the decomposition of vegetable matter and accompanies the fermentation of manure in heaps in the barn yard. When mixed with air it is

explosive, and it then produces the peculiar blue flames which occur by spontaneous combustion as the gas escapes in bubbles from wet marshes. It is also the gas which is found in deep crevices in the rocks far beneath the surface in localities where petroleum exists, and which is sought for by boring, and used for illuminating purposes and for fuel for engine furnaces.

Another compound of carbon with hydrogen is the common gas distilled from coal and used for illuminating purposes. Its more brilliant light is due to the fact that it contains twice as much carbon as the previously mentioned gas.

It also forms a part of all oils, fats, resins and wax; being combined in these with carbon and oxygen in varying proportions. It is a constituent of petroleum and all its products, including the beautiful aniline dyes which are made from it. It also enters into the composition of woody fiber, and the starch, gum, sugar and alcohols, which are products of it; both naturally and artificially. It is thus a most important element, and offers to the studious farmer a subject for study of great interest.

A number of very pleasing experiments may be made with it, such as its production by the decomposition of water; the formation of water by its combustion and union with oxygen; its combustion and oxidation by means of a porous substance, as spongy platinum and the formation of its compounds.

NITROGEN.

This gas was discovered in 1772 by a chemist named Rutherford. It is diffused extensively in nature forming four-fifths of the atmosphere; entering largely into the composition of vegetable and animal substance, and being a most indispensable part of the food of plants and animals. About one-sixth of all animal tissue consists of this gas. It forms a part of many of our powerful medicines, as quinine and morphine, and of the most dangerous poisons as strychnine and prussic acid. It is not found in any of the

rocks excepting those of an organic origin, as coal, which contains 2 or 3 per cent. of it.

Its name signifies the generator of nitre, because it exists largely in this substance in the form of nitric acid and may be produced from it. It may be produced from air by a very simple and beautiful experiment. A small piece of phosphorus is placed in a little saucer and floated on water in a dish or trough; the phosphorus is set on fire and covered with a bell glass. The combustion of the phosphorous produces phosphoric acid by its combination with the oxygen of the air, which is all taken up in this way; this acid is absorbed very quickly by the water and the nitrogen is left. It is then found to be a transparent gas, without color, taste or smell; which is unable to support combustion or life. A lighted match introduced into the gas is immediately extinguished and a mouse put under the bell glass dies in a short time for want of oxygen. It is not poisonous, but simply has no active properties, being when uncombined wholly inert, and for this reason was formerly called *azote*, or "life destroyer." Its purpose in nature, in its free state, seems to be to act as a diluent of the exceedingly active oxygen, and to thus adapt it to the conditions of life.

Water absorbs about $1\frac{1}{2}$ per cent. of its bulk of this gas, and it is not unlikely that plants may procure some of their nitrogen from this source.

Nitrogen is most interesting when we come to consider its combinations. It combines with oxygen to form five remarkable compounds. The first of these is nitrous oxide, called from its peculiar effects when breathed, laughing gas. This is a colorless transparent gas, of a sweetish taste and soluble in water to the extent of three-fourths of the bulk of the latter. It supports combustion actively, relighting a glowing ember when this is plunged into it and causing an intense combustion of ignited substances almost equal to the effect of oxygen. At a pressure of 750 pounds to the square inch it condenses into a clear liquid which boils only at the great heat of 1126 degrees, which is considerably

above the melting point of lead, and freezes at 150 degrees below zero. The second is nitric oxide, which, although it contains a larger quantity of oxygen than the preceeding, yet is averse to combustion and extinguishes flame. Nitrous acid is a gas, orange red in color, and is soluble in water to a large extent; by the absorption of oxygen it becomes nitric acid. This acid is of surpassing interest to the farmer because it is a form in which nitrogen enters into the substance of plants and without which, in sufficient quantity, farm crops cannot be produced profitably.

Nitric acid is a colorless liquid with an intensely sour taste, and when combined with potash, forms the well known substance, saltpeter or nitre. It exists thus combined in large deposits in South America, and is found in small quantities in large caves in the United States. In combination with soda, as nitrate of soda, or Chili saltpeter, it is found in very extensive beds in Peru, Chili and Bolivia and other places along the Pacific coast of South America. This substance is very largely used as a fertilizer, for which purpose it is exceedingly valuable.

Nitric acid is composed of nitrogen and oxygen combined and is an exceedingly active substance. On account of the large quantity of oxygen in this acid it possesses very active properties and is one of the most effective oxidizing agents known. It stains animal substances yellow and is thus used as a yellow dye. It corrodes metals very quickly and is used by engravers for "biting" in the etchings upon copper plates; it ignites oil of turpentine and powdered charcoal, and causes such rapid oxidation of phosphorous as to produce explosion.

Another most important compound of nitrogen is that with hydrogen, which is known as ammonia. This is a gas of a most pungent odor and acrid caustic taste, and has strongly alkaline properties. It is rapidly absorbed by water, which takes up more than 700 times its bulk of it, and then forms the water of ammonia or *aqua ammonie* of the druggist. It is produced by the distillation of horn, and as it was first made from deers horns, it was called

"spirits of hartshorn." It is largely contained in decomposing urine and causes the pungent odor of stables in which horses are kept. Being volatile, it escapes into the air with great ease, and unless combined with some acid into a permanent form it is disengaged readily from decomposing manure by fermentation and heat, and is lost to the farmer.

It has been supposed heretofore, that this gas was the source from which plants derived their nitrogen, but recent investigations go to prove that ammonia is oxidized in the soil and changed into nitric acid before it can become available for the nutriment and support of plants.

Ammonia combines freely with acids. With sulphuric acid it forms a stable compound, sulphate of ammonia; hence it is useful to employ solutions of sulphate of iron, (copperas) or sulphate of lime, (gypsum or plaster) to fix any escaping ammonia which may be in danger of loss from stables and manure yards. The employment of plaster in this way and for this purpose is quite common among careful and economical farmers, who scatter it liberally about the stables and yards, and so deodorize and purify them; make them more agreeable and healthful, and save all this exceedingly valuable fertilizing agent. The ammonia having an exceedingly strong affinity for sulphuric acid takes this from the sulphate of iron or lime and combines with it, leaving the iron in the form of an oxide, or the lime in the form of a carbonate.

CHAPTER VI.

THE COMBINATIONS OF ORGANIC SUBSTANCES.

It is one of the grand laws of nature, that however often matter may change its form, it is never lost. Matter is indestructible. It is changed and rechanged into infinitely numerous and varied forms, but it never loses a particle and there is no waste. Another universal law is that "of nothing, nothing only comes," and that mankind with all their work and labor can expect nothing more from the soil or from any natural element than it contains. Labor only changes the form of matter; it never creates anything. Another grand law of nature is that all matter of whatever kind, exists in the form of very minute particles, which are so small as to be invisible; that these are unchangeable; and that as the various elementary substances combine with each other, they invariably do so in precisely the same proportions. Thus 8 atoms or particles, (or pounds; the quantity makes no difference) of oxygen, and 1 part by weight of hydrogen, combine to make water; that potash consists ever and always of 39 parts of potassium and 8 of oxygen; and common salt of 35 parts of chlorine to 23 of sodium; and so on through the whole list of the 65 known elementary substances. Certain numbers, known by long continued experiment, and called combining numbers, or atomic weights, represent the proportions, by weight, in which the elements unite to form all their compounds. A compound is not a mixture. If we take salt and sand and mix them together, no matter how intimately, the salt remains the same and so does the sand, and they can be separated by adding water which will dissolve the salt and leave the sand as it was before. The salt and water are also mixed and can be separated by boiling away the water and leaving the salt dry. The water may be converted into steam or vapor;

but the only difference between the water and the steam or vapor is that the particles of the water are separated widely apart by the heat and they become invisible; but they exist still and can be brought together again and condensed into a fluid and reappear as water by the action of cold or the loss of the heat. These are mixtures. A chemical combination is entirely different. If we take some sulphur and burn it, it combines with oxygen from the atmosphere, and the solid sulphur becomes a powerfully corrosive gas which when mixed with water is known as sulphuric acid. This acid is a combination—not a mixture—of the two elements, and it cannot be separated into these without a complicated chemical process. If a piece of copper is put in a quantity of this acid, the copper disappears and the liquid becomes a solution of sulphate of copper. If the water is evaporated the copper sulphate remains in the form of clear blue crystals which are commonly called blue vitriol. This is a combination of the elements oxygen, sulphur and copper, but is not a mixture.

All organic vegetable and animal substance consists of the four elements which have been previously described. The peculiar characters or properties of organic matter by which they are distinguished from inorganic matter and on which their connection with the culture of farm crops depends, are chiefly the following.

They are all easily decomposed, or apparently destroyed by heat. Starch, sugar, cotton fiber, straw or wood, when subjected to heat or flame, turn black and take fire and are consumed. This is true of all vegetable substances. But clay, sand or stone cannot be thus decomposed.

They putrefy and decompose in warm moist air, and after a time almost wholly disappear. This is not the case with inorganic substance which is not subject to putrefactive decomposition.

They consist almost wholly of two or more of the few organic elements previously described.

They cannot be formed by art. Many of the inorganic compounds may be, and have been, produced in the chem-

ist's laboratory; but no chemist has yet produced starch or woody fiber, or sugar, or milk, or flesh, by combining the elements of these substances. This is an important distinction and is likely to exist permanently; although one cannot safely say what chemistry may not be able to perform in the direction of producing these articles of food, and of textile fiber, for which the world is now indebted to the art of agriculture, and so make the farmers labors useless. At present it is easy for the chemist to take apart, to analyze, but to put together and construct, has so far eluded all his skill, excepting in a very few instances.

The four organic elements enter into the constitution of plants in variable proportions. The following table shows the precise quantity of each element contained in 1000 parts by weight of the vegetable substances mentioned.

	<i>Carbon.</i>	<i>Hydrogen.</i>	<i>Oxygen.</i>	<i>Nitrogen.</i>	<i>Ash.</i>
Hay from young clover.....	487	66	369	38	40
Oats.....	507	64	367	22	40
Clover seed.....	494	58	350	70	28
Ripe Hay.....	471	56	349	24	100
Peas.....	465	61	401	42	31
Wheat.....	455	57	431	34	23
Hay.....	458	50	387	15	90
Potatoes.....	441	58	439	12	50

The above named products were dried at a heat of 230 degrees, sufficient to expel all the moisture from them. The quantity of water thus extracted was as follows:

1000 parts of potatoes.....	lost.....	722 parts of water.
“ “ wheat.....	“	166 “
“ “ early cut hay.....	“	158 “
“ “ late hay.....	“	140 “
“ “ oats.....	“	151 “
“ “ clover seed.....	“	112 “
“ “ peas.....	“	86 “

A large quantity of water is contained in the crops grown upon farms even when they are dried for use. When entirely free from water, the carbon is nearly one-half the weight; the oxygen is more than one-third; the hydrogen about 5 per cent. and the nitrogen varies from 1½ to 7 per cent.; the variation being greater than that of any other of these elements. These proportions represent very nearly

the relative weights in which the organic elements enter into combination in all the vegetable products which are grown for the support of animal life.

All vegetable products contain some inorganic matter which remains behind in the form of ashes when the plants are consumed by fire, or as dust when they are entirely decomposed and reduced by decay. In both cases, when these operations are entirely completed, the results are exactly the same. This inorganic remnant varies considerably; oats leaving but 4 per cent.; while ripe hay leaves 10 per cent.; but each variety of plant contains a certain proportion of inorganic matter which is pretty nearly constant and is peculiar to itself. These facts are exceedingly important in the practice of agriculture, and are simply noticed here, coming hereafter under special consideration when the nature of soils and the food for plants are under discussion.

After having studied the character of the organic elements it will appear very clearly that they will not enter into the substance of plants in their natural state, or as they exist free and uncombined with other elements. Carbon is a solid substance and is not soluble in water; and as plants cannot take up anything that is solid into their circulation and tissue, but only matter that is dissolved in water, or which is mixed with it in a gaseous form, or is in a free gaseous state, it is clear that plants cannot derive their carbon directly from the element itself, as it exists in nature. Hydrogen does not occur in the soil or in the atmosphere in a free state in any appreciable quantity, and in its simple condition cannot form any part of the food of plants. Oxygen and nitrogen exist in the atmosphere in well known proportions, in a gaseous state, and the former is absorbed or inhaled under certain conditions by the leaves of plants, while it is quite possible that nitrogen may also be absorbed in the same manner. But while it is known that oxygen is taken up by the leaves, there is no knowledge that nitrogen is; but every reason to believe that it is not. These two gases are slightly soluble in water and may occasionally be

absorbed with water by the roots of crops; but by far the largest quantity of these elements enter into plants in the form of simple or complex combinations, or chemical compounds of a distinct character, and these being absorbed by the plants, are separated or decomposed; the plants then selecting what they require for their subsistence, and rejecting the rest. It is then necessary for the farmer to study not only the nature of these compounds, but the laws by which their combinations are regulated and the manner in which they are effected.

The difference between a mixture and a compound has been already explained, and it should always be borne in mind in considering this part of our subject. Combination is not a mechanical but a chemical action, and results in a permanent change in some or all of the substances employed; decomposition is also a chemical action, and results also in permanent change of a combined substance or compound. When sulphur, a solid substance, is burned in the air, it is converted into a gas; which is a compound of the sulphur with oxygen from the air. When limestone is burned in a kiln it is changed into lime, which is quite different from the original stone. This is a case of chemical decomposition for the limestone is a compound of lime and carbonic acid, and the acid is driven off by the heat, and the lime is left remaining. The limestone is quite neutral and inert; it has no action upon water, nor any taste; but the lime is strongly alkaline and will effervesce strongly if put in vinegar or any other acid; if put into water, it will combine with it and produce great heat, and it will destroy any organic matter brought into contact with it.

If hydrogen gas is burned in the air and a piece of cold glass is held over the flame, the vapor produced by the union of the two gases, is condensed into drops of water on the glass. It is thus seen by these examples which could be extended almost infinitely; how important changes in matter are produced by chemical combinations and decompositions; gases are combined and form liquids or even solids; liquids and solids are changed to gases; mild substances become

corrosive and destructive; and corroding substances combined become mild and innoxious.

The laws which regulate chemical action are precise and inviolable, and the elements unite with each other only in constant and definite proportions: We can mix any two gases together, as oxygen and hydrogen; or oxygen and nitrogen, in any proportion we please; but we cannot combine them except in strictly definite quantities. We can burn a pound of hydrogen in any number of pounds of oxygen, but the hydrogen will unite with only 8 pounds of oxygen and make 9 pounds of water; and this proportion never varies. We can discharge an electric spark in a jar containing a mixture of oxygen and nitrogen, and 8 parts by weight of the oxygen will unite with 14 parts of the nitrogen and form an oxide of nitrogen. If there is any surplus of nitrogen it will be left, and any surplus of oxygen will remain; only so much of either will combine with the other, and no more and no less under whatever circumstances may exist. Moreover, the very same proportion in which any two bodies will combine with each other is precisely the same in which they will combine with any other. Thus 1 pound of hydrogen combines with 8 pounds of oxygen, and 8 pounds of oxygen combines with 14 pounds of nitrogen; therefore 1 pound of hydrogen combines with 14 pounds of nitrogen. These numbers are known as the combining or equivalent numbers; but there are multiple proportions required in some cases to produce definite compounds; for instance, to produce ammonia, it is necessary to take 3 proportions of hydrogen to 1 of nitrogen. The emblems of combinations or the mode of representing them is by using the initial letter of the element followed in case of multiple proportions or equivalents by a small figure. Thus $N H_3$ represents one proportion of nitrogen or 14 (pounds) and 3 proportions (pounds) of hydrogen, making 17 pounds of ammonia.

This beautiful law; beautiful in its precision and its simplicity exemplifies the general law of the universe; which is, order, invariable and unchangeable. This regulates not only the motions of the planets, the earth, moon and stars,

around the sun; but it also rules the formation of an atom of salt from its component parts; or the structure of the minute cells of a plant. Everything in nature is subservient to this unchanging law, that certain causes produce certain effects; which are constant and invariable under all circumstances. The farmer then as he cultivates his soil and watches the growth of his crops, knows that when he does his part; which is to prepare the soil properly, and to furnish whatever is required to fertilize it and feed the growing plants; nature provides the unfailing rules by which effect is given to his work. There is no chance or uncertainty about it; but the same surety that the results will appear in due time as that the sun will set in the west when the day is done, and will rise in due time to the fraction of a second in the morning. While the combinations of the four organic elements with each other are almost endless, there are but few which contribute directly to the growth of plants. Of these, carbonic acid, nitric acid, ammonia and water, are of the greatest importance; others being of less interest. The atmosphere, however, which is a mixture of the two most important elements, and which is the grand purveyor of vegetable life, contributing from 90 to 95 per cent. of their bulk to living plants, requires careful study and notice.

CHAPTER VII.

OF THE ATMOSPHERE.

The earth is surrounded by a gaseous body known as the atmosphere or the air, which is supposed to extend to a height of forty-five miles above its surface. The actual height however is indefinite and immeasurable, because being a gas, the air is capable of infinite expansion, according to the pressure upon it, and while we know that the pressure at the earth's surface of the vast mass of the air above it is equal to 15 pounds to the square inch, yet as the height above the surface increases, the pressure decreases; and as the pressure decreases, the air expands, therefore the extension of the atmosphere upwards cannot be marked by any distinct boundary, but gradually fades to a limit which cannot be precisely defined. The limit however of 45 miles is sufficiently precise for all practical purposes. The physical properties of the atmosphere however, are of the greatest importance, as a great many results interesting to the farmer as affecting the growth of his crops depend upon them.

Air, as has been already stated, consists of 79 parts by bulk of nitrogen, and 21 parts by bulk of oxygen; or by weight 77 parts of nitrogen and 23 of oxygen. These two gases are mixed or diffused together according to a law by which gases mixed together become evenly or uniformly diffused or mingled with each other, without reference to their weight. One may be much heavier than the others, yet it will diffuse itself perfectly through every part of them. If it were not for this law the air would not be fit to support life. In one place there would be masses of pure oxygen which would be equally destructive of life as the masses of pure nitrogen which has no vital qualities at all.

This law of diffusion has another interesting application as regards the behavior of the air, and moisture in the soil,

and the even distribution of plant food; but this will be noticed more fully hereafter.

The air contains, also evenly diffused through it, a very small proportion of carbonic acid. This averages about one part by bulk to every 2500 of air; and varies slightly according to circumstances. This carbonic acid is of the highest importance to the growth of plants, inasmuch, as it is from this source chiefly, that, as is believed, plants derive this necessary nutriment, from which is formed, the cellular tissue, the starch, sugar, gum and fats, which they contain, and which makes up so large a portion of their dry substance.

The air also contains a varying quantity of watery vapor diffused through it, amounting to 1 per cent. of its weight on an average of season and locality. This proportion is largest in summer, increasing with the temperature, and least in the winter; thus supplying the crops in their growing season out of the abundance gathered up for their support; as well as to moderate the heat. This moisture is condensed as the temperature is reduced, and forms clouds, which, floating in the air, shade and protect the earth from the too ardent rays of the sun, and at night they reflect the heat which is radiated from the earth's surface, the loss of which in cloudless countries causes intense cold in the night, following equally intense heat at midday, when nothing intervenes to intercept the burning rays of the sun.

The air also contains varying quantities of matter contributed by decaying organic substances and from the dry soil; as ammonia evolved from putrefying plants; decaying leaves, and decomposing dead animals, and the excrements of living ones, and dust from this dried debris of animal life. A ray of light or a sunbeam passing through a crevice into a darkened room, shows this contribution to the atmosphere—which is not without its use and importance to vegetable life—in a myriad of particles which glisten as they float in the light.

Air, like all other matter, has weight. This was first discovered about 200 years ago. A cubic foot of air weighs

538 grains, or more than an ounce, and the air contained in a room 40 feet square and 18 feet high will weigh a ton. The weight of the air, the ease with which a gas is moved, and the fact that the pressure of the weight is exerted in all directions, tend to force it into every vacancy, and to diffuse itself everywhere. Every pore and interstice of the soil is filled with it. There it yields up its oxygen to dead matter and quickly converts it into plant food; it carries with it its carbonic acid upon which the roots seize and convey it into the tissues of the plants, where it is elaborated into new cells and the starch which fills them. Like all other gases it expands with heat and contracts with cold. Every change of temperature therefore expels a portion of the air from the soil or impels a portion to enter it. This causes a constant current and change by which the air is renewed and that vitiated by the loss of its useful properties is replaced by a fresh supply. Every shower of rain expels it from the soil, and as the water sinks to lower depth, the atmospheric pressure forces air again into the vacant spaces. All this has a most beneficial effect upon vegetation, the results of which are to be considered hereafter.

This vast body of air, like the watery ocean, has its tides, its great currents, and its storms, which keep it in perpetual motion. When the farmer hies to his field in the summer morning, the gentle zephyr fans his cheek. In the season of storms the boisterous gale beats him from his path and forces him to take shelter. All these motions serve to mix the air; to purify the centers of corruption; and bring to them renewed springs of health and vigor. If one could float upon the surface of the atmosphere, great waves would be seen coursing over the vast aerial ocean. These extend for thousands of miles; have many miles of elevation and their courses extend across oceans and continents. These enormous waves and the following depressions, necessarily change the pressure of the air on the surface of the earth, and are marked by a change of the barometer. The result is an increased pressure under the wave with a rise in the barometer; and a decreased pressure under the depression

or trough of the wave with a fall in the barometer. This indicates the approach of wind. The high pressure under the wave forces the air to the center of the depression and the winds blow from all quarters to restore the pressure. Thus with every wave which ruffles the surface of the vast ocean above us, currents are set in motion around us, and the air is never still.

The watery vapor suspended in the air is affected by this oscillation of pressure to some extent ; but far more by the changes of temperature. When the air is heated, evaporation from the ocean and the land is active, and the atmosphere is charged with moisture. A wave rising in the north with a depression in the south, brings a cold wind. This strikes the warm moisture—laden air, and the vapor is condensed in clouds. The condensation increases with the fall of temperature ; the clouds become heavy and black, and soon the pattering rain drops fall upon the thirsty soil, refresh the crops and gladden the husbandman. Or the friction of the cool current passing over a warmer one, engenders electrical disturbance, when the lightnings flash and suddenly condense the gathered vapor, and the thunder showers pour down amid the deafening crashes and reverberations.

All these facts of surpassing interest and which explain so simply the causes of these phenomena, are based upon a series of natural laws, which are as beautiful as they are wonderful, and they have been unfolded by science within a few years past. Our fathers knew nothing of them, and vainly imagined causes for them. But we knowing them, find ever new delights in their contemplation. We see that the vegetable world is derived in greater part from the air, and consists of condensed gases that have been reduced from the atmosphere by the agency of the sun's heat. Animals which derive all the materials of their structure from plants, destroy these while living by respiration, and when dead by decomposition, and return them in gaseous form to the air again, whence they were taken. Thus the offices of plants and animals neutralize each other ; the one takes the materials for its substance from the air and builds

up its varied and beautiful organisms; the other consumes these and undoes the work so performed, and pours back into the air, the materials for a new generation of plants. And so the cycle is completed; but it never ends, because with each completed round a new round begins.

CHAPTER VIII.

WATER.—ITS RELATION TO VEGETABLE GROWTH.

Water is a compound of oxygen and hydrogen in the proportion of 8 parts by weight of the former to 1 part of the latter: and by volume or bulk of 1 part of oxygen to 2 of hydrogen. It is more universally diffused throughout nature than any other chemical compound, and performs the most important functions in regard to animal and vegetable life. Its remarkable properties are most wonderfully adapted to the existing condition of things and offer to the farmer and student of natural science the most interesting subjects for study and experiment.

It exists in the 3 forms; a solid, as ice; a liquid in its common form; and a gas; as steam or watery vapor. At 32 degrees of temperature it becomes ice and remains solid; at any higher temperature it melts and becomes liquid and at 212 degrees it changes to a gas, which continues to expand under the influence of increasing heat. Steam is 1700 times lighter and more bulky than water and is a little more than half as heavy (sixty-two one hundredths) as air. It therefore rises quickly and becomes diffused through the air. Liquid water is 815 times heavier than air and a cubic foot of it weighs $62\frac{1}{2}$ pounds.

Water in the form of ice and snow has an important action upon the soil and consequently affects considerably the interests of the farmer.

In the act of freezing—which is a process of crystallization—water expands in bulk about one-eleventh. This expansive force is irresistible, because water is incompressible and cannot be reduced in bulk by any amount of pressure which can be applied to it. A very small quantity of water that may be absorbed by rocks, in expanding as it freezes, bursts asunder the particles of the stone and these flake off and form soil. In the soil a similar action goes on. The water

contained among the particles of the soil expands and loosens these particles and separates them from each other. When the soil is thawed by returning warmth, a thin crust is loosened from each clod and fragment and falls apart into exceedingly fine particles, and as the warmth penetrates the mass this gradually crumbles down and forms a larger bulk of fine porous earth. Moreover the particles of soil themselves are ruptured; stones are gradually disintegrated, and new soil is made; and these particles are thus subjected to the solvent action of the water of the soil by which fresh plant food is liberated and the soil is enriched. This effect is the more remarkable when we learn that one single cubic inch of clay when reduced to fine particles by the action of frost presents in the aggregate superficial areas of the fragments, a surface of at least 100 square inches. The beneficial effect of this result of freezing upon the soil is of incalculable value to the farmer, both as regards the mechanical condition of the soil and its fertility. On clay soils both of these effects are produced to the greatest extent.

In the form of snow too water exerts a considerable effect which is beneficial to the farmer. The snow is exceedingly porous, being made up of a mass of crystals formed like 6 rayed stars, which lie very loosely upon each other. The interstices contain air and act as a non-conductor of heat, and as a protection against the severity of the cold, and also against sudden changes of temperature. In very cold countries, the snow covering the soil early in the winter, prevents the freezing of it altogether, and tender plants such as potatoes, often remain green under the snow the whole winter, without injury in the warm soil. Such a climate obviously favors very much the successful growth of winter grain. Snow has also the power of absorbing ammonia, oxygen, and nitrogen from the air. Ammonia held in the snow is gradually taken in by the soil and is not lost as when it is brought down by rain, which not only carries it off in floods, but also washes a more considerable quantity of it from the soil into brooks and rivers. The air which is held in the open spaces in the snow holds only 17 per cent.

of oxygen, against 21 per cent. in the ordinary atmosphere; the difference being absorbed by the snow, is carried into the soil with the water as the snow melts and thus conveys to the roots an additional supply of this vitalizing element.

In its fluid condition, water is the vehicle by which all nutriment of whatever kind, is carried into the circulation of plants. It is itself a most important nutritive element—food in fact—for all plants and animals, forming about three-fourths of their substance and weight. It thus softens all tissue and gives it elasticity and strength. It is a universal solvent; and thus brings to the roots of plants whatever nutriment is needed in such a form that it can be taken into their tissues. It dissolves about one-thirty-sixth part of its volume of air; and this air contains 10 per cent. more oxygen than other air. It also contains from two to twelve times as much carbonic acid as the ordinary air. One hundred volumes of water absorb directly 3.55 of oxygen; 1.53 of hydrogen; 1.47 of nitrogen; 106 of carbonic acid, or 7800 of ammonia. In this property we see how plants may derive the large supply of carbonic acid which they need for the structure of their carbonaceous tissue; and a large proportion of their nitrogen which may thus be procured from the dissolved ammonia.

Water is never pure. As an example of its solvent power over solid mineral substances the following analysis of the water of the Dead Sea is given.

Specific gravity of the water.....	1.172	
Chloride of sodium (salt).....	6702.73	grains.
Chloride of potassium.....	682.63	“
Chloride of ammonium.....	3.35	“
Chloride of lime.....	1376.75	“
Chloride of magnesia.....	4457.23	“
Chloride of aluminium.....	31.37	“
Chloride of iron.....	1.50	“
Chloride of manganese.....	3.35	
Bromide of soda.....	156.53	
Iodide of soda.....	trace	
Sulphate of potassium.....	trace	
Sulphate of Magnesia.....	trace	
Sulphate of lime.....	38.07	
Phosphate of soda.....	trace	
Carbonate of lime.....	—	

Silver	_____
Copper.....	_____
Lead.....	_____
Arsenic.....	_____
Silica.....	_____
Bitumen.....	_____
Organic matter.....	34.59
<hr/>	
Total in one gallon	13489.17 grains.
<hr/>	
Per cent.	19.73

The water of springs, wells and rivers is thus never pure, but holds in solution more or less of solid substances. Hence we find that land watered by irrigation from rivers produces much larger crops than that watered by rain; also that land that has been or is periodically overflowed by floods, becomes exceedingly fertile. Even rain water is not pure except in the wettest seasons, when the atmosphere has been washed clean from its impure matter which is brought down by the showers. In this way a large quantity of solid fertilizing matter, as well as of fertilizing gases, is brought within reach of the roots of the plants by the rain which is absorbed by the soil. The water also dissolves matter from the soil and presents it to the roots in such a condition that it can be absorbed and utilized as nutriment.

These facts prove how indispensable it is that the soil should be brought by thorough culture, and the use of the most perfect implements, into such a condition of porosity and mellowness that the water may be absorbed and held in it and not flow off from the surface and carry away into the streams, not only all its own burden of rich fertilizing matter but also rob the soil of a large portion of its own possession.

The solvent power of water is increased by heat, in regard to nearly all substances excepting lime and ammonia which are dissolved and absorbed by cold water more readily than by warm. This property will be further explained in a future chapter on HEAT.

Water has a strong affinity for various substances, indeed it exists in a greater or less proportion in almost all solid bodies and in every crystallized substance; forming in these cases what is known as "the water of crystallization."

When limestone is burned, water and carbonic acid are

driven off by the heat and lime remains. (This lime is the oxide of the metal calcium.) When lime is brought into contact with moisture, about one-third of its weight of water is absorbed and the lime, swells, breaks apart and falls into a very fine powder which is perfectly dry. This water is combined with the lime and cannot be expelled at less than a red heat. Gypsum contains in the same manner 21 per cent. of water; alum contains 24 parts of water to two of solid matter; Epsom salts contain 50.2 per cent. of water; and so on through a long list of crystallized minerals. It has also a strong affinity for clay and all the more so, as the clay is finely pulverized and disintegrated; carbonized vegetable matter also takes up a large quantity of water; hence the great advantage of securing as large a quantity of decayed organic matter, as may be possible in the soil.

This is quite distinct from the mechanical grasp upon water exerted by porous substances, which merely hold it in its interstices by capillary attraction, as is the case with a sponge, and give it out again with great facility and without any chemical action.

The elements of water are held together loosely and are combined with great ease. When hydrogen is burned in the air it combines with oxygen (as has been previously described) and forms water. If a piece of zinc is placed in a vessel of water—a glass bowl or a wide mouthed bottle, for instance—and a little sulphuric acid (a few drops) is added, the water is in part decomposed and the hydrogen is set free. As this experiment is a pleasing one and very simple, the chemical operation is here explained. The sulphuric acid acts upon the zinc and combines with it; but as this acid has only three equivalents of oxygen ($S. O_3$) and zinc requires one more equivalent to make the combination as sulphate of zinc ($Z. S.O_4$) this excess of oxygen is taken from the water, leaving the hydrogen free, when it escapes in bubbles apparently from the surface of the zinc. If the bottle is corked and a glass or rubber tube is put through the cork, the hydrogen gas may be collected. But as it is explosive when mixed with air, great care must be

exercised in igniting the gas, and the first which is set free should be permitted to escape until the air has been all carried off.

Water undergoes continual decomposition and recombination in the interior of plants and animals. As a fluid it finds its way into every cell and pore and passes out by transpiration after it has given up to the tissues the matter which is extracted from it. And so slight is the hold which its elements have upon each other, and so strong is their affinity for other elements, that they are ready to separate upon very slight impulses; the oxygen forming compounds with one and the hydrogen with others, as the production of the various substances of which the plants form themselves, require and demand. And when the nature of chemical combinations begins to be understood, there is no more wonderful fact in the study of vegetable physiology than the great variety of changes which are continually going on through the agency of the elements of water and others which it conveys into the tissues of plants and animals.

In the state of vapor too, water exerts a very potent influence upon the life and growth of farm crops. Vapor escapes from water into the air, or is absorbed by the air, not only at boiling heat, but at all temperatures. Even at a zero temperature the air takes up water, as is known by the housewife whose linen freezes dry in the cold, crisp, wintry, air. A piece of ice exposed to the air in the coldest weather gradually evaporates and disappears. It is however in the summer that the evaporation of water is most active; and it is then that the effects of the condensation of the atmospheric moisture is most perceptible and useful. Dew is the product of this condensation. The air charged with the vapor which has been gathered during the heat of the day, is cooled at night by contact with the soil, from which the heat is rapidly lost by radiation. The cooling of the air causes the moisture to condense, forming sometimes visible vapor, seen in the evening and night fogs which prevail in some localities; but always a burden of moisture which is too heavy to be suspended in the air. This moisture then

falls and settles in fine globules upon the vegetation, the soil, and upon all other objects which have been sufficiently cooled. This process goes on mostly at night, but constantly at other times when the temperature falls, and especially in the soil, in which with the constant circulation of air (previously described) there is always the accompanying moisture; which is condensed and deposited in the interstices and so supplies the demands of the plants. The more completely the soil is made fine and pulverized the larger is the deposit of atmospheric moisture.

This behavior of water under the beautiful and comprehensive laws to which it is subject, affords an instance of the provident as well as bountiful operations of nature. Every one of these operations tend towards the good of mankind. It is the cultivator of the soil who reaps the benefits of these universal and beneficent laws. Yet the rewards are not given to all alike. We are told that the rains descend, the dews are distilled and the sun shines upon the just and the unjust; upon the industrious as well as the idle and neglectful. An impartial and kind Providence offers these benefits with an open and generous hand; overflowing with good to mankind. But Providence does nothing more. The farmer who avails himself of these invaluable gifts and does his part by studying the nature of them and their adaptation for his purposes; and thus adapts them with skill and industry to the preparation of the soil and the culture of his crops, gains the highest rewards. The prizes are his; but the blanks in the distribution are for those who neglect these grand provisions and refuse to avail themselves of them. It is "the hand of the diligent which maketh rich:" the neglectful careless tiller of the soil has no promise of wealth from the free gifts of nature; these are for the farmer who uses every possible means to secure these gifts by the practice of an intelligent and effective culture of crops.

CHAPTER IX.

HEAT AND COLD.—THEIR INFLUENCE UPON MATTER AND VEGETATION.

Heat and cold are merely relative terms. Cold is a low degree or absence of heat, just as darkness is the absence of light, and has not in any sense, or in fact, any specific existence, as separate from heat. It is only quite recently that the nature of heat has been understood. It was formerly supposed to be an element, a subtle fluid to which the name *Caloric* was given; and whose entrance into a body produced warmth and whose loss produced cold. As some bodies, such as marble, felt cold and others, as wool, felt warm, it was believed that various substances contained less or more of this fluid stored up in its interstices according to their varying capacities. It was given, in fact, all the properties of a gas with some others which were believed to belong to it specifically. This ancient notion was exploded when it was discovered that heat was simply the effect of motion of the particles of a body, and that the intensity of the motion determines the temperature.

It is not the purpose here to discuss the various theories which are held in regard to the nature of heat; these may be studied in special works on the subject such as that of Prof. Tyndall. It is most important for us to consider how it affects those elementary and compound bodies which have a close relation to the growth of plants, and its effects upon germination and plant growth. It will be sufficient here perhaps to repeat the words of Dr. Locke uttered a hundred years ago in which the true idea of heat was enunciated. He said, "heat is a very brisk agitation of the insensible parts of any object which produces in us that sensation from which we call the object, hot; so that what in our sensations is heat, in the object is nothing but motion." A

familiar instance may be given. If a person slide down from an elevated place by means of a rope held in the hands and he descends rapidly he feels a burning sensation in his hands and the skin is blistered precisely the same as if he held a hot iron rod in his hands. This heat is the result of an intense vibration of the fibers of the muscles and skin of the hands; and is equal in degree exactly to the vibration of the particles in an iron rod whose heat would cause precisely the same sensation and result in the hands. To study the relations of heat with intelligence it must not be regarded as a thing, but as a condition of matter and an effect of the change of a condition.

The chief source of heat is the sun. All combustion is a source of heat, and as we have seen, combustion is a chemical effect. Mechanical force is also a source of heat; and friction, pressure, or any other result of force is accompanied by heat. Heat once produced is never lost or destroyed: it may disappear but it always exists. The heat of the sun communicated to the earth is absorbed in various ways, that is we use this expression; but in truth we should say the force is communicated to every object brought under its influence. It is absorbed by the waters of the ocean and their particles move and separate more widely apart forming vapor.

The amount of force (which we call heat) thus communicated has been accurately calculated. If we take an ounce of ice at 32 degrees and one of water at 174 degrees and put them together, the ice will be melted and there will be two ounces of water; but the temperature will be only 32 degrees. Where has the excess of 142 degrees of heat which has been apparently lost by the hot water, disappeared? It has not been lost but has become stored up in the water and has become the latent or hidden heat of the liquid. This latent heat can be found again when the water is frozen, for in the formation of ice precisely 142 degrees of heat are given out by the water in the gradual change of the liquid to a solid.

In the same way when water is changed to steam a very

large quantity of heat is rendered latent in the vapor. Water at 32 degrees absorbs 180 degrees of heat and reaches a temperature of 212 degrees which is the boiling point. But it does boil only slowly and steam is produced very gradually. It is found that if the consumption of one pound of coal will raise a quantity of water from 32 degrees to 212 degrees; $5\frac{1}{2}$ lbs. more will be required to change it all to steam of the same temperature. $5\frac{1}{2}$ times 180 or 990 units of heat will then have been expended, but have not been lost; they are stored in the steam and are the latent heat of the vapor of water. And when the vapor of water is condensed into liquid this heat is given out again.

And here is another most wonderful instance of the infinite wisdom and beneficent adaptation of the laws of nature to the stability of the universe and the comfort and happiness of mankind. The expansion of water as it changes into ice has been already mentioned. This is one more effect of heat, that is a reduction of it, upon this liquid, and has an intimate connection with this part of our subject. When water reaches its maximum density which is 39 degrees, under the influence of the abstraction of heat, it then begins to increase in bulk until ice crystals form when the total expansion amounts to one-eleventh of the bulk. Consequently the ice floats on the surface and after a time it becomes thick enough to protect the underlying water from the effects of cold. Were it otherwise, ice would sink to the bottom and as the surface water cooled it would also sink and the whole water would soon be changed into ice. The ocean would then become a vast bed of solid ice, which by the very force of this law would remain permanently and resist all the heat of the sun to change it. Then the earth would be uninhabitable. No green blade would appear on the surface; no animal would find subsistence; there would be no clouds, no rain; everything would be cold and drear and lifeless; a dead world.

Again, were it not for the gradual absorption of heat by the melting ice and the evaporating water, the earth would

be destroyed by the sudden catastrophe of an overwhelming flood at the approach of every spring. The accumulated ice and snow of the winter would be changed to vast bodies of water as soon as they reached the temperature of 32 degrees; and when the boiling heat should be reached, the water would change into steam with the force of an explosion and rend everything near it to atoms. Instead of being useful to man it would be a most destructive agent, which men would avoid as they would avoid nitro-glycerine. The contemplation of these thoughts gives a new force and interest to the fact that "the earth was given to man" and truly the gift was perfectly well adapted to his uses, and for his enjoyment.

It has been shown that the force equivalent to the heat required to produce 9 lbs. of steam at 212 degrees by the union of 8 lbs. of oxygen and 1 lb. of hydrogen is equal to that represented by the fall of a ton weight down a precipice 22,320 feet high: to change this vapor into liquid a force is exerted equal to that of the fall of a ton down 2,900 feet; and to change the water into ice the force is equal to the descent of a ton down 433 feet. And yet these enormous forces are going on in the soil and in the tissues of delicate plants, continually, silently, but omnipotently; without any outward indication. Prof. Tyndall has remarked of this latent force hidden in a drop of water, "I have seen the wild stone avalanches of the Alps; which thunder and smoke down the declivities with a force almost sufficient to stun the observer. I have also seen snowflakes, descending so softly as not to injure the fragile spangles of which they were composed; yet to produce from aqueous vapor, a quantity of that tender material that a child might carry, demands an exertion of energy competent to gather up the shattered blocks of the largest avalanche I have ever seen and to pitch them to twice the height from which they fell."

Combustion is a source of heat; and the decay of organic substance is a slow combustion. This fact is exemplified in the decomposition of vegetable matter. When the farmer

makes a heap of manure, or a hot bed, the mass soon begins to heat and in time is changed from its previous condition into a black powdery substance having no resemblance to vegetable tissue. The heat produced by the chemical action which has resulted in this change has been precisely equal to that which would have been required to drive off the moisture; set free the gases; and reduce the matter to its mineral, carbonaceous, and nitrogenous elements which remain in the mass. In like manner heat is produced by every chemical change. The union of water with sulphuric acid is accompanied by violent heat; so is the solution of a piece of copper in nitric acid. And as the decomposition of a vegetable cell in a manure heap is accompanied by heat so is its decomposition in the soil; and its formation in the plant.

The effects of heat—and cold—upon the soil are great and varied. It is the sun's heat, penetrating the soil which causes the germination of the seed. At low temperatures seeds will remain in the soil for many years unchanged. The heat of the sun does not penetrate very deeply and at a very moderate depth the heat of the soil is constant, during summer and winter. This is caused by the effect of evaporation, as well as by the nonconducting property of the air spaces between the particles of the soil. Seeds of weeds and plants which remain at some depth in the soil are thus kept dormant for many years, starting into growth whenever they are brought under the influence of the warmth of the sun's rays.

The heat of the sun also causes the evaporation of water from the soil and dries it and makes it fit for the labors of the farmer. But this result has also another effect which is unfavorable. It cools the soil and reduces the temperature, and when the soil contains an excess of water and the evaporation is copious, this cooling is exceedingly hurtful to the crops. There are soils which are called cold clays; and swampy lands are always cold and unproductive of the better class of crops, favoring the growth of mosses and ferns and other useless plants. This is due to the constant evap-

oration from the surface. To change the water into vapor, has been shown to require a large expenditure of heat; and precisely the same heat is drawn from the soil when vapor rises from it as is imparted by the fuel of a fire which produces the same amount of evaporation. This heat drawn from the soil necessarily reduces its temperature. An experiment which exemplifies this result may be made as follows: A few drops of ether are placed upon the skin; and the breath is blown upon it. The current of air evaporates the volatile ether quickly, and causes a large absorption of heat. The abstraction of the heat from the skin to supply this requirement of the evaporation causes a sensation of cold upon the skin. This is precisely the effect upon the soil, when the warm air blowing over wet clay or swampy land causes copious evaporation and is all the greater as the evaporation is excessive.

This effect operates to relieve persons from the results of excessive heat. When the temperature rises to 90 degrees and over, the animal system becomes oppressed. The blood whose normal heat is 98 degrees, rises in temperature and produces serious disturbance of the nervous system, which if not relieved quickly ends in what is known as sunstroke, and speedy death. But the evaporation of the water of the system in the form of perspiration relieves the oppression; carries off the heat; cools the blood and the skin; and prevents the fatal results of the unrelieved heat. When an incautious person suddenly plunges into cold water, or drinks cold water to excess, the pores of the skin are closed in the one case and a chill is produced in the other; either of which checks the perspiration; and prevents the escape of the internal heat; when fatal results are often produced. So the wearing of wet clothes abstracts heat from the body and thus produces pernicious effects; while the use of wet sheets in which fever patients are wrapped; rapidly cools the parched skin; induces natural perspiration; and saves the sufferer.

The abstraction of heat by evaporation is so great under some circumstances that water can be frozen by it. This

may be shown by a simple experiment. A shallow vessel containing sulphuric acid is placed in another containing water and both are placed under the receiver of an air pump. When the air is exhausted the vapor of the water is so rapidly absorbed by the acid that the water is frozen. By using liquid sulphurous acid which evaporates with intense force, and pouring it into a red hot vessel, and then adding water, the water is suddenly frozen into ice under the intense cold produced by the rapid evaporation of the acid.

The lowest degree of cold ever produced; 220 degrees below zero; was by means of the vaporization of liquid protoxide of nitrogen mixed with bisulphide of carbon in a vacuum. These examples however are not of practical interest to the farmer further than to exemplify the vast and varied changes produced in matter by heat and cold.

The same kind of result may be produced by the sudden liquefaction of solids. Thus a mixture of salt and ice causes the rapid melting of the ice and a sufficient reduction of temperature to freeze water. In this case both the solids are liquefied and the effect is intensified. The cold thus produced is 40 below zero. Four ounces of sal ammoniac and the same quantity of saltpetre, finely powdered and dissolved in 8 ounces of water, will cause a reduction of 40 degrees of temperature; and powdered Glauber's salts, drenched with hydrochloric acid, will sink the temperature from 50 degrees to zero. These mixtures are in common use as the so called freezing mixtures. The newly introduced ice machines by which ice is produced at a cost of one dollar per ton, are operated by the vaporization of ammonia in the gaseous form from its solution in water.

A very useful practical application of the liberation of heat by freezing is that often used to evade the freezing of the contents of cellars in very cold weather, by placing a pail full of water in the cellar. The water freezes more easily than any other liquid or solid containing liquid; as fresh vegetables and fruits; and in the act of freezing gives out the latent heat of the water which actually warms the cel-

lar. For the same reason the coolness of the early winter is subdued and greatly modified by the heat given out by large bodies of water in the act of freezing; and in this way lakes and rivers, as well as the ocean, have a very important influence upon the climate of adjacent localities. Late frosts are avoided and the intense cold is delayed until later in the winter. This fact has given rise to the common adage, "As the days begin to lengthen, the cold begins to strengthen," by which is meant that the cold does not become severe until the beginning of the new year, when the waters and the ground have become frozen and all their latent heat has been given out.

The heats of the summer are also much reduced in intensity by the excessive evaporation from bodies of water and from cultivated soil. It has been found that the climate of the great western plains has been favorably modified by the introduction of irrigation and the breaking up of the vast areas of dry prairie which have been brought under tillage. Evaporation of the water thus used, or gathered in the porous soil by the rains, which are absorbed instead of flowing as heretofore, from the dry hard surface in vast sheets and floods to the nearest stream, both cools and moistens the air; supplies the vapor for clouds which shade the soil and temper the sun's rays, and which in turn descend again to the soil whence they came in genial cooling showers. This is a remarkable instance of how man's industry modifies climate by changing the natural conditions prevailing and so fits the earth for his occupation and use.

CHAPTER X.

CARBONIC ACID.—ITS PROPERTIES AND FUNCTIONS IN PLANT GROWTH.

Carbonic acid is one of the three materials which together form the starting point of vegetable growth; the others being water and nitric acid. This acid is formed of carbon and oxygen in the proportion of one part of the former to two of the latter chemically combined. It is a colorless gas, having an acid taste and smell; is soluble in water; weighs one-half more than air and can be poured from one vessel to another, as a liquid may be; 100 parts of water dissolve 106 parts of this gas, and it is from this source that the roots of plants derive the needed supplies of it.

It is produced by the combustion of carbon in the atmosphere; when it unites with oxygen in the proportions mentioned. An easy way to produce it is to burn charcoal on an open hearth. In a close room this combustion takes the oxygen from the atmosphere and fills the whole space with carbonic acid. This necessarily is a dangerous proceeding and at times causes fatal results, by the keeping of charcoal fires, or even coal fires, in poorly ventilated apartments.

This gas is wholly unable to support life and when existing in an excessive proportion in the air not only destroys animal life, but is also fatal to vegetable existence. Neither will it support combustion. Fire is extinguished by it; but when mixed with certain proportions of hydrogen it becomes inflammable, and even explosive when mixed with air. It forms a large proportion of the rocks in combination with various mineral elements. One of the most common of the rocks,—limestone, and of which marble is one form, contains 44 per cent. of it and can be separated from it by the action of an acid or by burning. If a small quan-

tity of powdered marble be placed in any vessel and strong vinegar, or any acid, is poured upon it, active effervescence ensues and the carbonic acid is given off copiously. Chalk is a common form of this combination of lime and carbonic acid, the union of which forms carbonate of lime. One cubic inch of marble or chalk will yield 4 gallons or nearly half a cubic foot of this gas; and the burning of one bushel of charcoal will produce 2,500 gallons. It is also produced by fermentation. When cider is suffered to ferment; or any other liquid which contains sugar; bubbles of carbonic acid gas are evolved from it and rise through it and escape at the surface. This is caused by the change of the sugar into alcohol by which carbonic acid is formed. The same result happens when a solution of malt or glucose is fermented for the manufacture of beer: the foam which appears upon the fresh beer being caused by the escape of carbonic acid from the liquid during its confinement in the barrel or bottle. The foaming of sparkling wines is due to the same cause.

It is also produced by the decomposition of solid substances which contain starch, or other vegetable matter. The carbon of the starch, or cellular substance, is slowly consumed by the low heat of the decomposition, and unites with oxygen, giving off carbonic acid in the process; the residue left after final decay being mostly all mineral matter.

Carbonic acid is the principal food of plants and contributes largely to that portion of their substance, which is derived from the atmosphere. The supply of this necessary compound is derived both from the atmosphere, and from the water, which are always present in the soil. These entering into the substance of the plants, the former by the leaves and the latter by the roots, are taken into the circulation in the sap and elaborated into the solid cellular tissue, starch, sugar, and gum, which are compounds of carbon oxygen and hydrogen; or carbon and water; as the oxygen and hydrogen exist in these substances in precisely the proportions which go to form water.

Thus starch consists of 12 parts of carbon; 20 parts of hydrogen and 10 parts of oxygen; while it has been seen that water, consisting of 2 parts of hydrogen and 1 part of oxygen, the 20 parts of hydrogen and 10 of oxygen in the starch are equivalent to precisely 10 parts of water. But it is not certain that starch is made up of carbon and water; it is more probable that the three elements exist in starch in other forms of combination. It is certain however that carbonic acid is the source from which the carbon of the vegetable substance is procured: because carbon is insoluble in water and is a solid substance, and plants cannot take any solid matter into their circulation and their food must always be in solution in water. This part of our subject however will be more fully treated in a future chapter and under its appropriate head.

The air contains one part of carbonic acid in 2,500 and this proportion seems to be the most suitable for the healthful growth of plants. The sun light has a great influence upon this nutritive function of this acid. When plants are exposed to the sunshine, it has been found that they grew more vigorously in an artificial atmosphere containing one-twelfth of its bulk of carbonic acid; but when this proportion was increased the plants were injured. When the carbonic acid amounted to one-half the atmosphere, the plants perished in 7 days; and when the proportion was two-thirds, the plants stopped growth immediately. In the shade, any increase of the carbonic acid above the normal amount in the atmosphere viz one twenty-five hundredth (.0004) proved to be injurious. This fact is of importance; for the reason that although an increase in the quantity of carbonic acid in the air, might stimulate vegetable growth, yet it would seriously and even fatally disturb the balance of nature, because the air would then be unfit for the respiration of animals; and moreover although plants would grow more luxuriantly in such an atmosphere, in perpetual sunshine, yet they would suffer in the shade; and would also certainly require a proportionate increase in the supply of other food, to complete their

growth; for it is a well established law of vegetable growth that plants will not and cannot take into their circulation, to any considerable extent, any larger proportion of any one element of their structure than the normal quantity as found existing in them upon chemical analysis. Thus wheat plants contain certain elements in their composition, and these are found to be constant under all circumstances; and notwithstanding that the soil might contain an excessive quantity of any one of these elements, yet no more than the normal proportion would be taken up by the wheat. If one is increased, every one must be, and thus an increase of one would necessitate an increase of all. If then the atmosphere should contain an excessive quantity of carbonic acid and the growth of vegetation should be greatly stimulated thereby, it would lead to a very rapid exhaustion of the soil by the removal of the necessary mineral elements. This principle is a fundamental one, and applies generally to the growth of farm crops and should therefore be kept in constant remembrance by every farmer.

Carbonic acid unites with all the alkaline minerals in the soil: as lime; magnesia; potash; soda; also with ammonia; as the carbonates of these substances. Its solution in water gives this liquid an increased solvent power over mineral substances; thus common carbonate of lime is practically insoluble in pure water; but when the water contains carbonic acid, it is able to dissolve a considerable quantity of it, and this property applies to other mineral substances as well. This gives a practical importance to the functions of this acid which is of the greatest interest to cultivators of the soil. A simple experiment will illustrate this behavior of carbonic acid. A current of this gas passed through lime water will produce a milky appearance in it by the formation and precipitation of carbonate of lime. After a short time the cloudiness will disappear by the solution of the carbonate thus formed, in the acid water. By heating the water the carbonic acid is driven off and the carbonate of lime is again precipitated and appears.

The carbonic acid of the air is produced from a variety

of sources. It is given off copiously by the lungs of animals during respiration: it is formed during the process of fermentation, and the decomposition of all organic substances. But its absorption and reproduction in nature seem to be perfectly balanced. It exists primarily in the air to the extent named and is equally diffused throughout the mass of it. Plants spring up and grow and form their substance by its absorption from the atmosphere both directly and through the water which dissolves it. Plants decay and return their carbonic acid to the atmosphere. Animals feed upon the vegetation, convert the carbon into carbonic acid in their system by the production of vital heat, which is a true process of combustion; and exhale the gas from their lungs. Men dig coal from the bowels of the earth or cut timber from the forests and use these for fuel; in the combustion enormous quantities of carbon stored up in these substances are changed into carbonic acid, and are discharged into the air, in which it is immediately diffused. The succeeding generations of plants take this new supply and convert it to their uses and thus a grand routine is completed and the precise balance is maintained. This is but one of the many beautiful instances of the operation of a set of natural laws, the effects of which produce what is called the balance of nature; or the conservation of force. Both of these terms are well applied, and strictly correct, for as every operation of nature consumes force, it is the balance of these forces which maintains the equilibrium of the universe, preserving order and regularity of motion, which goes on undisturbed as generations come and go and centuries roll around; typifying the eternity of matter and the indestructible nature of elements.

CHAPTER XI.

NITRIC ACID.—ITS COMPOSITION, AND USES IN THE GROWTH OF CROPS.

Nitrogen itself is wholly inert and has no positive action in nature. Its office is wholly negative. But when combined with oxygen as nitric acid, or with hydrogen as ammonia, it becomes endowed with the most active properties; and enters into the most interesting and useful combinations in the structure of organic matter. Nitrogen forms one-sixth part of the animal tissues and the same proportion of the so called nitrogenous, or albuminoid portions of plants. But there is no evidence to prove that the nitrogen so combined in organic substance is derived directly from this element as it exists in the atmosphere; but on the contrary abundant reason to believe that it enters into the composition of plants in the form of nitric acid, which is a combination of nitrogen and oxygen. Moreover we are at a loss to know how this nitric acid enters into the composition of plant tissue; the general drift of the evidence gained by the most careful experiments going to show that it is carried into the plants in solution in the water of the soil, and is derived from the ammonia which is abundantly evolved from decaying organic matter in the soil and only to a very small extent from the contributions drawn from the atmosphere.

The sources of nitric acid are threefold; first; from the atmosphere in which it exists as a product of the decomposition of organic matter and from which it is washed by the rains which dissolve it; second; from a peculiar fermentation of organic matter, in the soil or in manure; which is produced by the agency of a low form of plant life; a germ or fungus which grows and spreads through the mass and causes the oxidation of the nitrogenous matter in it; or it

may be that it acts upon the nitrogen left free by the withdrawal of the oxygen from it and so induces its combination with oxygen; and, third; nitric acid is formed in the atmosphere by the action of electrical discharges by which the oxygen and nitrogen are brought into combination; in the manner previously mentioned.

The atmospheric sources of nitric acid are not sufficient to account for the large quantity of it which is found in any ordinary crop. Various experiments have been made for the purpose of ascertaining the amount of combined nitrogen, in either of its forms, which is gathered by plants from the atmosphere. The average of all the determinations which have been reached, give the quantity at about 10 pounds per acre. But the average consumption by the crops equals 44 lbs. per acre. So that this atmospheric supply is wholly inadequate for the growth of farm crops. This is one of seeming anomalies of nature, that while no less than nearly 20,000 tons of nitrogen, as it exists in the atmosphere, rest over one acre of surface, a crop cannot procure the small quantity of 44 lbs. per acre from all this vast atmospheric store. But this is quite consistent with the regular course of natural operations. The elements form combinations, as has been shown of an infinite number and variety, and it is only in these combined forms that they serve their ends. The elementary carbon can provide plants with their supply of carbon, only through its combination with oxygen; and in like manner the elementary nitrogen requires a certain preparation to fit it for assimilation by plants.

The small quantity of nitric acid which is procured from the atmosphere by the crops, is however sufficient for all the practical needs of the intelligent farmer. He does not depend upon the air to supply his crops with this scarce and most valuable nutriment. By a wise course of economical management he accumulates a large amount of organic matter rich in nitrogen, the decay of which he aids by his skillful methods, and so provides an abundant stock of food for his crops. If the atmosphere then contributes a fourth

of what his crops need, he is the gainer by so much, and by his abundant provision in the form of manure and fertilizers, his fields are yearly increasing in fertility. The formation of nitric acid and nitrates in the soil by the action of the special ferment alluded to is of paramount importance to the farmer. The manner by which this result may be produced artificially, and has been effected for the production of saltpeter, is as follows. A mass of soil rich in organic nitrogenous compounds, as urine, animal excrements, vegetable and animal matter of any kind, is put into a heap and mixed with a quantity of quicklime. The heap is put up loosely so that the air can penetrate easily through the mass. In course of time the mass is leached, and the liquid, highly charged with nitric acid, is neutralized with carbonate of potash; the solution is then evaporated and nitrate of potash or saltpeter is produced. These heaps are known as "niter beds" and the process was formerly used extensively for procuring saltpeter for the manufacture of gunpowder for warlike purposes, before the great natural deposits of niter in South America were discovered. These natural deposits are now the chief source whence saltpeter of commerce is procured, and yield thousands of tons yearly of nitrate of soda for use as a fertilizer. It is a probable supposition that the origin of these deposits was similar to that of the artificial niter beds. A vast mass of organic matter rich in nitrogen, such as fish, or plants of some kind, had accumulated in shallow lagoons of the ocean, and had been covered with mud by gradual deposition. The action of the atmosphere in the hot arid climate of Western South America favored the nitrification of the mass and the nitric acid formed, combined with the soda of the salt from the sea water to form nitrate of soda. One of the frequent convulsions of nature common to that coast elevated the surface of the land, gradually, during the formation of the deposit, and the gradual rise has left the niter beds in their present position at a distance from the ocean. The compost heaps made by the farmer, in such a manner as to favor this process of nitrification, form a source whence a

large supply of this indispensable plant food may be procured.

It is quite possible, not to say probable, that the oxidation of nitrogen may occur directly in these beds. A large quantity of free nitrogen is necessarily left in the mass by the consumption of oxygen in the decomposition of the organic matter. This nitrogen is dissolved to some extent by the water in the heap, the water is decomposed by the chemical action, and in the aggregate result of the vigorous chemical actions and reactions going on there is no violent assumption in the conclusion that the free nitrogen is seized upon to some extent by the omnipotent oxygen and reduced to nitric acid. The possibility or probability of this is all on the side of the farmer who may avail himself of it as far as possible, by providing the means for it and securing the results of it if there are any.

The earth is a great magnet and electrical disturbances are constantly going on, through its mass and upon its surface. Every spark of electricity, from the lightning flash, to the tiny discharge from weak currents in the soil, cause a union of the elements of the air and produce nitric acid. It is quite possible, and even probable, that many vexed questions in regard to the source of the nitrogen gathered by such plants, as clover, from the soil, may in time find their solution in this direction. So far we know that a crop of clover gathers an enormous quantity of nitrogen from some source. All we know of the subject tends to point out the soil as the source of it. A fertile soil may contain from two to three tons of nitrogen to the acre, and of this a crop of clover will gather in its roots and stubble and leave upon the soil from 150 to 180 lbs.; while no other crop could extract from it enough to supply the needs for any profitable yield. The clover has procured this nitrogen in some hidden way; how we know not; but we know the fact. This is sufficient for the purposes of the farmer, who may speculate upon the causes of it, while he avails himself of the results. It may be however that a large portion of this gathered nitrogen has been brought up from great depths

in the soil by the long tap roots of the clover plants and to which the roots of other plants cannot reach; and that some of this organic nitrogen, at least, may have been procured from nitric acid produced in the deeper soil by the action of electrical currents. Perhaps this source is over estimated; but it is certain that the action of electrical discharges through the soil, which are quite as frequent as those through the air, and from cloud to cloud, have as yet not been considered to any extent, if at all, in the discussions and investigations of this exceedingly important question: "where do plants procure their nitrogen?"

CHAPTER XII

AMMONIA.—ITS COMPOSITION, PROPERTIES, AND RELATION TO VEGETABLE GROWTH.

Ammonia has been previously mentioned as a compound of nitrogen and hydrogen gases. It has some very interesting and important properties in regard to organic matter, and has been made the subject of much study and experiment by agricultural physiologists. It is a colorless gas, but offers in its other remarkable properties, an instance of the wonderful changes in matter made by chemical combination. Its primary elements have neither taste nor odor, but when combined, this product has a most powerful penetrating odor; a burning acrid taste: extinguishes flame; is not combustible as hydrogen is; instantly suffocates animals; kills living vegetables, and corrodes their substance.

It is absorbed in large quantities by porous substances; charcoal absorbs 95 times its own bulk of it; peat takes up a large amount of it, varying with its own condition; decaying vegetable matter also takes up and holds it in its mass; porous soils, clay, and iron oxide mixed in the soils of a red color, are capable of absorbing and retaining it within their pores, when it is brought into contact with them.

But water absorbs ammonia to a far greater extent than any other substance. If a bottle filled with the gas is inverted in water, the water will instantly rush up and fill the bottle, absorbing and dissolving the ammonia and occupying its place. The solution of ammonia in water is lighter than water to the extent of one-eighth; and has the same properties as the gas itself.

Ammonia is an alkali and combines with acids; changes vegetable red colors to blue, and in combining with some acid gases forms solid substances; as for instance when carbonic acid gas is mixed with it, the two gases combine

and form solid carbonate of ammonia, in the form of minute particles appearing as a white cloud. A feather dipped into diluted hydrochloric acid, or in vinegar, and held over a bottle of ammonia water, or any substance from which ammonia is escaping, is soon covered with a white downy substance, which in the one case is chloride of ammonia, and in the other is acetate of ammonia. This test of the presence of ammonia is an easy method of distinguishing it where its escape from decomposing substances is suspected.

This gas is only little more than half the weight of air (59 hundredths); hence it rises and is diffused in the air with ease. It consists of 14 parts by weight of nitrogen (82.545 per cent.) and 3 parts by weight of hydrogen (17.455 per cent.).

In nature it exists in large quantity. It is almost universally diffused throughout the atmosphere and in the surface soil and the waters of the atmosphere and the earth; but it is not known to enter into any of the mineral compounds of which the earth is composed. One exception may be noted and this is guano; a substance supposed by some to consist of the decomposed excrements of sea birds, and by others of infusorial matter, having some relation to mineral substance. But in either case guano would be of organic origin and a product of the decomposition of organic matter. This substance when free from earthy matter contains a large proportion of ammonia, both free and combined, and is the most valuable and costly fertilizer known.

Ammonia chiefly exists in a state of combination as carbonate, but also as a chloride, and a nitrate. As it combines very freely with acids, and most easily with carbonic acid, it is rarely found free in the atmosphere, and then only temporarily; but it is as easily separated from its combinations, on account of its volatile character which makes it readily subject to the influence of heat.

The influence of ammonia upon the growth of plants is exceedingly active. It not only promotes the growth with

rapidity and luxuriance, but it appears to exercise a considerable control over the functions of vegetable life. In this regard there are several special properties of this compound which should be clearly understood, by the farmer and student of agriculture.

First.—It has a powerful affinity for acid substances, and unites with them with great facility as it escapes into the atmosphere, or meets with them in the soil. Hence when formed or liberated in the stables; in the cattle yard; manure and compost heaps and in other places where organic matter is in a process of decay; it unites with such acid substances and forms salts or saline compounds. And these salts appear to exert a considerable influence upon the growth of crops.

Second.—This affinity for acid substances however, is much less active and strong than that possessed by other alkaline compounds, as potash, lime, soda and magnesia. Hence if any one of these alkaline substances is brought into contact with a salt of ammonia, this is at once decomposed and its acid is taken up by the stronger alkali, while the ammonia is separated and set free in its gaseous state. If a small quantity of sal-ammoniac (chloride of ammonium) is powdered and is mixed with twice its weight of powdered quicklime, the ammoniacal gas is liberated, and the chlorine unites with the lime. This is one of the several methods of procuring pure ammonia, and is an instance of one of the very many useful functions performed by lime in the soil for the benefit of farm crops; especially upon lands which have been made rich in organic matter by liberal manuring, or which are naturally well supplied with decaying vegetable matter, as reclaimed swamps or peat bogs. It also shows the injurious effect of mixing lime with manure of any kind in which ammonia exists, or can be developed by the decomposing agency of the lime, unless at the same time, the lime is used in moderate quantity and a considerable amount of soil or other matters which absorb ammonia are used to counteract this result of the lime.

Third.—The salts and saline compounds which are formed

by the union of the ammonia with acids, are like the gas itself, exceedingly soluble in water. Two results of this property follow. The carbonate of ammonia which is formed in the atmosphere by the union of the ammonia and the carbonic acid, is readily dissolved, and is washed down and brought to the earth by the rains and dews; the soil is thus supplied with most useful food for the crops, while the air is freed from a noxious substance and is purified for the use of mankind and animals. Also whatever combinations of ammonia are formed in the soil, are dissolved and diffused through it by the rains, or other moisture derived by condensation, and are carried everywhere in all directions by the movements of this moisture among the fine particles of the soil.

Fourth.—As this gas is readily absorbed by porous earthy matter, it is readily taken up by the soil and held in reserve to be yielded up to the roots of plants with the water of the soil which draws upon this source for a supply. Hence the ammonia yielded by the decomposing organic matter of the soil, is held safely but loosely among the finest particles of the soil as an intermediate deposit, to be drawn upon for future use as it may be required by the crops. This property of fine dry soil is of great importance to the farmer for it is exerted to a large extent. All porous substances— as has been previously explained—have, among other properties, that of oxidizing organic matter. Hence it has been found that the dry earth used as an absorbent in the domestic earth-closets and urinals, so rapidly and effectively oxidize these matters which are rich in nitrogen, and in which the nitrogen is easily converted into ammonia, that they wholly disappear, and the dry earth after having been used repeatedly nine times in the closet, with alternate periods of rest, still gives no indication of having been used for this purpose in the slightest offensiveness, or appearance of containing any disagreeable substance. The organic matter has disappeared; having evidently been resolved by oxidation into its elements and the gases having been absorbed and held by occlusion in the interstices of the porous earth.

This fact is full of significance to the farmer who may perceive in it a proof of *the necessity of a thorough pulverization of the soil for the maximum growth and yield of his crops.*

Fifth.—In the state of carbonate,—in which it mostly exists, because of its affinity for this acid and the abundance of it in the atmosphere—ammonia decomposes gypsum (sulphate of lime) and changes acids with it; forming sulphate of ammonia and carbonate of lime. This action only goes on however when moisture is present. The beneficial action of gypsum (the common agricultural “plaster”) upon clover, corn and other crops has been ascribed to this single property. But popular impressions are easily formed and take a firm hold upon the popular mind, which does not stop to think and reason, or take pains and time to observe closely; hence the opinions thus formed are too often only superficial and partial and are not substantial enough to base a rule or principle upon. No doubt some of the favorable results of an application of “plaster” to the soil, in some cases, may be due to this mutual action of gypsum and carbonate of ammonia, or of gypsum and free ammonia upon each other; but there are other principles involved in the subject which must be referred to in a more appropriate place hereafter and to which much of the effect of gypsum is undoubtedly due. Nevertheless as it is a fact that gypsum and carbonate of ammonia do exert this mutual reaction upon each other, and under favorable circumstances the result may be conspicuously marked upon the growth of the crops. For 100 lbs. of common finely ground gypsum—a comparatively small quantity to be spread over an acre of land—will fix or unite with nearly 20 lbs. of ammonia, containing $16\frac{1}{2}$ lbs. of nitrogen;—a comparatively large quantity of this scarce and invaluable plant food, for it is equivalent to about 60 lbs. of nitric acid and nearly 100 lbs. of nitrate of soda, which is considered a very liberal use of this most active fertilizer. And this fact is one to be studiously considered and judiciously applied by every intelligent farmer.

Sixth.—The presence of ammonia in a soil which contains

decaying animal and vegetable matter, induces this matter to attract oxygen from the air with greater rapidity and abundance. That is, in simple words, ammonia assists in and hastens the decomposition of organic substances, and the result of this is that compounds are formed which react upon the ammonia, combine with it and form ammoniacal salts. When these are in their turn decomposed by lime or other substances in the soil, they become more available plant food, being more advanced towards a fit condition for this purpose and for assimilation into the circulation and cellular tissue of vegetables.

Seventh.—The most important property of ammonia, and that consequently of the greatest interest to farmers, is the ease with which it undergoes decomposition, in the air, the soil, and the interior of plants.

In the atmosphere it is intimately mixed with a large quantity of oxygen and it also comes into close contact with this gas in the soil. By certain influences already referred to it undergoes a slow and constant decomposition, or oxidation, its hydrogen being converted into water, and its nitrogen, wholly or in part, is changed into nitric acid. This change certainly goes on within the soil and most probably within the substance, or in the sap, of plants. That something of this kind goes on within the plants, as well as in the soil, seems to be clearly indicated by the extraordinary effect of a small quantity of ammonia or of its compounds; in a remarkably short period of time; upon the condition of vegetation. This is very conspicuously seen, in the simple experiment of growing plants in pots where the condition of the soil can be controlled and the effects of plant food noted. A few drops of ammonia added to the water used for the plants, will be seen to change the color of the leaves in a very short time; producing a deep vivid verdure, where before a pale yellowish color prevailed. Investigations are in progress to decide this question but a speedy solution is not likely to be reached. The conditions under which plants exist and the reactions of the compounds of which they are made up upon each other are so varied, that

a judicious student hesitates to form conclusions, and patiently repeats and verifies his experiments; and at the last when he is himself convinced of the truth of any result, he is slow to declare it to the world, but watches it and tries it in other ways until doubt has no longer any existence. Hence the slow progress of knowledge in the true science of agriculture and the caution with which farmers who are following up the experiments of professional students, should watch the results, and form practical conclusions therefrom.

But the peculiar action of ammonia upon plant growth, and the analogy which exists between its action and that of other compounds, lead us to believe that ammonia enters into the circulation of plants, and that the hydrogen of which it contains so large a proportion, there separates from the nitrogen, and combines with other organic elements which enter by the roots or leaves and thus aids in producing the various solid substances of which plants are constructed and made up. The nitrogen is then fixed in the flowers, helping to produce the bright coloring matter and the agreeable odors; and to form the gluten and albumen of the seeds, and other parts. These and other important considerations will be more fully considered in another chapter.

It may be exceedingly interesting to note here, the results of some careful tests made by a German agricultural chemist and experimenter, in regard to the effects of ammoniacal manures upon the yield of grain and the proportion of the nitrogenous substances contained in it under varying circumstances. A number of experimental plots were treated as follows, and were sown with wheat. Then from 100 parts of the produce of these plots the various amounts shown of gluten and starch, and the increased product, were estimated.

	<i>Gluten.</i>	<i>Starch.</i>	<i>Produce.</i>
Without manure.....	9.2	66.7	3
With rotted vegetable matter only..	9.6	65.94	5
Cow dung.....	12.0	62.3	7
Horse dung.....	13.7	61.64	10
Sheep dung.....	33.9	42.8	12
Night soil.....	33.14	41.44	14
Dried blood.....	34.24	41.3	14
Dried urine.....	35.1	39.3	12

These facts seem to show that as the ammonia in the manures increase, the yield of the crop grown is larger, and the more nitrogen is contained in the produce. Similar results have occurred in the ordinary operations of the farm and the facts have led farmers to use artificial manures rich in ammonia for the express purpose of procuring more valuable grain and a larger yield of it. Millers knowing these facts have taken special pains to acquaint farmers with them, with the purpose to procure a better quality of grain for making more valuable flour.

CHAPTER XIII.

THE SOURCES OF THE CARBON OF PLANTS.—HOW IT
ENTERS INTO THEIR CIRCULATION
AND SUBSTANCE.

It is obvious to the cultivator of the soil that the various plants of which his crops consist, are supported by the earth and the air, both. It is necessary to the intelligent culture of farm crops then to learn how much plants owe to each of these; and for which of their elements they are indebted to the soil and for which to the air. As carbon contributes the larger part of their substance to plants this element demands the first consideration.

Carbon is a solid substance and is therefore incapable of entering directly into the structure of plants. It must then present itself to the roots of plants in the soil, in solution in water; and to the leaves in a gaseous form; for it is a law of plant growth that no solid substance can enter into the roots; and no liquid or solid substance can enter the leaves or any other portion of the plant which is above the ground. Therefore the sources of all vegetable carbon must be the soil in which the roots of plants exist, and through which they penetrate; and the air in which the stems and leaves of plants are constantly bathed. There is always a large quantity of vegetable matter in a decaying state in the soil, and which is made up of the remains of previous vegetation; and the farmer is continually adding to this by the manure which he applies to the land for the purpose of feeding his crops. And it has been shown that about one-half of this matter consists of carbon. The question then arises; is this carbon of the soil, the source from which plants derive their supply; and do they feed upon it by and through their roots; or do they derive it from the air, in which we have learned that a vast amount of carbonic acid exists in the form of an evenly diffused mixture. It is not usual for far-

mers to consider this question with much interest, if at all; giving more attention to the other elements of plant growth and leaving the carbon to take care of itself. But it is a question which should be carefully considered, because of its importance and because other questions which draw attention from it, may become more prominent than they deserve.

We know that there was a time when no vegetable matter existed in the soil and when vegetation first covered the earth's surface. Then the first plants must have grown and matured without the aid of any vegetable or animal matter in the soil and could have derived their carbon from no other source than the atmosphere, directly; or indirectly, by its presence in the water in the soil. It is also known that soils which have been perfectly arid and have produced no vegetation, or very little previously, yield abundant crops when brought under culture by irrigation, and that plants are often grown in water and in some cases grow luxuriantly without having any connection with the soil. Further it is a common practice for farmers, when their lands are unable to produce maximum crops, to seed them to grass or clover and to leave them for years to recuperate and become enriched by the gradual accumulation of vegetable matter in the soil; and when these lands are again plowed a rich black soil filled with carbon is found, where but little organic matter existed previously. This also applies to lands under forest growth, and to the rich prairies of the west, where the dark vegetable mold lies many feet in thickness and contains an inexhaustible supply of carbon; as well as to the peat swamps in which enormous quantities of carbon have been accumulated. We may also take into consideration the vast beds of coal which have been made up of accumulations of vegetable matter, the luxuriance of which, proved by its remains, still to be recognized in the coal, almost surpass imagination; and may then ask, whence did all this vegetable growth procure its carbon, which has gradually accumulated in the soil to this vast extent; and which we can perceive still accumulates under our own personal observation?

Any reasonable person will be impelled to reply, the atmosphere must have been the first source of it; that all these plants must have existed upon such carbon as they could gather from the air, and that as they perished, they left a supply in the soil which was not fit to nourish succeeding generations, and hence accumulated during the vast periods of time which have elapsed since vegetable growth first began.

This reasoning is plausible and seems free from objection, and would seem to justify us in concluding that plants derive their carbon directly from the atmosphere. In some cases this must be certainly true, for there is no other explanation to be given of the circumstances. But as regards the culture of farm crops it would not be safe to conclude that the vegetable matter of the soil has no relation to the growth of plants, and that the carbon existing in the soil does not contribute to the carbonaceous substance of vegetables. For facts prove otherwise. Just now the public interest is in a lively condition of agitation in regard to the question, whence do plants gather their nitrogen, and the equally important question in regard to carbon is neglected. Farmers are actively engaged in procuring nitrogen in various forms at very considerable expense, believing this to be the chiefly indispensable agent in fertilizing their crops. But a few farmers of intelligence, and used to closely observe what is going on in their fields, have not lost sight of the importance of a large supply of combined carbon, and are adding to their fields as large a quantity of carbonaceous matter as they can procure, with such nitrogen as may seem to be adequate, and are thus avoiding the extreme to which the popular belief seems to have turned.

In considering this question in the light of present experience, it may be considered that at first only a very poor and weak growth of inferior plants covered the soil; or that by reason of the exceedingly active chemical changes which were then occurring, the soil was highly charged with carbon in such forms as were available for plant food. In the one case vegetable growth would proceed slowly to fill

the soil with decomposing matter and prepare it for a better product; and plants procuring a portion of their carbon from the air and gradually finding an increased supply in the soil from the decomposed organic matter, there would, in time, be a surplus, and this surplus would constantly increase, and gradually accumulate and fill the soil. In the other case the vegetation would be developed on an enormous scale, just as we have reason to suppose it was at the period when the carbonaceous matter which supplied the materials for the vast coal beds was deposited. Climate necessarily would have much to do with this, as it has now; for in tropical regions the vegetation is exceedingly luxuriant, forming dense jungles through which it is impossible to pass without laboriously cutting a way with axes, over an enormous deposit under foot of the tangled and decomposing remains of previous luxuriant growth.

We are forced to believe from the evidence that plants may derive a large portion of their carbon from atmospheric sources, and that they derive a considerable portion of it from the soil. That they are fitted by nature to draw sustenance from either source or from both; and that the proportion of their food which is derived from either source depends upon a variety of circumstances; such as the nature of the plant; the period of its growth; on the soil; on the abundance of provision furnished by the soil; upon climate; season; and other circumstances; so that the most reasonable conclusion would be, that plants, like animals, have a power of adapting themselves, to a certain extent, to the conditions in which they are placed, and of finding aliment, and supporting life, and of making growth, by the help of such nutriment as they may most easily reach. Just as sheep, which are herbivorous animals, under certain conditions are known to live upon fish, and to thrive as well to all appearances upon this unusual diet, as upon the pastures.

But supposing that plants derive the whole of their carbon from the air, or are able to do so; then knowing that no other compound of this element is found in the atmosphere

to any appreciable extent, than carbonic acid, and that this compound is everywhere diffused throughout the atmosphere and is always found in solution in water, the conclusion cannot be avoided, that it is from carbonic acid that the carbon of plants is derived, primarily. This conclusion is supported and confirmed by the knowledge that plants absorb carbonic acid through their leaves in the sunshine, and that they will die in an atmosphere from which carbonic acid is wholly excluded.

Again supposing that plants derive their carbon wholly from the soil or are able to do so, then, knowing that the most abundant product of the decay of vegetable matter is carbonic acid; and that in a well manured soil filled with decaying vegetable matter, this gas must be quite abundant; and that water dissolves it freely, we must be satisfied that it is from this carbonic acid, absorbed with the water of the soil by the roots that the carbon of plants is derived. In either case it is the carbonic acid which supplies the carbon, and it is most probable that this enters the plant both by the roots, and leaves. Thus whether from the earth or the air, this gas furnishes an unfailing supply of food for plants from which their carbon is derived.

But when water passes through the soil it takes up whatever soluble substance it may meet—potash; soda; lime; magnesia; silica; &c.; and conveys them into the plants by the medium of their roots. Do the roots exercise a supervision over the absorbed waters and reject every soluble form of carbon but that of carbonic acid? This is a question of interest too to the farmer and applies directly to the practice of manuring the land. This subject is out of place as yet, but the question is pertinent to the present enquiry. It is known that plants do not exercise such a watch and have no discretionary power over the water which they absorb; for various coloring matters as madder and the juice of poke root berries have been absorbed into the circulation of plants and have imparted their color to the flowers, and other parts. These coloring matters then undergo a chemical change in the plants and even afford nutriment. Sugar

gum and gelatine have been thus fed to plants, with the effect of making them grow vigorously. A great variety of organic substances containing carbon may therefore be absorbed into the plants and afford nourishment. Practical farmers act on this principle and it forms the basis of many of his operations and daily labors as he accumulates a stock of organic substances in the form of manures as food for his crops.

CHAPTER XIV.

SOURCES OF THE NITROGEN OF PLANTS.—ITS COMPOUNDS AND THEIR EFFECTS UPON THE GROWTH OF PLANTS.

While the quantity of nitrogen contained in plants is small as compared with that of other elements, yet its office in the structure of plants, and especially of their seeds, is so important that careful and patient study of the character and changes of this element is well worthy of the time employed. It is not always the most abundant elements in nature that are the most worthy of regard. The chief purpose of many farm crops is the seed, and although this part of their substance may be quite insignificant in quantity, yet it is often the most precious and highly valued; and it is in the seed that the nitrogen of plants is most abundantly stored. Again while the nitrogen in the more bulky crops may be but 1 to 2 per cent., this element is the most important for the profitable feeding of farm stock: as it contributes largely to the formation of the muscular tissue and supplies the waste of it by muscular exertion.

Moreover, any substance is to be valued according to the difficulty of obtaining it. A diamond is so highly valued as it is, because a whole year's labor of several men may be spent in the vain search for one, and its enormous price in commerce merely represents the labor spent in its successful discovery. Nitrogen is the most costly substance the farmer is obliged to procure for the purpose of feeding his crops, and although it is the most abundant constituent of the atmosphere, yet it is so inert and passive and submits to combination with other elements so unwillingly, that nature supplies only a small portion of what the soil requires of it, to produce a profitable crop. It is a most serious fact in regard to this point, that the greater part of the farmers

labor and his largest expenditures for fertilizing matter, are made necessary for the purpose of supplying his field with an adequate amount of nitrogen for the growth of good crops. Does he spend labor and care in the preparation of the soil? it is that nitrogen compounds may be developed in it. Does he feed his cattle with rich food purchased at great cost? it is that the manure may be enriched with as large a quantity as possible of this valued element. Does he laboriously gather organic matter and lime, and compost these with his manure, and sedulously watch over the decay of these materials? it is that the nitrogen developed may not be lost, but preserved for use to supply the never satisfied needs of his crops. And thus his thoughts by day, and his reflections by night; his labors; studies; and expenditures; all center upon this one most important, but otherwise inconsiderable element of vegetable matter.

With regard to an element so difficult to be procured, it is a serious fact that its consumption in the soil is comparatively large. A crop of hay takes 60 lbs. of it from one acre of the soil; a crop of clover removes 180 lbs. ; wheat carries off 45 lbs. Hereafter this subject will be pursued to its completion, here it is the purpose to consider the sources from which plants can procure their supply rather than the amount of it which they need.

When we come face to face with this question we are met with the fact, that the only source from which any large quantity of nitrogen can be obtained is the atmosphere. Nitrogen does not exist in the rocks excepting in those of an organic origin as coal; the atmosphere is the great storehouse of it. Organic matter contains a considerable quantity of it, and its decay in the soil furnishes the crops with a large part of their demands; but the first plants which covered the soil must have procured their supply, as they procured their carbon; viz, from the atmosphere, primarily. But in coming to this conclusion it by no means follows that the nitrogen of the atmosphere is directly absorbed by plants and made subservient to their growth; or that it is absorbed in an uncombined state through any other me-

dium. Though the leaves of plants are continually surrounded by nitrogen, and the roots may be bathed in water containing it in solution, yet there is no evidence to show that any plant is so constituted as to avail itself of this supply. Indeed there is a good deal of evidence to prove that the leaves do not absorb nitrogen and that if any uncombined nitrogen at all is contributed by the atmosphere and used by plants, it is through the roots that it must enter into their circulation. But that even this occurs is a matter of opinion only, with no evidence to support it.

It is an essential part of good farming to break up the land and reduce it by thorough tillage, by means of the most effective implements, to a loose and mellow condition, so that the air can have access to the decaying organic matter in the soil; as well as to the living roots which permeate the earth in all directions to considerable depths below the surface. When the air is thus admitted to the roots, it is not impossible that some of the nitrogen, as well as some of the oxygen, may be absorbed and made use of by the plant directly; but in the changes in the organic matter which occur, it is known that nitrogen is disengaged in a form in which it can be appropriated by plants; and it is probable that some atmospheric nitrogen may also be seized upon and converted into plant food at the same time. To what extent this may happen however we have as yet no certain results from which any definite knowledge has been reached. If any nitrogen enters the roots of plants in solution in water, the quantity is very small and uncertain.

When water is exposed to the air it gradually absorbs both oxygen and nitrogen; as has been previously mentioned. The whole quantity of these mixed gases thus taken up amounts to about 4 per cent. of the volume of the water and in rain water about two-thirds of this quantity consists of nitrogen. A hundred cubic inches of rain water will therefore carry into the soil $2\frac{2}{3}$ inches of this gas. But this water in passing through the soil dissolves also other substances; carbonic acid and various solid matters and in

doing so gives off a portion of the other gases which it had previously taken up and absorbed from the air. But if the water should actually carry to the roots and take with it into the circulation of the plants 2 per cent. of its bulk of nitrogen, the whole amount of this nitrogen would be quite inadequate to supply the requirements of a crop. For the whole rain fall in this country, during the season when a crop of hay, wheat, or oats is grown, amounts to about 8 inches; and of this at least one-half is evaporated very soon after it has fallen. If we suppose the quantity left in the soil during this period amounts to 6 inches there would be 864 cubic inches of water fall upon a square foot, containing of nitrogen about 17 cubic inches, or about 5 grains in weight. This would give something over 30 lbs. to the acre of nitrogen carried into the soil. But it would be unreasonable to suppose that more than one-third of this quantity would be carried into the roots and be transpired by the leaves of any growing crop. There would then be about 10 pounds of nitrogen carried into the circulation of the plants, which is only one-sixth part of that which is contained in a crop of hay, and one-eighteenth part of that removed from the soil in a crop of clover.

This is a rough estimation, but it affords convincing proof that plants cannot depend upon the atmosphere for their supply of this element; but that they draw their chief supply of it from its combinations with oxygen and hydrogen.

If it is asked how the first plants grown upon the soil, the origin of vegetable growth upon the earth, gained the nitrogen they required to build up their tissues, it may be replied, that in this case, the earliest plants grown were not of that highly organized character which demanded a large proportion of nitrogen. In the coal beds, which were formed of vast deposits of vegetable matter accumulated during lengthened periods of time, are found plants of a far lower character than those grown as farm crops. Mosses, ferns, and semi-aquatic plants made up the larger bulk of them, and as these died and decayed, the little nitrogen they possessed gradually accumulated in the soil in the mass of de-

cayed matter which remained. This process continually repeated, laid a foundation for a higher character of vegetable growth; until in time the soil became well supplied with organic matter; and fitted for the occupation of man, who afterwards appeared upon the scene, and entered into possession of a soil abounding in accumulated fertility. We know of our own knowledge that the soil we cultivate, however rich it may be at the first, is very quickly exhausted of nitrogen, and that a renewed supply is indispensable to the growth of crops. This exhaustion is so rapid that there cannot be any material addition to the supply, from the atmosphere.

The most important combination of nitrogen is that with hydrogen, known as ammonia; and that this gas enters into the circulation of plants is rendered probable by a variety of circumstances.

It is known that ammonia exists in the sap of many plants; as in the beet, birch, and maple, in which it is associated with cane sugar; in the leaves of tobacco, in elder flowers, in various fungi and in other plants. A species of chenopodium actually exhales ammonia from its leaves; it also appears in the odorous exhalations of many other plants and flowers.

Ammonia can be procured from nearly all vegetable substances by distillation; and many vegetable extracts are found to contain it. When wood is distilled in retorts for the manufacture of acid, ammonia is produced.

These and other facts of similar bearing are in no wise proofs that ammonia is the form in which nitrogen enters into the substance of plants; either through the roots or the leaves; because there are ways in which it could be produced in the plant by the same converting power which produces sugar and starch in the interior of the plant from carbonic acid and water; and while ammonia is easily produced from coal and wood, yet we know that it does not actually exist in these substances in their natural condition. In the case of tobacco, the production of ammonia by means of a high temperature may be illustrated by a simple ex-

periment. The sap and dried leaves of this plant contain nitrate of potash (saltpeter) and a small quantity of ammonia. When the dried leaves are burned ammonia is given off in sensible quantities with the smoke, and can be detected by bringing a piece of reddened litmus paper into contact with the smoke when the color will be changed to a blue; or by using a feather dipped into vinegar or any weak acid, the white cloud of carbonate of ammonia will appear. (Litmus paper is used for testing the presence of acids and alkalies. It is absorbent paper steeped in a red or blue vegetable coloring matter, as the juice of red cabbage, of the red beet, or of the berries of the poke root. Litmus is a red color obtained from some species of lichens, and is changed to blue by ammonia. An alkaline liquid or vapor will change the red to blue, and an acid will change the blue to red again. This test can be used by farmers in a variety of ways; in detecting the escape of ammonia from manure, or acidity in milk).

In this case however the ammonia may be in part produced by the combustion, which decomposes the water contained in the tobacco—to the extent of 14 per cent. in its usual air dry condition—and thus disengages hydrogen, which can easily combine with the nitrogen disengaged in the combustion of nitrate of potash present in the leaves, and so form ammonia.

But there are other circumstances which tend to favor the belief, in a much stronger manner, that ammonia does enter into the circulation of plants in many cases.

Experience has shown that plants grow most rapidly and luxuriantly when liberally supplied with manures containing animal substances. Dried blood; fish scrap; guano; the dung of fowls; decomposed urine and night soil; are all rich in ammonia and are the most efficacious of manures. The same is true of the salts of ammonia. These substances are used when in a state of decomposition and when the evolution of ammonia is in most active progress. Flowering plants also grow with greater luxuriance when a small quantity of ammonia is added to the water given to them. In

the writers garden at the present time is a bed of red cabbage; through the center of which flows a drain from the yard in which the manure from the horse stable is kept. On both sides of this drain, for about 3 feet, the red cabbages are blue: and their growth is far more luxuriant than that of other plants distant from the drain. Is not this a distinct illustration of the fact that the ammonia from the liquid manure; in which it is shown to be abundant by the litmus paper test; is absorbed by the cabbages and acts upon the coloring matter with its usual effect?

In all these cases however the proof is not decisive; but it is quite sufficient to make it appear that the probabilities are all in favor of the belief that ammonia does enter into the tissues of plants when brought in solution in water to the roots and to justify us in holding this belief. But actual proof is wanted before this can be asserted as a fact. The changes which occur in nature are so involved; so intricate; so sudden; and so unexpected when experience is at fault; that we should hesitate to found a belief upon any but the strongest evidence, or to base a principle, or a law for our guidance, upon anything but accurate and well determined knowledge. So far as the question under consideration is concerned this knowledge is wanting; but a mass of observed facts tending thereto is all that we possess. Other soluble compounds of nitrogen are formed during the decay and oxidation of animal substances and actually exist in the liquid manures of the stable and yards, and they are likely to be absorbed by the roots of plants when applied to the soil. Thus urea, a compound of carbon, hydrogen, nitrogen and oxygen, and containing about one-third of its weight of nitrogen, exists abundantly in urine, and by its decomposition produces carbonate of ammonia. Being very soluble this substance may enter with water into the roots of plants and be decomposed within the tissues and made to give up its nitrogen. The same may be applied to other compounds of nitrogen; so that while the fact that animal manures are very beneficial to the growth of plants, may be considered as favoring the probability that

the ammonia contained in such manures enters into the substance of plants and yields up nitrogen to them, it must also be considered that a portion of the nitrogen contained in plants and procured from decaying animal substances, may be obtained from other compounds of it than ammonia, and in which ammonia may not exist.

Nitric acid is invariably present in the juices of plants in combination with potash, soda, lime, and magnesia. Therefore all the evidence afforded by the facts above noted are also applicable to the belief that this acid is one of the sources, at least, from whence the nitrogen of plants is derived. This acid has been detected in tobacco, and the sunflower, and in the grain of barley in the form of nitrate of soda. If we were therefore to infer from these facts that this acid really enters the roots of plants we might draw a certain conclusion. Like other compounds of nitrogen, it may have been formed in the interior of plants during the many changes there effected, and hence its presence proves no more in regard to a solution of the question at issue than the presence of ammonia. The same uncertainty would still exist.

But the most recent investigations go to show that of all the forms in which nitrogen enters into plants, nitric acid is the most probable one. It exerts a powerful influence upon growing crops of grass and grains. It changes the color of the leaves to an intense green in a short time; and largely increases the quantity of nitrogenous matter in grain, as well as the yield of the crop. For instance it has been found that a dressing of nitrate of soda has increased the amount of gluten in wheat from 19 to 23½ per cent. reducing the starch from 55½ to 49½ per cent. Many other similar instances are recorded, all tending to show the favorable effect of nitric acid upon the growth of vegetation. Heretofore a still more striking instance has been given of similar results from the use of manures rich in ammonia. But recent researches of the leading investigators especially those at the Rothampstead farm in England under the supervision of Sir J. B. Lawes, aided by a most efficient

corps of assistants, have shown that there is much reason to believe that ammonia is oxidized and changed to nitric acid and in this form it is that the nitrogen enters into the circulation of plants.

To sum up the conclusions in regard to this question, of such surpassing interest to farmers, which are presented by a consideration of the facts known in this connection, the following propositions result.

First.—That uncombined nitrogen of the atmosphere may enter into the circulation to a small extent, either in its natural form of a gas or in solution in water ; and this probably does happen. But the quantity so gained by plants is very small and is wholly insufficient for their needs and only a small proportion of that which vegetables actually contain.

Second.—That ammonia *has the power* of entering into plants and of yielding nitrogen to them to a very large extent and actually in excess of their necessities so that the normal quantity of nitrogen in the product is largely increased ; and it does *appear*, but is not proved, that plants do derive nitrogen from this source.

Third.—That in like manner nitric acid *has the power* of entering into plants and of yielding nitrogen to them to a larger extent than they need to produce a normal product and there is reason to believe that plants do derive the largest portion of the nitrogen they contain from this source.

Fourth.—But there is also reason to believe that ammonia is changed to nitric acid in the soil, and perhaps in the plants, and in this combination it is that nitrogen enters the roots of plants and contributes to their substance.

PART SECOND.

CHAPTER XV.

THE INORGANIC ELEMENTS OF PLANTS.

When any vegetable substances are burned in the air, the whole of the organic elements disappear, and a small quantity of ash remains. The proportion of the substance which has disappeared varies from 88 to 99 per cent. This has all been derived from the air, and is made up of the four elements which have occupied our attention up to this point. The small remnant left after complete combustion constitutes the inorganic elements of plant growth. These are now to be studied.

The results of recent investigations have wholly exploded the notions which formerly prevailed, to the effect that this inorganic matter was of no serious importance to the crops, and was a mere accidental circumstance, and might be absent without any serious detriment to the growth of the plants. It was discovered in course of careful experiments that this ash of the plants represented exactly the various mineral substances which were taken from the soil, and that these, to the smallest proportion, were of vital necessity to the plants.

The results of long continued study, finally gathered into systematic order, showed that on whatever soil a plant might be grown and mature its seed fully, the quantity and character of the ash is nearly the same; and that though grown on the same soil, plants of different species and character leave an ash entirely unlike; the ash varying characteristi-

cally with the species. Moreover it was found that when a plant was grown out of the soil; and with its roots enveloped only in water; it grew with equal luxuriance as if grown in the soil, provided that the water held in solution the same mineral substances which were found in the ash of the same species, together with the needed quantity and variety of its organic elements. Thus the soil was found to possess functions of more importance to plant growth than the mere mechanical support for its roots, and really supplied to the plant a number of constituents without which, or any one of which, the growth was enfeebled or wholly failed. Hence there was no longer any doubt that the ash of plants represented really essential portions of their nutriment, and the farmer then was able to understand the whole secret of the art of manuring; viz; that to grow abundant crops every constituent part of the plants must be present in the soil, or if not, they must be supplied to it in the form of manures or fertilizers. This discovery necessarily modified the notions held by farmers, and regulated the practices of agriculture in every branch. One of the most useful reforms in thought and practice was to abolish the idea which was prevalent among unintelligent farmers, viz, that books and other literature were totally useless to them, and that the only way to become good farmers was to spend a life time in copying the ways and methods of older men, and learning from them what they knew of their art. We have now learned that while this is all useful, there is something else which is pre-eminently necessary; viz; to study the laws of plant growth and with the knowledge thus gained from books and other sources to give careful and intelligent consideration to the nature of the soil; the principles upon which its proper culture are based; the most perfect machinery for this culture; the art of manuring; the nature and use of artificial fertilizers; and the production of manure, made richer in the needed elements of plant growth by feeding cattle. And for the purpose of encouraging this study and of spreading abroad the necessary information for it; a special literature devoted to agri-

culture, consisting of books and periodical journals, sprang into existence, and was eagerly procured and read; and lastly special schools for teaching the science and art of farming were established jointly with farms and laboratories for experimental culture and chemical investigations. Thus step by step the art of growing farm crops became an intelligent industry, and farmers are respected in proportion to the importance and dignity of their vocation.

For all this we are indebted to numerous pains-taking men, who with unusual self-denial, patience, and perseverance, have spent their lives in industrious retirement; heard of by few and known by less; busy in their fields and experimental plots, or hidden in their laboratories; gradually building up, fragment by fragment, the grand edifice of knowledge which now represents what every man who desires, may know of the culture of farm crops.

One very important point of this knowledge is the fact that vegetables feed—that is, absorb and assimilate or build up their substance—upon mineral substances, as well as upon the remains of vegetable matter. That while these remains in the shape of completely decomposed farm manure, or animal matters, contain the various inorganic compounds which are found in the ashes of plants, and which are known to be necessary to their growth, yet the same compounds drawn from a mineral origin, are equally serviceable as plant food. Thus, lime procured from the lime kilns; potash from the rocks of which it forms a part; gypsum or plaster; phosphate of lime; soda in the form of salt, or as nitrate of soda; sulphate of magnesia; and other mineral substances; when finely ground, and made soluble, produce precisely the same results when used as fertilizers as the same substances in the ashes of plants, or in their decayed remains. They are absorbed by plants with equal facility, and are utilized in the same way and to the same extent, in forming the tissues of the plants. They are in fact plant food. Hence the common idea that these fertilizing substances are stimulants only, and merely encourage the crops to put forth some unusual effort, so to speak, by which

some unnatural and excessive product is yielded, is a wholly wrong and mistaken one. Wrong terms and ideas are injurious, notwithstanding that a name has no effect in changing the nature of anything; for they lead to wrong practices and grave errors in the management of the crops, and these cannot fail to result in loss.

The inorganic substances upon which plants feed and which they extract by their roots from the soil, have been mentioned in a previous chapter, but they may be conveniently repeated. They are lime; potash; soda; magnesia; sulphur and sulphuric acid; phosphoric acid; silica and chlorine. These, with the exception of sulphur and chlorine, which are elements, are the oxides of metals which are elementary substances. The first four are usually found in the ashes of plants combined with carbonic acid as carbonates; lime however is found as a sulphate being combined with sulphuric acid in the ashes of clover and a few other plants. There are a few other substances of inorganic origin which are occasionally found in plants, such as iron, manganese, iodine, &c. but these are evidently accidentally absorbed with the water in which they happen to be in solution, and being innocuous do not interfere with the development of the plants, but are not strictly plant food.

The proportion of the various mineral elements of plant growth varies greatly in the different species of vegetables; so much so as to become a leading characteristic with them. Thus there are what may be called potash plants; lime plants; soda plants, &c.; and these dominant elements will be found to have a considerable bearing upon the question of fertilizing crops, to be hereafter treated. Thus on reference to the tables given in the next chapter, it will be seen that the ash of the stems and leaves of potatoes contain from 39 to 46 per cent. of lime and 16 to 22 per cent. of magnesia; pea straw contains 38 per cent. of lime; but wheat straw only 6 per cent.; and the tubers of potatoes only 2½ per cent.; while the ash of the last mentioned contains 60 per cent. of potash; that of turnips 50 per cent., clover 35 to 50 per cent.; of young grass 56 per cent.; and of tobacco

27½ per cent. The dried tobacco plant has 24 per cent. of ash while the whole wheat plant has but 3½ per cent. It must not be supposed that these peculiarities are of no importance to the farmer, and that the fact that the ash of beets, turnips, and carrots, including leaves and roots together, contains from 12 to 24½ per cent. of soda, and from 6 to 11 per cent. of chlorine; while that of most other plants contain a very insignificant quantity of these substances; or that the ash of clover contains along with the large quantity of lime a considerable amount of sulphuric acid, and that this acid exists in the ash of turnips, cabbage, rape and kohl-rabi, mustard and other plants of the *Cruciferae* family to the enormous extent of from 8 to 16¼ per cent. For these facts explain the reason why an application of salt (chloride of sodium) and of gypsum (sulphate of lime) furnishes these elements to the crops mentioned, and thus supplies necessary food without which they could not grow. It results, in fact, that *the soil must contain all these substances, which are found in their ashes, in such quantity and in such form as to yield easily to each crop as much of each, as the plant specially requires.* This is the first grand law which controls the culture of farm crops. The second is that *the soil must be brought into such a proper condition by tillage, as to enable the roots of plants to avail themselves of the needed food which it contains.*

A special study should be made of the tables given in the next chapter and specially placed by themselves that they may attract the notice which they demand. For a third law controlling the growth of plants is, that *if one of these necessary substances is wanting in the soil, or is existing there in deficient quantity, the crop will prove a failure;* it will either be weak and diseased (for it is the weak and ill nourished plants—and animals equally—which are subject to disease) or it will fail to grow at all.

The intelligent farmer will then naturally ask what are these mineral or inorganic substances upon which plants depend for their successful growth, and in what proportion do they require them; and further, in what proportions do

these needed mineral substances exist in the soil; and when any of them are deficient, how can they be supplied in the easiest, most advantageous and most economical manner?

The first of these questions will be answered by the tables given in the next chapter and the others will be considered in their turn.

THE ASH, OR MINERAL PARTS OF PLANTS.

CHAPTER XVI.

THE ASH OF CULTIVATED PLANTS AND ITS VARIED COMPOSITION.

In the following tables collected from various sources in which the results of thousands of experiments by the most noted agricultural chemists and investigators have been published, will be found the average composition of the ash of the plants named. These plants have been gathered from the crops grown under ordinary circumstances, and when there has been any unusual variation in any samples, a large number of analyses have been made and an average taken. These analyses have been verified so often by more recent examinations that they have been accepted as the standard, and are used for all purposes, and for reference in all recent agricultural study. They may therefore be accepted by students with the utmost confidence and reliance. They are given in full because hereafter frequent allusions and references will be given to them in future chapters.

COMPOSITION OF THE ASH OF AGRICULTURAL PRODUCTS.

Substances.	Per cent of ash.	Potash.	Soda.	Magnesia.	Lime.	Phosphoric acid.	Sulphuric acid.	Silica.	Chlorine.
HAY AND GRASS.									
Ordinary hay.....	7.78	25.6	7.0	4.9	11.6	6.2	5.1	29.6	8.0
Young grass.....	9.32	56.2	1.8	2.8	10.7	10.5	4.0	10.3	2.0
Ripe hay.....	7.73	7.6	2.9	3.4	12.9	4.4	0.7	63.1	5.7
Timothy	7.1	28.8	2.7	3.7	9.4	10.8	3.9	35.6	5.0
Hungarian	7.23	37.4		8.0	10.8	5.4	3.6	29.1	6.4
CLOVER AND FODDER PLANTS.									
Red Clover.....	6.72	34.5	1.6	12.2	34.0	9.9	3.0	2.7	3.7
White Clover.....	7.16	17.5	7.8	10.0	32.2	14.1	8.8	4.5	3.2
Lucern.....	7.14	25.3	1.1	5.8	48.0	8.5	6.1	2.0	1.9
Alsike clover.....	5.53	33.8	1.5	15.3	31.9	10.1	4.0	1.2	2.8
Green pea (in flower).....	7.40	40.8	0.2	8.2	28.7	13.2	3.5	2.6	1.8
Green rape.....	8.97	32.3	3.8	4.5	23.1	8.7	16.3	3.2	7.6

ROOT CROPS (Roots.)

Potatoes	3.74	59.8	1.6	4.5	2.3	19.1	6.6	2.3	2.8
Beets.....	6.86	53.1	14.8	5.1	4.6	9.6	3.3	3.3	6.6
Sugar beets.....	4.35	49.4	9.6	8.9	6.3	14.3	4.7	3.5	2.0
Turnips	8.28	39.3	11.4	3.9	10.4	13.3	14.3	2.4	4.1
Ruta bagas.....	7.68	57.2	6.7	2.6	9.7	15.3	8.4	0.5	5.1
Carrots.....	6.27	36.7	22.1	5.3	10.7	12.5	6.4	2.0	3.2

ROOT CROPS (Leaves and Stems.)

Potatoes (green).....	8.92	14.5	2.7	16.8	39.0	6.1	5.6	8.0	4.6
“ (ripe).....	5.12	6.3	0.8	22.6	46.2	5.5	5.5	4.2	3.0
Beets.....	15.90	29.1	21.0	9.7	11.4	5.1	7.4	4.8	11.3
Sugar beets.....	17.49	22.1	16.8	18.3	19.7	7.4	8.0	3.1	5.7
Turnips	13.68	22.9	7.8	4.5	32.4	8.9	9.9	3.8	8.2
Carrots.....	13.57	14.1	23.1	4.6	33.0	4.7	7.9	5.6	7.1
Cabbage.....	10.81	48.6	3.9	3.3	15.3	15.8	8.5	1.2	2.5

STRAW.

Winter wheat.....	4.96	11.5	2.9	2.6	6.2	5.4	2.9	66.3	
Winter rye.....	4.81	18.7	3.3	3.1	7.7	4.7	1.9	58.1	
Springrye.....	5.55	23.4		2.8	8.9	6.5	2.6	55.9	
Barley	5.10	21.6	4.5	2.4	7.6	4.3	3.7	53.8	
Oats	5.12	22.0	5.3	4.0	8.2	4.2	3.5	48.7	
Corn	5.49	35.3	1.2	5.5	10.5	8.1	5.2	38.0	
Peas	5.74	21.8	5.3	7.7	37.9	7.8	5.6	5.7	6.1
Beans	7.12	44.4	3.8	7.8	23.1	7.0	0.2	5.4	13.1
Buckwheat	6.15	46.6	2.2	3.6	18.4	11.9	5.3	5.5	7.7
Rape.....	4.58	25.6	10.3	5.7	26.5	7.0	7.1	6.7	12.4

CHAFF.

Wheat	10.73	9.1	1.8	1.3	1.9	4.3		81.2	
Barley	14.23	7.7	0.9	1.3	10.4	2.0	3.0	70.8	
Oats.....	9.22	13.1	4.8	2.6	8.9	0.3	2.5	59.9	
Corn (cobs).....	0.56	47.1	1.2	4.1	3.4	4.4	1.9	26.4	

FIBER PLANTS.

Flax (entire).....	4.30	34.2	4.8	9.0	15.5	23.0	4.9	2.6	5.9
Hemp “	4.60	18.3	3.2	9.6	43.4	11.6	2.8	7.6	2.5
Hops “	9.87	26.2	3.8	5.8	16.0	12.1	5.4	2.5	4.6
Tobacco.....	24.08	27.4	3.7	10.5	37.0	3.6	3.9	9.6	4.5

LITTER.

Heath	4.51	13.2	5.3	8.4	18.8	5.1	4.4	35.2	2.1
Fern.....	7.1	42.8	4.5	7.7	14.0	9.7	5.1	6.1	10.2
Sea-weeds	14.39	14.5	24.0	9.5	13.9	3.1	24.0	1.7	10.1
Beech leaves.....	6.75	5.2	0.6	6.0	44.9	4.2	3.7	33.9	0.4
Oak “	4.90	3.5	0.6	4.0	48.6	8.1	4.4	30.9	
White pine “	1.40	10.1		9.9	41.4	16.4	4.4	13.1	4.4
Red pine “	5.82	1.5		2.3	15.2	8.2	2.8	70.1	
Salt black grass.....	5.30	36.6	6.6	6.4	9.5	6.4	8.7	10.9	14.2
Salt marsh grass.....	8.08	33.2	7.3	4.2	5.3	6.7	3.3	31.5	5.6

GRAINS AND SEEDS.

Wheat	2.07	31.1	3.5	12.2	3.1	46.2	2.4	1.7	
Rye.....	2.03	30.9	1.8	10.9	2.7	47.5	2.3	1.5	
Barley.....	2.55	21.9	2.8	8.3	2.5	32.8	2.3	27.2	
Oats.....	3.07	15.9	3.8	7.3	3.8	20.7	1.6	46.4	
Corn.....	1.42	27.0	1.5	14.6	2.7	44.7	1.1	2.2	

Rice.....	7.84	18.4	4.5	8.6	5.1	47.2	0.6	0.6	
Millet.....	4.49	11.9	1.0	8.4	1.0	23.4	0.2	52.3	
Sorghum.....	1.86	23.0	3.3	14.8	1.3	50.9		7.5	
Buckwheat.....	1.07	23.1	6.2	13.4	3.3	48.0	2.1		1.7
Rape.....	4.24	23.5	1.1	12.2	13.8	43.9	3.6	1.1	0.3
Cotton.....	7.80	37.42	8.6	16.10	3.0	33.16	0.27	2.8	0.2
Flax.....	3.65	32.2	1.8	13.2	8.4	40.4	1.1	1.1	0.1
Hemp.....	5.48	20.1	0.8	5.6	23.5	36.3	0.2	11.8	0.1
Mustard.....	4.30	15.9	5.8	10.2	18.8	39.0	4.7	2.4	0.4
Turnip.....	3.98	21.9	1.2	8.7	17.4	40.2	7.1	0.7	
Carrot.....	8.50	19.1	4.8	6.7	88.8	15.8	5.6	5.3	3.3
Peas.....	2.81	40.4	3.7	8.0	4.2	36.3	3.5	0.9	2.3
Beans.....	3.45	40.5	1.2	6.7	5.2	39.2	5.1	1.2	2.9
Clover.....	4.11	37.3	0.6	12.2	6.2	33.5	4.7	2.4	1.3

WOOD.

Grape.....	2.75	29.8	6.7	6.8	37.3	12.9	2.7	0.8	0.8
Birch.....	0.31	11.6	5.8	8.9	60.0	8.5	0.3	4.8	0.6
Beech.....	0.82	16.1	2.7	14.0	50.2	8.0	1.0	5.4	0.1
Oak.....	0.21	10.0	3.6	4.8	73.5	5.5	1.4	1.1	0.2
Willow.....	0.45	11.5	5.6	10.1	50.8	16.4	3.1	0.7	0.6
Elm.....	1.88	24.1	2.1	10.0	37.9	9.6	5.4	6.2	6.7
Linden.....	1.42	35.8	6.0	4.2	29.9	4.9	5.3	5.3	1.5
Apple.....	1.29	12.0	1.6	5.7	71.0	4.6	2.9	1.8	0.2
Red pine.....	0.25	5.2	26.8	6.2	47.9	5.1	3.0	2.0	4.0
White pine.....	0.28	15.3	9.9	5.9	50.1	5.5	3.0	6.0	0.2
Balsam fir.....	0.31	11.8	4.6	9.1	50.1	5.8	2.3	15.0	0.4
Larch (Tamarac).....	0.32	15.3	7.7	24.5	27.1	3.6	1.7	3.6	0.6

LEAVES OF TREES.

Walnut.....	7.01	26.6		9.8	53.7	4.0	2.7	2.0	0.8
Beech.....	6.75	5.2	0.6	6.0	44.9	4.2	3.7	33.9	0.4
Oak.....	4.90	3.5	0.6	4.0	48.6	8.1	4.4	30.9	
Fir (Balsam).....	1.40	10.1		9.9	41.4	16.4	4.4	13.1	4.4
Red pine.....	5.82	1.5		2.3	15.2	8.2	2.8	70.1	
White pine.....	6.24	3.7		1.1	12.1	8.5	1.9	66.6	
Maple.....	6.80	10.2	0.5	6.1	39.6	4.2	3.6	34.0	
Elm.....	4.88	13.7	0.6	4.1	48.5	8.0	4.3	20.8	

BARK.

Oak.....	3.21	5.7	3.2	8.7	42.0	7.1	1.5	21.0	1.5
Maple.....	1.37	15.0	3.1	9.0	45.1	6.7	1.4	11.0	
Birch.....	1.33	3.8	5.4	8.2	45.6	7.3	1.3	20.1	1.3
Beech.....		14.7	0.4	0.2	57.9	0.4	1.3	18.0	
Walnut.....	6.40	11.6		10.6	70.1	5.9	0.2	0.7	0.4
Elm.....	7.1	2.2	10.1	3.2	72.7	1.6	0.6	8.9	
Linden.....	8.5	16.1	5.7	8.0	60.8	4.0	0.8	2.3	1.2
Red pine.....	2.81	5.3	4.2	4.7	62.4	2.6	1.0	15.7	0.2
White pine.....	3.30	8.0	3.2	3.0	69.8	2.5	1.6	8.4	1.0
Fir (Balsam).....	2.01	3.0	1.0	1.4	43.7	8.3	0.8	31.1	0.1

Although the consideration of the organic substance of plants has been passed for the present, yet this being a convenient place for a table showing the amount of organic matter contained in the common products of the farm, this

is given here and will be frequently referred to hereafter. The organic matter is separated from the ash, and water, which are also given, and into two principal divisions, viz: that into which nitrogen chiefly enters, and which are commonly referred to as nitrogenous matter; or albuminoids or protein compounds; and that commonly called carbo-hydrates; the former consisting of carbon; oxygen; hydrogen and nitrogen; and the latter of carbon, oxygen and hydrogen. These are often distinguished also as non-nitrogenous.

COMPOSITION OF AGRICULTURAL PRODUCTS.

	Water.	Ash.	Nitrogen compounds.	Carbon & Hydro- gen compounds.		
				Fiber.	Starch, sugar, gum, etc.	Fat.
HAY.						
Meadow Hay, poor.....	14.3	5.0	7.5	33.5	33.2	1.5
“ “ better.....	14.3	5.4	9.2	29.2	39.7	2.0
“ “ medium.....	14.3	6.2	9.7	26.3	41.4	2.5
“ “ very good.....	15.0	7.0	11.7	21.9	41.6	2.8
“ “ extra	16.0	7.7	13.5	19.3	40.4	3.0
Red Clover, poor.....	15.0	5.1	11.1	28.9	37.7	2.1
“ “ medium.....	16.0	5.3	12.3	26.0	38.2	2.2
“ “ very good.....	16.5	6.0	13.5	24.0	37.1	2.9
“ “ extra	16.5	7.0	15.3	22.2	35.8	3.2
White Clover, medium.....	16.5	6.0	14.5	25.6	33.9	3.5
Lucerne, medium.....	16.0	6.2	14.4	33.0	27.9	2.5
“ very good.....	16.5	6.8	16.0	26.6	31.6	2.5
Swedish Clover.....	16.0	6.0	15.0	27.0	32.7	3.3
Hop Clover.....	16.7	6.0	14.6	26.2	33.2	3.3
Trefoil.....	16.7	5.1	12.2	30.4	32.6	3.0
Seradella.....	16.7	7.5	13.5	22.0	35.6	4.7
Fodder Vetch, medium.....	16.7	8.3	14.2	25.5	32.8	2.5
“ “ very good.....	16.7	9.3	19.8	23.4	28.5	2.3
Peas in bloom.....	16.7	7.0	14.3	25.2	34.2	2.6
Lupine, medium.....	16.7	4.6	17.1	28.5	30.9	2.2
“ very good.....	16.7	4.1	23.2	25.2	28.6	2.2
Fodder Rye.....	14.3	5.1	10.4	23.1	44.5	2.8
Timothy	14.3	4.5	9.7	22.7	45.8	3.0
Italian Rye Grass.....	14.3	7.8	11.2	22.9	40.6	3.2
English Rye Grass.....	14.3	6.5	10.2	30.2	36.1	2.7
French Rye Grass.....	14.3	9.9	11.2	29.4	32.6	2.7
Upland Grasses, average.....	14.3	5.8	9.5	28.7	39.1	2.6
Hungarian Grass.....	18.4	5.7	10.8	29.4	38.5	2.2

GREEN FODDER.

Grass just before bloom.....	75.0	3.1	3.0	6.0	13.1	0.8
Pasture Grass.....	80.0	2.0	3.5	4.0	9.7	0.8
Rich Pasture Grass.....	78.2	2.2	4.5	4.0	10.1	1.0
Italian Rye Grass.....	73.4	2.8	3.6	7.1	12.1	1.0
English Rye Grass.....	70.0	2.0	3.6	10.6	12.8	1.0
Timothy Grass.....	70.0	2.2	3.4	8.0	16.3	1.1
Upland Grasses, average.....	70.0	2.1	3.4	10.1	13.4	1.0
Fodder Rye.....	76.0	1.6	3.3	7.9	10.4	0.8
Fodder Oats.....	81.0	1.4	2.3	6.5	8.3	0.5
Green Maize, American.....	85.0	1.0	1.2	4.7	7.6	0.5
“ “ German.....	83.0	1.0	1.8	4.4	9.3	0.5
Sorghum.....	77.3	1.1	2.5	6.7	11.7	0.7
Hungarian, in blossom.....	75.0	1.8	3.1	8.5	10.9	0.7
Pasture Clover, young.....	83.0	1.5	4.6	2.8	7.2	0.9
Red Clover, before blossom.....	83.0	1.5	3.3	4.5	7.0	0.7
“ “ in full blossom.....	80.4	1.3	3.0	5.8	8.9	0.6
White Clover, in blossom.....	80.5	2.0	3.5	6.0	7.2	0.8
Swedish Clover, at beginning of blossom.....	85.0	1.5	3.3	4.5	5.1	0.6
“ “ in full blossom.....	82.0	1.8	3.3	6.0	6.3	0.6
Lucerne, quite young.....	81.0	1.7	4.5	5.0	7.2	0.6
“ at beginning of blossom.....	74.0	2.0	4.5	9.5	9.2	0.8
Sand Lucerne, at beginning of blossom.....	78.0	1.9	4.0	8.0	7.3	0.8
Esparsette.....	80.0	1.5	3.2	6.5	8.2	0.6
Trefoil.....	81.5	1.6	2.7	6.2	7.3	0.7
Hop Clover.....	80.0	1.5	3.5	6.0	8.2	0.8
Seradella.....	80.0	1.8	3.0	5.2	8.9	1.1
Lupine, medium.....	85.0	0.7	3.1	5.1	5.7	0.4
“ very good.....	85.0	0.7	4.2	4.5	5.2	0.4
Field Beans at beginning of blossom.....	87.3	1.0	2.8	3.5	5.1	0.3
Fodder vetch at beginning of blossom.....	82.0	1.8	3.5	5.5	6.6	0.6
Fodder Peas in blossom.....	81.5	1.5	3.2	5.6	7.6	0.6
Buckwheat in blossom.....	85.0	1.4	2.4	4.2	6.4	0.6
Green Rape.....	87.0	1.6	2.9	4.2	3.7	0.6
Fodder Cabbage.....	84.7	1.6	2.5	2.4	8.1	0.7
White Cabbage.....	89.0	1.2	1.5	2.0	5.9	0.4
Cabbage Stems.....	82.0	1.9	1.1	2.8	11.9	0.3
Potato Tops, October.....	78.0	3.0	2.3	6.0	9.7	1.0
Carrot leaves.....	82.2	3.6	3.2	3.0	7.1	1.0
Fodder Beet leaves.....	90.5	1.8	1.9	1.3	4.0	0.5
Rutabaga leaves.....	88.4	2.3	2.1	1.6	5.2	0.5
Kohl-rabi leaves.....	85.0	1.8	2.8	1.4	8.2	0.8
Artichoke Tops.....	80.0	2.7	3.3	3.4	9.8	0.8
Fermented hay from Maize.....	83.5	1.1	1.2	5.3	8.0	0.9
“ “ “ Lupine.....	79.9	2.9	3.1	6.8	6.5	0.8
“ “ “ Beet leaves.....	80.0	4.1	3.0	2.7	9.0	1.2
“ “ “ Potato Tops.....	77.0	5.3	2.9	4.7	7.5	2.6
“ “ “ Red Clover.....	79.2	2.1	4.2	5.9	6.4	2.2

STRAW.

Winter Wheat.....	14.3	4.6	3.0	40.0	36.9	1.2
Winter Rye.....	14.3	4.1	3.0	44.0	33.3	1.3
Winter Barley.....	14.3	5.5	3.3	43.0	32.5	1.4
Summer Barley.....	14.3	4.1	3.5	40.0	36.7	1.4
Oat.....	14.3	4.0	4.0	39.5	36.2	2.0

Summer Grain Straws medium.....	14.3	4.1	3.8	39.7	3.4	1.7
“ “ “ very good.....	14.3	6.7	6.9	36.7	32.9	2.5
Winter “ “ medium.....	14.3	4.8	3.0	42.0	34.9	1.3
“ “ “ very good.....	14.3	5.3	4.5	37.8	36.7	1.4
Fodder Vetch.....	16.0	4.5	7.5	42.0	29.0	1.0
Pea.....	16.0	4.5	6.5	38.0	34.0	1.0
Field Bean.....	16.0	4.6	10.2	34.0	34.2	1.0
Straw of Legumes, medium.....	16.0	4.5	8.1	38.0	32.4	1.0
“ “ “ very good.....	16.0	5.1	10.2	34.5	33.2	1.0
Lentils.....	16.0	6.5	14.0	33.6	27.9	2.0
Lupine.....	16.0	4.1	5.9	40.8	32.1	1.1
Seed Clover.....	16.0	5.6	9.4	42.0	25.0	2.0
Rape.....	16.0	4.1	3.5	40.0	35.4	1.0
Corn Stalks.....	15.0	4.2	3.0	40.0	36.7	1.0

CHAFF, HULLS, ETC.

Wheat.....	14.3	9.2	4.3	36.0	34.6	1.4
Rye.....	14.3	7.5	3.6	43.5	29.9	1.2
Oats.....	14.3	10.0	4.0	34.0	36.2	1.5
Barley.....	14.3	13.0	3.0	30.0	38.2	1.5
Vetch.....	15.0	8.0	8.5	33.0	33.5	2.0
Pea.....	15.0	6.0	8.1	32.0	36.9	2.0
Bean.....	15.0	5.5	10.5	33.0	34.0	2.0
Lupine.....	14.3	3.5	4.5	37.0	39.0	1.7
Rape.....	14.0	8.5	4.0	40.6	31.3	1.6
Corn Cobs.....	14.0	2.8	1.4	37.8	42.6	1.4

ROOTS AND TUBERS.

Potatoes.....	75.0	0.9	2.1	1.1	20.7	0.2
Artichokes.....	80.0	1.0	2.0	1.3	15.5	0.2
Fodder Beets.....	88.0	0.8	1.1	0.9	9.1	0.1
Sugar Beets.....	81.5	0.7	1.0	1.3	15.4	0.1
Carrots.....	85.0	0.9	1.4	1.7	10.8	0.2
Giant Carrots.....	87.0	0.8	1.2	1.2	9.6	0.2
Rutabagas.....	87.0	1.0	1.3	1.1	9.5	0.1
Turnips.....	92.0	0.7	1.1	0.8	5.3	0.1
Parsnips.....	88.3	0.7	1.6	1.0	10.2	0.2

GRAINS AND FRUITS.

Wheat.....	14.4	1.7	13.0	3.0	66.4	1.5
Rye.....	14.3	1.8	11.0	3.5	67.4	2.0
Barley.....	14.3	2.2	10.0	7.1	63.9	2.5
Oats.....	14.3	2.7	12.0	9.3	55.7	6.0
Maize.....	14.4	1.5	10.0	5.5	62.1	6.5
Millet.....	14.0	3.0	12.7	9.5	57.5	3.3
Buckwheat.....	14.0	1.8	9.0	15.0	58.7	1.5
Rice, hulled.....	14.0	0.5	7.7	2.2	75.2	0.4
Peas.....	14.3	2.4	22.4	6.4	52.5	2.0
Field Beans.....	14.5	3.1	25.5	9.4	45.9	1.6
Vetch.....	14.3	2.7	27.5	6.7	45.8	3.0
Lentil.....	14.5	3.0	23.8	6.9	49.2	2.6
Lupine yellow.....	13.3	3.8	36.2	13.8	28.0	4.9
“ blue.....	13.2	3.2	24.8	12.5	41.7	4.6
Linseed.....	12.3	3.4	20.5	7.2	19.6	37.0
Rape Seed.....	11.8	3.9	19.4	10.3	12.1	42.5
Hemp Seed.....	12.2	4.5	16.3	12.2	21.3	33.6
Cotton Seed.....	7.7	7.8	22.8	16.0	15.4	30.3
Acorns.....	37.7	1.6	3.5	7.8	46.6	2.8

Chestnuts.....	49.2	1.6	4.3	2.0	41.3	1.6
Apples and Pears.....	83.1	0.4	0.3	4.3	11.8	
Pumpkins.....	89.1	1.0	0.6	2.7	6.5	0.1

FEEDING SUBSTANCES.

Brewers Grains.....	76.6	1.2	4.9	5.2	11.0	1.1
Malt Sprouts.....	10.1	7.2	24.3	14.3	42.1	2.1
Wheat Bran, fine.....	13.1	5.4	14.0	8.7	55.0	3.8
“ “ coarse.....	12.9	6.6	15.0	10.1	52.2	3.2
Rye Bran.....	12.5	5.2	14.5	5.7	58.6	4.5
Pea Bran.....	12.3	3.0	8.0	43.7	30.5	2.5
Linseed Meal, new process....	9.7	7.3	33.2	8.8	38.7	2.3
Cotton Seed, whole meal.....	11.3	6.4	23.6	22.0	30.5	6.1
Cotton Seed Meal, without hulls.....	11.2	7.6	38.8	9.2	19.5	13.7

The above figures show precisely what inorganic, or mineral substances, plants draw from the soil. They also show that the quantity of inorganic matter contained in the same weight of different crops varies greatly. Thus while the grain of corn contains only 1.42 per cent. of inorganic matter; peas contain twice as much; oats two and a half times as much; and rice five and a half times as much. Also the quantity contained in the various parts of the same plant varies in a similar manner. Wheat grain has but 2.07 per cent of ash but the straw has more than twice as much and the chaff has over five times as much. Barley shows a still greater difference in this way and so on through the whole tables. The same facts apply to trees and their bark and leaves.

Another important point is peculiarly worthy of notice; this is the difference between plants in an early stage of growth and when they are mature. Young grass for instance contains considerably more ash than ripe hay and this ash consists of much more important elements of vegetable growth. The large quantity of potash and phosphoric acid shown to be needed by such grass as is used for pasturing, seems to disappear as it grows older and to be replaced by silica. What becomes of these two substances, so valuable and indispensable in the aliment of animals, and which gives to the young stock the materials for building up their growing muscles and bones; and how is it that the mature grass has so large a quantity of silica which is of no use as aliment to animals? But we see a purpose in this, although it operates to the disadvantage of the farmer. The first law

of nature is the survival of all living things, and the most perfect fulfillment of its purpose in creation. And we see an instance of the perfect order and wise adaptation of means to ends in nature, in this excess of silica in the stem of a ripe herb, for it requires stiffness and strength to enable it to hold up the seed until it ripens. Were it not for this silica in ripe hay and the straw of the grains, the stems would not have strength enough to stand upright and would fall and rot on the ground and the seed would perish.

These variations are not accidental, for they exist everywhere, on all soils and in all climates. They must therefore originate in some natural and universal law. That they are so, inures to the advantage of the farmer and makes agriculture possible. For otherwise, there would be no certainty that after he had prepared the soil and had sown his seed, he would reap the crop he desired; or that what his land produced would suit the purpose for which he intended it, either for the subsistence of mankind or for feeding his animals. But being based upon a universal law, the farmer has a safe and constant rule for his guidance, and may be able to furnish his crops with precisely what they need, when he has by long use lessened the original fertility of the soil to the point of impoverishment.

Moreover by this law the farmer can find a reason why various trees preponderate in the forest and learn from it sufficient of the character of the land under the surface soil to guide him in the choice of a farm. When he sees the land covered with plants of the heath family, the huckleberry; cranberry; &c.: or with a forest of balsam fir; or with birch or beech timber; he can as safely judge that the soil is light and sandy, as if it were all exposed to view; and on the other hand where oaks, elms, maples and basswood flourish and grow to a large size, he may be sure that the land is rich in potash, lime, and phosphoric acid; the most important elements of plant food; and that with judicious cultivation of such soil his labor will be rewarded with abundant crops.

CHAPTER XV

THE COMPOUNDS OF THE INORGANIC ELEMENTS OF PLANTS.

The inorganic elements of plants, viz. potash; soda; magnesia; lime; phosphoric acid; sulphuric acid; silica and chlorine, exist in combination; and never in their original elementary condition as simple substances. It has been shown that the organic substance of plants contains four elementary substances; oxygen, hydrogen, carbon, and nitrogen in various proportions; and that the inorganic part of them is made up of eight elements; mentioned in a previous chapter; and rarely of a very small portion of a few others chiefly, aluminium, iron and manganese. These eight elements are chiefly in combination as shown in the following enumeration of them.

<i>Name</i>	<i>In combination with</i>	<i>Forming</i>
Potassium	Oxygen	Potash
"	Chlorine	Chloride of Potassium
Sodium	Oxygen	Soda
"	Chlorine	Salt
Magnesium	Oxygen	Magnesia
Calcium	Oxygen	Lime
Phosphorus	Oxygen	Phosphoric acid
Sulphur	Oxygen	Sulphuric acid
Silicon	Oxygen	Silica
Chlorine	Metals	Chlorides

With the exception of sulphur these elementary bodies are not known to exist on the surface of the globe in their simple uncombined state, but in combination as above mentioned they form the greater part of the mass of the earth and of the soil upon its surface. It is these combinations which are of interest to the farmer in his study of the principles and laws of vegetable growth.

POTASSIUM AND ITS COMPOUNDS.

POTASSIUM is of most importance in its form of

CARBONATE OF POTASH,

a combination of potash with carbonic acid. This is the form in which potash exists in wood ashes; and in the potash and pearl ash of commerce. It has a most important influence upon the growth of plants, as may be seen by reference to the tables in the previous chapter. Its use for this purpose as a fertilizer dates back to the time of the ancient Hebrews, Egyptians, and Romans, and the value of wood ashes as a fertilizer has been mentioned by several of the ancient writers. Moreover it is well known that wood ashes are more favorable to some plants than to others, "bringing in," as it is termed, plants like the clovers which are rich in potash, and so crowding out useless weeds, and improving the land at the same time.

POTASH is extremely caustic, destroying all vegetable and animal matter very rapidly. It is easily produced as follows. 12 parts by weight of carbonate of potash are dissolved in water and boiled with half the weight of newly burned (or quick or caustic) lime slaked in water, the lime takes the carbonic acid from the potash and settles to the bottom, leaving the potash in solution in a caustic state. Caustic potash so readily absorbs water, from the atmosphere, that it can only be kept dry with difficulty. It is not known that potash in this form is of any service in the growth of plants, but it is thought possible, because of the action of lime upon the carbonate; and when lime is applied to the soil, as it frequently is, it is quite possible that it may exert this effect upon the soluble carbonate of potash with which it comes in contact.

POTASSIUM, may be obtained by mixing the dry caustic potash, procured by evaporating the solution above described to dryness, with powdered charcoal and iron filings, and submitting the mass to intense heat in a closed retort. The potash is decomposed; its oxygen combines with the iron, and the metal potassium is left pure in the form of a vapor which is distilled over and appears, on cooling, in the form of white silvery drops. This process was one of the remarkable discoveries of Sir Humphrey Davy to whom we are indebted for much that is known of agricultural

science. This metal can be kept only in some liquid which contains no oxygen, hence it is immersed for keeping in pure turpentine, or in naphtha, which are compounds of carbon and hydrogen. When exposed to the air it is quickly oxidized; when it is thrown upon water, it floats and absorbs oxygen from this fluid, so rapidly that it takes fire and burns. A curious experiment in this direction may be made by placing a small piece of the metal upon ice, when it at once inflames by combining with the oxygen of the ice. Hydrogen gas is of course liberated in the decomposition of the water. The oxide of potassium thus formed is caustic potash, and weighs one-fifth more than the potassium; the increase being due to the oxygen combined.

CHLORIDE OF POTASSIUM, is very useful as a fertilizer, furnishing to plants not only potash, but chlorine. It exists in sea water along with common salt; it is found mixed with salt in the salt mines and is extracted in large quantities from the salt mines of Germany, from whence it is brought as "muriate" (chloride) of potash to this country and sold as German potash salts. It consists of potassium combined with chlorine. It can be easily produced by dissolving pearl ash in hydro-chloric acid, until effervescence ceases and evaporating to dryness. It is extensively used in the manufacture of alum which is a double sulphate of alumina and potash. This salt of potash is found in the ash of nearly all plants, and in large quantities in sea weeds; salt marsh grasses; and sedges.

SULPHATE OF POTASH, consists of potash and sulphuric acid and is a most useful and cheap form from which potash may be furnished to the crops. It may be formed by dissolving the carbonate of potash in sulphuric acid until gas (carbonic acid) is no longer given off, and evaporating the solution. It exists in considerable quantities in wood ashes, and in the ashes of plants; and forms 18 per cent. of the weight of common alum. This salt has been found to act beneficially upon clovers; peas; beans; cabbages; turnips; rape and other plants: all of which will be found, on reference to the preceding tables to contain both potash

and sulphuric acid in notable amounts. Hence the favorable result of its use as a fertilizer for these crops.

NITRATE OF POTASH or saltpeter is a well known substance and consists of potash and nitric acid, and can be formed by dissolving pearl ash (carbonate of potash) in nitric acid and evaporating. It exists in large beds in South America and is generally diffused in the soil in small quantities, being produced wherever potash and decaying vegetable matter happen to be in conjunction in the soil, by the action of the nitrifying organism which exists in the soil and is supposed to aid in the production of nitric acid. This salt exerts a most remarkable effect upon plants; containing as it does two of the most important elements of plant growth and being extremely soluble. As little as 50 lbs. per acre, applied when the soil was damp has exerted a marked effect upon the vegetation in the course of a single night.

OXALATE OF POTASH.—Oxalic acid has not been mentioned heretofore, but it deserves a passing notice here because it exists in many plants which are known by their agreeable acidity. Sorrel, and the common garden rhubarb, owe their sourness to this acid; it is also found in the chick pea; several varieties of the rumex family (to which rhubarb belongs) as the docks; also in tormentilla; bistort; gentian; saponaria; and many others. Lichens and various mosses also contain this acid in combination with lime and soda. It is also noteworthy because it is closely akin to carbonic acid, being a derivative from the element carbon, consisting of two parts of carbon and three of oxygen, and can be easily formed in a plant by the addition of one equivalent of carbonic oxide (C. O.) to one of carbonic acid (C. O₂); forming together (C₂O₃) oxalic acid. This acid is very readily changed to carbonic acid by heat: thus when oxalate of potash is heated in a capsule over a lamp, it is decomposed and carbonic acid is left. It has been supposed that this salt of potash exists freely in plants and trees, and that this change occurs in their combustion, and the formation of the ashes. It may therefore perform an

important part in the changes which occur in the interior of plants, although its direct agency in this direction has not hitherto been distinctly understood.

TARTRATES AND CITRATES OF POTASH, exist in many fruits; the citrates abound in the citrus class of fruits, oranges, lemons, shaddocks, and limes; and the tartrates in grapes. These salts are easily decomposed by heat as the oxalate of potash is, leaving carbonate of potash. Few experiments have been made in regard to these compounds of potash; probably because of the slight difference between them and the carbonate and the ease with which they can be interchanged in the process of growth of plants.

SODIUM AND ITS COMPOUNDS.

Sodium is never found uncombined and of necessity has no relation to vegetation. It is of some interest however as being the base of various compounds which are intimately connected with the growth of plants. Like potassium it is a soft silvery white metal, light enough to float upon water, and like it will oxidize and burn on contact with this fluid. It is produced from soda in precisely the same manner. Its compounds are first

CHLORIDE OF SODIUM, or common salt. This substance is universally diffused. It forms $2\frac{1}{4}$ per cent. of the weight of the ocean and is found more or less in all soils; it also exists as a rock in enormous beds among the strata of the earth's crust, some of these being considerably over a thousand feet in thickness. It forms a portion of the substance of all plants and animals, and hence is of great interest to farmers, as being a most important manure for crops; for which purpose it has been used from the earliest ages. It consists of sodium and chlorine. It is so well known that its properties need no further consideration at this time.

SODA, is the oxide of sodium, and resembles very strongly the corresponding oxide of potassium; although its properties are not so strongly marked. It is extremely caustic and absorbs moisture from the air. The sodium compounds seem to be everywhere diffused, being found everywhere,

and even in the particles of atmospheric dust. But although their presence is universal, they possess a less marked importance in vegetable growth than the potash compounds; appearing in much less quantity in the ashes of plants. With the exception of salt, none of these compounds are used in agriculture, excepting incidentally as impurities in the more costly potash fertilizers. These consist of sulphate of soda and chloride of sodium chiefly, and are mingled to a considerable extent with magnesia salts in the so called German potash salts from the Strassfurth salt mines.

The universal diffusion of these compounds in nature supplies all the needs of the farmer for the growth of his crops, and if any one is thought necessary, salt will serve every purpose. This will be considered at greater length when the subject of manures is under consideration.

CALCIUM AND ITS COMPOUNDS.

CALCIUM, like the preceding two metals is silver white in color, and by its union with oxygen forms lime. It is not known to exist in an uncombined state in nature and therefore has no direct action upon vegetation.

LIME, is the oxide of calcium, and has so very great an affinity for water and for carbonic acid that it only remains in its pure state a short time. It is prepared from the common limestone, the crystallized form of which is known as marble, by burning it in a kiln. The carbonic acid is driven off in the combustion, leaving the lime in a caustic condition, or as it is termed quick lime, and loses 44 per cent. of its weight in the burning.

LIME, is by far the most important mineral constituent of plants and forms the greater part of the ash of the majority of them. Its relation to plant growth, and its action in many ways upon the soil, gives it a high position in the estimation of farmers, both as a direct fertilizer, and an indirect aid in the preparation of the soil for the growth of crops. It has an exceedingly destructive action upon all organic matter, quickly decomposing it and reducing it to its original elements, and preparing it for plant food. It has also

a solvent action upon silica, decomposing combinations of it with potash, and soda, and forming silicates of these substances which are soluble; thus forming a most important addition to the plant food in the soil. It gradually absorbs carbonic acid from the air, and from any decomposing organic matter brought into contact with it, and thus slowly returns to its condition of a carbonate of lime, in which it is inert, excepting when it is dissolved in water. Its many valuable properties will be more fully detailed in the chapter on manures.

CHLORIDE OF CALCIUM, is the well known chloride of lime, of daily use as a disinfectant. It has no important relation to plant growth although it has a most useful effect in various ways in purifying the air about farm buildings, manure yards and drains.

SULPHATE OF LIME or gypsum, is an exceedingly valuable compound of lime and deserves special study. It is composed of $32\frac{1}{2}$ parts of lime, $46\frac{1}{2}$ of sulphuric acid, and 21 of water; the water existing as water of crystallization which is driven off when the gypsum is exposed to a heat of 300 degrees. This substance is a translucent, yellowish or white, soft, rock; which is easily ground into a fine powder. It is inert and exercises no action upon other substances, but is easily decomposed when its constituents enter into other combinations, as will be hereafter described. It is a most valuable fertilizer, supplying the crops with sulphuric acid and lime, and enters in its combined form into some plants. It is soluble in 400 times its bulk of water. It is largely and beneficially used as an absorbent of ammonia in stables and manure heaps; exercising this action by the ease with which it parts with its sulphuric acid; giving this up to the ammonia, from which it takes in exchange carbonic acid; thus forming carbonate of lime and sulphate of ammonia.

NITRATE OF LIME, is little heard of in agricultural literature and yet it undoubtedly has a most interesting relation to plant growth. The production of nitric acid, artificially, in the so called "niter beds," has been already

referred to, but may be usefully recalled in this connection, because nitrate of lime is formed as a result of the combinations. This compound rapidly absorbs water, and is never found as a solid in its natural condition, but always in solution as a liquid. It is supposed to exist in all fertile soils, and to furnish most valuable plant food; but being extremely soluble and being rapidly changed to carbonate of lime by a low heat, it escapes detection in the analysis of soils or vegetable substances, while its constituents have entered into other combinations.

PHOSPHATE OF LIME, formed by the combination of lime with phosphoric acid is an exceedingly important element of vegetable and animal substance. It forms 57 per cent. of the dried bones of an animal and exists to some extent in every part of its body. It is largely contained in the seeds of plants, and in all the grasses. Next to nitrogen it is the most valuable constituent of manures and fertilizers, and its sufficient supply to the soil gives the farmer much care and anxiety in regard to the culture and perfection of his crops. It exists naturally in the rocks as apatite, or mineral phosphate of lime, and thus consists of $54\frac{1}{2}$ per cent. of lime, and $45\frac{1}{2}$ per cent. of phosphoric acid; bone phosphate of lime, containing $51\frac{1}{2}$ per cent. of lime, and $48\frac{1}{2}$ per cent. of phosphoric acid. A bi-phosphate of lime is found in animal manures, chiefly in the urine, in which there are $71\frac{1}{2}$ per cent. of phosphoric acid and $28\frac{1}{2}$ per cent. of lime. The phosphate of lime and bones, furnish the basis for the manufacture of superphosphate of lime which is one of the most valuable fertilizers.

MAGNESIUM, is a metal having many points of similarity to those above mentioned. It is white, easily inflammable, and when burned in the air unites with oxygen forming a compound or earthy oxide known as magnesia. It is of no direct interest in relation to vegetable growth. Its compounds enter into vegetable and animal substance, at times to a considerable extent.

CHLORIDE OF MAGNESIUM, exists in the water of the ocean to a larger extent than chloride of sodium and gives

to it its bitter taste. It is met with in the ash of plants, and also mixed with salt in the water of salt springs and in rock salt. It therefore forms a constituent of the German potash salts in which it exists in a considerable proportion; although it is not estimated at all in the market value of these fertilizers.

SULPHATE OF MAGNESIA, is the common Epsom salts. It has been used as a substitute for gypsum in the same manner, and for the same kinds of crops, but it is too costly for this purpose. It has been considered as injurious to crops by some farmers, and as it exists abundantly in almost all soils, and is an ingredient of widely distributed rocks, but little interest is afforded by its consideration.

CARBONATE OF MAGNESIA, is found abundantly in many kinds of marble and other limestone as an impurity, and is not considered of any value.

PHOSPHATE OF MAGNESIA, exists in the blood and tissue of all animals and in the ash of nearly all plants. It is in this form that it chiefly enters into the substance of plants; but as it exists in the soil in sufficient quantities it has never been brought to the notice of farmers as necessary for the growth of crops. No doubt there are conditions under which the soil may be benefited by an application of some form of magnesia, but this can easily be given indirectly with the potash salts or with lime. It forms a constituent of nearly all commercial fertilizers, in some combination or other.

PHOSPHORUS.—This element does not exist in a free or uncombined state in nature, this being impossible because of its extreme inflammability. It is a soft, colorless, translucent, wax-like substance which takes fire on the slightest friction and burns with much violence; emitting dense white fumes of phosphoric acid. It is insoluble in water. It was discovered by Brandt more than 200 years ago, and because of its intensely inflammable character, was much dreaded by the uninformed alchemists, who termed it "the Son of Satan." It exists in vegetable and animal substance; being a constituent of albumen and fibrin, and of the ner-

vous substance. It is a far more abundant element in organic nature than sulphur, which resembles it in many respects.

PHOSPHORIC ACID, is the form in which this element is of the greatest interest to farmers; because of the universal and most important relation which this compound bears to vegetable and animal life. This acid is exceedingly sour; is readily soluble in water, and is corrosive to vegetable and animal substances. It does not exist in a free state, although it is frequently mentioned as a constituent of the ash of all plants; but is always found in combination; chiefly with potash, soda, lime, and magnesia. In these forms it is universally diffused through nature and it is in these combinations that it is of interest in the study of its relation to plant growth.

SULPHUR, is too well known to need any detailed description. It is only of interest in its combined form as sulphuric acid and this in its state of combination with other substances. Alone, this acid is the most corrosive substance known, dissolving or decomposing all organic and many inorganic substances. When in combination with metals or alkaline substances it forms sulphates. These exist abundantly in nature and some of them, as sulphates of potash and lime are useful to vegetation, while others, as sulphate of iron or sulphate of alumina are hurtful.

SILICON, exists only artificially as a dark brown powder prepared with great difficulty by a tedious chemical process. In its oxide as

SILICA, it is one of the most abundant substances, forming the larger part of almost all minerals; being almost the sole constituent of the most common rocks and a part of almost every one of others. Its character is that of an acid, as it combines with alkalies, and forms silicates, as silicate of lime; of potash; of soda &c. It exists in the ash of all plants without exception, and quite largely in many, forming the outer coverings of the stems and seeds; thus providing support for the plant, and protection for the germ, or vital portion of the seed. These silicates are soluble in water or are easily decomposed by water containing some

caustic alkali, as lime, in solution; and the silica is then made available as food for plants.

The insoluble silicates of potash, lime, soda and magnesia exist in many mineral substances. The transparent glassy mineral known as mica, and often wrongly called "is-inglass" and which is used for the windows of stoves, is a silicate of alumina and potash, being composed of 46.3 per cent. of silica; 36.8 per cent. of alumina; 9.2 per cent. of potash, with a little iron; the very common mineral, feldspar, is another silicate of alumina, containing 16.95 per cent. of potash: another abundant mineral, prehnite, contains 26 per cent. of lime in combination with silica and alumina; other similar minerals have soda instead of potash, and some have magnesia in their composition. As these minerals which form vast rocks, and mountain masses, are slowly decomposed by the action of the atmosphere and the carbonic acid contained in it and by the rains; or are broken up by the frosts of repeated winters, the debris is carried down and borne to the lower grounds and forms the richest soils. The glistening specks of mica which are seen so abundantly in the soils over extensive areas, all tell the story of inexhaustible stores of potash, and soda, held safely until the slow action of the weather, the effective labors of the farmer, and the chemical agency of the manures and fertilizers he applies to the soil, unlock them from the close embrace of the silica and release them to become aliment for the crops, and bring comfort and wealth to mankind.

These silicates are a subject for most interesting study, and although silica is rarely considered by farmers as of any value to them, it is really one of the most important of the inorganic elements. But it exists so abundantly in nature, and in such a readily available form, that like the air and the water which come to us unbidden, this really precious plant food is furnished as a free gift, without money or price and is lavished most abundantly upon us, so that the farmer is in no way concerned in regard to it.

CHLORINE, is a gas of a most pungent and offensive character; of a greenish yellow color; and is one of the elements

which, combined, form hydro-chloric acid ; commonly called muriatic acid. This element fortunately does not exist in a free state but is quite abundant in combination ; forming 60 per cent. of common salt ; (chloride of sodium). It is easily produced by decomposing salt by means of the black oxide of manganese, mixed with it, and placed in a bottle or jar and pouring sulphuric acid upon the mixture. The chlorine is separated from the salt and is given off in the form of the gas described. It is a most characteristic element. It extinguishes fire ; but it causes phosphorus ; gold (in the form of "leaf") ; potassium ; sodium ; and many other metals, to take fire when immersed in it, and burn ; combining with them and forming chlorides. It is $4\frac{1}{2}$ times heavier than air, and may be poured from one vessel to another. Animals cannot breathe it, and when unmixed it destroys all living vegetables. Yet its solution in water promotes the germination of seeds.

It exerts a strongly destructive effect upon organic matter, and hence is employed as a disinfecting agent, to decompose the noxious gases which emanate from putrid vegetable and animal matter. It also quickly destroys colors, and on this account is used for bleaching cotton goods. It is extensively distributed in nature as may be seen by its universal presence in the ash of plants, in some combined form. It is also present in all the secretions and other fluids of animals, and forms, as hydro-chloric acid, a portion of the gastric fluid of the stomach. This acid is composed of chlorine and hydrogen.

We have thus enumerated and described, as far as may be useful, the inorganic elements of plants, and those parts of them which are derived from the soil. The nature of the soil itself next claims our careful consideration.

CHAPTER XVIII.

THE SOIL.—ITS ORIGIN AND FORMATION.

A study of the principles of geology will be found very useful and instructive to the farmer, for they explain how the soil which he prepares for his crops, and from which the subsistence of man is procured was formed; from what materials it was derived; and how it came to be available for his purposes.

The earth was once “without form and void and water covered the great deep.” This is the testimony of inspiration as given in the Scriptures and it is the testimony given by the rocks themselves. Everything in relation to the rocks and the soil which has been derived from them, prove the combined agency of great heat and of water, in their construction. The solid earth is composed in greater part of a few elements only; the larger part of the 64 which are known to exist, are found only in small quantities; and when we enumerate the 8 inorganic substances already mentioned as contributing the mineral elements of vegetation and add to them the single one alumina which is chiefly represented by clay, we have all the elements which make up the vast bulk of the globe and form the soil which covers its surface.

The solid rocks which form what we call the crust of the earth are of two kinds, viz: those which give evidence of having been erupted from a molten mass and of having been cooled into a solid state, and those which give evidence of having been deposited by the agency of water. It may perhaps best explain our subject by giving a short history of what is believed to have been the manner in which the earth was brought into its present condition.

The condensation of the gaseous materials of which the earth is composed, at its original formation, produced a heat

incomprehensible to our minds in its intensity, and of which we have an example in the present condition of the sun. In course of ages the gases became condensed to fluids and by a gradual process of cooling the various elements became plastic and more adherent; separating from each other by molecular attraction and forming layers or masses, which formed a crust around the central portion, still fluid from the retained heat.

At this period of the earth's history it was surrounded by a dense atmosphere of steam; produced by the vaporization of the water by the heat. Upon still further gradual cooling the watery vapor became condensed, in part; and the heated masses of plastic rock were enveloped in an ocean of boiling water, above which floated the dense volumes of steam. Here was indeed chaos, and the darkness which covered the waters and the earth. As the cooled crust hardened, it shrank, and as the pressure of the molten mass within it burst the thin shell, it was vomited forth into the ocean, causing explosions and outbursts of steam, which ascending, became cooled and fell in tremendous torrents of rain, into the ocean. A seething, boiling, tumultuous ocean, thus enveloped the globe; while vast eruptions from beneath it forced mountain masses of plastic rock far above its surface, and these were washed with the descending rain torrents. The soft rock was thus broken down into mud which flowed into the depressions, forming vast beds at first horizontally spread out. All this went on during vast ages; a period of terrible commotion and chaotic disturbance. As the gradual cooling proceeded, the disturbances became less frequent. At times the pressure from below the hardened crust lifted this slowly, breaking it into fissures and throwing up the rocks upon their edges, or into vast waves. These waves of rock were sometimes burst at their summit, when melted matter flowed over them and filled the depressions between them; or one side of the broken crust would fall back to a lower level leaving a precipitous wall of rock on the other side. The ocean beating upon these heated rocks, quickly wore them down into mud or sand; and

these spreading out under the great depths were soon pressed and hardened into the slates or the sandstones which we know so well. The hot water holding silica in solution gave up its burden as it cooled, and gradually added it to these beds furnishing the cement which bound them into a firm mass; or it filled the fissures and formed the quartz beds and veins so prominent among the existing mountain masses.

Then came long periods of rest. The ocean cooled and no longer gave forth the vast clouds of steam which hid the sun. Then came the light, and the day and night. The dry land was formed by the lifting up of the earth's crust along continuous lines; the rocks being broken and tilted on their edges, and higher in places than in others, formed lines of islands through the enveloping ocean. Thus were formed the great chain of the Rocky mountains, and the lesser chain of the Blue ridge and Appalachians which stretch from Georgia to the north into lower Canada, and of which the White mountains and the Adirondacks are a part. A great broad valley was formed between these mountain chains, and a gradual slope on either side down to the depths of the ocean. By gradual shrinking of the still cooling crust, the mountain chains were lifted up and great depressions were formed into which the ocean withdrew, leaving broad continents stretching from the south to the north poles. All these changes of course were accompanied by vast floods which washed the loose materials into depressions and formed layers of gravel, sand, clay and earth, much as we find them to-day when we excavate the banks of earth on the hill sides.

Then came the ice period. Everywhere over half the earth's surface were vast beds of ice. These spread from the mountain tops down their sloping sides to the valleys. As the lower portions melted, the pressure of the enormous masses above, forced these beds of ice downwards, slowly but continuously; as the glaciers of the present age move down the mountain sides. The tremendous pressure ground down the rocks into powder; wearing away thousands of feet from the top, cutting off the crests of huge bends and

waves: and as the ice melted under the heat of the pressure and friction, great floods emerged from under the glaciers and carried the broken down rock, sand, and mud, with them, and spread them in the valleys; forming broad shallow lakes which eventually dried up and left wide areas of soil.

Thus were formed the broad plains and prairies; the gently swelling vales and the broad valleys; and the hills and mountains were left to give birth to the rivers which cut their ways through the soil, on their passage to the source from which the all powerful beams of the sun first drew them.

Then came the first plant; a humble moss or lichen, covering the soil in the first ages of vegetation, and gradually gathering from the atmosphere the carbon, nitrogen, oxygen, and hydrogen; and the various inorganic elements which have been described; furnished by their death and decay the sources from which future ages of life might spring. And by the gradual accumulation of stores of carbon and nitrogen in the soil, a better and richer vegetation was evolved, until the time came when the sweetly odorous flowers; the verdant meadows; the glorious forests; the teeming fruits and the nutritious grains covering the prolific soil; made a fit home for man; and the earth was given to him for his eternal heritage and dominion.

Thus was the soil formed and man became a tiller of the ground.

CHAPTER XIX.

THE ROCKS.—THEIR COMPOSITION AND INFLUENCE UPON THE SOIL.

Rocks are divided by geologists into two great classes; one termed primary; igneous; or unstratified; such as granite; quartz, &c: the other, secondary; stratified; or sedimentary; as sandstones slates &c.; by which is meant that the latter has been formed from the debris of the former as has been explained in the previous chapter. One other class is termed, generally, the tertiary or third formation; and this consists, of the water worn pebbles; gravels; marl beds; clays and sandstones which have been formed by the later changes on the earth's surface *and since animals of the kinds which now exist appeared on the globe.* For this class of rocks are distinguished by the frequency of animal remains in them, which are similar to or identical with species which now exist.

These three classes are divided into various sub-classes called systems and these again into formations; each of these having some common resemblance, which shows that they were deposited under nearly the same general physical conditions of the earth's surface. Thus there is the carboniferous system, consisting of a series of limestones; sandstones; iron stones; and beds of coal; which contain animal and vegetable remains of the same species, and are thus shown to have been formed at one special era of the earth's history. From the characteristics and formation and order of deposition of these beds, the geologist or an attentive intelligent student, can form as clear an idea of what occurred during the age in which these plants grew and these animals lived, and these rocks were deposited and formed, as if he had the open volume before him in which he might read the history. This is a study of the most intense inter-

est to the farmer, who plows the soil and reaps his crops from the land made rich by the remains of past ages of vegetable and animal life; and the history of which is recalled as he turns up in his fields the fossil or stony remains of creatures which existed, we know not how many ages ago.

The composition of the various rocks is of great interest to the student, because, as the soil is formed from the rocks, and its character is recognized by fragments of the prevailing rocks of which it is made up, the nature of the soil is necessarily similar to that of the rocks of which it consists. This knowledge of the rocks is indispensable to farmers, for without it they cannot know what they should of their soils, and the adaptability of these to the crops which they grow. For there are wheat lands; corn lands; grass lands; soils for fruit; for the vine; for the dairy; for sheep; and for other special crops as hops, tobacco, &c., and a right choice of land for a special purpose is indispensable to successful agriculture.

Granite is the foundation rock of the globe. It is the basis of the oldest mountain ranges whose granite peaks, bare and rugged, point their pinnacles to the noon-day sun and defy the foot of man to reach them. This rock is of great importance in the formation of the soil; for it contains the most indispensable elements for vegetable growth; viz: silica; potash, alumina and soda; and in veins which are contained in it, lime; magnesia; phosphoric acid; sulphur and chlorine are found. Thus from this one rock and its accompanying minerals may be furnished to the soil, every inorganic element needed for the successful growth of crops. It is made up of crystals of quartz, feldspar, and mica, cemented together most compactly and making a rock of extreme hardness. The quartz is the clear, glassy, white, mineral; which makes up the larger portion of the ordinary sand; the feldspar is a flesh colored, or white, milky colored substance, softer than the quartz, and is usually in the form of square or rhomboidal crystals; the mica is in white yellow or black scales.

There are no richer soils than those derived from granite,

the component parts of which contribute every necessary element for abundant and vigorous vegetable growth; while the large proportion of silica existing in them, with the alumina and magnesia, give them a loose open texture which makes them easy of cultivation and permeable to water. These soils produce wheat and all the grains, grasses, fodder crops, and fruit, to perfection. They may be readily distinguished by the glistening of the small bright particles of mica which glitter in the sunlight, and by their loose open mellow texture. They bear a forest growth of oak, hickory, elm, basswood and white pines of the largest dimensions and finest quality; and having a deep surface soil with an open subsoil rarely require artificial drainage.

The principal constituents of the feldspar of which these soils largely consist are silica, alumina, potash, and soda; the soda feldspar is called albite; the potash feldspar is called orthoclase. These minerals have the following composition.

	<i>Orthoclase.</i>	<i>Albite.</i>
Silica.....	65.21	69.09
Alumina.....	18.13	19.22
Potash.....	16.66	—
Soda.....	—	11.69
	<hr/> 100.00	<hr/> 100.00

The mica contained in the granite has a varied composition, one kind containing magnesia in considerable proportion. The following are analyses of these two kinds:

	<i>Potash Mica.</i>	<i>Magnesia Mica.</i>
Silica.....	46.10	40.00
Alumina.....	31.60	12.67
Oxide of iron.....	8.65	19.03
Potash.....	8.39	5.61
Magnesia.....	1.40	16.33
Fluoric acid.....	1.12	2.10
Water.....	1.00	—
Titanic acid.....	—	1.63
	<hr/> 98.26	<hr/> 97.37

When the granite contains hornblende in place of mica it is called Syenite. Hornblende is a black glassy mineral, very tough and hard; and contains the following substances.

	<i>Basalt Hornblende.</i>	<i>Syenite Hornblende.</i>
Silica.....	42.24	45.69
Alumina.....	13.92	12.18
Lime	12.24	13.83
Magnesia.....	13.74	18.79
Oxide of iron.....	14.59	7.32
Oxide of Manganese.....	0.33	0.22
Fluoric acid.....	—	1.50
	97.06	99.53

This variety of granite is distinguished by the absence of potash and the presence of lime in notable quantity.

Granite also contains a number of other minerals in veins, or scattered through the mass. Among the most important of these are apatite or phosphate of lime; marble or crystallized carbonate of lime; tourmaline; epidote and crysolite. These furnish to the soil the phosphoric acid, which is indispensable for vegetable life and growth, and contribute lime, magnesia, potash and soda as well. Where these minerals abound, the soil is fertile and bears abundant crops. The greater parts of New England; northern New York; eastern Canada; Pennsylvania, parts of New Jersey, West Virginia and southward along the mountains and eastward to their feet, are covered with soil produced by the decomposition of this class of rocks and prove by the high culture and value of the soil, how well it is furnished with the elements of plant food.

The same may be said of all the other rocks of this class; which consist of similar minerals varying more or less in proportion. This variation naturally has an effect upon the character of the soils derived from these rocks. For when phosphoric acid is deficient, no surplus of other elements will make up a fertile soil; and when the lime or potash has been washed from the soil on the higher lands into the valleys, the sandy land which remains has no good quality to attract the husbandman.

The most fertile soils are those derived from the decomposition of limestone rocks. When the traveller across the continent passes the Appalachian mountains, he enters the grand valley of the Mississippi and Missouri rivers, and traverses a vast region of the utmost fertility, renowned as

the granary of the world and surpassingly rich in cattle. The blue grass region of Kentucky, Missouri, Ohio and Iowa; the inexhaustible bottoms of the Ohio rivers; the "loess" soils of Nebraska and Kansas and the rich prairies and forests of the north western states, are all underlaid with limestone rocks and covered with a limestone soil of unsurpassed fertility. These lands have made the United States the richest and most powerful nation of the world; for they have attracted the many millions of industrious enterprising immigrants which have covered these lands with fertile farms, the produce of which has given employment to the great railroads and fleets of steamships which carry abroad millions of tons of grain and provisions and bring back more of the wealth of muscle and brain, which makes up the strength and power of this great nation. The following table exhibits the character of the soils referred to.

	1	2	3
	<i>From Kentucky blue grass region.</i>	<i>From the Ohio valley.</i>	<i>From Nebraska.</i>
Silica and fine sand.....	76.20	85.14	80.51
Alumina.....	8.51	5.66	6.81
Oxide of iron.....	2.59	1.22	0.31
Lime.....	3.92	1.56	4.40
Magnesia.....	1.68	.31	1.16
Potash.....	1.14	.48	2.13
Soda.....	0.64	.02	.21
Phosphoric acid.....	1.65	1.60	1.22
Gypsum.....	.01	.02	.09
Chlorine.....	.01	.03	.03
Carbonic acid.....	—	.08	—
Organic matter.....	2.62	3.38	2.44
	<hr/> 99.97	<hr/> 99.50	<hr/> 99.31

Every element required for the abundant growth of crops is here represented in such proportion as will ensure lasting fertility under judicious management. Everywhere that limestone prevails fruit is unusually excellent; grass grows with profusion; and sheep cattle and horses are unexcelled. The cattle, horses, and the pastures of Kentucky furnish types of the fertility of the limestone soils.

The so called drift soils are those made up of materials transported from a distance by the floods and ice beds, of the later periods of the geological ages. These soils are

marked by the utmost diversity and irregularity of character, as may well be supposed from their origin. Beds of gravel or of sand; interspersed with patches of coarse boulders, or of mixed soil covered with the hard heads, which can scarcely be broken, overlies hard pan of gravel packed so firmly as to resist the passage of water, and these alternate so frequently that at times a 10 acre field has several kinds of soil in it. The action of the drift and of the ice, which has been explained, necessarily produces such a condition of soil, which is the effect of the currents and eddies made by the varying circumstances of the continually changing flow of water. Thus the drift soils are mostly of inferior character and offer few advantages for the farmer, who should scrutinize closely, when he is in search of a farm, the soil which he expects to cultivate.

Another inferior class of soils is derived from sandstones, which consist mostly of quartz cemented together with silicious matter. These soils are exceedingly light and porous, and while they are easily cultivated, their porosity is a serious disadvantage, and with the absence of the more valuable minerals required to form a fertile soil, render them undesirable for general farming. These soils are excellent for gardening, and when underlaid with clay which is in reach of the plow, they produce the finest quality of wheat and corn, but are not suitable for grass. In general a farmer should reject land of this character unless there are some special circumstances which go to mitigate the undesirable character of it.

One other class of soils remains to be mentioned viz. the alluvial "bottom lands" so called because they occupy the low level grounds on the borders of rivers, and have been formed by deposits brought down from higher lands by periodical floods. These lands are generally of the richest character, formed as they have been of the surface soil of the higher lands along the banks of the rivers which has been washed down by the rains. The soil thus formed is exceedingly rich in organic matter and potash, and indeed in all the soluble compounds of both organic and inorganic

elements, and are practically inexhaustible of fertility. Some of them have been under cultivation for 100 years, and under ordinary fair treatment and a judicious rotation of crops are now yielding as much as when first cleared of the original forest more than 100 years ago.

The practical conclusions to be derived from the preceding considerations may be summed up as follows.

First.—Soils are derived either wholly or in part from the rocks upon which they rest; and when the soil is made up of accumulations of drifted materials brought from a distance, these are more or less mixed with materials derived from the rocks upon which they lie.

Second.—That the condition of the rocky materials of the soil may be made a guide as to the relation of the soil to the underlying rocks: for when these fragments are sharp and angular, it proves that they have been derived from adjacent sources and have not been transported any great distance; while the roundness and smoothness of the drift indicate the more or less distant sources from which they have been brought.

Third.—A knowledge of the composition of the rocks from which any soil has been derived, enables the farmer to form an accurate judgment of the quality and general nature of the soil and becomes a safe guide to him as to the details of its culture and management.

Fourth.—That as a result of the foregoing a study of the outlines, at least, of the science of geology is of great importance to the farmer and will be a most useful aid in the intelligent and successful culture of farm crops.

CHAPTER XX.

THE PHYSICAL PROPERTIES OF SOILS.

While the later and more accurate knowledge regarding the relation of soils to the growth of crops, has rendered obsolete many of the former views and opinions held by agricultural students in respect of the importance of this relation, yet the practical farmer will easily recognize the fact that the physical conditions of the soil; that is, its density; the fineness of its particles; its firmness and adhesive power; its capacity for imbibing and retaining moisture; its color; the amount of contraction upon drying; its porosity and consequent power of admitting air, and gaseous substances with it: that all these are of primary importance to its successful culture and worthy of careful consideration and study.

Some soils are much heavier than others; not only in reference to the ordinary sense in which the terms "heavy" and "light" are used to denote clay or sandy soils; but as regards the absolute specific gravity and the weight of equal bulks. Thus a cubic foot of

Dry sandy or limestone soil weighs.....	110 lbs.
Clay loam, half sand.....	95 "
Heavy sandy loam.....	80 to 90 "
Pure clay.....	75 "
Rich garden mold.....	70 "
Peaty soil from swamps.....	30 to 50 "

Sandy soil, largely made up of quartz is the heaviest and the weight of soil is less as the proportion of clay and vegetable matter increases. This quality of the soil is not without practical importance: for the heavier a soil is the less it is compressed or packed by the passage of loads or of cattle over it; the less it is washed by heavy rains; and according to a number of experiments made in Germany it has been shown that the denser and heavier the soils, the

longer the sun's heat is retained after night fall, or after a change in the weather. The exemption from frosts of light sandy lands while peaty soils are more subject to them is another result of this quality.

The state of division of the particles of a soil is intimately connected with its density and weight. The exceedingly fine particles of which the "loess" soils of Nebraska and of the Mississippi bottoms consist, and the coarser nature of the gravelly lands of New England, certainly have much to do with their productive character and money value, because these are controlled by ease of working and facility of management, quite as much as by their fertility; and this property is not to be lightly passed over or ignored, in this consideration. Some considerable quantity of stone is not considered by many farmers as injurious or even objectionable; for when the stone is not large enough to interfere with the employment of the implements, the plow, harrow, drill, and mower and reaper, it is really a benefit, for it warms the land in the winter and cools it in the summer, condensing moisture around it in the latter case and so aiding considerably in the growth of the crops. The fragments of certain kinds of rocks, especially the fossiliferous slates and limestones, are quickly worn down by the weather and contribute to a useful extent to the mineral plant food of the soil; so that there are cases in which a moderate quantity of loose stone in the soil is a benefit rather than an incumbrance, in more ways than one. This is the case in western New York where the fossiliferous limestone prevails and in eastern Pennsylvania and southward along the mountains, where the micaceous schists and slates and the magnesian talcose rocks abound; and in their gradual wearing down furnish new supplies of plant food to the land.

When soils cohere and become hard and cloddy, or, bake into a hard crust on the surface after rain, this is objectionable; as compelling the farmer to spend a good deal of labor in reducing the clods and pulverizing the surface by frequent cultivation. Sandy loams and light clay loams have not this objectionable coherence; while stiff clays are

especially subject to it, and are consequently difficult to work and at times the crops suffer on such soils. Then thorough drainage, or the admixture of a large quantity of sand or vegetable matter or lime, or all of them are needed to secure the largest possible crops. In the end these methods will bring the stiffest clay soil to a condition in which it may be worked to advantage, but the cost of all this is to be taken into account when a farm is examined with a view to its purchase, or when methods are required to bring it to a condition of suitable pulverization. In this case the farmer will do well to study the character of the implements he employs very carefully, and choose those which are the most effective for this purpose, so that the land may be most perfectly and economically worked.

Some soils are extremely adhesive and clog the implements even when made of the best, the hardest, and the smoothest metal. All soils are more resistant to the plow when wet, than when dry, and also to an iron than to a chilled or steel plow. While the resistance of a sandy soil when wet, is equal to 4 lbs. to the square foot of the surface which passes through it, a fertile vegetable soil or a rich loam, exerts a resisting force of about 6 lbs. and clay soils from 8 to 25 lbs. to the square foot. These differences will certainly form considerable items in the calculation of a farmer who is estimating the cost of working, or the effectiveness of it, and the consequent value that may be put on the land.

The capacity for absorbing and holding water is of paramount importance to the soil, for the ability to produce crops depends greatly upon this quality. Soils vary greatly in this respect; as will be shown in the following instances. When a sample of soil is dried thoroughly in a moderately cool oven, or on a plate placed over boiling water, and is then spread out on paper in the open air, it will take up watery vapor from the atmosphere, and will thus increase in weight. The capacity of the soil in this respect may be easily tested by weighing accurately 100 ounces of soil dried for 24 hours in the manner above described. Rich garden

loam thus treated will absorb about 2 per cent. of moisture from the atmosphere in a night of 12 hours. In dry seasons this quality of the soil is very useful in restoring the moisture which was lost during the day and that which has been exhaled by the plants—and this is usually more than is lost directly by evaporation from the soil.

Different soils possess this property in very unequal degrees. Thus it has been found that 1000 lbs. of

Quartz sand will gain.....	nothing.
Limestone sand gains.....	2 pounds.
Sandy loam soil gains.....	21 “
Clay loam soil gains.....	25 “
Pure clay gains.....	27 “
Peat gains.....	80 “

This last figure should not be passed by without calling attention to the value in this respect of a large admixture of decayed peat or swamp muck to all kinds of soil. The author has found that the addition of 100 loads of swamp muck, well composted with quick lime, per acre, spread upon very light sandy soil, saved a crop of corn from injury during a very dry season, in which the corn upon adjacent land not so treated, curled and wilted and made no more than half an ordinary yield of ears and fodder. The corn dressed with the compost remained dark green in color; and never curled on the hottest days, while the adjoining rows of corn were dry and yellow. The most fertile soils possess this property to the largest extent, hence the farmer who cultivates his soil and treats it in the most liberal manner secures the highest recompense for his labor.

Soils also vary in their capacity to retain water. If water be poured drop by drop upon a piece of dry clay the interstices of the hard clod will be gradually filled with water and then will hold no more. At length the drops will fall from the bottom of it as they fall on to the top of it. All sorts of soil possess this property to some extent. The rains fall and are quickly drank in by the pores or interstices of the soil and are there firmly held until the water is driven off by long continued heat and exposure to hot dry air. But after long continued rains the soil is saturated and the

overplus either runs off from the surface or sinks into the subsoil or escapes through the drains. In drained land this power of retaining or holding water in the largest quantity is of the highest advantage, for, while the injurious excess is carried off and removed a large supply remains for the sustenance of the crops. The difference between soils in this respect is quite large. Thus 100 lbs. of the following named soils will begin to part with water, if it be

A pure sand when it has absorbed.....	25 pounds.
A limestone sand when it has absorbed.....	29 “
A sandy loam soil when it has absorbed.....	40 “
A limestone clay loam when it has absorbed...	45 “
A pure clay loam when it has absorbed.....	50 “
A pure clay when it has absorbed.....	70 “
A dry peat when it has absorbed.....	180 “

The best arable soils are therefore able to hold within their interstices from 40 to 70 per cent. of their weight of water; while the best grass lands will easily hold even more than their own weight. As grass thrives all the better, the larger the supply of water may be, the most retentive soils are therefore better used for meadows than for grain crops.

In the climate of America this ability to hold water during the frequent long drouths of the growing season, gives a high value to those soils which possess it in the highest degree; and also has a noteworthy bearing upon the question of drainage; for where a soil is able to, and will, retain more water in its pores, without parting with it by percolation, it is all the more necessary and the least injurious to supply the land with an escape for the surplus. For the more water that is held by the soil, the less air can be contained in it and air is quite as useful for the growth of plants as water is, for while water is the vehicle by which nutriment is conveyed into plants, it has been shown that a large quantity of food is derived by plants either directly or indirectly from the atmosphere, which requires this vehicle for its conveyance.

A fact of much interest in this connection is that those soils which absorb the most water resist evaporation for the longest period. The power of absorption is due to the sur-

face attraction of the particles of the soil for water. The finer the particles of the soil, the greater quantity of water is absorbed, because the total surface is greater. The natural result of this is, that the slower is the evaporation from the soil, because the natural affinity of the surfaces for moisture being greater it is proportionately harder to overcome it by evaporation. The following table gives the results reached by Schubler in experiments in this direction. In the first column the figures are nearly a repetition of those given in the last preceding table, but they are here placed in juxtaposition with the second column, which shows the quantity of water which was evaporated in 4 hours when the samples of the soil were spread over equal surfaces and exposed to the same conditions.

	<i>Per cent. of water absorbed.</i>	<i>Per cent. of water evaporated in 4 hours.</i>
Quartz sand.....	25	88.4
Limestone sand.....	29	75.9
Clay with 40 per cent. sand.....	40	52.
Loam.....	51	45.7
Common arable land.....	52	32.
Heavy clay 20 per cent. sand.....	61	34.6
Powdered carbonate of lime.....	85	28.
Garden soil.....	89	24.3
Peat decayed.....	181	25.5

This resistance to evaporation is not only due to the adhesion of the water to the surfaces of the particles of the soil, but is due to capillary attraction. If a capillary tube, that is one having a very small diameter, is dipped into water a portion of its length; the water within the tube rises considerably above the level of that without it. This is due to what is known as capillary attraction. If a piece of woollen cloth is hung over the edge of a pail half full of water, so that one end is in the water, the water will rise through the fibers of the cloth; these forming capillary tubes; and will flow over the edge of the pail until the pail is emptied. If two sheets of glass are placed in a vessel of colored water, and the two edges are brought into contact at one side and separated a small space at the other side, the colored water will be seen to rise between the plates and

form a curve, or line which marks the gradual approach of the two. The liquid rises higher as the space between the plates is closer. This is due to capillary action. The same action is exerted in the spaces between the particles of the soil; the vertical spaces forming tubes through the mass.

When water is poured into the saucer of a flower pot the soil gradually draws it up until the top is moistened. This takes place in the soil of a field; the water being gradually drawn up from below until the capacity to hold it is fully exercised. Thus there is a constant ebb and flow of water in the soil. The rains descend and sink into the soil finding an outlet in springs at a lower level; or a resting place in the subsoil; and it is gradually brought to the surface again by this capillary attraction to supply the crops. The soil is charged with saline and other soluble plant food; and as the water is everywhere diffused through the soil these fertilizing matters are spread through it, finding their way with the waters among the interstices between the smallest particles. As the soil is filled with water in wet weather, and the water sinks, it necessarily carries this saline matter with it, but this is all brought back again as the surface dries and the moisture rises again in obedience to this natural law. Successive portions of water rise to the surface, evaporate into the air, or pass by transpiration through the leaves of plants, leaving fertilizing matter behind them. Thus in the growing season a large supply of food for plants is brought up from below, within the reach of their roots, and diffused intimately through the soil, so that the finest fiber of the feeding roots is supplied, and as this ascent of water and evaporation of it, go on all through the dry weather of the summer, the fertilizing matter accumulates in the surface soil about the roots of the crops and places within their reach an ample supply of every soluble substance which is existing in the soil. As one may make a fire and see the smoke ascend and become diffused throughout the atmosphere and disappear, but yet perceive its odor even at a long distance from the fire, so the fertiliz-

ing matter existing in the soil, or applied to it by the farmer, spreads and diffuses itself among the particles of the soil and disappears from view, but its aliment is tasted by the plants, and absorbed by them and changed by the wonderful processes of natural chemistry into vegetable tissue and solid substance, which affords appropriate subsistence for animals. This capillary action and consequent process of diffusion in the soil is of the greatest importance and is intimately connected with the profitable culture of the crops. *It goes on most effectively in thoroughly pulverized soil; hence the farmers business—understanding this process—is to use the best possible means, by thorough working with most effective implements, to produce this necessary condition of his fields.*

All this goes on within the view of the farmer who gives his mangel crop a dressing of salt, for which this crop has a strong liking. The white covering of the soil quickly disappears; being dissolved in the moisture and carried by diffusion everywhere through the soil. It may not be quite evenly spread on the surface but it is soon very evenly scattered through the soil and the rains carry it down into it. A chemist, by analysis, might detect it although it has disappeared to the eye, but as the surface soil is dried by the heat it will reappear in a white efflorescence on the ground where it is brought up by the evaporating water from below; and this crust is gradually increased in thickness by repeated accessions as each particle of water, brings up its load of the saline matter, and evaporating leaves it on the surface; from whence it is again carried down by the next rain to circulate over again in the same manner. This diffusion of water through the soil is precisely similar to that of the atmosphere. The air circulates through the soil spaces by the force of expansion and contraction caused by the effects of heat and cold; and the water circulates in precisely a similar manner, by the same agency, and in hot dry climates this diffusion of moisture by capillary attraction going on without intermission, secures the safety of the crops and makes agriculture possible. In some of our Western States and Territories, this process may be seen going on now as

it has been going on for ages, in the constant accretion of extensive beds of salt; borax; soda; and other saline substances which have been deposited on the surface, by the long continued evaporation in the dry arid climate, of the water of the soil which has held them in solution. The niter beds of Peru and Chili, which are many feet in thickness have been deposited in the same manner; the vastness of the accumulations showing the great amount of the evaporations which have been going on.

The contraction of the soil by drying is a property which is exerted in proportion to the power of absorbing water. Some soils, such as pure clays and peat diminish in bulk by drying, very considerably. A sample of compact black peat tested by the author, weighing 8 lbs. when taken from the swamp, shrank when perfectly dry to 1 pound in weight thus losing $87\frac{1}{2}$ per cent. of water, and to one half its bulk. Clay soil shrinks about 25 per cent. in its bulk in drying, while a sandy loam loses scarcely anything. The more clay or vegetable matter the soil contains the more it contracts, and the cracking of the surface thus occasioned is often seriously injurious to the roots of the crops; rupturing the roots as the fissures open. A strong clay soil has been known to be fissured in this manner down to the drains at a depth of four feet, so that the next rain poured down into the drains in floods without soaking the surface. This property of clay land is one of its disadvantages which should be noted and should encourage its improvement by a considerable admixture of vegetable matter which will add to its porosity and make it less subject to an injurious evaporation.

The relation of the soil to the atmosphere, in regard to its physical properties, is a part of this subject which should not be neglected: for the power of absorbing gaseous substances from the air is of great importance to the growth of crops. The absorption of oxygen by porous substances has already been referred to, and the more porous soils exert this power to the largest extent. A supply of oxygen is required for the germination of a seed as well as for the

growth of a plant. It is of consequence to the farmer therefore that this oxygen should gain access to every part of the soil and thus to the seed and the roots of the plants. This easy access is of course facilitated artificially by the perfect working of the land and making it as porous as possible. But there are some soils which absorb oxygen with more rapidity and in larger quantity than others. Clays absorb more oxygen than sandy soils: and vegetable soils and peat more than clays. This is due in part to the natural porosity of the soil and in part to its chemical composition. Clay containing oxides of other minerals, for instance, absorbs oxygen which enters into combination with it, and decaying vegetable matter takes up much of it to assist in its decomposition.

These remarks all apply to the power and natural tendency of soils to absorb carbonic acid from the atmosphere, together with the ammonia which rises from the earth from decaying matter, and nitric acid which may be formed in the air by electrical agency, and these contribute to some valuable extent to the natural fertility of the land, but necessarily in proportion to the power of absorption which is due to its condition of porosity. Nothing more positive than this, however can be asserted, because of the absence of satisfactory experiments in this direction as to the relative capabilities of soils to extract vegetable plant food from the atmosphere; but one fact has been clearly ascertained, viz: that all soils absorb gaseous substances of every kind most readily and in the greatest abundance when they are in a moist state. The rain fall, and the deposition of dew, as well as the condensation of moisture in the soil from the atmosphere which circulates within it, will all, therefore, favor this absorption of fertilizing gaseous matter; and this will be greatest in those soils which naturally possess this power in the greatest degree; and when the artificial condition of the soil, produced by thorough culture and pulverization, assists its natural proclivities most effectively.

The power of absorption of the sun's heat is another exceedingly important property of soils and this also varies

with the character of the land. It has been found that the surface of the earth acquires a much higher temperature when the rays of the sun beat down upon it, than the surrounding air. A temperature of 110 or 120 degrees is quite commonly acquired; while at times it rises to 150; while the air is no warmer than 70 or 80 degrees in the shade. Thus the soil is provided with a supply of heat which is of the greatest importance to the growing crops: especially to those subtropical plants, such as corn, which delight in this genial warmth. Every farmer knows how his corn shoots up in its growth on those warm moist nights, following hot days, when the accumulated heat of the soil is retained, and intensifies those chemical agencies which change the plant food in the soil into vegetable tissue and thus force the surprising growth which is noticed under such favorable circumstances. A corn plant has been known to increase in height nearly 2 inches in the 8 hours between the light of two days in August, at a season when the growth is most luxuriant.

This power of absorbing heat depends upon the color as well as the texture of the soil. Every one knows how the sun's heat is absorbed by dark colored clothes, and that it is for this reason that light colored clothing is worn in the summer; also how a black kettle will heat water over a fire more quickly than a bright one. In the same way and for the same reason a dark colored soil absorbs very much more heat than a light colored one, and hence the vegetation upon dark soils will be more luxuriant than upon light ones. The black prairie soils of the Western States produce more and better corn for this reason than the white or grey soils of other localities, and when light sandy soils are darkened in color by a liberal admixture of peat compost, they are improved very considerably.

This power of absorbing heat possessed by dark colored soils, however, is not accompanied by a corresponding tenacity or power of retaining heat; for black peaty soils will cool as much in one hour after night fall as a light sandy or clay soil will in three. This difference however does not

operate wholly to the disadvantage of the dark soils, for as the cooling progresses most rapidly the dew is deposited with equal facility; and it is doubtful if this accession of moisture may not be of greater benefit to a parched soil than the longer retention of the warmth might be. Besides as the dark soils become heated more abundantly than others, they can better spare their excess of heat than lighter soils can, and yet have an abundance remaining for every need of the crops.

Such then are, in the main, the most important physical properties of the soil. Over much of them the intelligent farmer has easy and effective control as will be explained in a future chapter. He can drain land that is excessively wet or which is sealed below by an impermeable subsoil and thus open it to the beneficent influence of the vitalizing atmosphere with all its burden of fertilizing agencies; and to the vivifying influence of the sun's heat. He can plow and pulverize it and make it more open and porous and so give effect to its chemical influences over such organic matter as it may contain as will more quickly prepare it for the aliment of the crops. He can stiffen and darken the lighter sandy soils and loosen and soften the heavier clay, by mixing composts or manure with them and thus make either more valuable for his purposes.

But while the physical properties of the soil have much to do with its productive power, these are only secondary and helpful to its primary condition of fertility. It may be neither too heavy nor too light; too wet nor too dry; too cold nor too warm; too fine nor too coarse; too high nor too low; may be situated in the most propitious climate; and consist of a well proportioned mixture of sand and clay; contain an average quantity of vegetable matter and have every benefit of a warm and favoring locality; and yet it may disappoint the expectations of the farmer or be wholly barren. The want of one of the indispensable elements of plant food in it may forbid the growth of one spear of grass, and make of it a barren waste. Therefore the physical properties of the soil are only accessory to its chemical consti-

tution; and make available its natural fertility without adding to it.

But the study of these physical properties of soils is not without an important practical value. For a farm may have a fertile soil and be endowed with an abundance of fit food for crops. It may have every provision for this valuable use, and yet its condition may be such that only the lowest and most useless plants can support themselves upon it. It may produce reeds and rushes; sour unwholesome sedges; useless moses and ferns, and weeds which are wholly valueless for the support of animals, and yet the skillful farmer knowing the principles which relate to the physical properties of soils, may take such an undesirable farm and by a judicious course of improvement may make a garden of it, and wring from it the hidden stores of wealth which lie within it. But to do this he must recognize and understand what the functions of the soil are; that these are of two kinds and each of these are distinct and separate but important and necessary to the growth of plants. These are

First.—To uphold and sustain the plant and afford it a safe and secure anchorage.

Second.—To absorb air, water and heat and retain these for the promotion of the growth of crops.

These are its mechanical and physical functions.

Third.—To supply to plants food of whatever kinds may be required for the profitable growth of crops.

Fourth.—To give effect to all those chemical changes which are required to produce the changes in the various elements of this food by which they are prepared for admission into the roots and circulation of plants.

These functions of the soil are performed in a very inadequate manner by nature, and while nature contributes the materials, and the forces by which the materials may be made available, yet the use and direction of these are left to mankind, whose labor gives effect to them. And all the operations of the farmer are intended to make these materials and forces available; to aid and assist in, and give full effect to, the performance of these functions of the soil by

all those methods which are included in the term "culture." The consideration of the questions which arise in a description and discussion of these methods by which the culture of farm crops is made effective and profitable will be taken up in the following chapters.

PART THIRD.

CHAPTER XXI.

THE EXHAUSTION OF THE SOIL.

The soil may be compared to a manufactory, to which is attached a storehouse for the keeping of the raw materials which are from time to time worked up in the factory; and the manufactured products, which are made up. When in time of active business an excessive demand occurs for the finished goods beyond the power of the factory to supply them, the stock is exhausted; and no more sales or deliveries can be made until the factory has had time to refurnish the store with a new stock. But if one needed material, wool; cotton; dye stuff; oil for the machinery; fuel for the furnace for driving the engine, or money to pay for the labor, is wanting, the work stops. There may be everything but a little oil even; or one single color in the dye house; yet everything must stop until this necessary article is supplied. The experienced owner and manager, however, makes it his business to see that every one of these needed articles are kept in stock ready for instant supply when called for. He keeps a stock book in which is entered all receipts and all expenditures of all these supplies, and he carefully looks over this book at stated times and notices how the consumption is going on, that a fresh stock may be laid in before the old is exhausted and work might be stopped for want of some one little thing.

This is precisely what the farmer should do and must do for the most successful culture of his crops. He has a store of raw materials in his soil, and nature carries on there a manufactory in which these raw materials are used for the

production of crops. Nothing is or can be taken from the soil unless from the materials which are stored in it, or are added to it from time to time as the store is drawn upon. The store consists of those elements of plant growth which have been previously described, and which, as may be seen by the figures which represent their various proportions, (given below) exist in definite and known quantities. They are therefore far from inexhaustible, and all the more so, that only a very small quantity of the most valuable of them exists in an available condition. If a farmer should be led to think otherwise and hope to grow crops until the entire stores are used up, he will be quickly undeceived by the early and rapid lessening of the yield, until in time only puny weak plants are grown, having not enough of vigor and strength to produce a seed. Then the soil is exhausted, or as he says it is worn out; run down and impoverished; and the supply of raw material having given out, the manufactory is obliged to stop until the stock is replenished.

The amount of plant food in an acre of good arable soil 9 inches deep, which is equal to about 3,000,000 lbs. when dry, is shown in the following table :

COMPOSITION OF A FERTILE SOIL, 9 INCHES DEEP OVER
ONE ACRE.

Silica.....	2,308,700 pounds.
Alumina	255,000 “
Oxide of iron.....	132,000 “
Lime.....	60,900 “
Magnesia.....	79,800 “
Potash.....	34,200 “
Soda.....	36,200 “
Phosphoric acid.....	19,500 “
Sulphuric acid.....	1,830 “
Chlorine	1,800 “
Organic matter.....	70,000 “
	<hr/> 2,999,930 “

There are fertile soils which do not contain more than a tenth part of the above quantities of lime, soda, potash, and phosphoric acid; and it must be remembered that it is not so much the total absolute quantities of these elements, but their condition of availability; their solubility in fact; upon

which the actual fertility of the soil depends. The composition of a barren and unfruitful soil is given in the following table.

COMPOSITION OF A BARREN SOIL EXHAUSTED OF SOME ELEMENTS, 9 INCHES DEEP OVER ONE ACRE.

Silica and sand.....	2,333.400 pounds.
Alumina.....	284.700 "
Oxide of iron.....	174.000 "
Oxide of manganese.....	3.150 "
Lime.....	25.980 "
Magnesia.....	21.840 "
Potash.....	trace only
Soda.....	trace only
Phosphoric acid.....	90 "
Sulphuric acid.....	trace only
Carbonic acid.....	6.000 "
Chlorine	trace only
Organic matter.....	150.840 "
	<hr/> 3,000.000

The failure of this soil to produce crops is clearly due to the absence of potash, soda, sulphuric acid and chlorine, and the exceedingly small quantity of phosphoric acid, and which the abundance of other elements has no power to neutralize.

The actually available amount of plant food of any fertile soil is exceedingly small. No more of any quantity, however large it may be, then is soluble in water can be absorbed by the roots of a plant; and it is rarely that any quantity that is soluble in water, can be discovered by the most delicate analysis, existing in 100 pounds of any soil. In analyzing soils the chemist uses acid solvents, but plants have the aid only of water, with a very small quantity of carbonic acid, to prepare their food for them. Consequently the exhaustion of the available plant food from an apparently inexhaustible soil is the work of only a very few years. Twenty years at the most, is the period during which the fertile virgin soils of our forests or prairies will bear satisfactory crops unless they are manured and brought under a judicious rotation.

The amount of organic and inorganic matter which is removed by the ordinary farm crops from an acre of soil is shown in the following table.

THE AVERAGE WEIGHT AND COMPOSITION OF ORDINARY CROPS IN POUNDS PER ACRE.

	Weight of crop. Dry.	Ash.	Nitrogen.	Sulphur.	Potash.	Soda.	Lime.	Magnesia.	Phosphoric acid.	Chlorine.	Silica.
Wheat grain, 30 bushels.....	1530 lbs.	31	33	2.7	9.7	0.9	1.0	3.7	14.3	0.2	0.5
straw,	2653 "	158	12	5.1	18.2	2.5	9.2	4.0	8.4	1.7	110.6
Total,	4183 "	189	45	7.8	27.9	3.4	10.2	7.7	22.7	1.9	111.1
Barley, 40 bushels.....	1747 lbs.	46	35	2.9	9.8	1.0	1.3	4.0	16.2	0.4	12.0
straw,	2080 "	100	12	3.2	21.6	4.2	8.5	2.5	4.4	3.2	51.5
Total,	3827 "	146	47	6.1	31.4	5.2	9.8	6.5	20.6	3.6	63.5
Oats, 45 bushels.....	1625 lbs.	54	38	3.2	8.5	1.4	2.0	3.9	11.8		24.8
straw,	2353 "	140	14	4.8	29.6	5.9	9.8	5.3	7.1	5.5	69.3
Total,	3978 "	194	52	8.0	38.1	7.3	11.8	9.2	18.9	5.5	94.1
Meadow hay.....	2822 lbs.	208	49	5.7	56.3	11.9	28.1	10.1	12.7	16.2	57.5
Red clover hay.....	3763 lbs.	255	102	9.4	87.4	4.1	86.1	30.9	25.1	9.4	6.8

Beans, 30 bushels.....	1613 lbs.	57	77	4.4	23.0	0.8	2.9	3.8	22.3	1.5	0.8
straw,	1848 "	130	22	4.9	58.1	4.9	30.2	10.3	9.2	18.1	6.9
Total,	3461 "	187	99	9.3	81.1	5.7 "	33.1	14.1	31.5	19.6	7.7
Turnips, 17 tons.....	3126 lbs.	218	71	15.2	108.6	17.0	25.5	5.7	22.4	10.9	2.6
leaves,	1531 "	146	49	5.7	40.2	7.5	48.5	3.8	10.7	11.2	5.1
Total,	4657 "	364	120	20.9	148.8	24.5	74.0	9.5	33.1	22.1	7.7
Ruta bagas, 14 tons.....	3349 lbs.	163	74	14.6	63.3	22.8	19.7	6.8	16.9	6.8	3.1
leaves,	706 "	75	28	3.2	16.4	9.2	22.7	2.4	4.8	8.3	3.6
Total,	4055 "	238	102	17.8	79.7	32.0	42.4	9.2	21.7	15.1	6.7
Mangels, 20 tons.....	5628 lbs.	410	96	4.9	191.1	75.4	24.2	19.7	34.0	40.6	16.4
leaves,	1654 "	280	51	9.1	71.4	65.2	29.1	27.2	15.1	49.8	9.2
Total,	7282 "	690	147	14.0	262.5	140.6	53.3	46.9	49.1	90.4	25.6
Potatoes, 6 tons.....	3360 lbs.	126	47	2.7	75.4	2.0	2.9	5.7	24.1	3.5	2.9
stems and leaves,	954 "	50	20	2.1	1.1	2.0	22.7	12.4	2.7	1.9	2.1
Total,	4314 "	176	67	4.8	76.5	4.0	25.6	18.1	26.8	5.4	5.0
Corn, 50 bushels.....	2550 lbs.	52	41	3.0	8.2	0.5	0.7	4.5	13.7	—	0.8
stalks,	3500 "	141	15	11.7	49.8	1.5	15.0	7.8	11.4	—	58.7
Total,	6050 "	193	56	14.7	58.0	2.0	15.7	12.3	25.1	—	54.5

An inspection of the table above presented gives only a faint idea of the extent to which the elements of fertility are withdrawn from the soil in the regular course of cropping. If we figure up the amount of mineral matters carried off during the ordinary 4 course rotation of wheat, oats, corn, and clover for 2 years, on a well cultivated farm, we have the following results.

	<i>Wheat.</i>	<i>Oats.</i>	<i>Corn.</i>	<i>2 years Clover.</i>	<i>Total.</i>	
Nitrogen	45.	52.	56.	204.	357.	lbs.
Sulphur.....	7.8	8.0	14.7	18.8	49.3	
Potash.....	27.9	38.1	58.0	174.8	298.8	
Soda.....	3.4	7.3	2.0	8.2	20.9	
Lime	10.2	11.8	15.7	172.2	209.9	
Magnesia.....	7.7	9.2	12.3	61.8	91.0	
Phosphoric acid....	22.7	18.9	25.1	50.2	116.9	
Chlorine	1.9	5.5		18.8	26.2	
Silica.....	111.1	94.1	54.5	18.6	273.3	
	<u>237.7</u>	<u>244.9</u>	<u>238.3</u>	<u>722.4</u>	<u>1443.3</u>	

The amount thus taken from the soil in 5 years is very large, and considering that it is all derived from the stock of soluble plant food existing in the soil, it is no matter for surprise that 20 years of such cultivation should leave the soil destitute of fertility and unable to bear the same abundant crops. Indeed to such a condition of sterility have a large portion of the cultivated lands in New England and the Southern States been reduced by this process of exhaustive culture that a larger expense will be required for their restoration to even a moderate degree of fertility, than would be equal to their value when thus restored. No farmer who lives by his mere labor, and who has not a large capital to spend in fertilizers and a slow costly process of recovery, can hope to do anything with these farms, many of which are abandoned to the slow process of recovery by natural methods and the gradual accretion of carbon and nitrogen from the sparse contributions of the atmosphere, which may sustain a thin growth of weeds and humble plants during a long series of years, the remains of which may in time gather a sufficient provision for a new culture.

It has been explained that some of the mineral constituents of a fertile soil exist in sufficient abundance for all the requirements of cultivated crops for all time. Alumina and

silica however are the only parts of the soil which are thus bountifully provided by nature. Every one of the others, even lime, of which 30 tons per acre are contained in many soils—and in some there is much more than this—is quite rapidly exhausted, so far as the requirements of a full crop are concerned, by a few crops; for although there may be many tons of lime still remaining in the soil only a small quantity of it is available because it is soluble in water to a very small extent. The same is true of the potash; soda; phosphoric acid; and magnesia; all indispensably necessary to the crops as has been shown above.

A small quantity of all these elements of plant food is dissolved in the soil by the rain water, aided by the carbonic acid which (as has been previously explained) the water holds in solution. The quantity so set free in the soil is the measure of its natural fertility: just as the 7 to 10 pounds of nitrogen which is known to be contributed by the atmosphere in the form of ammonia and nitric acid, and the few pounds of carbon supplied by the carbonic acid which is also derived from the atmosphere, are the measure of the natural resources of the soil in these respects. This natural fertility is able to support the common spontaneous growth of soil which contains no accumulated stock derived from the decay of previous crops. If the soil dug from a deep well is thrown out on the surface and sown with seeds and cultivated, the yield would represent precisely this natural fertility. A very poor growth would be the result. If the precise quantity of all the available elements of plant growth in such a soil could be ascertained and the amount deducted from the known quantities drawn from the cultivated soil by a full crop, we could then calculate with reasonable exactness what the soil loses each year, and what the farmer must supply to it to prevent its final exhaustion and preserve it in a fully fertile condition.

But there are so many accidents of season, and other circumstances, which interfere with the growth of the crops, that the farmer could not safely depend upon such a calculation. To be safe, he must leave a very liberal margin

to cover these risks; and on the whole he will not feel safe until he supplies to his fields at least as much as, and if possible more than the crops draw from them, and not only retain the original stock of fertility and accumulate each year the contributions of the atmosphere, but keep adding to these, either by direct additions in the shape of manures, or of green crops or other vegetable matter plowed in, or procure some additional matter from the soil through the agency of tillage.

It is a frequent supposition that crops of different kinds are constant and unchangeable in regard to their constituents and the quantities of the various elements they draw from the soil. And while it has been stated as a rule, that these drafts made upon the soil are in so great a measure constant and regular that they are typical of the various crops grown, yet within narrow limits; a certain variation is found to exist which is the result of distinct differences in soils. Every farmer has known in his own personal experience, or through the experience of others, that any particular crop, as wheat, varies in character according to the nature of the soil. That upon soils of a silicious or sandy character with an abundance of lime in it, the wheat has a bright clean thin husk and a stiff bright clean straw, while upon other soils containing a large quantity of organic matter and being deficient in silica and lime, the grain has a soft thick husk, a very weak chaff, and straw that is not able to bear the weight of the ear and lodges very easily. Similar differences have been experienced in regard to other crops; oats; barley and potatoes; and even with forest trees and many other plants and their fruits. Wheat straw has been known to vary so much in this respect that various samples of 100 lbs. of it grown upon different soils, have contained $3\frac{1}{2}$ lbs.; $4\frac{1}{4}$ lbs. $6\frac{1}{2}$ lbs. $15\frac{1}{2}$ lbs. and $16\frac{1}{2}$ lbs. of ash, varying with each particular soil. Where the ash was the heaviest the soil consisted of a limestone gravel; while the straw with the lightest ash was on reclaimed swamp land.

The same variations are well known to occur on the same

farm in different fields where the soil varies much in character; and there is no crop that is grown which is not subject to modification in this respect. Even the amount of organic matter in plants is affected by the differences of soils; for some lands produce wheat much richer in gluten than other kinds, and much above the average quantity contained in this grain, and thus draw from the soil a larger quantity of nitrogen in which gluten is exceptionally rich. Sweet corn is much richer in sugar, as is also sugarcane when grown upon lands rich in carbon, while potatoes grown upon reclaimed—but well drained and dry-swamp lands, rich in the same element, contain the largest proportion of starch; and onions grown upon the same soil yield far more abundantly.

These instances tend to show that the exhaustion of the soil is not an element in the culture of crops that can be figured out with precision, as is pretended by some persons, and that it is therefore exceedingly unsafe and unwise for the farmer to run close to the limits indicated by the figures. He must provide sufficiently for the demands of his crops, as shown by the tables previously given, without depending to any large extent upon the store which he has reason to believe exists in the soil, and thus maintain a large balance in hand to serve in cases of any possible and unexpected exigencies.

To sum up the interesting considerations which present themselves in this regard, it may be stated;

First.—That plants appropriate from the soil varying quantities of inorganic, or ash, substances, as their age and condition of growth may vary; and that the different parts of the plant draw from the soil, some more, and some less of these substances than others.

Second.—That if the substances necessary for the growth and perfection of one part of a plant more than another, abound in any soil, the crop will be chiefly developed in that direction; one will run to straw, another to leaf and so on; but as long as the crop can find food in the soil, it will take it if only partially.

Third.—Some substances appear to enter into the circulation of plants, not so much as actual and necessary constituents but more as agents by which other compounds may be conveyed into them. Salt for instance appears to enter into the substance of plants chiefly for supplying chlorine in some cases, and soda in others. In such cases when these substances are found to exert any marked effect upon the vegetation, it is to be concluded that the soil is deficient in them, and that their use necessarily causes a larger draft upon the soil for other kinds of plant food to supply the larger growth of the crops.

Fourth.—That while the soil may contain a very large quantity of the substances required for the growth of vegetation, yet the most of these may be in an unavailable condition for the use of the crops.

Fifth.—That every soil possesses a certain amount of natural fertility, which has been accumulated during past ages, and that this stock is exhausted in a comparatively few years, and during this time it will produce full crops in proportion to the amount of plant food which it contains.

Sixth.—That when this store of accumulated fertility is exhausted, or any one element of it, the crops fail and finally refuse to grow.

Seventh.—That the soil then is able to afford a certain amount of plant food, which is derived from its natural resources; and that these consist of certain contributions from the atmosphere and from the mineral compounds which exist in the soil: but these are wholly inadequate for the production of crops.

Eighth.—That when the soil has been reduced to this low condition of natural fertility, the farmer is obliged to supply an adequate amount of available plant food for the growth of crops, in the form of manures, composts, or fertilizers.

Ninth.—That it is not safe for the farmer to depend wholly upon the analyses of the various crops as to the amount of plant food required by them; but should supply

a surplus in the form of manures or fertilizers so that the soil may be kept in a constantly fertile condition.

Tenth.—That thorough culture and pulverization of the soil, are indispensable for the development of the plant food contained in it.

CHAPTER XXII.

IMPROVEMENT OF THE SOIL BY MECHANICAL METHODS.

The facts given in preceding chapters afford indubitable proof that the natural capacity of the soil for the production of farm crops varies so considerably, that the ability of the farmer to grow them profitably is at times very much restrained. Every soil encourages by its natural condition, a kind of vegetation best suited to it, and is unable to produce anything different or better until this natural condition is changed. A knowledge of the laws of vegetable growth, and of the nature of the organic and inorganic elements of it, with the obstacles to the development of these into food for plants, which exist by reason of the unfavorable physical conditions of the soil, will enable the farmer to take such means as will overcome and remove these obstacles and enable the soil to entirely change the character of its products.

The farmer can change the character of the land itself; he can alter its physical condition, and its chemical constitution; and can thus fit it for growing other species of plants than it naturally bears, or if he chooses, can cause the land to produce these with greater luxuriance and in more profitable quantity. It is in fact the production of these changes by the exertion of rightly directed labor and skillful management which constitutes the whole art of agriculture, and the laws which control and make possible these changes, comprise the whole science of this art.

To attain these desirable ends the farmer may drain the wet lands; irrigate dry lands; lighten heavy clays by deep plowing and subsoiling, and the addition of lime, composts, sand, or peat; consolidate light sandy soils by similar methods; darken the color of light soils by adding composts of

swamp muck; and by any other means consistent with his opportunities to remove the difficulties which stand in the way of the most productive culture of crops.

An excess of water in the land is hurtful in several ways. The roots of plants are drowned in it and perish for want of the needed air and oxygen; for where water is air cannot go, and where it comes the lighter air is driven out. Plants are starved, because the abundance of water so weakens the solutions of plant food, and presents this to the roots so much overcharged with water, that the plants are unable to pass the large quantity which is necessary to supply the requisite solid nutriment, through their leaves, and they perish for want of aliment.

The soil is cooled by the excessive evaporation and made incapable of growing crops for the want of sufficient heat to nourish them and by which the necessary circulation of air in the soil is produced. The warmth of the sun cannot penetrate a wet soil, however ardently its beams may descend upon it; for heat cannot penetrate water from the surface. A fire may be built upon ice and will melt it only very slowly; while if a stratum of boiling water is carefully poured upon the top of a quantity of cold water or ice, the heat will penetrate only to a very little depth. And if the heat of the sun should warm the surface of the soil and set in action the consequent evaporation, this will immediately convey away the heat as fast as it is absorbed, and the soil will remain cold below, where the roots of plants must find room to push their fibers.

The excessive water soon becomes charged with injurious acids produced by the decomposition of the organic matter, and these are deadly in their effects upon vegetation. The oxygen which is required for the change of this decomposing matter into plant food being denied entrance into the soil, no aliment is prepared for the plants; but instead of food, matter which is injurious is offered and there can be no healthy or useful vegetation.

But when the first step for the improvement of a wet soil is taken, all this is changed. The drains carry off the stag-

nant water, and give a ready escape for all that may rise from springs, or which falls in the rains. A flowing current is at once established and life and health at once take the place of the unwholesome effects and death, which accompanied the stagnant water. The active current brings in oxygen and carbonic acid which is given up to the soil; the atmosphere takes the place of the withdrawn water and the heat of the sun enters the now porous soil and starts the active circulation within it, which represent precisely, but in a minute way the air currents above the earths surface, which we call winds; but which are caused and controlled by the same changes of temperature which occur in the dried soil. Every operation of nature which inures for the encouragement of plant growth is now actively at work in the soil, and the production of plant food goes on without hindrance. The soil, solid and compact before, is now open, loose, porous and friable; the frosts pulverize it; the just sufficient water dissolves it; the acids are oxidized, or neutralized by the alkaline solutions which ebb and flow through it; and the farmer no longer delayed when the seasons work presses is able to plow and plant in due time. Every shower then refreshes and fertilizes the land; brings down with it useful substances from the atmosphere, which are absorbed at once by the soil, instead of being wasted and washed away, as they were when the surface of the land was saturated and flooded; and at the same time it renews the air within the soil, causing fresh accessions of such plant food which the air may supply. Moreover this mode of improvement of the soil is equivalent to a considerable deepening of it, for it opens it to the plow and permits the roots to forage to a depth as far down as the drains are placed. It thus enables the farmer to vary his crops and grow such kinds as he may wish and which will be most profitable to him.

Lastly the farmer who drains his wet fields, confers a benefit upon the locality in which he lives. The greatest pest of the American farmer and to his cattle as well, is the ever prevailing miasma which rises from stagnant water, below,

as well as above the surface of the soil, and which is known by the common term malaria. This miserable disease which makes the life of the American citizen uncomfortable and wretched the greater part of the year, is bred in swamps and undrained lands; and when these are improved and freed from the constantly evaporating water, the pestilence is laid and health is restored. The chilling dampness which loads the air with poisonous gases no longer rises in foul vapors from the land; and the air becomes pure and healthful. The farmer thus confers a blessing upon his neighbors, while he improves his own circumstances, and thus affords a new proof of the fact that he who helps himself helps the world, and that no man works for himself alone; much less the farmer, whose vocation makes him the feeder and clothier of mankind.

The practice of irrigation is the converse of draining. It consists in bringing water from distant streams or other sources, by means of canals and ditches, and spreading it over lands where the rainfall is not sufficient for the growth of crops, or in many cases where the ordinary climate prevails, water from adjacent streams or springs is brought and spread over lower lands which are laid down in grass and are kept in permanent meadow. No other country in the world, than ours, offers such a vast scope for the improvement of lands by this means. Millions of acres of land unsurpassingly rich in all the elements of plant growth want only water to make them fruitful and productive of all the varied farm crops; and by means of this mode of improvement millions of farmers may find homes and a comfortable subsistence and furnish great wealth to the community, where now desolation and solitude prevail. At the same time many farmers, whose grass crops are cut off and whose winters supply of hay is greatly reduced by drouth have an abundance of water running to waste upon their farms by the use of which the yield of grass and hay might be doubled. Comparative poverty might thus be turned to actual wealth by the mere employment of water at a little cost, which now flows away uselessly, or perhaps spreads out injurious-

ly into a pestilential swamp. Grass is the grand crop of the farm. It is the pivot of our agriculture. It supports all our live stock in one way or another, and is the very basis of our agricultural prosperity. No farmer ever yet had too much of it: and very many are constantly mourning over the scarcity of it. A large proportion of these have the power in their own hands to double the product of it; by merely conducting such streams, as may be so carried, over the land and spreading the water upon the grass. Water-meadows exist in Europe which have been producing green forage and hay for centuries, without any manure and no labor except cutting the grass. The growth is enormous. One inch per day during the summer, or 120 inches in the aggregate, has been cut from the Rye Grass meadows of Italy; and in England 6 tons of hay per acre is a common yearly product. The water of the streams comes loaded with fertilizing matter which keeps the land increasing in productiveness notwithstanding the large product.

The largest crops of grain and vegetables on record are now produced in Colorado and some Western Territories, where 10 years ago not a blade of grass grew and no civilized human inhabitant had a home. The prevailing sage brush and cactus gave a somber and dreary view to the broad plains, and the wolf chased its prey among the brush, where now the self-binding reaper sings its clattering songs and scatters the golden sheaves; and villages and surrounding homesteads cover the land. All this is the grand transformation worked by the fairy water; one wave of the magic wand, and the stream flows to one side and scatters itself through thousands of channels amid the smiling verdure which has sprung up from the arid barren soil at the touch of the creative, life giving fluid. The fairy is human industry and enterprise and the magic wand is human labor. In another chapter, this subject will be further treated, and some few practical directions given, so far as space will permit, for the practice of this most profitable method of improving soils.

Plowing and subsoiling for the improvement of lands is a practice which has been but little practiced, and much less understood and appreciated in America. The practice has been in use for several centuries in Europe where farm land bears a higher value than it has here. But our cheap lands are now nearly exhausted and it no longer pays to make a farm, ruin it by wasteful culture, and then abandon it to sterility and weeds, and seek a new one which will be treated in the same manner. With a rapidly increasing population, the division of the land among the citizens has been nearly completed and the far distant territories do not offer sufficient inducements for young farmers to go through the wasteful practices of their parents. A few years ago this book would have been a premature work; but now that the best culture of farms and the most profitable culture of farm crops are the only ways to success in gaining a comfortable subsistence. Every known and possible method of improving the land and increasing its productiveness, and every means for study and for acquiring information leading to these desirable ends, become of the greatest interest to farmers.

Hence practices and operations which would not be thought of or undertaken a few years ago, now become indispensably necessary, and what has been done in older countries is to be studied and repeated with such improvements as better knowledge and larger experience may make possible. Plowing is a most important part of the farmers art, but it has been scarcely studied at all, and has been very imperfectly practiced hitherto by American farmers. The plow has been used, not for the permanent improvement of the soil, but merely to loosen it sufficiently to make a bed for the seed and to cover up the debris of the preceding crop. Mechanics and inventors have spent much thought and study upon the perfection of plows and other implements of tillage; and no other country has such a diversity of excellent plows as ours; but the farmers have certainly been neglectful of their opportunities and advantages in regard to the use of the plow in improving their lands.

Very few farmers ever plow a field twice in preparation for a crop and it is nothing uncommon to see the land a mass of hard clods, which the farmer is vainly endeavoring to break down by the use of the spike tooth harrow or the roller, into a fit condition for the reception of the seed.

The soil is quite as rarely ever plowed to a sufficient depth and nothing is feared so much by American farmers as permitting the plow to run an inch or two more deeply than usual or to turn up "the yellow clay" to the surface. All this is an injury to the soil. The passage of a plow back and forth over the same bottom of a furrow for several years hardens it makes it tough and compact, and impermeable to air and water; and really reduces the depth of the soil from which plants can procure their food to the few inches which the shallow imperfect plowing turns over. Nor is the plowing even. The plowman is not instructed in the art of holding or guiding the plow, nor in the necessity for keeping the furrow of even depth and width, and of avoiding balks by which the plow is thrown out and a portion of the soil is left wholly unturned. In many parts of the Southern States the soil is not even turned, but is merely torn by the common bull tongue which leaves the soil only scratched in lines and a large part of it is not touched. In the great states of Ohio; Indiana; Illinois; and others; wheat is sown upon the corn stubble and simply covered by a harrowing and this with a most ineffective implement. The soil is not turned and is not pulverized. From what has been said in previous chapters this sort of culture is seen to be wholly ineffective for its intended purpose, and is utterly useless as a method for improving the soil after it has been exhausted and wasted by this treatment.

The plow is constructed for the purpose of cutting loose and turning over a portion of the soil, having a cross section of 5 x 7 inches up to 7 to 10 or more; depending upon circumstances. American plows are made with shorter and more curved mold boards so as to break up the furrow slice by bending it at a short and sharp angle and are exceed-

ingly effective for the purpose of breaking up the ground. But for the improvement of the land and for increasing its fertility one plowing alone is quite insufficient. The soil should be broken up and pulverized thoroughly all over the field, and the sub-surface over which the horses have trodden and which the sole of the plow has rubbed and hardened and made solid and impermeable, should be broken up and opened to the admission of water and air. Several plowings should be given. A wheat crop should never be put in without at least two plowings and the land for a corn crop should be thoroughly well and deeply plowed in the fall. Plowing at this season for a spring crop is a most effective way of improving the land. The land roughly thrown up in ridges is left with as much surface as possible exposed to the frost, that the soil may be pulverized and made fine and mellow. A winters exposure in this way will liberate much mineral plant food by disintegrating the soil and bringing it in larger part into a soluble condition. The newer soil brought up by the fall plowing is thus brought under the free action of the atmosphere, and aided by the effects of the frost, this develops the plant food in it and makes it available for the crops. A consideration of the principles discussed in previous chapters which relate to the relation of the atmosphere, water, and heat and cold, to the soil; with a knowledge of the precise purposes for which the plow is intended; will enable any thoughtful farmer to work out the requisite methods for improving his land by plowing, for himself.

Subsoil plowing, has been a bugbear to many farmers because the practice of it has been mistaken. It is commonly supposed that this term, means the use of one plow behind another in the same furrow, for the purpose of turning up 8 or 10 inches more soil on the top of the first turned over. This is not intended and would result in a permanent injury to the land. All that the subsoil-plow should do, is to follow the first plow and break up the sub-surface and the hard crust left by previous surface plowings. This hard crust seals the lower soil against the entrance of air and

water, and offers an obstacle to the deeper penetration of the roots of crops.

The presence of oxygen is indispensable in the soil wherever the roots of plants may go. It is—or should be—obvious to the intelligent reader that the more of the soil that can be occupied by the roots of a crop, the better for the crop, for it extends the feeding ground. It is something like opening a second field, by removing a fence, and throwing it open to a herd of cows or a flock of sheep. It increases the food supply proportionately, and as plant food is always being carried down into the lower soil by the water, the farmers desire should be to give the roots of his crops the utmost facility for extending themselves in their search for food. Roots are very enterprising in this way, and farmers cannot do better than take a lesson from the instincts of the plants which they cultivate. Wheat, which is considered a shallow rooted plant, has been known to send its roots down 8 feet into the subsoil. The author has traced the roots of corn in a deep washout nearly 10 feet from the surface; clover sends its roots down 10 or 12 feet; lucern—a most eager feeder and consequently exceedingly productive—has been known to extend its roots 18 feet down into the subsoil. Common grass roots often go down 3 or 4 feet in the soil where inducements in the shape of available food are given. No doubt these are exceptional cases, but they show what plants will do in their search for food, and in every case these deep rooted plants are the most vigorous in growth, proving that their purpose in sending down their roots was successful. Where these roots went there were air, and oxygen, and carbonic acid with it; and had not the soil been porous and accessible to these nutritious gases the roots could not have penetrated into it. It is not necessary to break up the soil to this depth; all that is needed is to break up the crust under the surface, by running the subsoil plow a sufficient depth under the first furrow, to let in the air and open a way for the rains to enter freely, and to permit both air and water to pass and repass, under the influences of heat, and expansion and contraction, with the

most perfect freedom.

Deep surface plowing should be done gradually. It is not wise to bring up a subsoil until the air has had time to act upon it. All soils, as we have seen, contain sulphuric acid and iron, and the combination of these substances form a most noxious substance viz, sulphate of iron or copperas. This is frequently found in subsoils to which air has not penetrated and when the roots of plants touch it, the crop sickens, turns yellow and perishes. By the admission of air, with its oxygen, this noxious compound is decomposed; the sulphuric acid is divorced from the iron, and is set free to be appropriated by the crops in other and useful forms, and the iron unites with the oxygen forming a useful substance—oxide of iron—which enters to a small extent into all vegetable growth. For this and other reasons of like import the subsoil should be broken up by the subsoil plow; but the subsoil should be brought to the surface only as it has been acted upon by the atmosphere and by the manure. A soil may be plowed as deeply as it is occupied by plant food and new soil may be gradually mixed with this by gradual deeper plowing. An inch a year, brought up in the fall, and left to the influences of the air and weather and then mixed with the other soil on the surface, may be safely and usefully added to the depth of the cultivated soil, until 8 or 10 inches has been enriched and fitted for the aliment of plants.

A farmer intent upon the improvement of his soil should not rest until he can safely plow the land to this depth. A table previously given shows how much fertilizing matter may be contained in 9 inches of arable soil over an acre. When the soil has been brought into this condition by mechanical means, then the farmer may use all methods for making this vast store of plant food available. What might be the maximum yield of crops has never yet been ascertained. 240 bushels of grain corn per acre have been produced: the author has grown 125 bushels per acre, and 99½ bushels per acre over a whole field, more than once; and 80 bushels frequently. 6 tons of timothy hay per acre has

been gathered at one mowing: 80 bushels of wheat per acre has been produced and more has been claimed: 65 bushels per acre has been commonly grown by the best English farmers in good seasons. 125 bushels of oats and 80 of barley have been produced on favorable soils. 1329 bushels of potatoes have been made per acre by one farmer by ordinary methods of culture: 600 bushels is a common yield in the rich potash and lime soils of the Southern mountain region. 75 bushels of buckwheat per acre has been grown by the Author, 80 tons of mangels has been produced in England and 1200 bushels per acre of this root have been grown as an ordinary crop. These are not to be supposed to be unsurpassable. No one knows what a fully fertilized soil may produce under every favoring circumstance, but it is the business of the farmer to provide everything in the soil for as large a product as may be possible and then to accept what a kind and favoring Providence—ever ready to recompense honest effort, and sustain the industrious energetic faithful and conscientious worker—may enable him to secure. It is very certain that he who does not sow, will not reap, and it is equally certain that he who sows with pains will reap joyfully.

It is scarcely necessary to extend these considerations to a greater length than to merely mention a few other mechanical methods of improving the soil. The principles involved have been perhaps—and as we hope—made sufficiently clear. Heavy clay soils have been greatly bettered by a mixture of fine sand and gravel. As has been explained the presence of silica in the soil exerts a beneficial effect upon all crops, but especially upon the grains. This process is not so costly as it may seem. Where a supply of sand is conveniently situated 160 loads per acre or one to the square rod is spread in the winter on the fall plowed land, left in ridges and as rough as possible to get an even mixture. This may be done for \$40 per acre if the work is hired; but if in the season of leisure, the farmer and his workmen undertake it, the work may be done at a nominal cost. Where 10 acres are to be sanded, it will greatly

lessen the cost to lay a portable track of 2 x 4 timbers and run a self dumping truck upon these rails. In this way farms have been sanded in Germany at a cost of \$10 per acre and the outlay has been returned the first year by the increased crop. The land is plowed and cross plowed in the spring by which the sand becomes evenly mixed with the clay; the texture of which is very much improved.

Sandy soils are equally improved by the admixture of decayed swamp muck. As this class of soils are usually well adapted for special cultures for which the addition of clay would partially unfit them, this operation is not recommended unless in special cases; but 100 or 200 loads per acre of peat composted with lime has been known to entirely change the appearance of the soil and to largely increase its productiveness. As 100 tons of good peat free from sand or clay will contain 2000 to 4000 lbs. of nitrogen, this with the addition of lime in the porous soil, freely entered and occupied by the air, will enable the process of nitrification to go on with great rapidity, enriching the soil with nitrates to a large extent, and thus ensuring a great improvement in the fertility of it. Perhaps—draining excepted—there is no mode of mechanically improving soils that is so effective in increasing their value and productiveness as this.

The addition of lime to peaty or heavy clay soils has the effect of removing most of the objections to them; but unless it is previously drained the labor is thrown away and ineffective. Lime fits peaty soils for growing grain, but is greatly aided by a mixture of sand. A limed swamp meadow at once changes its product of grass, and if seed is sown, the better kinds of grass thrive excellently. The lime loosens and mellows heavy clay, and makes it less retentive of water and productive of better grain. This however will be more fully treated of when the use of lime as a fertilizer is taken up in a future chapter.

CHAPTER XXIII.

HOW TO DRAIN LAND.

The manner of draining land necessarily depends upon several conditions such as the character of the soil; the amount of water; the manner in which the water exists in the soil or in which it arrives there, the kind of materials at hand; the outlet for the water and others which may present themselves in any particular case. A few general principles however will enable the farmer to adapt his methods to his circumstances without difficulty.

The soil.—Whenever, in early spring, the water appears on the surface, or in the furrow after the plow, or remains upon the surface after rain and interferes with the cultivation, the land requires drainage. It may be that the water can be carried off by open surface ditches; or that the sources of the water may be tapped by a few converging drains meeting in one main ditch by which the whole of the water may be carried off from the land. It may be on the other hand that the subsoil is full of springs which are supplied from distant sources and that in this case deep drains are necessary to cut off the water and carry it away. Or the soil may be of stiff impervious clay under the surface, or an impermeable hardpan prevents the surface water from passing down and making its way from the land. All this must be studied and known before any work is done, lest a costly job of draining may be done unnecessarily or without useful effect. To learn this, it is proper that the subsoil should be examined by digging with the spade 3 or 4 feet deep.

Springs, frequently fill a large area of low land with water, which flows under the surface and immediately upon a hard bed of clay or gravel hardpan. To understand clearly how this occurs, it may be well to explain the nature and action of springs.

Water being a fluid seeks its level under all circumstances, being forced to this level by its gravity or weight, and the extreme mobility of its particles among each other. It is clearly evident from common experience that water cannot be heaped up as sand or earth may be; nor can hollows exist in the surface of a body of it. If a barrel of it is set upon high ground and the contents are let out they will flow readily to any lower level; but the water cannot be made to flow up again of its own motion or gravity or weight.

Now, when water falls in the form of rain upon high ground which is underlaid by clay or hardpan, it sinks down to this impervious stratum, and not being able to pass through it, it flows along its surface down to lower levels, until, gathering there in excessive quantities, or being arrested in its flow by some obstacle, it makes its escape to the surface by some easy way; through a bed of sand or gravel in the form of springs; or it spreads through this open and permeable soil and forms swamps or fills the soil with stagnant water at certain depths, less or greater as the case may be. When one digs down through the surface to this under current of flowing water and taps it, the water rises and makes a well, in which it maintains a height equal to the level of its source or nearly so. Thus a well is an artificial spring under these circumstances, but when the water flows into the well from the surrounding soil and does not rise from the bottom it is not a spring well but simply a cistern which is supplied from above by ordinary drainage.

Remembering this fact, it is easily seen that when low land is saturated with water which comes from a higher level it may be effectually drained by cutting a ditch to intercept it at the foot of the slope; and by carrying off this water to a convenient outlet the whole of the lower land may be freed from it in a very easy and economical manner.

Ditches, required for drains should be 3 feet deep; but under certain circumstances this depth may be less or more. It has been already explained that soil has the property of capillary attraction by which water is raised above its level

in and among the spaces or interstices between the finer particles of the soil. This necessarily has a close connection with the depth of the drains; and in this manner.

If the level of the stagnant water, or the under current which flows from higher land, be, 1, 2, 3 or 4 feet below the surface and the drains are made at either of these depths, it will be clear that the water will flow in the drains; but that if the drains are 20, 30, 40, or 100 feet apart, the capillary attraction of the soil will cause the water to rise at the center line between the drains, to certain heights, varying with the distance between the drains. Thus if the drains are 20 feet apart the tendency of the water to seek its level and flow into the drains will overcome the capillary attraction and the tendency of the water to rise in the soil, to a greater extent than if the drains were 30, 40, 50 or 100 feet apart. Therefore the distance between the drains must be regulated by this property of the soil, the quantity of water which exists in the soil, and the character of the land in regard to its absorbent power and its ability to retain the water in its pores. In clay land or in peaty soil the drains would need to be closer than in open gravel or sandy loam soils, which are underlaid by clay or hard pan; and necessarily they should be made deep enough to reach and pass through this impervious water bed.

Upon these principles it is not difficult to decide upon the depth of the drains and the distance between them to make them most effective.

Open ditches should be made not less than 4 feet wide for 3 feet in depth, or 3 feet for 2 feet in depth; and if the surface soil is open and porous and the water rises from the subsoil, a depth of $2\frac{1}{2}$ or 3 feet will be sufficient. As a rule, the water flows into the drains from the bottom; the pressure of the surface water, tending to force its way downwards, causing the water to rise in the drains just as it does in the case of a spring or a well; as has been explained above.

Ditches for covered drains need be made no wider than is required for the convenience of working in them and the

depth may be from $2\frac{1}{2}$ to 3 feet; and very rarely more; as the case may require. 18 inches at the surface gives ample room for working in such a ditch; and 6 inches is sufficient for the width at the bottom. In estimating the cost of digging these ditches, the question should be considered, if 4 feet ditches at 100 feet apart would not be cheaper than 3 feet ditches 60 feet apart: the cost would be less certainly, for the labor of excavating 6 ditches 4 feet deep would be less than making 10 ditches 3 feet deep and the ground covered would be the same in either case.

The materials, for making the drains in covered ditches are tiles, stones, gravel and wood; and each has its good and bad points.

Tiles are pipes made of clay burned like brick in kilns. They are made of various diameters from one inch for the short lateral drains up to 6 or 8 inches for the main and outlet drains; and are about 15 inches long. They make the best and most lasting drain, when well made and laid with accuracy. They should be hard burned so as to ring when struck; free from flaws; straight, and smooth at the ends, so that they will make close joints and exclude sand or sediment which might choke them. The ditches should be finished to an even grade with a narrow scoop made for the purpose, which digs out a hollow the exact size of the tile and thus provides a bed for them in which they lie easily and in a line, and may be placed quickly. To lay the tile the workman stands on the bank of the ditch (all the earth is thrown out on one side only, to give room for this work) and picks up each tile with a rod provided with a straight projecting arm at the end, which is put into the tile; and lifting it into the ditch the workman places it in the hollow in line with the one before it, taking care that the joint is made close. The ditch should be wholly finished before the tiles are laid, and the work is begun at the upper part so that there is no possibility of anything being washed into the drains by the flowing water.

By making the drains in this way there is no risk of making any mistake in any way, either in the grade or in

laying the tiles. As the tiles are laid they are covered with sufficient earth to protect them from injury by any accident, and the filling in of the ditches may be finished after the tiles are all laid.

One inch tiles are sufficiently large for the lateral drains, unless these are longer than 500 or 600 feet, when the lower part should be $1\frac{1}{2}$ inch. Drain tiles carry 4 times as much water for twice the diameter; (increasing in capacity as the square of the diameter, or the diameter multiplied by itself.) Thus a 2 inch tile carries as much water as 4 one inch tiles; 9 times as much for 3 times the diameter; 16 times as much for 4 times the diameter and so on, thus increasing as the square of the diameter. If 16 one inch tiles are discharging to their full capacity, a 4 inch tile will take all the water; but as an excess of water stops the flow and backs up the water, and favors the deposit of sediment, it is advisable to have the main and outlet pipes larger than is absolutely necessary so as to secure as rapid a discharge of the water as possible.

Stones make an excellent and permanent drain when well laid. A clear channel is made by placing long narrow stones along each side of the ditch and covering these with flat ones placed crosswise. These are covered with round stones packed closely, and these again with small and flat stone over which earth is thrown. This method is economical when the land is stony, and gets rid of stone cheaply and permanently.

Gravel, may be used for making drains where it is abundant and near at hand. The drains in this case are made 6 inches wide at the bottom and are filled in with clean gravel 18 inches deep; over this the earth is filled in. The gravel should be clean and free from clay or sand which would be washed into the bottom of the drains and choke the flow of water.

Wooden pipes may be used in draining marshes and quicksand bottoms, with good effect. These are best made of hemlock boards—which are the most durable under water—6 inches wide, and nailed together in the shape of a V;

the top being made of strips nailed across, so as to form many crevices for the entrance of the water. By extending the end of one board a foot past the end of the other the laps in the drain may be joined firmly. These drains are placed with the narrow part down, by which the flow is made more rapid and the deposit of sediment is avoided.

The outlets of the drains should be amply large to avoid back water and should discharge if possible above the level of any high water. If in time of freshets or floods water is backed up into the drains, or there is any danger of it when making the outlets, it is advisable to fit a gate to the outlet, so that when the water rises it may be closed against the entrance of sand or mud, and opened when the water has subsided, so that the discharge may be rapid and carry off any sediment that may have settled in the drains.

In plowing drained lands, the open furrows should never be made over drains, lest the water lying in them should find its way down and make a channel through the soil by which sand or mud may be carried into the drain. The location of every drain should be marked by permanent stakes or posts in the fence so that it can be reached when desired without difficulty.

IRRIGATION.

CHAPTER XXIV.

IRRIGATION OF FARM CROPS.

No other country in the world offers so wide a scope, and such enormous opportunities, for the application of irrigation to the profitable culture of farm crops, as the United States. A grand chain of mountains, in which are the sources of several of the largest rivers in the world, presents a watershed of enormous proportions, which supplies a myriad of streams whose waters flow down into dry plains, deprived of rain by the interception of the mountains. The summer rainfall and winter snows which fall upon the mountains, are thus carried down into the arid plains, where a wealth of the richest soil lies uselessly, for want of rain. When the streams which thus flow down, are turned from their natural channels into canals provided for the purpose, and the water is carried over the land in irrigating ditches, the soil yields the finest crops with the greatest ease. No adverse weather interferes with the labor of the husbandman. The unclouded sun, beams down upon the verdant fields, and ripens the crops, invigorated to most abundant fruitfulness, by the constant and ample supply of water thus provided.

But it is not only in these arid climates that irrigation becomes a most valuable aid to the farmer in the culture of his crops. Wherever streams can be turned to this use, and their waters poured out upon lower ground, the grass crop may be doubled or trebled; and what is of more account, may be made safe against all the adverse contingencies of weather. The common and necessary rotation of crops in ordinary farming may be an obstacle in the way of the general use of irrigation, but for permanent meadows it will be found invaluable and exceedingly profitable. There are thousands of opportunities for making these meadows along

the river bottoms which are periodically overflowed, but which are torn up and washed by the floods instead of being fed and enriched.

The mode of procedure is as follows. A dam is made across the stream in the most convenient situation, and the water is carried out on one side in a ditch, as if for the purpose of running a mill. When the ditch attains a sufficient elevation to cover the desired space of ground, the water is let out through gates and small channels on to the land. The land is previously leveled and made smooth by repeated plowing and scraping, until an even surface has been formed. It is then sown with the kinds of grasses best suited to this mode of cultivation; but any of the best varieties, as timothy; perennial rye grass; orchard grass; meadow fescue; red top; meadow oat grass; fowl meadow grass; may be grown under this system. As the land will slope a little towards the river bank, the space between this and the ditch will be best laid out into broad terraces, enclosed with low dams, by which the water is retained over the smooth level surface at a depth of 3 inches, or thereabouts, in each division, whenever the grass needs the water. This may be weekly, in the growing season, and the water may be turned on for one night in every week, to soak the ground thoroughly, and prevent it from drying so as to stop the growth of the grass. There is no danger of injury to the ground, because the gates are made to discharge into ditches which gradually overflow until the whole surface is covered. When this is effected, the surplus water flows off through gates on the border of the river; and through the lower dam or bank. Thus a continuous sheet of water is left flowing over, or through the grass, carrying the most luxuriant vigor to the crop, and stimulating the growth enormously. The more water that passes over the grass, the more of the most valuable plant food is brought within reach of the roots. Every blade of grass acts as a filter which retains matter that may be in solution, or is carried in suspension in the water which slowly passes over the ground. Any solid matter that may be carried in the water is thus deposited on the land,

and adds a large amount of the most valuable elements of fertility to it. Thus the meadows need no manuring excepting at rare intervals, to restore the exhaustive drafts upon the soil made by the enormous crops that are grown in this manner. 80 tons of green grass, equal to 20 tons of hay per acre, have been produced annually upon irrigated meadows in England, for more than a century; and no manure, more than that brought down in the water, has ever been applied to the land. This process of irrigation may be used in both summer and winter, where the climate permits of it. All through the southern states, and the lower middle states, winter irrigation will not only feed the grass, but protect it; and the water may be kept on the land—but always in motion—during the greater part of the winter, or from December to March, with benefit to the grass. Where the winters are cold enough to form ice, and the water can be raised to a sufficient height, it may be permitted to flow under the covering of ice; thus avoiding the injuries which result from alternate freezing and thawing during the cold season.

In the spring, when cold nights follow warm days, and frost occurs, the water is let on to the grass as a protection to it, lest the tender, succulent, growth produced by the watering may be injured. When the weather is dry, it is advisable to flow the water over the grass every night, and so keep the growth unchecked even in the hottest and driest weather.

Meadows of this kind are not suitable for pasturing, but are kept only for hay, or for cutting for soiling cattle on the green fodder.

Where the supply of water is insufficient for full irrigation, it may be gathered into reservoirs during six days of the week, and the whole used on the seventh day. Or the land may be divided into sections, and the water which has been turned on to one may be let on to the next one the next day, and so on, until it has been all absorbed. Where springs only can be thus utilized, and the supply of water is small, a reservoir may be constructed to gather the water; and

when it is full, the water may be discharged by an automatic arrangement (such as is described in the Authors work on Irrigation for the Farm, Garden, and Orchard; in which the full details of the preparation of the land and all appliances for the use of the water in the culture of all kinds of crops, are given).

In many cases, the water of springs rising on high ground may be used for partial irrigation of grass lands, by conveying it in furrows back and forth down the slope, at such an inclination as will cause a sufficient flow. In this method a furrow is turned down the slope so as to form a channel for the flow of water. Here and there the furrow slice is cut through, and the water is permitted to escape down the slope. By stopping these openings with sods, the flow is stopped, and turned through others on to fresh ground. This simple method of irrigation may be made available on many farms, where now the water escaping uncontrolled, is a source of injury to the land.

In other cases, a number of springs, the waters from which formed previously a useless swamp, have been connected by ditches, and the gathered water conveyed on to lower land for watering the grass. Thus a serious and injurious evil has been turned to a double benefit, by reclaiming, upon one hand, a useless marsh, and greatly increasing the product of land which formerly suffered by want of sufficient water. All these different points should be studied by the farmer, who may be on the alert to turn every opportunity which comes to him, to his own advantage.

But there are other methods which may be turned to profitable uses under circumstances which at first sight might seem to be unavailable. The water may be raised by mechanical means, from rivers on to lands upon a higher level. Several cases have come to the Authors notice in his practice as an Agricultural and Hydraulic engineer, in which land has been irrigated in this way; the water having been raised from rivers and small streams by the motive power of the streams themselves. A very simple water wheel moved by the current, works a force pump, by which

the water is raised to a sufficient height; or a submerged rotary or "propeller" pump raises the water; or a windmill may be used. In short, where water can be procured, and it can be used with profit upon the land, there is no reason why it cannot be made available through the skill of the engineer or the enterprise of the farmer; either by the force of its own gravity, or by some mechanical application.

The quantity of water used in irrigating farm crops, varies from one cubic foot per second for 200 acres, to double that quantity. That is, a stream of water flowing through a gate having one square foot of area, or 144 square inches, at the rate of 60 feet per minute, is sufficient to water 200 acres of land. But meadows consume a much larger quantity of water than this. In some of the irrigated meadows in the South of France, where the climate is hot and dry, the extraordinary quantity of water is poured over the grass, as to be sufficient to cover the surface 1300 feet in depth in the whole year. In other cases, water to the equivalent of a total of 27 feet in depth has been used in 6 months of the growing season. In general it has been found that the more water that can be made to flow over the grass, the greater will be the product.

From what has been said in a previous chapter, on the relation of water to the growth of plants, it is easily realized how important it is to the farmer to make use of this practice of irrigation wherever and whenever he can; how it may be made to secure and increase crops under the ordinary circumstances of the farm culture, and as an aid to the natural rainfall, and how, by the use of it, the desert may be made productive of every crop of the farm, and to support an industrious and enterprising population, where formerly no useful plant could grow, and where the wild beasts roamed and howled in search of their prey. Thus it is that man has dominion over the earth and all that it contains, and turns it to his uses, and for the good of his race, by all the natural forces which his knowledge, experience, and skill, enable him to make available for his purposes.

CHAPTER XXV.

PLOWING.—ITS PURPOSES AND ITS RESULTS.

The plow is the principal implement of farm culture. The name of it has become typical of agriculture and of peaceful industry; as the sword typifies war and slaughter. Its precise purpose in agriculture, however, and the principles of its construction and action, are very rarely understood by those whose business it is to use it, and whose subsistence is procured by its use. At first, the plow merely stirred and loosened the soil, and consisted of a crooked beam of wood, a limb of a tree, guided by a handle and drawn by an ox. For thousands of years this imperfect implement served the purposes of the cultivator of the soil. At this day, and in our own enlightened country, the plow in use over a large portion of the land, is little better than that which prepared the ancient fields of Egypt, India, and Rome, for the reception of the seed. In the north and west, however, the plows in use are the most perfect productions of the mechanical inventors genius and thought, and of the manufacturing art. Its curves have a deep purpose and significance, but these are unknown to most of those who handle it. And yet a knowledge of this purpose and significance is necessary to the most effective use of it.

No plows in the world are able to do better work than the American plows, and no others are so light and easily handled. But it is a sad truth, which cannot be denied or excused, that worse plowing can scarcely be seen than the average work on American farms. Perhaps this is the reason why the average yield of our crops is smaller than that of any other civilized country, and that American farmers complain that their business is not profitable. If the foundation is weak and ill constructed, the edifice cannot be firm or substantial; and when the plowing is imper-

fectly done, and the soil is not well turned, no after operation can be fully effective however well it may be performed; and the crops must necessarily suffer.

The mold board of a plow has a complex curve intended to raise the furrow slice and turn it over on its edge at varying angles, or to entirely reverse it. The latter operation is rarely practiced, and generally the furrow slices are laid over at an angle not far from 45 degrees. This is the best position for all sorts of plowing, excepting perhaps for fallowing land and destroying weeds; but this last mentioned necessity should never occur in the best culture of farm crops, and it is one of the purposes of this work to show how this necessity may be avoided by thorough culture of the soil. American plows are made with a short, sharply curving mold board, which bends the furrow slice so much as to crack and break it, and so to leave stubble land partially pulverized, unless the soil is quite stiff clay, and then it is considerably loosened and broken, when it is in the right condition for plowing, and not too wet or too dry.

The soil should be in this right condition before the plow is put into it. When it is too wet, the passage of the plow through it draws over and plasters the surface, and instead of breaking it, leaves it tough and compact. Then the furrow slices dry hard and cloddy, and no amount of harrowing will reduce the land to a fine tilth. Not even, the Acme harrow, the most perfect implement of the kind that has been devised or made, can fully overcome the injury thus done to the land, which may remain for many years. When the soil is too dry, the plow can scarcely be kept to the proper depth, and the land is turned up in clods which are equally refractory under the harrow. This of course refers more particularly to clay soils, but lighter loams may be injured for the season, or for years, by being plowed when too wet.

The farmer who desires to secure the best results of his labor in plowing, should choose the time when the land is moist but not wet, and when it may be pressed by the hand into a ball which will cohere and retain its shape, until it

is dropped to the ground, and then it will break apart into loose, small fragments. Then the soil will turn over and break apart and offer the very best opportunities for the final working and thorough pulverization by the harrow, if this is not deferred too long.

The plow will do the best work when it is hitched by the traces, so that it runs the required depth without any effort on the part of the plowman to keep it down to its work, or to prevent it from running too deeply. This is to be secured by a few trials, and such adjustment of the draft as will produce the desired effect. Then the plowman has three important things to attend to, viz; *to keep the depth of the furrow even and regular; to preserve the width of the furrow exactly the same; and to make the furrow perfectly straight.*

These three points comprise the essence of good plowing, and no other sort of plowing will secure the best culture of the crops, and the highest yield attainable.

When the furrow is not of even depth, there will be some parts of the land too hard and compact to furnish the requisite depth of pulverized soil for the proper growth of the plant. Not only will the roots be unable to penetrate to a sufficient depth in the soil, but the atmosphere will be excluded from a considerable portion of it, and all the various effects of the circulation of the air through the soil which have been particularly pointed out in previous chapters—and the importance of which will be now realized, if it has not been before—will be missed, to the serious detriment of the crops.

When the furrow is not of even width, there will be still more unevenness of the soil. A portion of the land will not be cut and turned over at all, the slice of soil will not be severed at the wide part but be simply bent over, leaving a strip of land wholly unplowed. The turned soil will lie upon this hard space, and just there, will be a barren spot upon which the crop will surely fail to some considerable extent. The error first made will be repeated in every subsequent furrow, unless the careful and painstaking plowman will remedy the fault by taking less land at the next furrow.

at these places, and so bring it out even again. But even then the previous mistake and injury is only balanced by a second one, and two bad spots are left in the field.

When the furrows are not straight it is impossible to keep them of even width; and to plow the land evenly and keep it free from hard spots upon which only weak plants will grow. For the result of such plowing is, that a certain portion of the land is not plowed at all, and these unplowed spots will show, not only in the succeeding crop, but for years afterwards, and the repetition of such irregular plowing will leave a field spotted over with these infertile patches upon which the crop will appear quite inferior to the rest of the field. It is this bad plowing to which the "spotty" appearance of the land when covered with crops is owing, and it goes without saying, that this is necessarily accompanied by serious loss to the farmer.

When a field is well plowed, one may walk over it and thrust a stick down through the soil anywhere, and find everywhere the same depth and the same ease of penetration; the foot will sink in the soil everywhere to the same even depth; and when the harrow passes over such a field, it hugs the land closely, every tooth doing its service, and the implement will not jump and bound as it does when there are hard unplowed spots to throw it out of the soil.

But the soil varies very much in composition, character, and surface; and each variation calls for special treatment. Level ground offers no difficulty whatever to the passage of the plow, but clay soils require different management from that of lighter land. One purpose of plowing is not only to break up the land to fit it for the crops, but to expose as much of it as possible to the influence of frost, and rain, and the air, to bring it into the finest condition; to set free a large quantity of mineral plant food in it; to decompose the organic matter in it; and to enable it to absorb as much as possible of carbonic acid and nitric acid from the air. This purpose is best attained by fall plowing; and this should be done as early as possible so as to give time for the desired effects to be produced.

The stiffest clay soil is brought to a fine and mellow condition more easily by frost, than by any other means. The expansion of water in the act of freezing separates the particles of soil from each other, and breaks up their cohesion. When the soil thaws, the particles fall apart and form a loose mass. A rough plowing in the fall, by which the land is broken up and a large surface is exposed to the weather, is thus the very best preparation for the spring crops; and the land thus plowed, is fitted in the very best manner without any more plowing, by the use of the harrow; especially the Acme harrow and pulverizer; which breaks down the softened clods; turns over the surface; smooths and levels it; and thoroughly mixes the soil. Thus, fall plowing and the subsequent exposure to the winter of as large a surface of the soil as may be, is a very important operation in the culture of farm crops.

Sloping ground requires a special kind of plow, by which the land is always turned down the hill, and an even mellow surface is procured. It is impossible to turn a furrow up the hill as evenly as it can be turned down the slope, hence the use of a common plow on sloping ground is objectionable. There are several kinds of hill-side plows now made, which do excellent work and should be used on this kind of ground in preference to any other. From many years use of this kind of plow, some farmers prefer them for use on level land. The great advantage in their use on level ground, is, that there are no open furrows or ridges in the field, as the land is all plowed one way; or by beginning in the middle, one half the field is plowed one way first, and the other half is turned the other way afterwards. To prevent ridges in any kind of plowing, either with the hill-side plow or the ordinary kind, the simple plan may be followed of first plowing out a wide open furrow and then reversing it, so as to fill the furrow level, and leave a plain smooth surface. This should be done in all kinds of plowing, as it avoids the disadvantage of leaving a strip of unplowed ground under the back furrows, in the center of each land; and the consequent waste of a considerable portion of the soil.

The use of the subsoil plow is a very important accessory to the best culture of farm crops. It is used to follow the common plow in the same furrow, and breaks up the hard bottom for several inches in depth. The advantages of this cannot be overrated. It gradually deepens the fertile soil by bringing the subsoil under the influence of the air, and of heat; and also of the decaying vegetable and animal matter which goes into the soil in the form of manures; as well as of the chemical influences of lime, potash, and other special fertilizers.

The importance of this operation of tillage has always been recognized by the most intelligent and thoughtful farmers, and should not be overlooked or slighted. "Tillage is manure," has been an accepted principle of agriculture since it was first tersely propounded by Mr. Jethro Tull, an English farmer, about a century ago; and it is now, more than at any previous time, that the truth of it is recognized and realized.

The results of good plowing are varied. They secure a fitting bed for the seed, and afford favorable opportunities for the growth of the roots, and their most perfect penetration in and through the soil. The soil is opened to the admission of the atmosphere and of the rain and dews; the heat of the sun penetrates it and sets in action the various currents, which, flowing in and out of it, bring in oxygen, carbonic acid, and nitrogen; all of which have a most intimate and effective relation to the growth and perfection of the crops. Good plowing facilitates, and makes more effective, every subsequent operation of culture, and thus helps, to a very great extent, towards the ultimate end of the farmers labors; which is large crops, and a satisfactory return for the labor and capital employed. It is in fact the foundation for the profitable culture of farm crops, and as such, deserves the closest study and most intelligent application of every good farmer.

CHAPTER XXVI.

HARROWING.—ITS EFFECTS UPON THE SOIL AND ITS
RELATION TO THE GROWTH OF CROPS.

The harrow is undoubtedly the most important implement that is used in the preparation of the soil for farm crops. While it follows the plow, and as a rule cannot be used until the plow has done its work in breaking up the soil, its effect in pulverizing the ground is still more necessary to the growth of plants. If a proof were wanting, the exceedingly low average of the yield of the crops in the South, where good harrows are rarely seen, would furnish it sufficiently to convince any intelligent farmer. Where a naturally rich soil, under a favorable climate produces no more than 5 bushels of wheat; 10 bushels of corn; 150 lbs. of cotton to the acre; there must be something wrong; and this is, beyond a doubt, to be found in the most imperfect tillage of the soils.

When the land is plowed the soil is turned over in layers lying side by side, and having, more or less of open space between these layers. Unless these layers are perfectly broken up and the soil is pulverized so as to fill up all these spaces, the seed falls into these vacancies, where it germinates and sends out its spire and roots. The young plant, at first subsisting upon the nutriment contained in the seed, soon pushes its roots into the soil for the purpose of finding food, and moisture whereby it can absorb this food. The roots thus pushed out under the unfavorable circumstances here described, fail to find any mellow compact soil into which they can enter, but vainly spreading in search of it wither and perish, and as soon as the seed is exhausted of the nutriment in it the young spire also dies. This is the reason why, of the more than one million seeds that are contained in a bushel and a half of wheat, and which are sufficient to give 25 plants to every square foot in an acre, or

one to every 6 square inches, or to a space $2\frac{1}{2}$ inches apart each way, the majority fail to germinate successfully and perish in a short time; thus leaving not more than a fourth of their number of vigorous plants to survive and make a crop. One peck of seed on well prepared and fertile soil, will cover the ground with plants thick enough to make a yield of 50 bushels per acre at the harvest. *Defective harrowing is the cause, then, of the loss of millions of bushels of seed, and the reduction of the yield to the low general average of 12 bushels of wheat, and other crops in proportion, per acre.* This enormous loss, which is felt in the same way with every crop grown, may very reasonably be held to be the sufficient grounds for the common complaint that "farming does not pay," and extinguishes to a most enormous extent the possible—nay the certain—results of the farmers work were it performed in a perfect manner.

There are several kinds of harrows in use, some of which are very inefficient and unfit for the purposes for which they are used. The purpose of this implement is too commonly supposed to be to smooth the surface, and to cover seed. The first intention is rarely carried out because of the inferior plowing, and the other can scarcely be consummated because the implement is by no means fitted for covering seed. It does this in a most irregular manner by scratching small furrows in the soil with which the seed is pushed by the hinder teeth, and is partially covered by the superficial stirring of the ground. The usually uneven surface of the ground and the irregular motion of the harrows, interfere greatly with this intended effect, and lead to the waste of seed and the inferior yield of the crops above mentioned. The common spike tooth harrow is the most objectionable in this respect; but the objection prevails equally against all forms of this implement which merely tear the soil and do not systematically pulverize the land; compress, smooth, and level the surface; and thoroughly mix and turn the soil; and when used to cover seed, thus do not leave it under a layer of fine mellow soil which might provide every requisite and desirable condition for its most perfect germination,

and the successful growth of the crops. The definite and special purpose of the harrow should be to prepare the soil for the seed, leaving the seeding and the covering of the seed to be performed by the seed drill.

The effects of plowing the soil which have been described, make necessary more effective implements than the kinds of harrows above mentioned. A great improvement was made when the coulter harrows were introduced. These are provided with sloping cutting teeth which penetrate the plowed ground easily, and cut and consolidate, while they pulverize it, in a more effective manner. The gradual improvement in this class of harrows has culminated in an implement which does the work in a more thorough manner than any other. This is necessarily a combined implement furnished with an iron bar or frame which crushes the clods, and levels the surface; a set of teeth which slope backwards and further break and pulverize the soil; and lastly, a double coulter which turns over the crushed soil, in the manner of a set of small plows, to a depth of 3 or 4 inches or more, which is easily regulated by the operator. It may not be out of place to refer to this implement by name as the Acme Pulverizing Harrow, Clod Crusher and Leveler, because this name perfectly well describes not only what the implement does in the soil, but what a harrow should do to effect its purpose in preparing the soil for the growth of crops.

This purpose and preparation consist in tearing apart the furrow slices; breaking and crushing the clods; cutting up and compacting the soil as far as the plow has penetrated; and pulverizing the whole ground; and leaving the surface fine mellow and open for the circulation of air and the absorption of moisture; as well as the reception of the seed.

From a consideration of previous chapters, and the knowledge of the relations of the atmosphere; the various elements of the soil; of heat; of moisture; and the chemical effects and reactions of the various combinations of these, to the growth of plants, it is easily seen of what importance it is that the pulverization of the soil should be as complete and

perfect as possible; and how indispensable it is for the successful growth of crops, that the implements used to effect this purpose should be most perfectly adapted for it.

Harrowing will be the most effective and useful the sooner it follows the plowing. As soon as the soil is turned it begins to dry very quickly; and if at all adhesive, it forms intractable clods which resist all efforts to pulverize them. But when the harrow follows the plow, the moist soil is easily and quickly reduced to a fine tilth, and when well pulverized it does not dry out as when left untouched for a few days after the plowing. This is very important when preparing the soil for fall crops, because the plowing should be done as early as possible and before the dry weather bakes and hardens it. Then an immediate harrowing breaks it up and mellows it, and repeated harrowings consolidate it and fit it in the best manner for the seed.

CHAPTER XXVII.

CULTIVATING CROPS.—THE EFFECT UPON THE SOIL
AND UPON THE GROWTH OF THE CROPS.

The cultivation of crops during their growth is not by any means the least important mechanical process for the improvement of the soil. Although it is a temporary process, and is used for a special purpose, yet its results are quite as permanent in improving the land as any other process which can be used to gain the same effect. Every farmer who reads and studies the literature of agriculture, has learned that the culture of root crops has a beneficial effect upon the land. The farmer who grows a good crop of corn by means of thorough cultivation of the soil during the growth of it, knows that the following oat crop is benefited by it, and yields better for the work which has been done the previous year. These are simply the necessary results of the frequent stirring of the soil by which the contributions of all the atmospheric agencies are secured to add to the amount of available plant food; and while the growing crop is benefited, a surplus remains for the next crop.

Summer fallowing, or the frequent working of the bare soil during the growing season, was formerly considered an effective means of improving the soil. This mechanical operation consisted in plowing, harrowing, cross plowing, and repeated harrowing. The effect was to destroy weeds, and to pulverize the soil so that the air and the atmospheric moisture might contribute to it whatever they could, and also by their chemical action develop the fertility which was latent in it. The operation was no doubt a useful one, but it was thought, in time, that the advantages accruing from it were gained at too great a cost; and the loss of a crop was too great a price paid for the benefits received. This truth was finally accepted, and the growth of a cultivated crop was substituted for the bare fallow. Certainly

everything that could be gained by the working of the bare ground was secured by the cultivation of a growing crop; and more; for the shading of the land preserves the moisture. and chemical action goes on more effectively in the moist soil than in the dry. Thus the gain resulting was found to be a profitable crop and the improvement of the soil to as great, or nearly as great, an extent as though no crop was taken and the labor was spent on the bare ground.

No farmer dreams of summer fallow now. He prepares the land for corn, potatoes, beans, mangels, or some crop which can be thoroughly worked during its growth; and thus gains all the benefits which can result from this thorough working. What then are these benefits which result from this summer cultivation of the land ?

It has been shown in previous chapters that the soil derives a considerable amount of valuable plant food from the atmosphere, and necessarily these contributions are greater in proportion to the quantity of air which passes through, or into and out of the soil; by circulation. It is known that the soil gathers from 7 to 10 lbs. of nitrogen every year, in the form of nitric acid and of ammonia from the atmosphere. But this result was proved by experiments made in the cool climate of England and not upon cultivated soil. It is well known that heat is a most active agency in developing nitric acid and ammonia; and that if nitric acid is produced in the atmosphere by the action of lightning, and if ammonia is produced by the decomposition of organic matter, that in our hot summer climate, when electrical disturbances are most active, and when decomposition is most rapid, we may expect the fullest and most effective results of these agencies and a correspondingly large product of these forms of combined nitrogen. Thus the contribution of these forms of plant food are more copious during the summer season than at any other.

But these contributions are brought down by the rains and by the air which circulate in the soils. It is evident and obvious that the more the air can be made to circulate through the soil, and the more water that passes through it,

the larger will be these contributions of the richest kind of plant food. It is equally evident that the more the soil is worked and stirred, the more the changes from hot to cool, and from moist to dry, will affect it; and thus in consequence of all this, the soil that is cultivated during the summer must gain the largest accessions of plant food from the atmosphere. This is the first and greatest benefit that thus accrues from the summer cultivation of a growing crop.

It has been shown too, that a large quantity of carbonic acid is brought to the soil by the atmosphere which circulates in it, and by the rain which descends upon it; and that carbonic acid has most distinct and important relations to plant growth. It furnishes the carbon, of which more than one-half of the dry substance of plants consists. Moreover, water containing carbonic acid exerts a strong solvent action upon the mineral compounds of the soil, decomposing them and fitting them for use as food for plants. This is another and most important benefit accruing from this mechanical operation upon the soil; for the larger amount of water received and passed through the soil by evaporation, the more effect is produced by the action of the carbonic acid dissolved in it.

The same may be said of the oxygen which is absorbed by the rain water, and of the effect of the nitrifying influence of the peculiar germ known to produce nitric acid in the soil. These too, exert a more potent influence in porous and moist soil than in compact and dry soil. Thus in many ways we are able to perceive the useful results of the frequent working of the soil during the growth of a crop.

But this is not all. The summer fallow was designed for the destruction of weeds, as well as for the reduction of the soil to a mellow and pulverulent condition. When a cultivated crop is worked as it should be, every weed is destroyed most effectively. And just here a most important point for consideration comes up. As a rule the summer cultivation of the soil is not sufficiently thorough. Some weeds are permitted to escape. This is an injury to the soil

and to the crop, and should not be suffered by any good farmer. The full purpose of cultivation is not secured, unless the weeds are destroyed before they appear above the soil. When the cultivation is the most effective one may see on examination of the soil, a vast number of newly germinated seeds; which, had they been permitted to gain a foot-hold in the soil, would have drawn nutriment from it and would have checked the growing crop. A large portion of them would have gained a sufficient foot-hold, or root-hold, to resist the shock of the overturning and could not be wholly destroyed by the disturbance of their roots. Thus the land will not have been kept clean, and injurious weeds will have been perpetuated. These remarks are certainly justified by the appearance of the corn and root fields on nearly every farm. The crops, half smothered in weeds, are robbed of their necessary food. A vast quantity of water, indispensable to the full growth of the crops, is appropriated and exhaled by the weeds; and in this way too, the soil is deprived of its fertility, and the farmer of the expected rewards for his toil and time.

No weed should be permitted to appear above the ground in such a case. If it does, the main purpose of the cultivation is not effected. This is not to kill weeds, so much as to improve the soil, and were the soil wholly free from weeds, the regular working should be carried on in the most thorough manner. The weeds are destroyed incidentally; and the farmer should not wait for them to appear before the cultivator is started in the rows. This should be done before the young plants of the crop have appeared above the ground, and should be continued at such short intervals as may be necessary to keep the soil loose and mellow.

THE CULTURE OF FARM CROPS.

CHAPTER XXVIII.

MANURES.—THEIR MECHANICAL EFFECTS UPON THE SOIL.

It has been shown in a previous chapter how the mingling of vegetable matter in the soil affects its character; giving it a larger capacity for absorbing moisture, and for holding it against evaporation; and thus greatly improving its value for the production of crops. The art of manuring is one that should be well understood by the farmer, for it is somewhat intricate, and has more than the one result of adding plant food to the soil. This useful addition of plant food is by no means the only thing necessary to secure good crops. There must be with it, as has been previously explained, a certain condition of the soil by which the plant food is made available. Just as it is unavailing to a starving man to know that a store of food is contained in a solid stone building closed with iron doors, and secured by great bars and locks, which he cannot open, so it is unavailing for the crops that the soil may be rich in all the elements of plant food, and yet its mechanical condition is such that the roots cannot reach this food or the atmosphere make it soluble and nutritious. Manuring not only adds plant food to the soil, but it so affects the mechanical condition of the soil, when it is used in the right manner, as to quickly reduce it to a state of decomposition and make it soluble in water. Manure may be buried in the soil, or left exposed on the surface, and in either case be of little or no use to the crops; for if this be their only dependence, the young plants would be starved before the roots had gained strength and growth enough to reach the manure.

This mechanical effect of manures on the soil is of great importance, for it affects the value and usefulness of the manure itself, and exerts a considerable effect upon the growth of the crops, beyond the mere supply of the crude

elements of fertility. This effect should be understood, lest labor and manure, both, be wasted.

If the manure be plowed under with a flat furrow, for instance, it is buried out of reach of the influences of the air, by which oxidation and conversion into plant food are effected. The seed sown upon land so prepared may germinate and put out roots, but the growth will be weak until the manure is reached; when there will still be weak and slow growth because the manure has not become available for plant food by decomposition. This is therefore a loss of material and of time; the mechanical effect of the manure upon the soil is missed; and the soil is neither made more absorbent, nor more retentive of moisture. When the manure is spread upon the land as a top dressing, the same absence of useful results prevails; and there is no change in the soil; although, if rains intervene, the soluble part of the manure is carried into the soil and is made available for the crops.

When the manure is spread upon the soil, and is then plowed under with lap furrows, which are laid over at an angle of 45 degrees or thereabouts, there is an intimate mixture of the manure with the soil. These are intermingled in alternate layers set on edge. All the furrow slices of 5 or 6 inches in thickness have between them a layer of manure, and the edges of all the layers are fully exposed to the atmosphere and to the rain. Decomposition of the manure and the chemical reaction of this process upon the mineral particles of the soil, go on with rapidity and perfection. The soil and the decaying organic matter are further intermingled by the harrowing after the plowing, and if the harrowing is done in an effective manner the intermixture is perfectly made.

The result of this is a more or less altered physical condition of the soil in proportion to the quantity of manure which has been used. It matters not so far as the mechanical effect upon the soil is concerned, whether this mixture is rich manure from the stables or consists of composted vegetable matter, swamp muck, green crops grown for the pur-

pose, or a sod of grass or clover. The decayed organic matter of considerable bulk, and porous, and absorbent, opens and loosens the soil; makes it able to absorb and retain moisture; admits the air with its enriching gases to it; and by changing the color, warms it by the absorption of the sun's rays. This is the result of the mechanical effects only; the chemical results are not now considered. And these are seen to be so important in so many ways to the growth of the crops, that the farmer desirous of procuring from the fields, the largest possible product, will make every exertion to increase the quantity of this bulky vegetable matter which he can turn to such valuable uses.

There is no scarcity of this kind of matter. Straw; leaves; coarse weeds—which should always be free from seeds; swamp muck; the wastes of woolen mills; charcoal waste; sawdust; lime; refuse from breweries; soap factories; sugar factories; tanneries; sweepings of streets; burned clay; and the refuse of brick yards and lime kilns; as well as the excrements from animals; and nightsoil; all these and any other matters that can be turned to this purpose—whether they be rich in fertilizing matter or not, should be gathered by the farmer for the mechanical improvement of the soil.

Clay soil and sandy land are equally benefited; the one is opened and made loose and porous; the other is made more compact; and both are made more absorbent and retentive of moisture by this means. So that the farmer may not stand upon the order of his performance, but do this work how and when he can. If one season is preferable to another it is the fall, when there is a large quantity of useful materials that may be collected, and when leisure permits the time to be given to the work. The preparation of the composts may go on through the winter season as well as during the summer; but the best opportunities occur in the fall. Many opportunities are missed for want of thought or knowledge of the facts. Every village may supply hundreds of loads of available materials, which, unused, are a costly burden to be got rid of. Every city is overburdened with the most valuable waste matters; the

woods are deeply covered with them; and the thousands of factories are concerned how to get rid of the troublesome surplus. The farmer need not make a very close search to find them within easy reach.

PART FOURTH.

CHAPTER XXIX.

THE IMPROVEMENT OF THE SOIL BY CHEMICAL MEANS.—ANIMAL MANURES.

The various methods of improving soils by chemical means, are based upon the following principles which have been already explained.

First.—Plants obtain from a fertile soil a variable proportion of their organic nutriment, and the greater part of their nitrogen is derived from this source.

Second.—The inorganic food which they require, they procure solely from the soil.

Third.—Different kinds of plants require a special supply of different kinds of inorganic food, or of the same kinds in varying proportions.

Fourth.—Soils vary considerably in respect of the various inorganic compounds they contain, some soils may be deficient in some of them, and others may contain an abundance of all of them; therefore the growth of plants upon various soils differs accordingly.

The whole art of improving the soil by chemical means, or of manuring and fertilizing it is based upon these few principles.

There are three distinct methods of improving the soil in this way.

First; by removing from it some injurious substance, and affording it an outlet by means of drains, in a word, by draining.

Second; by the addition of some substance which may remove, or change the character of noxious substances; or so change inert substances as to make them available by them-

selves, or by reaction upon other substances. For instance, by adding lime to peaty soils or reclaimed swamps, we may neutralize noxious acids, and develop the nitrogen and other inert substances which they contain, into available plant food.

Third; by adding to the soil various substances which afford food for plants. This is done by manuring the soil; although as yet we are not able to determine whether what we add to the soil actually feeds the crops or only prepares food for them. There is however reason to believe that some substances, as lime, potash, soda in various forms, but chiefly as salt, act in both capacities; now feeding the plants and then liberating from the soil and preparing other nutriment which enters into the circulation; at other times or at the same time entering themselves into the substance of the plants. This distinction makes it necessary to classify all these substances which either enter into the substance of plants or prepare other substances to do this, or which perform both functions, as manure.

In this sense we may call these substances either simple manures—such as common salt; lime; nitrate of soda; gypsum; or as mixed or complete manures, as barn yard manure; and the various artificial mixed manures which contain all the elements of barn yard manure, and which are now in common use and are largely sold.

But in considering specially these various manures which improve the soil or promote the growth of crops in any way, we may take them in the following order, viz: animal manures; vegetable manures; and mineral manures.

ANIMAL MANURES.—Animal substances have always been considered as exceedingly valuable manure, because they are highly concentrated and so readily decomposed that their action upon vegetation is both immediate and remarkably apparent. The various animal manures may be included in the following list, the solid excrements of farm animals and of human beings, and their urine mixed with litter and various vegetable substances which are used as absorbents; flesh; blood; horn; hair; wool; bones; and guano.

The excrements of animals, both solid and liquid, with the litter used in stables, is the main supply of the farmer for the feeding of his crops. These vary in character, but not as is commonly supposed as the animals themselves differ, but on the contrary, as the kind of food varies. Horse manure is considered the best of this class, but it is because horses are fed chiefly upon grain and hay; in like manner the manure of sheep, cows, and pigs, varies in quality as these animals are fed upon grass, straw, or grain.

The liquid excrement of animals—the urine, so called because of the large quantity of urea contained in it—is richer in the valuable elements of plant food than the solid droppings. Urine contains a large quantity of water, thus in 1000 parts,

	<i>Water.</i>	<i>Organic matter.</i>	<i>Inorganic matter.</i>
Human urine contains.....	969	23.4	7.6
Horses “ “	940	27.0	33.0
Cows “ “	930	50.0	20.0
Pigs “ “	926	56.0	18.0
Sheep “ “	960	28.0	12.0

The urine is the most important and valuable of all natural liquid manures, and instead of being wasted and made a source of offense to the sensitive membranes of man and animals by reason of the pungent ammoniacal vapors evolved from it, it deserves to be most carefully saved and preserved for use in fertilizing the soil and in feeding crops. The need for this is shown in the following figures, which give the amount of the most valuable elements of plant food contained in it.

COMPOSITION OF URINE IN 1000 PARTS.

	<i>Of Man.</i>	<i>Horse.</i>	<i>Cow.</i>	<i>Sheep.</i>	<i>Pig.</i>
Water.....	933.0	940.0	926.2	960.0	926.0
Urea.....	30.1	27.0	40.0	28.0	56.0
Uric acid.....	1.0				
Mucus and other matter.....	17.4				
Sulphate of potash.....	3.7	33.0	31.8	12.0	18.0
Sulphate of soda.....	3.2				
Phosphate of soda.....	2.9				
Phosphate of ammonia.....	1.6				
Chloride of sodium.....	4.5				
Nitrate of ammonia.....	1.5	1000.	1000.	1000.	1000.
Various phosphates.....	1.1				
	1000.0	1000.	1000.	1000.	1000.

	Carbon.	Hydrogen.	Nitrogen.	Oxygen.
Urea consists of in 100 parts.....	20.0	6.6	46.7	26.7

Nearly one-half of the solid matter of urine consists of nitrogen, and it is therefore far richer in this invaluable element than flesh, blood, or any other fertilizing substance of which the value is supposed to exist in the nitrogen it contains.

Urea possesses a further valuable property, in that when it ferments, which it does very rapidly, it changes entirely to carbonate of ammonia. The ammonia thus formed however at once begins to escape into the atmosphere, and it is this volatile gas, thus escaping, which causes the pungent odor of unclean stables. The absolute necessity then of preserving this valuable substance—the urine—from loss, either by waste when fresh, or by decomposition afterwards, is paramount, and cannot be neglected by the farmer who expects to succeed fully in the culture of his crops. The enormous waste resulting from the common neglect of farmers in this respect, is illustrated by the following figures which represent the quantity of urine yielded by a man, a horse, and a cow, during a whole year, and the solid matter contained in it.

	there are	of solid matter.	Urea.	Ammonia.
In the urine of a man.....	1000 lbs.	67 lbs.	30 lbs.	17 lbs.
In the urine of a horse.....	1500 lbs.	90 lbs.	45 lbs.	25 lbs.
In the urine of a cow.....	13000 lbs.	900 lbs.	400 lbs.	230 lbs.

These figures are given by Sprengel, and differ from those by Boussingault who increases the amount of the ammonia in the case of the horse by 50 per cent. and reduces that in the case of the cow. But as has been observed these results depend very considerably upon the kind and quantity of food consumed by the animals.

Many farmers give considerable attention to the amount of ammonia which the soil gathers from the air, or which is brought down in the snow; but if the total amount of this which is believed to be thus derived is certainly gained, the quantity secured by 30 acres is not more than is produced by one man, and a horse, and a cow, in the urine alone. How important then is it that this latter source of fertility of the soil should be most jealously guarded.

The solid excrements of animals, man included, contain every element of plant growth; but by no means in the perfect proportion required by the crops.

The constituents of ordinary mixed farm manures are as follows (in 1000 lbs).

	<i>Fresh.</i>	<i>Half rotted.</i>	<i>Wholly rotted.</i>
Water.....	710	750	790
Organic matter.....	246	192	145
Mineral matter.....	44.	58	65.
Nitrogen (in the organic matter)...	4.5	5.	5.8
Potash.....	5.2	6.3	5.0
Phosphoric acid in the ash.....	2.1	2.6	3.0
Lime in the ash.....	5.7	7.0	8.8
Magnesia in the ash.....	1.4	1.8	1.8

Horse manure is considered more valuable than any other part of the common stable manure. It heats quickly and gives off ammonia copiously, and is really richer than other manure because of the less quantity of urine voided, although the horse may be no better fed than other animals. But when cows or fattening oxen are well fed upon bran and oil meals, their manure heats as readily and exhales ammonia by its rapid decomposition as copiously as horse manure. The difference between the manure of a horse and a cow is very slight as may be seen by the following analyses of the dry excrements.

	<i>Horse dung.</i>	<i>Cow dung.</i>
Carbon (per cent.).....	38.7	42.8
Hydrogen “.....	5.1	5.2
Oxygen “.....	37.7	37.7
Nitrogen “.....	2.2	2.3
Ash “.....	16.3	12.0
	100.00	100.00
Water “.....	300.00	566.00
	400.00	666.00

The moister condition of the cow manure explains the reason why it heats less rapidly than that of the horse.

Night soil, or human excrement, is generally a rich and valuable fertilizer; but it is commonly so mismanaged that the most valuable portions are lost by exhalation, or by solution and waste. When mixed with dry earth, or peat, or powdered charcoal, it can be handled without offense and waste. It is a matter of public loss and general offense,

that this useful fertilizer should be wasted in the manner in which it now is, and the vast quantity of plant food in it should be worse than thrown away. China sustains a population now 8 times as large as that of the United States, and supports all its vast consumption by its own products; and yet without any fertilizers but those derived from the night soil, which is carefully preserved for this use by mixture with earth.

The excrements of the sheep furnishes a manure second only to that of the horse, and is highly valued by the best farmers, especially for the production of grain. The feeding of sheep is, on this account, made a special business upon grain farms where their manure, and the profit from their flesh and wool, are found to be exceedingly desirable and satisfactory.

The value of stable manure depreciates by the length of time during which it is kept and by exposure to the weather. The loss sustained in keeping manure in open yards for 3 months is fully one-half; partly by washing by the rains, and partly by the escape of the ammonia evolved during the decomposition. The values above given are those of the best preserved manure, and the farmer who wishes to realize these values must take measures to so keep his manure, as to preserve all its fertilizing qualities. This is easily done by putting it in flat heaps which will gather the rain that falls upon it, and no more, and to control the heat of the fermentation by turning it over before the heat becomes injurious. Overheated manure is of little value; but overheating will rarely occur when all the manure of various kinds are regularly mixed together and kept in a compact heap, flat on the top, to receive the rain. The liquid manure should be carefully saved by the use of absorbents, of which dried swamp muck is the best, or by tight drains through which it is carried to an underground cistern in which the solid manure is kept to absorb it. The escape of ammonia is easily prevented by the free use of powdered gypsum scattered on the stable floors and about the yards, and through the manure heaps.

Poultry manure is considered to be a valuable fertilizer, and is in fact richer in useful plant food than any other kind of manure from farm animals; but it is not nearly so rich in this respect as is generally believed. Its composition is as follows:

ANALYSIS OF HEN MANURE.

	<i>Dry.</i>	<i>Fresh.</i>
Water per cent.....	8.35	45.73
Phosphoric acid.....	2.02	.47
Lime.....	2.22	.97
Magnesia.....	0.68	
Potash.....	0.94	.18
Nitrogen.....	2.13	.79
Insoluble matter.....	34.65	39.32
Value per ton.....	\$10.55	\$ 3.42

The cause of its higher value than that of ordinary farm manure, is, that it contains the solid and liquid evacuations together; these being expelled together by birds; hence the urine is intimately mixed with the solid excrement. The grain, and animal food in the form of insects, consumed by poultry, tend to give the manure a high value. It is however but little, if any, more valuable as a fertilizer than equally dry manure from well fed horses or sheep. Its concentrated composition enables it to be used with advantage in the common form of compost, with plaster and wood ashes; in which it is very often applied to corn, cabbage, and garden crops. It is however too valuable to be neglected as it frequently is, and might be saved and used with profit in the above named compost and as top dressing for grain crops in the spring, for which its soluble character, and its pulverized condition, make it both useful and convenient.

CHAPTER XXX.

VEGETABLE MANURES.—THEIR ACTION UPON THE
SOIL AND THEIR VALUE AS PLANT FOOD.—
GREEN MANURING.

Vegetable manures consist of green crops grown for the purpose, plowed into the soil; of the roots and remains of the crops; and of any vegetable matter which may be gathered for the purpose of increasing the bulk of the common farm manures. Green manuring is the plowing in of any green crop in its fresh state and while growing upon the soil. It is necessarily an economical operation as regards labor, and is especially well adapted for the manuring of distant fields, or of hilly land where manure could not be hauled except with much labor and expense. But this practice is advantageous in other respects. Air and water—it has been shown—are most effective agents in the decomposition of organic matter, and green vegetable substances contain much water in themselves and are much mixed with air when loosely covered with soil; hence they decompose very rapidly and become serviceable when thus mixed with the soil.

The sap of plants contains certain compounds of nitrogen which not only very readily decompose, but have the property of inducing by their own decomposition, the elements of other substances, with which they come in contact in the soil, to assume new forms and to undergo various changes by which they enter into new combinations. The sap of plants, in its own rapid decomposition, quickly propagates in the woody fiber and other substances of the plants, an active fermentation which results in the speedy decomposition of these substances of which the plants are composed. Then the elements of which sap and the solid substance of the plants are composed form new compounds, which are useful to the growing crops, and which supply them with food. This action going on, in and under the soil, is not

accompanied by any waste as would occur were the decomposition to be completed in the open air, and when carbonic acid and ammonia would be produced, and being gases, would escape into the atmosphere. Moreover if this green vegetable matter were to be exposed to the weather during its decomposition, a considerable quantity of its mineral elements would be washed out and wasted, the potash for instance would be almost wholly lost in this way, but in and under the soil there is no loss. Hence the practice of green manuring, or of the use of any green vegetable matter in the making of composts, is exceedingly advantageous to the farmer, and greatly assists him in the growth of large crops.

Some of the results from which these advantages accrue, are as follows:

First.—Growing plants, especially the deeper rooted ones as clover, bring up from the deeper soil where the roots of other plants cannot reach them, several substances which are useful to these more shallow rooted crops, and retain them in their leaves, stems and roots; and when these are plowed under the surface, they contribute these acquisitions to the upper soil and greatly enrich it. Thus, although nothing may be gained to the soil but what is taken from it, yet the gain is made from a portion of the soil which could not be reached by the crops to be benefited by it, to the portion where these crops can reach it. Thus it results in practically largely deepening the soil and extending the growth of the roots.

Second.—This manuring is effected with the least loss and the greatest economy, and in no other manner can the same crop carry back to the soil an equal amount of fertilizing matter as in that of its growing leaves and stems. And the farmer will sooner and more cheaply fertilize his land by plowing in green crops than by any other method whatever.

The selection of plants to be grown for this purpose is to be made from among those which grow most rapidly, and which produce the largest amount of vegetable matter in the shortest time, and at the least cost. There are a large number of plants which may be used in this way.

BUCKWHEAT grows rapidly, and two crops may be grown and plowed under in the course of four or five months. It is too well known to need further notice.

SPURRY is a plant not much known in America, but is extensively used in Germany for this purpose. Three crops may be grown where the season permits; the first sowing may be made in May, and the last is plowed in for the following wheat crop in September or October. This plant is thus well adapted for this use in the Southern States.

WHITE LUPIN is another crop largely grown in Europe for green manure. It matures in less than 120 days and furnishes 10 to 12 tons of herbage. It is particularly rich in nitrogen and belongs, as clover does, to the leguminous family of plants.

RAPE AND MUSTARD are plants of the cabbage and turnip tribe; the former may be sown in the fall for use in the spring; the latter is sown in the spring.

RYE is a crop of considerable value for this use, as it may be sown in the fall and plowed in, in May; and then followed by two crops of buckwheat before the time for sowing fall wheat arrives. No other crop affords so much vegetable matter in the period of its growth, at so little cost and at such an early season as this. For a manure for a corn crop it is the most convenient, for these reasons.

TURNIPS may be sown in August, and will produce 10 or 12 tons of green matter to be left to decay on the surface and then be plowed under in the spring. This crop has been used with advantage in the summer seeding of clover and grass, in August, for the purpose of being left during the winter for the protection afforded by the leaves, and in the spring for the manure afforded by the decaying roots.

RED CLOVER is the most popular green manure on account of its surpassing richness in nitrogen, yielding from a full crop as much as 180 pounds of this element to the acre. But its growth is slow, and it is only the second years crop which can be used for this purpose. One cutting may be made in June for hay, and the second growth turned under in September for wheat. Its large, fleshy, solid, tap roots,

furnish a very large quantity of rich fertilizing matter for plowing in. The character of clover however prevents it from being used for the improvement of poor land. Its use is better adapted for the manuring of soils in good condition, and as a substitute for barn manure. Land has been kept in the most productive condition by the use of this crop alternating with wheat; two years being given to the clover and the second growth of the second year being plowed in for the wheat; gypsum being the only fertilizer used. The yield of wheat on this land, which was a naturally rich limestone clay loam in central New York, during over 40 years, averaged 40 bushels per acre.

The quantity of fertilizing matter added to the soil by the various crops above mentioned is given in the following table.

Plant.	Yield per acre.	of dry matter in 1000 lbs.		Depth of roots.	Crops in a year.	For what soils best fitted.
		Organic Matter.	Mineral matter.			
Spurry.....	6500	199	21	14 inches	3	Dry, sandy.
White lupin.....	25000	188	12	25 "	1	Any kind.
Buckwheat.....	8000	170	10	12 "	2	Dry, sandy and clay.
Rape.....	16000	214	16	8 "	1	Rich and fertile.
Rye.....	8000	221	16	8 "	1	All.
Turnips.....	12000	77	21	12 "	1	All.
Clover.....	8000	250	14	25 "	$\frac{1}{2}$	Fertile, of all kinds.

It is important to bear in mind in regard to the practice of green manuring, the following suggestions, viz:

That a sufficient quantity of seed should be sown to keep the ground well covered and to secure as large a yield as possible, with the most effective smothering of weeds.

That the crop should be plowed under at the time when the plants are about to burst into flower, for the purpose of securing the most advantage from their condition at that time, and to avoid stocking the land with seeds.

That the vegetable matter should not be plowed under more than 4 or 5 inches, and that it should be completely covered with soil; using, to secure this end, the usual chain loop attached to the beam of the plow and the end of the double tree; so that the decomposition of the matter may be rapid and perfect, and that there may be no waste.

That this practice is adapted for the improvement of all soils.

It is a common practice among farmers to plow under a sod of grass grown for the purpose, as manure. The usual seeding of clover and timothy is thus intended for breaking up at the end of the second year for the corn crop. It will be interesting to know what amount of fertilizing matter is thus contributed to the soil. The following table affords this information.

AMOUNTS AND COMPOSITION OF ROOTS AND STUBBLE OF THE FOLLOWING CROPS.

	Pounds of air dry substance	Nitrogen in organic matter		Phosphoric acid.		Potash.	
		per cent.	per acre.	per cent. in the ash.	per acre.	per cent. in the ash.	per acre.
Clover.....	6580	2.15	180	3.91	71	4.26	77
Wheat.....	2240	0.68	22	1.08	11	1.70	17
Rye.....	3400	1.26	62	1.55	24	1.90	30
Oats.....	2200	0.71	25	2.08	28	1.48	24
Timothy.....	1982	1.40	28.5	.03	6.5	.04	7.7
Peas.....	2400	1.76	53.	2.24	14.	1.70	11.0
Mixed grasses and clover	5000	2.00	100	2.10	58	1.80	48.

These figures will probably be found below the average of what are called good crops. For it has been found that the living roots and stubble of a four year old sod has been equal in weight to one-sixth more than the weight of the last years crop. Also, that in an old pasture or meadow which has been laid down for many years, the actual vegetable matter contributed to the soil has been ascertained to be equal to four times the weight of the last years vegetation above the surface. The author has found by careful measurement and weight, that the amount of vegetable matter contributed to the soil per acre by turning under an old growth of quack grass, (*Triticum repens*), was equivalent in weight and bulk to 80 tons of ordinary stable manure.

When land is in grass for a number of years there is a very large accumulation of organic matter in the soil from these sources, viz: the contributions from the atmosphere of combined carbon and nitrogen; from the dead and decaying roots and stems of the grass; and from the mineral parts

of the soil which is favorably affected by the chemical action of the decaying vegetable matter. The total amount of this accumulation is not accurately known, but is certainly very large. And when the grass or hay from the land is all consumed upon the farm, and the manure is returned to the land, the soil of a permanent or old meadow becomes exceedingly rich in plant food, from the annual top dressings which it receives naturally from the decay of the leaves and stems and of the matured and used up roots.

CHAPTER XXXI.

COMPOSTS.

There are a large variety of substances which are not precisely manures, but which contain more or less of valuable fertilizing matter, that may be gathered by farmers, and mingled in such a manner as to induce a process of mutual decomposition by which valuable plant food may be procured. The art of mingling these substances, and of decomposing them so that they may be used as manure, is known as composting. It is not much practiced in America, because farmers have scarcely been brought as yet to the point of exercising the strictest economy in this respect; but the time has come when every available opportunity for gathering fertilizing matters and converting them into food for crops, must be strictly and perseveringly sought and seized. The most important of these are, peat; sea weed; salt marsh mud; leaves and the undergrowth of woods and forests; the waste from tanneries, consisting of the fleshings, hair, tan bark, and leather scraps; the waste from cider mills; from breweries; from starch and sugar factories; from fish packing establishments; from oil mills; sweepings of the streets of cities and towns; ashes of various kinds; wastes from slaughter houses; and in fact any waste matter which can be decomposed by the ordinary processes which the farmer can employ.

To facilitate the consideration of this interesting subject, and before proceeding to describe the process of composting the various materials and reducing them to a fit condition for use, the following table of analyses of the various matters referred to may be studied.

COMPOSITION OF VARIOUS MATERIALS FOR COMPOSTS.
Dried at 212° Fahr.

Substances 100 lbs.	Water.	Lime.	Magnesia.	Potash.	Phosphoric acid.	Nitrogen.	Value per ton.
Lobster shells.....	7.27	22.24	1.30		3.52	4.50	22.0
Swamp muck.....	34.40	1.24	.29	.26	.23	1.64	5.0
Salt mud.....	46.36	.66	.31	.33	.15	.39	1.75
Bone black waste.....	10.65				29.64		23.70
Fish packers waste.....	71.11				.60	2.21	4.58
Starch waste.....	8.10	.18		.16	.29	2.62	9.33
Rotted Brewers grains.....	78.77	.26	.15	.04	.43	.72	2.91
Refuse hops.....	81.00	.27	.10	.11	.20	.98	3.62
Tobacco stems.....	10.65	3.39	1.12	7.22	.51	2.65	14.66
Apple pomace.....	82.00	.19	.16	.87	.10	1.24	5.09
Cotton seed meal.....	9.90	.22	.56	1.21	1.26	3.73	15.00
Ash of salt marsh grass.		3.7	2.9	23.1	4.7		
“ forest leaves.....		25.8	1.7	3.0	3.4		
“ ferns.....		8.3	4.5	25.2	5.7		
“ potato tops.....		5.5	2.7	2.3	1.0		
“ beet sugar cake...		2.5	0.5	3.6	1.2		
“ grape skins.....		2.1	1.0	8.0	3.4		
“ sea weeds.....		16.4	11.2	17.1	3.7		
“ Cotton seed hulls		11.63	15.24	38.82	13.67		50.30
“ “ “ “		13.34		24.16	10.69		39.00
“ hard wood (pure)		70.0		12.25	6.0		20.00
“ “ (leached)		74.0		1.60	6.80		10.40
“ Soft wood.....		32.0		12.0	4.0		16.80
“ Corn cobs.....		20.0		45.0	4.50		50.00
“ Tan bark.....		41.0		2.50	1.20		4.50
“ Soft coal.....		5.0		.20	.14		.40
“ Hard coal.....		2.50		.10	1.05		.16

The above table offers a guide as to the value of the above substances to a partial extent. It gives a basis for calculating the precise value of the fertilizing elements mentioned in a ton, or a load of each; but it does not give any clue to the other valuable properties of these substances in the way of their mechanical or chemical effect upon the other materials of the compost, and upon the soil, after the compost has been used.

From what has been previously said upon these effects, it will be readily perceived that they must be considerable, and that the addition to the soil of a large quantity of any of these materials with the other portions of the compost, must be of very great value. Indeed a few years of the use of such composts to the land has very much changed its char-

acter, and has not only added much to its natural fertility, but it has developed this to a remarkable extent.

In making composts, the bulk of the materials are inert and may not readily decay. It is therefore necessary to add to the mass something which may act as a ferment, and by which the necessary chemical action to effect decomposition may be started.

Lime is usually employed for this purpose; but at times fermenting manure is used; and sometimes both manure and lime are employed. The process is as follows. The various materials, some wet and some dry—but the bulk of them are wet, so that the dry substance may be saturated with moisture, and chiefly the whole are wet—are placed in layers of several inches thick and roughly mixed together. The lime or the manure, is mixed in layers through the mass; or at times the mixture is more perfectly made; and the heap is built up compactly, and well trodden, into a square flat form; having the top somewhat shallow to catch and retain the rain water.

Fermentation soon begins and spreads through the mass. The organic matter decays with more or less rapidity, and the earthy matter or the peat in the heap, absorbs any ammonia that may be formed and holds it firmly; or the sulphuric acid that may be liberated in the decomposition will combine with it and form a stable compound. When the heat has spread through the whole mass, the heap is turned and again mixed, by beginning at one end and forking or shoveling it over and forming a new heap similar to the original one. The exposure to the air and the fresh mingling of the substances, soon produce a new fermentation and heat by which the mass is still more decomposed, and the nitrification made more complete. In a few months—and sooner in the summer—the compost becomes a homogeneous mass, dark in color and without any appearance of the raw materials of it by which they could be recognized. It is now manure, and in proportion to the character of the materials that have been used, it is equal to, or better in quality, than ordinary farm manure.

When materials rich in the elements of plant food are used, such as swamp muck; sea weed; cotton seed; wood ashes; and lime; the resulting compost will have a value far exceeding that of barn yard manure, and will be proportionately effective in producing large crops. In this way the farmer may very largely extend the manurial resources of his farm at little expense, and by the expenditure of a moderate amount of labor at such times when other work is not pressing.

Composts are used mostly for top dressing, on account of their finely pulverized and concentrated condition, and because of the solubility of the plant food they contain. They are used for meadows, and for grain crops in their early stages of growth; and are especially useful for roots, which require a large quantity of manure rich in available plant food. But a heap of well decomposed compost will never come amiss for any crop, at any time, when the farmer may want to get the best return for his labor.

CHAPTER XXXII.

MINERAL MANURES.

Although the mineral parts of plants—the ash—form a very small proportion of their substance, yet they are indispensable to their growth. Without silica, the corn or wheat plant could not stand erect, but would lie upon the ground; without lime and phosphoric acid, there could be no seed, and vegetable substance could not support any animal. The mineral elements of plant substance, in fact, form the skeleton or frame so to speak, upon which the organic matter is built; just as the bones of an animal support the fibrous and vascular tissue which make up the apparent structure. Some plants indeed are so well supplied with mineral matter that their remains after the organic matter has decayed and has been dissolved away, make the most delicate and beautiful tissue, which remains intact after thousands of years during which vast masses of these skeletons or shells have been consolidated into clay or stone. Being thus indispensable to the growth of plant substance, the mineral elements of plant food bear a most important relation to the culture of farm crops, and furnish a subject of study to the farmer which he cannot ignore.

Knowing what mineral substances are contained in plants, and knowing that these are all derived from the soil; also knowing that while the soil contains a large amount of all these mineral substances, they are not in an available condition for the food of plants, it is not difficult to arrive at a conclusion in regard to what must be supplied to the soil to ensure a satisfactory growth of crops.

Moreover, it has been learned by long experience and careful experiment that certain alkaline substances exert a remarkable effect upon organic substances in the soil, when they are brought into contact with each other; and further that they have a very intimate relation with various changes

which occur in the character of many mineral compounds in the soil, by which these are fitted to act as nutriment for plants. So that, on the whole, mineral manures or fertilizers are of quite as great importance to the farmer as the other classes of manures, and should be equally well understood.

The most important of the mineral manures are lime; gypsum; wood ashes; salt; phosphate of lime; potash; and guano. In these are contained every inorganic element of plant substance that is ever necessary for the growth of crops. Lime is the most important of them, not because it is any more requisite or indispensable than the others, but because of its peculiar effects upon the soil, and the large proportion of it which enters into the structure of vegetable tissue.

LIME, as has been explained in the description of the metallic element calcium, is never found naturally excepting in a state of combination, and mostly as a carbonate, consisting of 43.7 per cent of carbonic acid with 56.3 per cent. of its own substance.

Carbonate of lime is one of the most common of the rocks and is best known in the form of marble. It is frequently combined with carbonate of magnesia, which consists of 51.7 per cent. of carbonic acid and 48.3 per cent. of magnesia. The carbonate of magnesia is combined in varying proportions with the carbonate of lime, and sometimes some alumina and phosphoric acid are mingled with these. When the magnesia and alumina are in excess, the lime has the property of setting hard under water and is known as hydraulic or water lime. This class of lime is useless, if not injurious, for agricultural purposes. Lime is procured by calcination, in kilns, of the limestone; in which process the carbonic acid is driven off and the caustic or quick lime remains. 2000 lbs. of limestone yields 1126 lbs. of quick lime, and increases about one-third in bulk. Its affinity for water and carbonic acid is very active; in a moist atmosphere or by mixture, it absorbs about one-third its weight of water, (9 lbs. for every 28) swells to three times its original

bulk, and falls into an extremely fine dry caustic powder, which is hydrate of lime. This is a true chemical combination and is accompanied by much heat, sufficient to inflame wood. It also slowly absorbs carbonic acid from the atmosphere until it regains the normal quantity, when it becomes carbonate of lime again and loses its caustic burning or decomposing property.

Lime is used as a manure in its caustic or quick condition, and in the form of the fine, dry, pulverulent, hydrate. It is then spread over the land at the rate of 20 to 50 bushels per acre. It is prepared for use by leaving the fresh lime in heaps in the field exposed to the air and to the rain, until it has absorbed the requisite quantity of moisture, and is then spread evenly with a long handled shovel. A very convenient way is to drop the lime in heaps of one bushel at distances of 2 rods—33 feet—apart; which is equal to 40 bushels per acre. It is then easily scattered with the long handled shovel, $16\frac{1}{2}$ feet each way from each heap, which makes an even distribution over the land.

Lime is thus used when the land is sown with wheat in the fall, and grass and clover seed are to be sown in the spring. It is spread over the land after the manure has been plowed in and the surface has been harrowed once; the seed is then sown and harrowed in with the lime or drilled in, in the usual manner. Sometimes lime is used in the spring when a grass or clover sod is plowed under for corn. The results are the same in both cases.

When lime is thus applied to the land it has the following effects.

First.—It affords direct nutriment to the crop, being so finely divided and soluble in water—to the extent of one part in 700 of cold water and one part in 1100 of hot water—it is readily taken up by the water of the soil and is carried into the roots of plants and circulated through their tissues, where it is deposited, by the escape of the water in a pure state, and free from the lime, through the leaves.

Second.—It exerts a very strong decomposing action upon all organic substances, rapidly reducing them to their

elements and preparing them for plant food. Its action in freshly manured soil, to which it is usually applied, is therefore of the greatest advantage to the crop; this action going on slowly in the soil and providing a continuous supply of nutriment for the crops.

Third.—It exerts a peculiar action as a nitrifying agent in the soil by which nitric acid is produced, and by its combination with this acid as a nitrate, by which the acid is fixed and retained in the soil, to be afterwards taken up by the potash or other alkaline substances, and finally absorbed as food for the crops; and thus become a most important source of the nitrogen found in the plants.

Fourth.—It exerts a strong solvent action upon the silicates in the soil, by which inert and insoluble combinations of silica with potash, soda, magnesia, &c., are broken up; and these foods for plants are made available for the crops.

Fifth.—Its strongly alkaline properties neutralize whatever injurious acids may exist in the soil; and these are rendered innoxious, or in many cases beneficial to the growth of crops.

Sixth.—It has a most beneficial mechanical action upon all soils; loosening, and mellowing, and warming, heavy cold clays; and compacting and making more retentive of moisture light sands; and converting cold peaty soils into warm vegetable mold and fitting them for arable purposes. In addition to these most useful properties, lime has a direct beneficial action upon the growth of wheat and other grains, but especially upon grass and clover; the latter crop growing most luxuriantly whenever lime has been applied to the land.

MARL, is an impure form of carbonate of lime. It is frequently found underlying swamps, or in low grounds which are the dried up beds of former lakes or ponds in which minute shell fish—or more correctly molluscs—have existed. The shells of thousands of generations of these creatures have been collected at the bottom of the ponds; and have formed beds of considerable depth; leaving a mass of white pulverulent clayey matter intermingled with shells

more or less broken, and compacted into a firm substance, which falls on exposure to the air into a coarse white powder. This substance is of considerable value. It may be burned into a fair quality of lime, when it is of use for the same purposes as stone lime. Or it may be spread on the land after it has dried and become pulverized, as a substitute for lime, with considerable benefit.

SHELL LIME, procured by burning the shells of oysters and other marine animals, has every useful property that stone lime possesses; and as the lime is pure, with the exception of a small quantity of phosphoric acid—which is valuable—this form of lime becomes a most important source of supply to farmers near the sea coast or on the shores of the large tidal rivers.

LIMESTONE, ground into fine powder, has been offered to farmers as a fertilizer of late years; but its almost insoluble character renders it of questionable value, as compared with lime, which can be procured at less cost because it needs no grinding. Ground limestone is soluble only in water containing considerable carbonic acid in solution, and then only to a small extent. Its value in special cases *may* be such as to make its use desirable; but experimental tests are always required to discover its usefulness. No general rule can be given in regard to it, excepting that its value is wholly disproportionate to its cost, as compared with any other form of lime.

GYPSUM, is a compound of lime, sulphuric acid, and water, in the proportion of $32\frac{1}{2}$, $46\frac{1}{2}$, and 21 quarts of each, respectively. Its remarkable action upon some crops, as clover; peas; corn; cabbages; and turnips; has led to some erroneous notions as to the causes of this action, and the errors have been unfortunately fostered to some extent by inexperienced writers upon agricultural topics. These erroneous views are chiefly as follows.

That gypsum gathers ammonia from the air and thus contributes this useful substance to the plants.

That it gathers moisture from the air and furnishes it to

the crops during a dry season, when the supply in the soil may be inadequate.

That it is a stimulant to plant growth and thus tends to exhaust the soil.

These errors are very evident when the character of this substance is understood.

First.—While gypsum in solution enters into a combination with carbonate of ammonia and is decomposed by it, with the result of the formation of sulphate of ammonia and carbonate of lime, it has no more affinity for ammonia than the water of the atmosphere has, and whatever ammonia is derived from the atmosphere by plants through the rain water, is carried into the soil and from thence by the water into the roots of the plants. Hence there is no necessity for the use of gypsum in the performance of this nutritive function of plants.

Second.—That gypsum does not absorb water, having already in combination as much as it can take up.

Third.—That plants cannot be stimulated into excessive growth by any one substance; but when any necessary nutritive element is deficient, the crop suffers and only gains its natural luxuriance when the absent element is supplied.

Fourth.—The peculiar effect of gypsum upon the growth of crops containing a large proportion of nitrogen, is due to the contribution of sulphuric acid by it; the sulphur being required to form the nitrogenous compounds known as albuminoids; all of which contain a notable proportion of sulphur.

Thus the albumen, gluten, and legumin, of plants, are made up of nearly the same proportions of carbon, hydrogen, oxygen, nitrogen, and sulphur; and without the sulphur these nitrogenous compounds could not be formed. And it is a fact, that the plants which contain most abundantly these nitrogenous compounds, are largely benefited in their growth by the use of gypsum.

Gypsum is easily dissolved in 400 times its weight of water, and hence the small quantity—rarely exceeding 100 lbs. per acre—usually applied is very quickly carried into the

roots of plants—but never through their leaves—and thus exerts its notable effect. If reference is made to the table in which the composition of the ash of plants is given, it will be seen that red clover, the grasses, white clover, and other leguminous plants; and cabbage, turnips, rape, mustard, and other plants of the cabbage or cruciferae tribe; all contain a large amount of sulphur and sulphuric acid in their ash. Thus is most clearly explained the peculiarly favorable results of an application of gypsum—100 lbs. of which convey to the soil $46\frac{1}{2}$ lbs. of sulphuric acid.

WOOD ASHES, containing as they do all the inorganic elements of plants in a condition in which these are readily appropriated, necessarily make a most effective manure, and are useful to all crops and upon all kinds of soils that are in a proper condition to bear crops. It is unnecessary to say further than this in regard to them.

PHOSPHATE OF LIME, exists naturally in the form of an abundant rock and is widely dispersed through the soil. It also exists in vast beds, chiefly in North and South Carolina near the coast and along the banks of the tidal rivers in the form of remains of marine animals which have existed in past ages. This substance is used in its raw state finely ground, and is known in commerce as Charleston floats—from the locality where it is chiefly dug and manufactured. In this condition it is slowly soluble and has been found to exert a favorable effect upon such crops as it has been applied to, chiefly those however which are grown for their seed, as cotton; corn; wheat; and other grains. It is of most importance however in regard to its use for the manufacture of super phosphate of lime—to be hereafter described. In the form of “floats” it is used at the rate of about 1000 lbs. per acre. These floats are ground as fine as flour, and although practically insoluble in pure water, are dissolved to some extent by water containing various acids, more especially carbonic acid, which acts upon the lime and so releases the phosphoric acid. This form of phosphate of lime contains from 24 to 49 per cent. of phosphoric acid, and the low price at which it is sold and the favorable me-

chanical condition in which it is offered for sale, render it of considerable interest to farmers.

POTASH SALTS, form one of the most important sources from which potash manures are derived. They are procured from the German salt mines and are largely imported into this country and sold at a low price, compared with their actual fertilizing value. They consist of varying proportions of potash in combination as sulphate, and chloride, with similar compounds of soda and magnesia. They are known in the trade as muriate (chloride) of potash, sulphate of potash, and kainite.

MURIATE OF POTASH is the most valuable of these salts as regards its contents of potash; but the excess of chlorine contained in it is believed to be injurious to some crops; while it is preferable for others which require this element in considerable quantity. It contains on the average 50 per cent. of potash with some soda and magnesia, and at the common price of about \$40 per ton, the potash in it costs about 4 cents a pound which makes it the cheapest source of this material.

SULPHATE OF POTASH, is a more popular form of these salts, and contains about 35 per cent. of potash. The sulphuric acid contained in it is also valuable, and any excess of it in the salts is quickly combined with other alkaline matter in the soil and rendered useful, which is not the case with the chlorine of the muriate. Hence the sulphate bears a higher proportionate price in the market, and the potash in it costs nearly 7 cents per pound. A lower grade of sulphate of potash contains 25 per cent. of potash, with considerable sulphate of magnesia; the potash in this form costs nearly 7 cents a pound.

KAINITE, is the name given to the inferior grades of these salts. A sample of a lot used by the author with excellent results on grass, fodder corn, and turnips, had the following composition, viz:

Water.....	2.15 per cent.
Lime.....	.82 "
Magnesia.....	11.30 "
Potash.....	16.43 "
Sulphuric acid.....	21.91 "

The potash in it, at the price of \$14 per ton, cost, without allowance for the sulphuric acid, a little more than 4 cents per pound.

SALT, is the only form of soda which is used as manure; and this because of its cheapness. As it can be purchased at about \$6 per ton and contains but few impurities, it is a cheap manure for the return given. Some farmers have found no benefit from its use, but others have a high opinion of it. Crops such as mangels and beets, whose ash contains much soda, would naturally seem to be much benefited by it, upon general principles, and this expectation is confirmed by the results. 600 lbs. per acre of salt has greatly benefited this crop as grown by the author, and a dressing of 500 lbs. per acre has been found useful to wheat, grass, and clover. A mixture of 100 lbs. of salt and 100 lbs. of gypsum per acre on one half of a timothy and clover field, had a most favorable effect; the whole field of 13 acres yielded $27\frac{1}{2}$ tons of hay at the first cutting; the dressed half gave 17 tons and the other half $10\frac{1}{2}$. The difference was very apparent and was equally so at the second cutting, when the dressed half gave 9 tons and the other half was not thought worth cutting. A flock of sheep pastured on the aftermath gave their whole attention to the part which had been dressed, and spent but little time on the other part. The following year the field was in corn and was dressed with the same mixture of salt and gypsum with manifest benefit.

Salt has been used as a manure from the earliest historical periods, and this fact alone would give great weight to the prevalent belief in its value, although no doubt many extravagant claims have been made for it. It has been used for all crops, but more especially for wheat, barley, potatoes, grass, turnips, and mangels. Its effect on the grain crops is to stiffen the straw and produce a thin clear husk; the latter is especially valuable with barley, and increases its market value for malting and brewing. Wheat is also much improved in the same respects.

It has been used for top dressing grass lands by English

farmers with marked benefit on thin light soils, adding more than one ton of hay per acre to the usual yield of $2\frac{1}{2}$ tons. This fact, considering that England is surrounded by the ocean, and no part of it is beyond the influences of the moist winds which come over the sea, effectually disposes of the objection that salt is of no value upon land subject to the influences of the sea air. No doubt there are many cases in which no good results have been derived from the use of salt. But this may be taken as a proof that the land in such cases has been already fully supplied with it and that some other kind of plant food was needed.

A very interesting experiment to show whether the soil contains salt in any appreciable quantity may be made as follows: one pound of the soil is taken in dry weather and washed with a pint of distilled, or pure rain water. The water is filtered through unsized or blotting paper and the clear liquid is collected in a clean glass bottle. If salt is present in the water, a white precipitate will be thrown down on the addition to it of a solution of nitrate of silver. Every 10 grains of the dried precipitate represents 4 grains of salt in the pound of soil tested. If a pound of soil yield one grain of salt, it will be equal to 500 lbs. upon an acre 12 inches deep. If no more than this is contained in the soil, it will be very safe to conclude that salt may be usefully applied to it.

GUANO, may properly be classed among mineral manures; for although it has been supposed to have been derived from the droppings of sea birds upon the islands where it has been procured, yet it is quite certain that some of the guanos imported and used as manure are of mineral origin although perhaps it has been—like coal—derived from organic matter. The composition of guano varies considerably. Formerly the best guano brought from Peru and the adjacent islands, contained as much as 17 or 18 per cent. of ammonia, and from 30 to 45 per cent. of phosphate of lime; and was sold at the high price of \$150 to \$200 per ton. The best now imported has only from 7 to 10 per cent. of ammonia and 25 to 30 per cent. of phosphate of lime; while

the phosphatic guanos are almost devoid of nitrogen in any form and contain from 20 to 50 per cent. of phosphate of lime; equivalent to about half as much phosphoric acid. The guanos now in the market are practically phosphatic manures, and are reduced to superphosphate by means of sulphuric acid, as will be explained in the next chapter under the head of superphosphate of lime.

All these mineral manures are of exceedingly great value for the culture of farm crops; so much so that no farmer can afford to neglect them. They furnish plant food in the most available form and when used with skill and judgment return a large profit on their cost. The example given of the production of 15 tons of hay by the use of 600 lbs. each of salt and plaster costing less than \$10 while the hay was worth at that time \$300 is perhaps an unusually favorable one; but thousands of cases are on record in which the use of this class of manures has returned in profit several times the money expended, while extra labor has been only required to take care of the increased harvest. When an acre of land is made to produce double its former yield by the use of manures liberally applied, the cost of the manure is all the extra charge; the land, the labor in preparing it, and in the culture of the crop, are all the same whether the yield be 10 bushels of wheat or 40; or 25 bushels of corn or 80. The enhanced crop then, less the cost of the manure, is the measure of the profit.

CHAPTER XXXIII.

MANUFACTURED MANURES.

The necessity for the production of the largest possible crops to meet the exacting competition of the very extensive and fertile grain producing regions of the North-west, opened by the trans-continental railroads; together with the general depression of prices of agricultural products during several years past, has led to the introduction and use of a variety of manufactured manures; commonly called artificial fertilizers. These consist chiefly of Superphosphate of Lime, made from bones, either raw or which have been boiled to extract the glue from them, or from the various mineral phosphates; the so called Special Fertilizers or complete manures, prepared for particular crops; Sulphate of Ammonia, a waste product of the gas manufacture; Fish Scrap or Fish Guano, a refuse of the fish oil factories; Dried Blood and Flesh; Ground Bone; Wool Waste; Castor Oil Pomace; Leather Waste; Soot; Cotton Seed Cake, and other oil cakes; all of which furnish a very large amount of most valuable plant food for crops, and which form the basis of a trade at present amounting to many million dollars, and rapidly extending and increasing in value and importance to the farmers. The most important of these is

SUPERPHOSPHATE OF LIME.

This fertilizer consists of phosphate of lime in the form of bones; or the mineral apatite; or the organic remains of prehistoric animals which are found buried in vast quantities near the sea coast of North and South Carolina, and known as Charleston phosphates; which are treated by sulphuric acid. This acid decomposes the phosphate of lime, and unites with a portion of lime, leaving the phosphoric acid in a separated and soluble condition. The discovery of this process is due to the eminent German chemist Liebig, who was led to it by a series of investigations in regard to

the cause of the favorable action of ground bone upon certain crops. It was long supposed that this action was due to the organic matter of the bones, and it was not then suspected that the mineral part of the bones, which was known to consist in large part of phosphoric acid, had anything to do with the luxuriant growth of grass and root crops to which bones were applied. The experiments of Liebig proved that the phosphoric acid was really the most important element of the bones, and this was further shown by the fact that burned bones, bone ash, or "earth of bones," as it was called, exerted a very marked effect upon crops to which it was applied. But it was found that the phosphate of lime, both as it existed in fresh bones and in the remains of extinct animals, was too slow in its effects and a large quantity was required to show any profitable results. Hence further experiments were made and it was found that when the ground bones were digested with a certain quantity of sulphuric acid, mixed with water, they became changed in character; that a portion of the lime in them was dissolved and united with the sulphuric acid forming sulphate of lime or gypsum, leaving a double portion of the phosphoric acid combined with the remainder of the lime. In this state, the phosphate of lime or the phosphoric acid in it, was partly soluble in water and still more so in acidulated water; hence this double phosphate or bi-phosphate of lime exerted a very much more active effect upon the crops than the bones did. It was further found that it was possible to take still more of the lime from the bones, leaving but one-third of it in combination with the phosphoric acid, and proportionately increasing the ratio of the acid; the resulting single lime, or mono-calcic or treble phosphate being called superphosphate of lime. This compound is soluble in water, and hence its effects are still more active than the former one upon crops to which it is applied.

But in effect, this form of phosphate of lime is unstable, and easily reverts to its former condition by combining again with lime which it finds in the soil, or with iron or other bases, and thus becomes less soluble.

But it is still more soluble than the simple natural phosphate and is therefore more available as plant food.

This process of manufacture is carried on upon a large scale, and a large number of factories are now in operation making superphosphate, either from raw bones, boiled bones, or bone charcoal; and from the mineral phosphates. There is no difference in the result from any one of these materials so far as the phosphoric acid is concerned, this is the same in all; but the raw bone contains a large quantity of organic matter containing nitrogen, hence the superphosphate made from this kind of bone has more value than the other kinds. The extent of the manufacture of this class of fertilizers may be realized from the fact that more than 400 different brands of it were analyzed by the Pennsylvania Agricultural department in 1883.

From the wide field thus open to the nefarious purpose of dishonest persons, the manufacture of this class of fertilizers is placed under the purview and control of the various State governments and stringent laws have been enacted to secure honest dealings on the part of the makers of these fertilizers. That this is necessary, and that it is also necessary for farmers to look closely to their own interests in this respect, the following analyses of various brands of superphosphates is a very clear proof.

<i>Superphosphates from</i>	<i>Phosphoric acid.</i>	<i>Soluble.</i>	<i>Cost per lb. of soluble acid.</i>
	<i>Claimed.</i>	<i>Found.</i>	<i>Cents.</i>
Bone black.....	18.00	17.32	7.10
“	17.00	12.75	8.3
“	17.00	16.47	8.4
“	18.00	16.93	7.7
“	17.00	16.28	8.6
Bones.....	31.00	28.92	8.5
“	18.00	17.01	7.8
S. Carolina Rock.....	13.00	8.76	6.9
“ “	12.00	6.03	10.5
“ “	13.00	7.07	10.3
“ “	12.00	10.56	6.7
“ “	15.00	13.36	6.3
“ “	12.00	5.99	10.3
“ “	12.00	5.26	10.0

Of these brands, it is seen some cost for the available phosphoric acid nearly twice as much as others, and it is of course requisite that great circumspection be used in the purchase of these costly forms of plant food.

If the farmer wish to do so, he can make his own superphosphate from bones in the following manner. A wooden vat is provided in which the bones, coarsely broken or ground fine as the case may be, are heaped and thoroughly wetted with water. Sulphuric acid is carefully poured upon the heap of bones, and a strong effervescence at once takes place accompanied by considerable heat. The bone is shoveled over to keep it in condition to be acted upon by the acid. About 50 lbs. of acid is required for 100 lbs. of bones to make a complete decomposition. In course of time the bone is reduced to a pasty condition when it may be dried by the addition of wood ashes, or potash salts, and fish scrap, which will add the potash and nitrogen to the fertilizer to make it a complete manure for crops; that is one that contains nitrogen in an available form, soluble phosphoric acid, and potash. When the potash salts are used, there will be magnesia, soda and chlorine also added.

Superphosphate of lime reverts to the condition of biphosphate or ordinary phosphate, when there is lime in the soil. This change however occurs slowly unless the lime is in excess, when the present use of the phosphate is neutralized because it is made insoluble. Hence superphosphate should never be used when the land is limed.

It is usually applied to the fall grain crops in quantities varying from 200 to 400 lbs. per acre, and is sown by means of an attachment to the drill which drops it in the row near the seed, and thus makes it immediately available for the crop in its early stages and when the young plants need an abundant supply of food. Or it is sown broadcast as soon as the seed is sown and both are harrowed in together, when the drill is not used. It is also used for the corn crop either dropped in the hill at planting, or harrowed in before planting. From its soluble character it should be brought as near the seed as possible, that it may be absorbed by the

roots as soon as they are capable of foraging in the soil for their food. It is also used as a special fertilizer for turnips, cabbages, and mangels; upon which it has a most beneficial action. It is used for these crops at the rate of from 300 to 800 lbs. per acre, according to the necessities of the soil. As a top dressing for meadows and pastures it is of the greatest use.

This is readily seen when it is remembered that young animals are fed chiefly on grass and hay, and that from this food they must build up the solid frame upon which the fleshy form is built up. As more than half the substance of bone consists of phosphate of lime, it is then very necessary that the young growing animal, as well as the cow which is yielding milk—which is rich in this compound as is requisite for the nourishment of young animals—should be supplied with food that contains this bone-making material in abundance, hence the necessity for supplying grass lands with this indispensable fertilizer.

COMPLETE OR SPECIAL MANURES are mixed fertilizers, which contain every element of barn yard manure except the carbon, which is supposed unnecessary, as the soil contains an abundance of it. The principal elements of plant food, the nitrogen; phosphoric acid; and potash; are provided in about the same proportions in which they exist in good stable manure. A comparison of a complete fertilizer, according to Prof. Villes formula, with barn yard manure, is given in the following table.

<i>Composition of</i>	<i>Stable Manure, 2000 lbs.</i>	<i>Complete Manure, 100 lbs.</i>
Nitrogen.....	7 to 10 lbs.	7½ lbs.
Phosphoric acid.....	4 to 9 lbs.	5 to 7 lbs.
Potash.....	9 to 15 lbs.	7 to 8 lbs.

Thus 100 lbs. of the complete manufactured manure at a cost of about \$2. contains about as much fertilizing matter as one ton of the best stable manure, and in an immediately available condition for crops.

SULPHATE OF AMMONIA, is a refuse of the gas manufacture and is a distillation from mineral coal. It has been made at times by the addition of sulphuric acid to stale

urine, and the evaporation of the mixture to dryness. It consists of 35 parts of ammonia; 53 lbs. of sulphuric acid; and 12 lbs. of water. It is thus an exceedingly concentrated fertilizer and can be used only in combination with other substances or in very small quantities evenly spread over the soil. It is soluble and active in the soil, and exerts a correspondingly rapid and useful effect upon vegetation, hence it is sold at a high price; the nitrogen in it being valued in the market at $18\frac{1}{2}$ cents per pound. The present market price (wholesale) of this substance is \$60 per ton, and at the estimation of $20\frac{1}{2}$ per cent. of nitrogen, this is thus procured at about 15 cents per pound.

The action of this fertilizer is a matter of importance, as it may affect the growth of leaf or grain. Experiments with it have shown that it is especially useful for turnips, an application of 100 lbs of it having increased the crop from 13 tons on unmanured soil, to $24\frac{1}{2}$ tons upon the fertilized part of the field. Generally it has a most notable effect upon the foliage; but this is to be considered in relation to the effect of a luxuriant foliage upon the quantity of starch or gluten, which may be stored in the plant or in the seed. Thus a crop of wheat dressed with 100 lbs. of this salt per acre, gave not only an increased crop of grain, but the flour made from the grain yielded $10\frac{1}{2}$ per cent. of gluten which was one per cent. more than that from any other application of manure, and somewhat more than the yield from nitrate of soda. This is an instance of how a fertilizer containing a large proportion of nitrogen, increased the quantity of nitrogen in the crop. There has rarely been an instance in any experiment with this salt of ammonia, of its failure to increase the growth of leaf and grain. The large quantity of sulphuric acid no doubt has something to do with the increase of the gluten in wheat, as this substance contains sulphur; and on this account the use of sulphate of ammonia is often recommended in preference to the nitrate of soda for the supply of nitrogen to the soil.

FISH SCRAP is the waste of the fish oil manufacture. The fish, chiefly menhaden, which come near our coasts in enor-

mous shoals, are steamed for the oil they contain; the resulting mass of moist flesh and bone is then dried and finely powdered. The substance thus produced is called fish scrap. It is one of the nitrogenous manures, but contains some phosphoric acid and a little potash. It has, as might be expected, somewhat the same character as Peruvian guano, which is derived from the excrement of sea fowl which feed upon fish. An analysis of fish scrap gives the following, from a good sample.

COMPOSITION OF FISH SCRAP DRIED AT 212°

Moisture.....	9.00 per cent.
Phosphoric acid.....	11.72 "
Reverted phosphoric acid.....	4.41 "
Insoluble phosphoric acid.....	7.31 "
Potash.....	.89 "
Nitrogen.....	8.16 "
Insoluble matter, lime, etc.....	3.70 "

Value per ton, \$49.35

This is seen to be a valuable fertilizer, and by mixture with potash salts would make a most useful manure. Not being immediately soluble, but yet decomposing freely in the soil, it becomes available for the crop gradually; hence it may be applied early in the season, and its effects will continue to be apparent during the whole period of growth. It has been found especially useful for corn; market crops; potatoes; and for grass and clover. Many farmers have found its useful effects much increased by treatment with sulphuric acid, by which the ammonia contained in it, or evolved during its decomposition, is changed to a sulphate; and its phosphate of lime becomes superphosphate; when its solubility being very much increased, it becomes much more available for the feeding of crops. The coarse fish scrap, unground, sells for a much less price than the kind of which the analysis is given above, and it makes an excellent material for enriching composts. One ton of it added to 10 tons of fresh swamp muck, with a ton of potash salts and a ton of ground gypsum, has been found to make a most useful substitute for stable manure, and when used for a crop of mangels gave a very satisfactory yield, equal to that upon adjoining parts of a field which were manured, one

with 20 tons of good stable manure at a cost of \$55., and the other with 1200 lbs. of complete artificial manure at a cost of \$30. These quantities were equally divided between 6 acres, and the yield over the whole field averaged a little over 1200 bushels per acre, with but little difference between the different parts of the field; the difference being in favor of the complete artificial manure which yielded roots of large size. This result is what might be expected from the solubility and consequent availability of the complete manure, which was made up of superphosphate of lime, muriate of potash, and sulphate of ammonia.

DRIED BLOOD AND FLESH.—The refuse of the large slaughtering establishments and the meat canning factories, furnishes a large amount of most valuable plant food which was formerly wasted. This is however mostly used by the manufacturers of fertilizers in the compounding of complete manures, or in the enrichment of superphosphates of the class known as ammoniated fertilizers. The rapid decomposition of these preparations of blood and flesh, causes the free production of ammonia, the loss of which is avoided by its combination with the free sulphuric acid of the superphosphate and the formation of sulphate of ammonia. The composition of this substance is given in the table at the end of this chapter, along with that of the following waste matters used for manures.

BONES have been used for manure for farm crops for many centuries. It is supposed that their value in this direction was first discovered by the extraordinary fertility of ancient battle fields which were brought under cultivation, and in which the decaying bones formed a considerable element in the soil. Some years ago ground bones were the only artificial manure used to help out the always inadequate farm manure, and it was the beneficial results from this fertilizer which started the investigations which resulted in the discovery of the value and method of making superphosphate of lime and ended in the present enormous manufacture and use of what are called artificial fertilizers.

Bones when dry, consist of 35 per cent. of gelatine; 55 per cent. of phosphate of lime; 4 per cent. of carbonate of lime; 3 per cent. of phosphate of magnesia; and 3 per cent. of soda; potash, and common salt. Usually the gelatine of bones is too valuable for the glue which is made from it to be left in the bones used for manure, and as this contains a large proportion of nitrogen, the manurial value of the bones is considerably decreased by its loss. The bone mostly used is that which has been steamed to extract the gelatine, and consists of phosphate of lime and the other mineral matters. These however are exceedingly valuable as plant food, and are desirable for their permanence in the soil. The good effects resulting from an application of 1000 lbs. of crushed bone per acre to grass land, have been perceptible at the end of 30 years; thus showing bones to be one of the cheapest, if not the cheapest, of all manures.

As phosphoric acid, of which bone phosphate contains 48 per cent. of its weight, is a constituent of all farm plants, bones are found valuable under all circumstances; upon all soils, and for all crops; and never come amiss. The supply is however limited to the product from the animals slaughtered and the refuse of the factories where bone is used in the arts. An analysis of common bone manure is given in the table above referred to.

WOOL WASTE from woolen factories is an exceedingly valuable fertilizer for some special uses. It is used extensively in the European and English hop yards, and is applied yearly, being dug into the soil about the roots. Its principal fertilizing property is derived from the nitrogen and the sulphur it contains. Its analysis will be found below.

CASTOR OIL POMACE; SOOT FROM SOFT COAL; COTTON SEED; AND LEATHER SCRAPS; are used for manure in localities where they can be procured without too much expense for transportation. With the exception of the last mentioned, these waste substances are of considerable value, chiefly for the nitrogen they contain, and form an excellent basis for enriching composts, or for top dressing grass lands.

LEATHER SCRAPS are difficult to decompose, and decay very slowly; but they contain a large proportion of potential nitrogen, and when plowed into the soil slowly give it up to the crops.

The nitrogen they contain is thus of the least value of any kind used in fertilizers. As the leather is very cheap, it has offered a temptation to some unscrupulous dealers in fertilizers to mix it with their goods for the purpose of showing on analysis, a large percentage of nitrogen; but as it is practically unavailable, the quantity of nitrogen thus shown is misleading, and unless explained is fraudulent.

COMPOSITION OF VARIOUS FERTILIZERS. PER CENT.

	Moisture at 212°	Nitrogen.	Phosphoric acid.	Potash.	Sulphur.	Lime.	Magnesia.	Insoluble.	Value per ton.
Dried blood.....	7.65	8.10	6.23					1.08	\$36.64
Bone and flesh....	14.93	4.36	10.52	4.91					32.01
Ash of cotton } seed hulls..... }	2.30		13.67	30.82		11.63	15.24	21.65	50.30
Ground bones.....	4.78	2.03	29.83			18.61			34.79
Dried fish.....		9.24	6.20						40.00
Dried flesh.....		12.05	1.96						50.00
Ground horn.....	10.00	13.53	1.36		2.00				23.28
Wool Waste.....		17.71			3.66				34.00
Soft coal soot.....	12.50	†14.73	1.5	4.5	*2.00	25.46	.05		
Cotton seed.....	13.00	3.50	3.50	3.00					20.00
Cotton seed meal..	14.00	7.00	3.00	2.00					35.00

* In the form of sulphuric acid.

† As ammonia.

PART FIFTH.

CHAPTER XXXIV.

THE STRUCTURE AND GROWTH OF PLANTS.

Having considered the nature of the various elements which enter into the structure of plants, and their relations to vegetable growth, the nature of the soil, its formation, composition, and its relation to the growth of crops, with the various methods by which it may be improved and better fitted for the purposes of cultivation, it remains now to consider the nature of vegetable life and growth, and how these are dependent upon the labors and intelligent skill of the farmer for their full and profitable development.

In considering this part of our subject as it relates to the culture of farm crops, we are brought face to face with the great mystery which lies beyond the reach of the most acute mental power; which defies every effort of human intelligence to understand or explain; and eludes the grasp of the most profound philosophy. This impenetrable mystery is Life. However this is viewed, it is a transcendent miracle. Its mere consideration throws us back upon our own powerlessness to reach even a comprehension of what it is. We can perceive the approaches to it; the chemical operations by which it is made possible and which start its development; but as one might look over a road crossing a rounded hill in front of him, and the way appears plain until the crest is reached, and then the sight plunges into infinity, and finds no resting place in the ethereal blue beyond its scope; so the mind follows all the various changes and processes which precede the bursting of a germ into active life, and recognizes the relations of these to certain natural laws, and to known forces, but the nature of the vital power which

controls all these, which sets in action the weak but yet invincible germ, which guides with unerring instinct the plant in the choice of its food, the potent agency which works so silently, but yet exerts a power which is incomprehensibly great, the life which springs from death, which is constantly perishing and rising from its ashes, the *Vital Principle* which crowns the labors of the farmer with success, which covers his fields with verdure and in the season with golden grain and fills his barns with wealth, making animal existence possible and supporting the higher life of man with his still more wonderful intelligent mind—all this living system is a miracle before which the mind of man lies helpless and confesses itself unable to comprehend it. This brings us in fact face to face with the omnipotent Creator; whether this be the personal existence which some believe, or a process of evolution by which a primeval germ has gradually progressed from the lowest form of organized matter, up to the highest organized form of life—a reasoning man.

We cannot consider this from a chemical point of view, because vital force overrides chemical laws and is beyond our comprehension. But all force is mysterious. Gravitation is something, the essential nature of which we cannot penetrate, yet we can understand its manner of action and its relations to matter; but while gravity cannot be suspended, vital force may be and all the wonderful potential agency which exists in a seed may remain undeveloped for years. This seems to comprise the sum of all the differences between other forces and vital force or life.

Vital force, has been described as a collective term embracing all those causes upon which the phenomena of life depend. Plants and animals, as living beings, are only parts of the great universe; are governed by its laws; and are to be studied by the same methods as all other phenomena of nature.

Every plant springs from a seed, and every seed contains a rudiment of a new plant, called the *embryo* or *germ*. The germ is imbedded in the seed, in a protecting mass consisting chiefly of starch and gluten. If a grain of corn is cut

across through its thinnest part, an oval receptacle is found in which is seen the germ surrounded by the starchy substance of the grain. Here the germ lies dormant, at the disposal of certain agencies by which the principle of life contained in it is awakened and brought into active existence. These agencies are moisture and heat.

It has been shown that these two agencies, moisture and heat, are necessary for the development of chemical action; and the vitalizing of the living principle in the dormant germ is due to this action. When the conditions necessary to develop this required chemical action are effected, the germ awakens from its slumber, puts forth its latent power, starts into motion, and begins to form new cells by which its substance is increased at the expense of the enveloping matter, which is decomposed and absorbed. This process is called germination.

When a seed is placed in the soil and covered from the light, it absorbs moisture. Unless the temperature is above a certain point no action is developed; but when the temperature reaches the right point which varies considerably with different seeds, some of which will germinate in ice and some require a heat equal to that of boiling water, oxygen is absorbed, and the gluten is in part changed to diastase, which is a peculiar substance not well understood as yet, but which has the property of changing starch to sugar. One part of diastase is able to convert 2000 parts of starch into sugar, and it is this substance which exists in the malt or grown grain, that furnishes the agency for the conversion of the barley or corn meal into sugar for the purposes of brewing. This conversion of the starch of the seed into sugar precedes the action of the embryo; for the germ cannot increase its substance except from the matter absorbed by it, and which furnishes the materials for building up new cells. The germ now expands by the formation of new cells, and pushes forth the radicle or root, which strikes into the soil in search of nutriment; and the spire or stem, which extends upwards into the air, where it puts forth leaves. The plant now passes into a new stage of existence and be-

comes self-supporting; exercising a power to organize the elements of plant growth which it finds in the soil and in the air, and which contribute to its nourishment. Heretofore it has merely assimilated the already organized sugar which has been derived from the starch of the seed; just as the chick in the egg subsists upon the organized matter of the yolk which is absorbed and converted by a mere change of form into animal tissue. Now it begins to exercise a true vital function, viz: the change of inorganic matter into organized substance, the tissue of plants, which transformation is effected by the aid of the air which is inspired through the leaves.

The mechanism of plant growth consists of very minute bodies called cells, and in these the vital function is concentrated and performed. These vary in size from a twenty-fifth, to one fifteen hundredth part of an inch in diameter, and are usually round or oval in form. When compressed in the act of growth, these cells take on various other shapes as the pressure may cause them; and become flat or disc like; hexagonal; elongated; and angular. The cells are easily perceived by the aid of a microscope in the pith of a corn stalk, or of the elder, or in the pulp of fruit, or the flesh of a potato.

The cells consist of an outer wall or membrane, a lining sac, and within this a nucleus or small body which is the truly active principle of vitality. The outer wall consists of cellulose or woody fiber, which is identical in composition with starch, and is insoluble in water or alcohol. It is nearly pure in elder pith, and in the cotton and linen fiber. Its chemical formula is $C_{12} H_{20} O_{10}$, which is precisely the same as that of starch. Gum is represented by the formula $C_{12} H_{22} O_{11}$ which is that of starch increased by one atom of water, viz: $H_2 O$; while the addition of one more atom of water changes the gum into sugar, represented by $C_{12} H_{24} O_{12}$. Thus it is seen that the change of the starch of the seed into sugar in the process of germination, is simply produced by the combination of 2 atoms of water ($H_4 O_2$) with the atom of starch $C_{12} H_{20} O_{10}$.

The cell contains a viscid albuminous fluid called protoplasm, (the beginning of life) in which numerous small granules float. These granules are the germs or nuclei of new cells, and the foundation from which growth of plants proceeds. The perfected cells burst and set free the enclosed granules. A delicate membrane appears on the surface of the granule, and gradually extending beyond its boundary, forms a new cell. The new cell immediately absorbs the requisite material for its vital contents of protoplasm, and granular matter from the sap of the plant, and thus completes its functions. Thus the building up of the plant tissue goes on until it is arrested by the fulfillment of its purpose; the ripening of its seed; and its subsequent death; when the tissue begins to decay and is decomposed finally into its elements and furnishes food for a future race of plants.

Other cells increase by division. The contents of the cell become separated, and a new wall is formed between the separated granules; thus producing new cells each containing its granule or nucleus. This granule increases in size and separates, forming a mass which in its turn separates into individuals; and the formation of new cells is repeated. In this manner the plant tissue grows and increases from its termination or borders; the subdivision going on indefinitely as long as the material is furnished for the growth of the cells.

A simple illustration of this beautiful process may be given. If we suppose the cell to be a brick, and the brick to divide itself into separate parts by the elongation of each end, and the widening of its sides and faces, and each part to grow to be a complete brick, and each of these then to subdivide itself again into separate parts, as before, and that this process goes on continually and in such directions as to form walls, with cross partitions, and the angular boundaries and openings for doors and windows and every other requisite for a building, we may then form some idea of how a plant is formed and grows, and is built up into root and stem and leaves and fruit, until the whole is completed.

The nutrition of the plant is accomplished by means of a peculiar property of the membrane which forms the wall of the cell. This property consists of a power of the cell membrane to combine with the fluid in contact on one side of it, and to decompose it, and thus pass it out on the other side of it; or to transpose it in some way through its substance. Thus if a piece of wet bladder is tied over the end of a tube, and the tube is filled to a certain height with alcohol and then immersed in water, the water immediately begins to pass through the bladder and mingles with the alcohol; while the alcohol passes through the bladder and mixes with the water on the other side of it. The same movement takes place with solutions; but the cell membrane has the power of retaining what it requires for the nutriment of its contents; and building up its own tissue; and then of permitting the transmission of the remainder through its walls to the next cell. In this way the water of the soil containing in solution the food which the plants require, is absorbed through the cells of the fine feeding roots, and is passed through from one to another of the many millions existing in the plant, until it reaches the leaves; when, disburdened of its load of nutriment which is all absorbed by the cells, it passes off through the pores of the leaves by evaporation into the outer air.

Cells are the minute factories of the universe, in which the vast forces which we call Life are constantly operating to change and transform inorganic matter into organized structures, by means of a constant flow and transmission of fluids through them. The force by which these fluids are transported from the distant termination of a root to the uttermost leaf at the top of the highest tree, is the delicate one above described, and is called *osmose*. What the power is by which the matter in solution is changed into organized living and moving substance we know not; but we call it vital force, and although its action is imperceptible to us except by its results, yet the power exerted is so enormous, that each pound of carbon fixed in the substance of a crop, requires an equivalent of power which is sufficient to raise

a weight of one ton 500 feet high; or 500 tons a foot high. What wonderful exercise of power is then going on unperceived by the farmer as he sees his crops growing and combining a thousand pounds of carbon in his crop of hay upon each acre; thus exerting a force equal to that of throwing a weight of a ton 500,000 feet, or 100 miles up above the surface of the earth. Truly the farmer lives amid the most wondrous forces of nature, equal in intensity to those which produce earthquakes, cause volcanoes to burst with liquid fire, and rend mountains asunder; yet he does not perceive it, until the mind's eye is turned upon the hidden secrets which lie in the tender rootlet and the verdant leaf, as well as in the great stem of the most ancient monarch of the forest.

CHAPTER XXXV.

THE FUNCTIONS OF THE ROOTS.

The roots of plants perform two offices; one is to support the plant in the soil; the other is to gather food and convey it into the plant. In fact the roots of plants are the mouths by which their food is introduced into the circulation.

The roots possess a power of selecting suitable matter from the soil for the nutrition of the plant; but whether or not they have the ability, or exercise any power, to prepare the food for assimilation, is not certainly determined. There is reason to believe, however, that to some extent the roots not only select suitable nutriment from the soil but also prepare such food as may be required from the imperfect materials which exist in the soil. Roots seem to have the power of rejecting unsuitable or unnecessary matter which may have been absorbed, and has answered its purpose; but for which there is no further use. All these functions have a most intimate relation to the growth of crops, and hence furnish a most important subject for the careful study of the farmer.

The absorptive function of the roots is exercised by exceedingly numerous and very fine hair like fibers, which are attached to the ultimate thread like ramifications of the visible roots. From the difficulty of separating these minute and exceedingly weak rootlets from the soil in which they are enveloped, and which they grasp firmly, it is difficult to examine closely the form of the root to its smallest fiber; but a very good example may be obtained by starting a seed to grow in fine sand in a small pot, and watering it with weak manure water until the sand is filled with the roots. The ball of sand is then washed from the roots, and the very large comparative growth of them as compared with the small size of the plants, and their peculiar structure

can be easily studied. The root hairs will be found attached, much like the bristles to a bottle brush, to the smallest fibers of the root. These so-called root hairs are the absorptive organs of the roots. As the plant grows, the roots gradually become stronger harder and more woody, as is consistent with their mechanical purpose to uphold the plant; and the latest growth of roots only, become feeders. The precise way in which roots absorb the plant food, and their functions are accomplished, is still a matter of some uncertainty; but the process of osmose is probably that by which the solutions of the various substances of which plant food consists are absorbed. The dissolved matter in the soil in which the roots are immersed, passes through the cell membranes in the manner previously described, together with as much water as may be needed to supply the needs of the plants. It is common to say that the food enters through the pores of the roots; but this is more a figure of speech than a reality; for under the present belief in regard to the action of osmose the existence of pores or openings in the membranes is not necessary. However it is very well ascertained that no solid substance, however finely divided it may be, can enter the roots of plants; and only such as is dissolved in water.

Nor do the roots absorb air or other gaseous matter unless it is dissolved in water. If a plant is grown in water in which carbonic acid gas is dissolved, the gas gradually disappears as it is extracted by the roots. If a plant is grown with the roots in a bottle partly filled with water, the air in the bottle is gradually deprived of its oxygen to replace that which has been extracted from the water. But if instead of air, the bottle is filled up with carbonic acid, the plant will droop and soon die; the same will happen if nitrogen, or hydrogen gas, is substituted for atmospheric air. This should not be accepted as a proof that these gases are noxious to plants, but rather that they exclude the oxygen which is indispensable for all living beings; plants or animals.

That roots select their food from a variety of substances

in the soil, precisely as fowls will select grains of wheat from among sand or gravel or sawdust cannot be doubted. If any necessary substance required for the growth of plants is absent from the soil, the crop will refuse to grow. If a seed is sown in pure quartz sand the young plant will perish as soon as the nutriment of the seed is exhausted. If the plant is fed with a mixture of lime, phosphoric acid, and the other elements of its composition, it will grow to maturity; but if one of these are absent it will not survive. If other substances are offered to it in place of its needed food it will not take up those instead of these. It will not appropriate magnesia in place of lime; nor soda instead of potash. If various plants are grown side by side in the same soil, each will still extract from the soil its own peculiar food and will leave in its ash its own peculiar proportions of various mineral matters. If a bean be grown near a stalk of corn, the ash of the corn will contain a large proportion of silica, but that of the bean very little. Abundant proof is not wanting to show that plants select their food from the soil, according to their own necessities, and exhibit in this way an instinct much like that of animals.

Moreover plants refuse to absorb useless matter, or if it is necessarily taken into the roots, it is returned to the soil; it is not stored up in their tissues; and they perish when noxious matter is absorbed by which the chemical action and assimilation of their proper food is interfered with.

On the whole, the conclusion seems to be reasonable, that the roots of plants select from the soil, in preference, those substances which their nature and composition render necessary for them, and in certain proportions; that to a certain and very narrow extent they have the power to substitute other substances in place of those which they would prefer naturally; and that they refuse admission to certain useless or injurious substances, although they are unable certainly to discriminate against and reject everything that may be hurtful or useless to them.

Another function of roots is the power to prepare food for themselves from the store of inert matter in the soil, in

the absence of a sufficient supply to meet their wants. It is known that the roots of plants exert a corrosive action upon the stones in the soil, and upon rocks with which they come in contact. This they do by the excretion of acetic acid, and this acid is found in the soil in which young plants have been grown for experimental purposes. Roots of plants have been known to form a network of lines upon stones and rocks against which they have grown, and to have caused the solution of the mineral matter for their own use. Lichens constantly exert this effect upon the rocks upon which they grow. Roots of grape vines have been known to wholly envelop a bone with a mass of fibers, and to have caused the decomposition of the bony matter for their own support.

Still another function of roots is the power to excrete useless matter from their substance. This is shown by the fact that at various periods of growth plants contain different proportions of certain mineral matters. Thus a wheat plant contains about 8 per cent. of ash previous to the blooming period; $5\frac{1}{2}$ per cent. when in flower; and but $3\frac{1}{4}$ per cent. when fully ripe. It may be supposed that this diminution of the ash may be caused by the increase in organic matter which affected the ratio. But there is a very important change in the character of the ash at these periods; for instance, the silica in it varies from $12\frac{1}{2}$ to 26 and 51 per cent. according to the variation of time mentioned. Thus while the silica is increased 4 times, the total ash is reduced nearly one-third. There must then have been a diminution of other parts of the mineral matter, which can only have taken place by their rejection from the plant through the roots.

This process of rejection of useless matter however is not of sufficient importance to affect methods of culture of different crops. It was formerly believed that the matter rejected or excreted by one crop was of great use as food to a succeeding one; and this was made the basis for explaining the beneficial result from a rotation of crops. But this theory is now obsolete, and the advantage of a rotation of

crops is more satisfactorily and reasonably explained, as will be shown in a succeeding chapter.

More as a matter of special than general interest, another function of the roots is mentioned in passing. It is the power of storing up matter sometimes differing from any kind found in the plant, and at other times having a close similarity with it. Thus we have roots which contain substances entirely different from any found in other parts of the plant but which must necessarily have passed through the plant and returned to the root. The various medicinal roots; the root of the cotton plant; and of rhubarb; are examples of this kind. Of the other kind are those roots, as the turnip, carrot, and parsnip, in which a very large quantity of starch, sugar, etc., is stored up; and also those tubers, as the sweet potato, and the common potato, which contain much starch. All this matter has been elaborated in the plant and returned to the roots.

CHAPTER XXXVI.

THE FUNCTIONS OF THE STEMS.

The stem performs two offices as the roots also do; to sustain the leaves and fruit, and to convey from the roots to the leaves the nutriment which the former have gathered from the soil; as well as to return to the roots whatever sap or nutritious matter the roots require for their growth; together with any excess of it which has not been used by the plant. It may be questioned if there is ever any excess of such matter taken into the plant, and if the roots do not absorb precisely so much and no more food than the plant requires. But we have seen that the roots do discharge from the plant some matter which is in excess of that required, and it is probable that a constant circulation always goes on through the plant, from the roots through the stem to the leaves, and back through the stem to the roots.

Plants are divided by botanists into two great classes, Endogenous, or those whose stem increases by additions of cellular tissue within it; and Exogenous, or those whose stems grow by additions to the outside. The first class is represented by the palm tree, and all the great grass family of plants, which include corn, wheat, sorghum, and all those plants which have hollow and jointed stems, or a pithy center surrounded by a hard outer casing; but do not have bark; the other class is represented by the majority of plants, which like trees, increase by layers of tissue on the outside of the stem between the wood and the bark. The plants of greater interest to the farmer belong chiefly to the first class; but in both, the stem exerts similar functions and has similar relations to the growth of the plants.

The stem is a prolongation of the upper portion of the root, and consists of a mass of longitudinal, hollow, tubular, vessels, through which the sap circulates from the root to

the leaves and back again. This, with the support of the leaves, is the mechanical function of the stem. But the stem has a chemical or nutritive function also; for as the sap ascends through it to the leaves it undergoes certain changes, by which it is fitted for assimilation in the leaves.

The water which enters the roots and which contains certain nutritive substances in solution, passes on to the stem and ascends to the leaves where it diffuses itself over their exceedingly large aggregate surface, and then descends through the stem to the roots. When the sap, or what remains of it after having deposited its load of aliment through the leaves, branches, and stems, reaches the roots again, it is necessarily much changed in character, having been exhausted of its burden or so much of it, as has been utilized by the plant. It then deposits in the cells of the roots what these require for their growth, and it is then perhaps completely used up or has been deprived of its dissolved matter. At any rate then it either mingles with the upward current, or it escapes from the roots as useless matter.

But what causes this upward and downward motion of the sap? It has been attributed to the action of the absorptive and decomposing agency of membraneous matter referred to as osmose; and this is the most probable cause of it; it has also been explained by the action of capillary attraction; by the pressure of the atmosphere acting upon a vacuum produced in the plant; but whatever may be the nature of the force by which the circulation is produced, its results are the same, and its effects upon the growth of the plant are not changed.

The outer covering of the stem of a tree which is called the bark, and the leafy envelope of the stem of a grass have much in common in regard to the nutrition of the plant, and what happens in one case is duplicated in another with but very little variation; excepting that in such plants as wheat, which have but little foliage, the assimilating functions of the leaves are performed by the stems in great part. The sap then which is conveyed upwards from

the root through the stem is exposed to the action of the oxygen of the air which is absorbed, and is elaborated into nutritive matter which is deposited in the cells of the leaves and of the stem, as the current descends, as woody fiber; starch; and albuminous matter. This process is analogous to the circulation of nutriment through the digestive and assimilative organs of animals, into and through the lungs and through the arteries and capillary vessels which are scattered in the finest network all through the tissue, and from which the solid substance of the animal is deposited. Thus the stem increases in growth by deposit of new matter; but in the manner above described as the character of the plant differs. This deposit is made on the inner part of the stems of most of the plants which are grown as farm crops, but on the outside of the wood and under the bark of trees, forming what is called the cambium layer, between the wood and the bark.

But by far the larger part of the water absorbed by the roots and passing upwards through the stem is evaporated by the leaves. A small sunflower plant no more than 3 feet high, draws up from the roots through the stem to the leaves and exhales from these, about 30 ounces of water in 24 hours; and the enormous quantity of water which passes through the stems of the trees upon one acre of forest land is estimated at several tons per day.

CHAPTER XXXVII.

THE FUNCTIONS OF THE LEAVES.

Leaves consist of a woody and a cellular part. The woody part consists of a framework of ribs and veins upon which is spread cellular tissue. These serve not only to strengthen and support the leaf, but also to introduce and distribute the ascending sap through the veinlets and cellular tissue. The cellular portion is the green pulp, and is nearly the same as the green layer of the stem. So that the leaf may be considered as an extension or expansion of the fibrous and green layers of the outer covering of the stem, and the whole of it is covered by a skin or epidermis like that of the stem.

The green pulp of the leaf consists of cells of various forms loosely arranged, and leaving many irregular spaces between them; these spaces form air passages which communicate with each other throughout the whole leaf. The green color is due to minute green grains which lie loosely in the cells. This coloring matter is known as chlorophyll, or the green of the leaf. It is this green matter, when decomposed into the primary colors of yellow and blue, which is supposed to give the rich yellow color to the butter of cows, and the yellow color of leaves which have ripened and faded in the fall of the year. The green tissue of leaves differs on the upper and lower sides of the leaves; the former being of a darker green, because of the close contact of the cells; the under side being light green because of the many open spaces between the loosely placed cells.

The leaves are provided with a vast number of pores called "*stomates*," which afford communication between the passages among the cells and the air. Through these, the vapor of water, air and gases, can readily escape or enter as the case may be. A pair of cells acting as valves guard the opening of each pore; and when dried, these contract and close the opening so as to promptly arrest the escape of

moisture in dry weather, and expand and open it when moist. It is the action of these contracting cells which cause leaves to curl in very dry weather. These air pores are very numerous on the under side of the leaves, varying in number from 1000 to 170,000 to the square inch of surface. A leaf of corn will therefore have many millions of these breathing pores upon its surface; and an apple leaf, which is not so well provided with these organs, has only about 100,000 of them to each leaf.

It is through these pores that the leaves perform their most important office, viz: that of elaborating the crude sap into organic matter which is deposited throughout the plant, and from which its substance is formed. The water in excess of the needs of the plant is exhaled through these pores, and thus the solid matter of the sap is deposited.

It is also by these pores that air enters into the leaves, and mingling with the sap produces such chemical changes in it as fit it for its purpose. The air also enters and brings in with it the carbonic acid which is mixed with it, in the proportion of one twenty-five hundredth part of its bulk. This carbonic acid is supposed to furnish a large part of the carbon of which plants consist, but as the water taken in by the roots also contains carbonic acid in solution, there is no doubt that a large part of the carbon of plants is derived in this way through the soil. Water and carbonic acid taken in by the leaves (or by the roots) are the raw materials of which the fabric of plants are mostly made up; and to change these dead mineral matters into living organic matter is the principal function of the leaves.

This function is performed in the green leaves alone, and only in the light of the sun. The sun beam is the giver of life to the dead matter, and the grand chemical agency of all plant growth. The proof of this is one of the simplest rational propositions.

First.—The green part of leaves exhale oxygen only in sunshine or bright daylight.

Second.—To give out oxygen is all that is required to change water and carbonic acid into cellulose or plant food.

Third.—10 parts of water and 12 parts of carbon make up the composition of cellular tissue; of which the chemical formula is $C_{12} H_{20} O_{10}$. As water consists of $H_2 O$; 10 parts of it furnish the $H_{20} O_{10}$, which added to C_{12} , make up the cellulose ($C_{12} H_{20} O_{10}$).

Hence when the leaves absorb carbonic acid, or receive it in the sap from the roots, and the sun shines upon them, the carbonic acid is decomposed and the oxygen of it is exhaled from the leaves while the carbon forms a union with the elements of the water and becomes plant tissue. In this combination the required mineral elements, and the nitrogen of which the gluten and albumen are formed, and which are derived from the sap, take their share; forming the contents of the cells and the supporting framework of the whole plant.

Thus the leaves complete the work of building up the fabric of the plant from the materials furnished by the soil, or by the farmer when the soil is not fully provided with them. And they not only build up the plant, but they store up in it the starch of which the seed mainly consists; and the gluten and albumen of which the germ is formed; and thus provide for a future generation to succeed them after their work is done. They also, by a most mysterious change, in which the very same elements are simply transposed in some way, produce this starch from the cellulose; and by the addition of more water, convert starch into the sugar which makes the grape and the peach and the other fruits so delicious to our palate; thus affording not only the simple necessities of animal life, but the delicacies and luxuries which make up a large part of the enjoyment of our existence.

But these functions of the leaf have a very close relation to circumstances which are under the control of the farmer. The vigor and luxuriance of plant growth are closely connected with the yield of the fruit, or the seed, which is the hope and aim of the cultivator of the soil. Hence how important it is that he should encourage this leaf growth by *the most perfect preparation of the soil that is possible; by per-*

fect pulverization and fertilizing, that the roots may be fully developed and gather food from the soil in abundance; giving support to a stout vigorous stem and nourishment for an abundant foliage; by which all his efforts and labors are crowned with success, and profitable crops reward his industry, in proportion to the intelligence and skill with which he aids the forces of nature to perfect their and his work.

CHAPTER XXXVIII.

THE FUNCTIONS OF THE FLOWER.

The flowers, or the blossoms, are the reproductive parts of a plant and contain the fructifying organs. They are not specially constructed but are simply altered branches; and the several parts are altered leaves. That is to say, that certain buds, which might have grown into and produced branches with leaves, under certain circumstances and for a special purpose become developed into blossoms. At an early stage of the growth of these buds it is impossible to say whether they will develop into a branch or a flower.

The parts of a flower are the stem; the calyx or leaves which enfold the petals; the petals; the stamens; and the pistils. In some flowers these change into each other, there is no distinctly fixed line between them, and sometimes the whole flower consists only of a cluster of leaves, as in the green roses which are grown as a curiosity in some gardens.

The principal parts of the flower so far as they relate to our subject, are the reproductive portions, which are concerned in the growth and perfection of the seeds. These are the stamens and pistils. It is not the purpose to give a complete botanical description of these organs; this can be learned by reference to any hand book of botany; but an explanation of their nature and relations to each other, and to the development of the seed, will be of interest and value in removing some popular errors in respect to the reproduction of species and in aiding the farmer in many ways to make the culture of his crops successful and profitable.

The reproductive organs of plants have a very close analogy to those of animals. They are male and female, and the relation of these to each other, and of the latter to the production of fruit or the reproductive germ, bear a close resemblance to those among animals.

THE STAMENS are the male organs, and in the normally constructed flower surround the pistil which is the female organ and is connected with an ovary in which the fecundated germ develops into a perfect fruit, or as it is commonly called, a seed.

A flower of the normal kind has both stamens and pistils and is called perfect. Such a flower is the blossom of the apple or cherry, and of wheat and rye. When a flower has only stamens and no pistils, or only pistils and no stamens, it is called imperfect; the former is called a *staminate* or *sterile* flower; and the latter a *pistillate* or *fertile* flower. The corn plant gives an instance of these kinds of flowers; the tassel being the *staminate* or male flower; the silk being the ~~pistils~~ pistils which proceed from the *pistillate* or female flowers which are carried on the cob which is the stem. Sometimes these imperfect flowers are borne upon different plants, and not the same individual, as in the case of some varieties of strawberry; the hemp; hop; in which one plant has only *staminate* flowers, and other plants only *pistillate* flowers. Such plants are called *diœcious* (meaning in two households or families). These plants, such as corn, castor oil, and the chestnut tree which bear both kinds of flowers upon the same stem, are called *monœcious*, meaning in one household or family.

This distinction is important to farmers for it is necessary in growing such plants to distribute a certain number of male or *staminate* plants, among the *pistillate* or female plants, for the purpose of impregnation and fertilization; just as he would mix a certain number of rams among a flock of ewes for the same purpose.

The stamen consists of two parts, the *filament* and the *anther*.

THE FILAMENT is the stalk or support of the anther; the anther is the essential part of the stamen. It is a sort of case which is filled with a fine powder or dust called pollen. This pollen is the fertilizing agent of the flower. It is usually of a yellow color and is so abundantly produced that it impregnates the air over a wide space, and is carried

on the winds to considerable distances. It is sometimes seen covering the shores of lakes after heavy showers which wash it down from the air, and has been thought to be sulphur produced by the lightning, by persons not acquainted with its character and origin. A field of evergreen sweet corn grown by the author, half a mile from any other corn field, and with a large piece of woods intervening, was so much fertilized by the pollen from this distant field as to have been spoiled for seed.

The pollen of various plants differ so much in appearance when examined under a microscope as to be easily recognized as belonging to its special plant. The minute grains of it are thus exceedingly interesting objects for microscopical study. These grains of pollen vary in shape; some are round; some oval; some angular and many sided; some triangular; others double; treble; and in other ways are exceedingly diversified. They are made up of two coats, the inner one being filled with a fluid of a thickish consistence, in which are mixed a great number of minute grains.

THE PISTIL is made up of an *ovary*, a *style*, and a *stigma*. The ovary and the stigma are the most essential parts; the style being the stalk which holds up the stigma, and the connecting channel between the two. The ovary is the receptacle for the *ovules* or embryo seeds, which adhere to the inner sides of the cell or cells, as may be seen in the pea; the ovary or pod of which contains the seeds arranged along its length and attached to the side of it. The ovules, consist of a mass of pulpy tissue called the *nucleus* and are covered by one or two coats.

The embryo is formed in the nucleus, and the coats become the coverings or skin of the seed. There is an opening through the coats of the ovary near where the apex of the ovules is situated, and an orifice in the ovule which corresponds with it.

FRUCTIFICATION, or the process of impregnating or vitalizing the seed, is the final function of the flower; and is effected as follows. When the flower is ripe for the performance of this function, the anther bursts and the pollen

grains escape. They either fall upon the adjacent stigma; or are carried to it by insects, to whom the pollen grains adhere by their points or their viscosity, and who are in pursuit of honey. Or they are blown by the winds and fall upon the stigma, and adhere to it by means of a viscid fluid which exudes from it.

The grain of pollen which falls upon the stigma immediately begins a process of growth. It sends out a prolongation of its inner coat, which is extremely thin and delicate, into the soft substance of the stigma, and through the interior of the style into the ovary; just as the slender rootlet from a seed sinks into the soil. It then penetrates the orifice of the ovule, and reaches the embryo, when it discharges a portion of the soft pulpy mass which becomes the germ of the embryo.

THE GERM consists of a vesicle or cell, which has a very delicate membranous coat or envelope in which there are a small quantity of mucilaginous fluid, some minute grains, and a soft pulpy mass called the nucleus.

Thus we have now traced the whole process of plant growth, and the structural development from its original cell to the final accomplishment of its purpose, which is seen to be the reproduction of this original cell, enormously increased in number; some plants producing many millions of seeds and such cells. And we have returned to this rudimentary cell, with its albuminous germ imbedded in the starch, which is formed in the substance of the seed, as will be explained in the following chapter.

It may be asked, however, at this point, how and by what general natural provision the perpetuation of species is effected; and how a destructive mixture of kinds is avoided when this diffusion of pollen is so general in the atmosphere. Just here we are met with the common natural law which provides that different species cannot mingle, and that the foreign pollen shall be inert and unproductive. Thus the pollen from a pear tree may fall upon the flowers of an apple tree to any extent, but there is no reciprocal relation or action between them; the foreign pollen grains

meeting with no affinity, dry up and perish. This law gives us an example of the wondrously perfect adaptation of means to ends in nature. It may be a growth of long continued selection and natural variation of plants by which one species has become differentiated from another so much, that no reproductive relations can exist or take place between them. It may be an example and proof of design in creation, and the result of the most perfect wisdom and creative power. In either case the power and wisdom which promulgated and which enforces the law of selection and gradual evolution of peculiarities, and the fixity of type from a single germ; and that which might create and maintain each distinct variation, are equal in every respect; for it is impossible to have considered the amazing fitness and beauty and perfect adaptation which mark the various process by which a plant is produced from its elements, and made to minister to the welfare and happiness of mankind, without being impressed with the belief that these things did not happen by accident, and are not self created; but are the result of a wise and beneficent power whose existence and action we cannot comprehend; and which is equally worthy of our veneration and regard, whether it emanates from some supreme creator, or is the result of some force that has been set in action by some grand controlling influence which pervades the universe. The power and wisdom behind these natural laws is the same from whatever source they may spring.

CHAPTER XXXIX.

THE FRUIT; ITS FORMATION AND ITS CHARACTERISTICS.

During the formation of the fruit, which begins to be effected when the bud first opens into a flower, several important chemical changes occur in the plant. As the formation of a seed is the grand climax of the process of plant growth, and is a return to the point from which the plant first started; so we find the chemical action which controls the various changes in the plant, to return to its point of departure and complete a circle of results.

The germination of a seed is accompanied by the change of starch into gum and sugar, and the growth of the plant is due to the change of these into woody fiber; the blossoming of the plant being a period when these changes are the most active. The sap of the maple tree, becomes less sweet when the flowers begin to appear and the sugar in the beet root and the sugar cane is less abundant when these plants begin to blossom.

Thus the maturity of a plant is marked by a reversed chemical action; and whereas in its earliest stages starch was converted into sugar, at its mature period sugar is converted into starch which is concentrated in the fruit, and stored up for the nutriment of the germ when it is in its turn awakened into life and action in the soil.

The husk or envelope of the future seed, of wheat or corn for instance, is at first filled with a milky liquid which gradually becomes more sweet and dense, and finally consolidates into a mass of starch and gluten. This process of ripening the seed is exactly the reverse of that of the germination of it; and it is a curious fact that while we can perform the same operation of changing woody fiber and starch into sugar and sugar into acid, we cannot convert acid into sugar nor sugar back to starch or woody fiber. This is a process of nature which we cannot imitate, and

consequently cannot explain, as we can the converse change of woody fiber into starch and starch into sugar.

The term seed is agricultural, botanically the seed is the fruit; and what is commonly called a fruit is the receptacle of the seed. Thus a melon or an apple is the receptacle in which the seeds and fruit are contained; a strawberry is a fleshy receptacle upon which the fruit or seeds are implanted. Here however the popular meaning is given to these terms and fruits and seeds are understood in the common use of the words.

The seeds of a plant, as we have seen, consist of a mass of starch cells enclosed in a husk, and in which is imbedded the germ with its nitrogenous gluten surrounding it. These starch cells are enclosed in several envelopes; a grain of wheat having three distinct coats differing in character; the inner ones containing potash, gluten, and phosphoric acid, in larger proportion than any other part of the seed. Some of the grains have husks which contain a large quantity of silica; oats for instance having 46 per cent. of silica in the ash; and the ash of millet containing $52\frac{1}{2}$ per cent. of this mineral.

During the process of ripening of the seed this excessive deposit of silica is most remarkable in the stem. As an important function of the stem is the support of the seeds, this deposit of silica in it is necessary to strengthen it and enable it to sustain the comparatively heavy weight of the seeds. But this large deposit of earthy matter is an important consideration to the farmer whose business it is to produce as much nutriment in his fodder crops for the subsistence of his animals as he can, and as silica is of no use in the alimentation of animals, its presence in the fodder is not desirable.

Young grass contains only as much silica as makes up 10.3 per cent. of its ash; while the ash of the ripened hay has 63 per cent. of it; the potash in it amounts to only 7 per cent. against 56 per cent. in the ash of the young grass. This change in the composition of vegetable tissue affects all plants; for as the starch and gluten are stored up in the

seeds, and the stem is strengthened by the deposit of mineral matter in it, it follows that the woody fiber and the ash of the stems are increased, not only directly, but relatively by the decrease of starch sugar and albumen.

The ripening of fruit which is a process closely related to the ripening of the seeds, is accompanied by an equally considerable and interesting change. This change is more intelligible than that which occurs in the ripening of seeds, because it is one that can be produced by the chemist, and its process and results represented by figures.

The common fruits, the apple, pear, plum, grape, etc., in their immature stage, are tasteless and consist almost wholly of woody fiber, filled with flavorless sap and tinged with the green coloring matter of the leaf—chlorophyll. The young fruit at this time performs some of the functions of the leaf; absorbing carbonic acid and giving off oxygen; and thus gathering carbon from the atmosphere and building up cellular tissue of this carbon and the water which it receives from the roots. After a time the fruit becomes sour by the formation of acid in it, and the acid gradually increases. While this acid is increasing, less oxygen is given off than before. The process by which the fruit acids and fruit sugar are produced may be explained as follows. Tartaric acid (the acid of grapes) is represented by the formula $C_4 H_4 O_5$; or 4 equivalents of carbon; 4 of hydrogen and 5 of oxygen. This acid may be formed in the fruit in two ways: either from the carbonic acid absorbed by the grape, and water, with the exhalation of oxygen; or from the gum and sugar always in the sap by the absorption of oxygen from the atmosphere. Thus

To produce this acid then, the vines may absorb carbonic acid from the atmosphere, combine it with the water of the sap and throw off into the sunshine the residue of oxygen. And as we know that all these processes do go on in plants, it is reasonable to assume that this result is due to them.

By another change which is quite as simple, but not necessary to explain, grape sugar or the sugar of fruits may be changed into tartaric acid by the absorption of oxygen and the escape of water. The malic acid of the apple, and the pear, and other fruits, may be formed in precisely the same ways; and it differs from the former acid only in having one equivalent less of oxygen in its composition.

When the seed is ripe the functions of the animal plants of which the common farm crops consist, are discharged. The absorption and decomposition of carbonic acid by the leaves, and the supply of nutriment to these are no longer required, for their growth is completed. The leaves therefore begin to absorb oxygen, and decompose; lose their green color and turn yellow; and prepare to return to their original elementary substances of which they were at first compounded.

Perennial plants however have a further function to perform. A supply of food has been deposited in the seeds for the sustenance of the germs which may spring from them, and in the buds which have been formed to begin the growth of another year. When the leaves have ripened and wither and fall, the sap which has circulated through them is converted into woody fiber and starch. In some plants this starch is stored up in the stems, as in the potato; the tubers of which are but thickened stems and the eyes merely buds; the starch being intended for the nutrition of the buds when they shall start into growth to renew the plants. The woody fiber of trees is deposited between the bark and the wood of the stem, to form the annual layer by which the tree increases in bulk. This layer of new wood however is deposited only under the bark and around the stem and consequently the stem increases only in thickness, and never in

length; the only way in which the growth of a perennial plant is elongated being at the extremities of the branches and from the terminal buds. Then the work of the year being finished, vegetation rests and slumbers until the renewed warmth of the sun in the returning spring awakens it, and life once more starts into full and vigorous action.

The seed, we have seen, bears a specific character. It is the product of a plant having marked and special characteristics and habits. Plants of the same species always produce like seeds, and their seeds produce always—within slight variations—the same kinds of plants in every respect. A wheat plant always produces wheat; the seed may vary to some slight extent, but it is wheat, and never barley, oats, or corn. And a grain of wheat always produces a wheat plant, and never oats or any other plant. Thus the common belief that under some unfavorable circumstances a wheat seed may produce a plant of chess, or a wheat plant may change to a chess plant, which is an entirely distinct and different species, is as impossible as that a cow under unfavorable circumstances might change into or produce a sheep or a rabbit. It is fortunate that the increase and spread of accurate knowledge and of intelligence among farmers is such, that these and other delusions are fast disappearing; for they mislead and confuse farmers in their work, and induce them to suppose that freaks of nature are responsible for the results of their own mismanagement, and that the poor yields of crops may be caused by circumstances beyond their control. To some extent this may be true; but it is equally true that the well managed crops grown by intelligent and careful farmers never, or rarely, suffer in the ways which those of the careless unskillful and ignorant farmer do; and that the rigors of the season are destructive mostly to the crops ill put in; in poor soil; and in defiance of all the best methods of culture. The cultivation of farm crops is successful only when it is carried on under rules and practices based upon the laws and facts hereinbefore described and explained; and when it is thus carried on its results are as certain as those of natural laws in other re-

spects; as those of gravitation; and of heat and of other chemical action; and of those physical laws which regulate all matter. The processes of vegetable growth can all be explained as subject to these natural laws, which are unchangeable; omnipotent; and eternal; as the great source from which they received their first impulse.

CHAPTER XL.

THE IMPROVEMENT OF PLANTS BY BREEDING
OR CROSSING.

The increase of varieties by natural or artificial means, is one of the most important methods by which improvement in the culture of farm crops has been effected. As regards farm animals this course of improvement has been most effective in increasing the value of live stock and in adding vast wealth to the world. The original stock of cattle, horses, sheep, and swine, were very different both in variety and character from the present improved kinds, which far surpass in usefulness and value the ancient types. This improvement is largely due to the system of crossing by which the better qualities of two races are united and combined; while the inferior characteristics of each are neutralized or bred out. Thus large bony animals being crossed with more compact, fine boned, fleshy ones, have produced equally large progeny with equally fine bone and heavy flesh; and it has been in this way that the magnificent short horn breed of cattle; the splendid horses; the most useful sheep and swine, have been gradually developed from inferior stock.

As there is a close analogy between the nature of animal life and that of vegetable life in other respects, this similarity also exists in this respect; and a similar course of improvement which has been carried on during many years of intelligent and careful study and labor, and which has in some cases been aided by unlooked for accidents, has resulted in the most important and valuable results. All our farm crops, vegetables and fruits, have been greatly improved in this way, and the course of improvement is now broader and more rapid and effective than it has ever been before, thanks to the wide spread of knowledge among cultivators of the soil, and the large development of enterprise and genius which has been due to this increase of intelligence.

The breeding of plants is as nearly alike to the same process among animals, as the physical characters of plants and animals approach in similarity.

It has been shown how nearly alike in principle the reproductive processes are; and it is quite evident that these are as amenable to control and direction in one case as in the other. A study of these principles and their relation to the growth of plants will enable any farmer or gardener to turn them to his own advantage in the improvement of the varieties of the plants which he cultivates. During a few years past a large number of farmers have been working in this direction, and hundreds of new kinds of potatoes; tomatoes; corn; wheat; oats; barley; roots; and several other valuable agricultural plants have been introduced. The early rose potato is one instance of this improvement, and the actual money value of the benefit thus accruing to the farmers from this one variety is certainly more than one hundred million dollars. Several varieties of wheat, the Clawson; the Fultz; the Schumacker; and others have been equally valuable; and the same is true of other crop plants.

It has been explained that the fertilizing influence exists in the pollen of the plants which is contained in the anthers upon the summit of the stamens. That this pollen is scattered by various methods, some direct and some indirect, so as to reach the receptive stigmas upon the pistils. As a rule, the stamens are so placed, that their pollen cannot easily reach the pistils of the same plant; hence a sort of natural crossing between unrelated organs is secured. But nature never does all for mankind. Man was given dominion over nature; and to secure the most benefit from her work he must control and direct it. Nature secures some method of reproduction and avoids extinction, but it is with enormous waste of effort and resources. By cultivating the soil and planting and saving seeds, man avoids these wastes; and by controlling the fecundation of the plants, he can avoid natural or accidental deterioration and secure improvement. The accidental processes of nature in this direction by means of winds and of insects, are insufficient for our purpose; and

so farmers in their methods of planting, endeavor to direct the fertilization of their crops as far as they can in a general manner.

No improvement, however that is at all satisfactory, can be reached in this way; and so the operation of crossing, by using the pollen of one variety of plant to fertilize the pistils of another kind, is practiced.

This is done in the following manner.

Some plants, as has been described, have their stamens and pistils borne by different individuals. Strawberries and hops, are examples of this kind. With these it is a very easy matter to effect a cross fertilization. All that is required is to protect the pistillate plants from the reach of any pollen but that which is used in the operation; and by taking flowers of the staminate kind, at the time when the pollen is ripe and is being shed, and when the pistils are in a receptive condition, and scattering the pollen over these. This is all that is required to produce a new variety which may differ from each of the parents in a marked degree, and yet possess the better characteristics of each.

We say *may* differ; because while the probability is that there will be a difference, yet the tendency of reversion to inferior types is so strong in nature that of ten thousand seedlings not one may be any improvement upon the parents, and yet every one may differ in some respect. At the same time there may be some valuable distinct and new kind which may be worth all the trouble that has been expended upon the remainder. This has been the case in every instance, and yet the few valuable results which have been gained, have enormously overpaid for the aggregate effort.

When perfect flowers are subjected to the operation of crossing, a more difficult process is required. The anthers from the selected flower are cut off as soon as they appear by means of a slender pair of scissors; and the end of the branch with the flower, is covered with a bag of fine gauze of linen or silk, to protect it from pollen other than that which is desired. The flowers chosen for their pollen are gathered when in the right condition and brought to the

selected one; the pollen is carefully taken from the anthers upon a soft camels hair brush, and is placed upon the receptive stigmas; the flower being then covered as before. If the pollen is received the pistils soon begin to wither and the ovaries swell; showing that the ovules have been fecundated.

There are other cases in which a still more careful operation is required. Some plants are self fertilizing, and cannot be crossed with the pollen of other plants even naturally. Wheat is such a plant; hence it is impossible for varieties to change excepting by what is known as "sporting." To cross wheats then, it is necessary to proceed as follows. Before the flowers open and the anthers appear, the glumes or coverings of the buds, which answer to the calyx of other flowers, are carefully opened or removed; and the organs of the flowers are exposed. The anthers are then cut off as above mentioned, and the pistils are fertilized with the chosen pollen communicated as before described. The ear of the plant is then enveloped in a protecting covering of fine gauze, and the operation is complete. Most important results have been reached in this way and the field for experiment is boundless.

In crossing corn all that is necessary is to grow some plants in a plot by themselves; to remove the tassels as soon as they appear; and to protect the silk by gauze coverings. When the silk is in the right condition, the mature tassels from the desired plants are shaken over the silks to scatter the pollen upon them, by which the fertilization is effected. This operation should be repeated daily until it is seen that the silk has received and absorbed the pollen, which is shown by its withering and drying up.

In regard to the fertilizing of corn by the natural process a very important point might here be mentioned. This is the crossing by an imperfect plant. A perfect plant of corn is one that has both kinds of flowers; that is, a tassel, and an ear and silk. Such a plant is productive. But in a field of corn there are a large number of stalks which do not produce an ear, and have the tassel or staminate flow-

ers only. These are unproductive; and as their presence is of no benefit in supplying pollen to other plants, and as their influence upon other plants is injurious as it tends to the reproduction of their own kind, and is detrimental to the seed produced, it is advisable to emasculate them, as a stock breeder would do with his inferior male animals, by cutting off the tassels as soon as they appear and before they can shed any of their pollen.

In practicing this method of improving seed one more point should be noticed. This is to procure the very best development of the parent plants by selecting the best samples of seed, and by giving them the highest possible cultivation. This is analogous to the high feeding of those breeding animals which are selected for their excellent natural qualities for the improvement of their races. Plants are affected in this way precisely as animals are. "Like produces like" among plants and animals alike; and in the improvement among vegetable species the principles which govern the breeding of animals should prevail.

Pedigree is the development of peculiarities by the continuous selection of parents. Plants are subject to this development to the fullest extent, and a most remarkable improvement has been effected in many of the plants grown for farm crops by the continuous selection of the best seeds from the best plants. This principle is not new by any means. It was expressed many centuries ago by Virgil who in effect says: "Unless the largest and best seed is carefully culled out by hand the plants will degenerate." This is the invariable experience of farmers at the present time who realize to the fullest extent that "as they sow, so do they also reap."

There have been some remarkable instances of the beneficial results of this breeding of seeds. Wheat has been increased in size of ear from 3 to 9 inches in length; and in yield from 30 grains per ear to more than 100. The weight of the grain has been increased up to 66 lbs. per bushel, and the yield per acre from 30 to 70 bushels. Corn has been gradually brought to bear more ears upon the stalk, from two to seven; and to enlarge the product up to 125

bushels of grain to the acre. Oats have also been equally improved up to a weight of 50 lbs. to the bushel, the growth of mangels has been brought up to a weight of 60 or 70 lbs. to the root, and a yield of 120 tons per acre. The improvement of farm and garden vegetables has been equally conspicuous, while the success of the florists has been most remarkable in the improvement of flowering plants

This selection of seed is one of the secrets of the successful growth of crops by the best farmers who know how to avail themselves of it and to profit by it. But it is to be done with judgment. The effects of climate are to be considered. Some crops succeed best in a cool climate; others in a warmer one. Oats reach a weight of 55 lbs. the measured bushel in Scotland and Ireland where a long cool season of growth favors the development of the plant. Potatoes yield 600 bushels per acre under ordinary cultivation in the mountain region of North Carolina and Tennessee; while in Nova Scotia the yield is but little less. Wheat reaches a weight of 66 lbs. to the bushel in Dakota, and contains a much larger quantity of gluten than the average. Hence seed that is brought from these localities reproduce their peculiarities elsewhere, and continue to do so for some time; the continuance being proportionate to the care given to the cultivation of the crop—until the influence of climate prevails or by persistence a new and better type is fixed.

All these considerations are of great importance. They show how man by intelligent direction can change natural forces to a large extent for his own advantage. And it is an encouraging fact, to impel effort in this direction, that it is the destiny of mankind to possess the earth; to have dominion over the soil of it and all its products; and to replenish it and develop all its possibilities by the best cultivation of its products as far as his physical power and his intelligence permit him.

The term "sporting" has been used in reference to the self variation of wheat, upon a previous page. This term is used to express a natural variation from the original type without any apparent cause; a sportive fancy of the plant.

as it may be said, or an accidental departure from the regular course.

This accidental occurrence is taken advantage of to reproduce the variation by such a process as will fix the new type and preserve its peculiarities. A great many such cases have occurred. Most of our valuable fruits have thus originated; many varieties of grains have been produced in this way and have been fortunately preserved by the observant farmers who have noticed the departure from the regular course of growth. The well known late rose potato was thus originated from a cutting of early rose; which remained green long after the other plants of the crop had ripened. A notable case recently occurred with a new and strange rose, which appeared upon a branch of an old kind, and which was so admirable in form and color as to strike the notice of the florist in whose green houses it appeared. The branch was divided into cuttings and propagated with the result of a profit of several thousand dollars in two or three years.

So many fortunate prizes have been discovered in this manner that the farmer who is constantly observing what is going on around him, can scarcely fail to find something, in some way, that will be of interest or value to him. And he who is the most thoroughly versed in all the fundamental knowledge of his business, and understands the principles upon which his work is based the best, will be most likely to secure his share of these prizes which the grand lottery of nature offers to those who take a share in it.

PART SIXTH.

CHAPTER XLI.

THE CULTURE OF FARM CROPS.

The previous chapters have been devoted to the explanation of the principles upon which the culture of farm crops depends. This knowledge is indispensable to successful practice in farming, and throws a flood of light upon the otherwise mysterious operations of nature, as we meet with them in farm work. The reader who has followed us through the previous chapters will now be prepared for the discussion of the practical questions which arise in the daily labors in the field; and we now take up the subject of the culture of farm crops in its practical bearings, applying to it the principles which have been heretofore explained.

When a farmer has worked his land for a number of years, he finds the richest soils to gradually decline in productiveness; to become worn out and exhausted in fact; and he will not be surprised by this, after having read and studied what has been said in regard to the nature of the soil and of plant growth, and the relations of these to each other.

Continuous cropping removes from the soil—as has been shown—a very large quantity of its soluble fertile constituents; and in time, takes from it the available plant food which has accumulated during a very long period; we know not how many centuries or ages, of gradual storing up of this available fertility; and brings it back again to its original condition when the mineral elements of the soil and the atmosphere, were the only sources from which plants could derive materials of which to form their substance. The continuous growth of such crops as wheat and corn, year after year, very soon carries off the available plant food and brings the land to this impoverished condition. But under

the best culture, and with the most economical practice in regard to feeding stock and using the manure, the natural resources of the land are so well husbanded that the soil may be kept in a condition of fertility, quite equal to that when the farmer first took possession of it. It is the business of the conservative and skillful farmer to thus preserve these resources from waste, by the practice of the most thorough tillage; by the use of manures made upon the farm; and such artificial fertilizers as can be procured in the markets.

A few years ago, when the rich virgin soils of the west were first opened to settlement and yielded enormous crops, the early farmers who had been used to the comparatively sterile soils of New England, which had been wholly exhausted of all their available fertility by a wasteful system of agriculture, perceiving the surprising richness of the newly broken land, thought there would be no end to its productiveness; and ridiculed the cautions and suggestions of experienced persons who foresaw that the universal laws of nature could not be violated without producing the inevitable results, and that the burning of straw; the repeated crops of wheat and corn; the removal of all the produce from the land; and the waste of such manure as was made by the feeding of the working cattle and the cows which were the only animals kept on the farms; must certainly end in the wearing out and exhaustion of the soil. These farmers now experience the very same results which happened in their former homes, and which must occur everywhere. They have learned that there is a limit to the productiveness of the richest soils; and that the end is reached in time as certainly as the seasons roll around, and the years come to an end.

But even now, the very same unwise course of continuous cropping of the land, and the repeated growth of grain crops is practiced in spite of past experience; and we may well repeat the warning, that but a few years will elapse—and all the fewer as the culture is more perfect—before partial sterility will take the place of virgin fertility, and the

soil be reduced to its primitive condition when it was without any accumulated stores of available plant food. This term "available," perhaps needs a word of explanation, lest it may be misunderstood.

If a man possesses a sum of money in coin or current funds, it is available for the purpose of trade. He can purchase food; clothing; houses; lands; and any other property with it, without any difficulty. If he should invest his funds in such property that is readily salable, his means are still available; and he can turn his possessions into money again, with ease. But if he spends his money foolishly; buying property which is not desirable; as for instance tracts of land far beyond the boundaries of settlement; his means are used up and are not available; he can neither sell the property, nor borrow upon it; and if he needs money for his present uses, he will find himself as poor as the ragged vagrant who begs food from door to door.

Just so in regard to the fertility of the land. The farmer grows crops and takes from the soil a certain quantity of plant food; this plant food was available; and the plants could take what they wanted of it. In time, by an exhaustive process of culture, all this ready formed soluble matter is used up; spent; and gone; and the soil is left, still containing thousands of pounds of the same kind of matter, but it cannot be reached by the plants, because it is not soluble, excepting to a very small extent. All this plant food; the nitrogen of the atmosphere and of inert organic substance in the soil; and the various mineral matter of the soil; all these are in existence, but are not available and the plants starve upon the soil with all this unavailable food in it.

For the profitable culture of farm crops, therefore, the farmer must see to it that the fertility of the soil is kept in an available condition; that as it is drawn upon by the crops, it is replaced by the application of manure; and that fresh supplies are brought forth from the soil by thorough tillage with the most effective implements.

CHAPTER XLII.

IMPLEMENTS OF TILLAGE.

No man can work without tools; and to do the best work, the best implements are required. In a work of this character, upon "The Culture of Farm Crops," some reference to the best implements for preparing the land, and for securing by their right use, all the benefits which accrue from the operations of the natural laws which have been explained in previous chapters, should not be missed.

Plowing is the first work in the culture of crops; for the land must thus be prepared for the seed. After plowing, follows harrowing; an equally important work; and in some respects of greater significance in regard to the culture of the soil. With these two implements, every kind of soil that is dry enough for tillage may be thoroughly well fitted for the seed and for the growth of crops.

A plow is constructed upon certain scientific principles, and much study has been given by the best mechanics and inventors to the perfection of these implements. Its purpose is to cut a slice of the soil, raise it, and turn it over; either partly so as to stand on edge in a sloping direction; or completely so that the earth is reversed in position. The former method is that mostly used in ordinary farm work, and for all the purposes of preparing land for seed is quite sufficient, and we think preferable to the other in every respect. To effect this purpose the plow is provided with a pointed and edged share to cut the slice of earth; and with a curved mold-board to lift and turn it. The share is thus necessarily made in the form of a wedge, and the mold-board in the form of a section of a cylinder, or of a cone. As the share cuts the furrow slice loose from the solid ground, it lifts it so that it passes on to the mold-board, which further lifts it, and at the same time by means of the curved surface, turns it over and deposits it on its edge; pressing it close and compactly against the previously turned soil.

It is quite easy to follow this action of the plow, in the mind; and as the farmer follows his plow in the field and watches the furrow slice turn and fall into its place, he can very readily perceive why the plow is formed in this manner and how it completes its purpose. But this is not all. It is the mere beginning of the knowledge of the plow; for the farmer himself has to guide it; to hold it to its work, and to handle it so that its proper purpose is made effective. A vast amount of poor plowing is done, and although American plows are the best and the most easily handled of any, yet as a rule, the average plowing is a wretched piece of work, and quite sufficient to explain why the American farmer produces smaller crops than any other civilized farmer; and this, notwithstanding our excellent climate and fertile soils.

To do good work, the plow should be attached to the traces so that the sole rests on a line which meets just behind the point of the share, with another line which is a continuation of the line of draft as shown by the direction of the traces. If this latter line touches the line of the sole of the plow too far behind the share, the plow will run too deeply; if the point of intersection of the two lines is ahead of the point of the share, the plow will run too shallow, or out of the ground; and the plowman will have to raise the handles to keep the plow down to its work. In either case the plow will not run right, and the labor of plowing will be increased. So that the first thing to be looked to in using a plow is to fit the draft right.

The draft being properly regulated, it will run evenly except so far as the inequalities of the soil and any obstacles it may meet with, as stones; hard clods; or previously ill-plowed parts of the land. It is very rare indeed that these interferences do not exist in any field; and where they do, special pains must be taken to remove or overcome them. The plow must be run at an even depth, the furrow must be of even width; and the furrow slices must lie over at the same inclination; before the land can be said to be well plowed. If the relation of the condition of the soil to the

growth of plants, as previously explained, is remembered or recalled, it will be realized how very important it is that the plowing should be perfectly well performed so that the next operation of harrowing may be equally well done.

The harrow, up to a recent period, has been a most imperfect implement, chiefly because its purpose in the culture of farm crops has not been understood. It has been supposed when a farmer has thought at all about it, that the harrow was used to smooth the surface and level the ridges left by the plow. In effect it has been mostly used to cover up and hide the bad work of the plow, and to put a superficial smoothness upon the soil, leaving the under portion in an exceedingly unfavorable condition for the growth of plants. But during some years past the attention of agricultural mechanics and inventors of improved machinery has been turned towards the improvement of this implement; and after many disappointments and failures, something like perfection, if not perfection, has been reached. The first great improvement was the sloping tooth, which smoothed the soil and pressed it down; without tearing up the debris of the previous crop or the manure which had been covered by the plow. The next improvement was the coulter harrow; which cut the furrow slices and broke them up. But the spike tooth harrow, and its more recent relative the spring tooth harrow, differing nothing in principle, but both mere scratchers of the surface still furnished the majority of the implements which were in use.

The Acme pulverizing harrow, one of the happiest inventions which mechanics has bestowed upon agriculture, was introduced about 8 years ago. It was the invention of a well known agricultural mechanic, Mr. Nishwitz; who gradually improved his first designs until at last the most perfect implement of its kind was produced. This harrow consists of a smoothing and leveling bar, which is provided with a set of (10) flat crushing teeth and ten curved coulters sloping backward, so that the ridges on the surface are leveled and smoothed and clods are crushed. In the rear of this leveling and smoothing bar, is another bar which is

provided with ten more cutting coulters, very much like the long narrow mold-board of a plow. These are curved in a direction contrary to the ten on the front bar and are sloped behind so that they crush and cut the furrow slices, already smoothed and leveled and pulverized on the surface, to a considerable depth; the depth being regulated at the will of the driver; who may if he desires, add his own weight to this effect by riding on the harrow on a spring seat provided for this purpose. These cutting coulters not only dissect the furrow slices, but turn over the pulverized soil, by means of the curve of their blades, which are in effect so many small plows. There are 20 of these cutting blades which altogether take up 6 feet of space; thus covering one thirty-fifth of a square acre per every 210 feet passed over. It thus performs its work very rapidly, as well as in the most thorough manner, by pulverizing the soil; crushing the clods; leveling the ridges; and fitting the ground perfectly for the reception of the seed. Indeed from the authors personal experience in the use of this harrow for several years past he has found it to be a most effective seed coverer, replacing the seed drill perfectly; leaving a covering of firm mellow soil of 2 inches over the seed; and compacting this pulverized earth over and about the seed in precisely the manner required for its perfect germination, and the vigorous growth of the young plants. This use is quite beyond its claimed purposes, but it shows that while this implement is called a harrow, and does all that any other harrow can do, or has ever done, it does much more; and in some cases does the work of a plow, and in all cases does the work of a clod crusher, and smoother, and a roller as well. In short, it answers perfectly all the purposes of the farmer in fitting the plowed soil for the germination of the seed, and conforms in every respect to the requirements which have been so emphatically pointed out in previous chapters, for the most effective consummation of the natural laws which control the relations of the soil to plant growth; the principal one of which is the thorough pulverization of the soil.

CHAPTER XLIII.

THE ROTATION OF CROPS.

It is not impossible to grow the same crop year after year, upon the same land successfully. Permanent meadows are instances of this kind of continuous culture. But it is necessary to fertilize the soil in such a way as to restore precisely what the crops have withdrawn from it. This continuous culture however is not practicable in ordinary farming, although it has been shown by Sir J. B. Lawes on his experimental farm at Rothamstead in England, that forty continuous crops of wheat, barley, or roots, can be grown in as many years, by the use of suitable manures or fertilizers and without any diminution in the yield.

In ordinary farming it has been found that when the same crop is grown consecutively for a number of years upon the same land, the product gradually decreases until it no longer pays the farmer for his labor. But he finds that although one crop, such as wheat, begins to fail the second or third year, some other crop, as corn, potatoes, turnips, clover, or grass, will thrive; and that a succession of these may be grown in a number of years without any deterioration. And not only is this found to be the case in regard to farm crops, but we find it to be the case in the natural growth of the land; for when a forest of hard woods is cut down, and the land is left to grow up with trees again, the new growth consists of evergreens; and on the other hand when a pine forest is cut down, oaks, poplars, and other deciduous trees take the place of it. The reason for this change of product is not difficult to perceive. When we consider the nature of each growth we see that each kind differs remarkably. For instance, in the following table we give the analyses of leaves, wood, and bark, of the two kinds of trees which thus follow each other; and it is easy to see why one kind follows the other and not its own kind.

COMPOSITION OF THE ASH OF

Leaves of Walnut.....	Potash, 42.7 per cent.	Silica, 1.2 per cent.
“ Pine	“ 1.5 “	“ 70.1 “
Wood of Elm.....	“ 24.1 “	“ 6.2 “
“ Pine	“ 6.8 “	“ 15.9 “
Bark of Linden.....	“ 16.1 “	“ 2.3 “
“ Balsam fir.....	“ 3.0 “	“ 31.1 “

This striking difference prevails through the whole list of hard and soft woods.

Evergreen trees require a large quantity of silica, and in gathering this from the soil, separate it from its combinations with potash, lime, and magnesia; leaving these in the soil in an available condition to accumulate in excess of the requirements of the then growing trees. When in course of time, the lumberer, or the farmer, or the accidental conflagration, removes the pines from the land, a forest of hard woods soon takes their place; and *vice versa*; when the hard woods have taken up the potash and lime, and have left a large accumulation of silica, and they perish, or they are cut off in their prime, the evergreens succeed them.

Precisely a similar occurrence takes place in the growth of farm crops. If the table given in a preceding chapter (Chap. XVI, page 100) is referred to, it will be seen how a crop of wheat, in the straw, takes much silica and little potash from the soil; while red clover takes more than three times as much potash; $8\frac{1}{2}$ times as much lime; and only a twentieth as much silica as the wheat. But more than this, that as a large quantity of the red clover consists of roots and stubbles, and these are left in the soil, a considerable quantity of nitrogen, potash, and lime, are thus accumulated after a crop of clover has been removed; and the stubble has been plowed under; and these furnish precisely the kind of food which will contribute to the needs of a crop of wheat. Moreover, clover is a deep rooted plant, and finds its food far below the reach of the shallow rooted wheat; so that the clover brings up to the surface a large quantity of plant food, and leaves it there, just where the wheat can find it. Hence it is that an abundant wheat crop follows clover; and a crop of clover plowed under is the very best prepara-

tion for wheat. The same facts apply to peas and beans, and explain the advantages which follow the growth of wheat after these crops.

But another point is to be considered. We have dwelt often and particularly upon the necessity for thorough culture of the soil; the effect of the atmosphere; of moisture; and of heat; and the oxidizing and nitrifying effects of porous soils upon organic substances contained in them. Hence it is a great advantage for the farmer to grow crops which require cultivation in alternation with other crops; both for the purpose of destroying the weeds and cleaning the land; and of gaining all the benefits from the repeated stirring of the soil during the summer. Hence it is that the practice of a rotation of crops became customary in the infancy of agriculture, and has always prevailed, although the farmers who followed it could not explain the reason for it, but simply followed it because experience had taught them its value. (*"Sic quoque arva requiescent, fetibus mutatis."*—*"Thus also the fields rest, the produce being changed."* Virgil).

But if a rotation of crops is advantageous and profitable, it follows that the best rotation; that which will confer the most of these beneficial results upon the land; will be the best for the farmer to follow. And we would suggest the consideration, whether or not, the present rotation commonly followed, of four crops or "four courses," viz: wheat, grass, corn, and oats; might not be very much improved, and a corresponding advantage be secured by the farmer.

The present ordinary rotation is based upon one green crop—a grass and clover sod—plowed under; one cultivated crop—corn; and one manured crop—wheat. But three exceedingly exhaustive crops are grown, one after the other, viz: corn, oats and wheat; and it is questionable if the general low average yield of wheat is not due in a great measure to the exhaustion of the soil by the two previous exacting crops. Corn is a gross feeder, and oats pick up very eagerly what the corn leaves behind it. Thus the wheat meets with decidedly unfavorable circumstances, when from

its character it should be favored as much as possible.

The largest addition of plant food of the best kind to the soil, is made by a grass and clover sod plowed in; and the soil is most favorably affected by the frequent cultivation given to what are known as hoed crops. Now, if instead of 5 years crops as at present in vogue in the common 4 course rotation, with the single green crop plowed in, the single cultivated crop, and the single manuring, there could be 8 years crops with two green crops plowed in, two cultivated, and two manured crops; it is unquestionable that the land would be greatly improved in condition; and the yield of the crops would be increased; and all with corresponding profit to the farmer. The two rotations would compare with each other as follows:

Present rotation.

Wheat (manured).
Grass and clover.
Pasture.
Corn (with sod plowed in).
Oats.

New rotation.

Wheat (manured).
Grass and clover.
Pasture
Corn (with sod plowed in).
Roots (manured).
Oats or barley.
Clover hay.
Clover seed (sod plowed in).

Moreover there would be a crop of roots to be fed to stock with the hay and straw, and some bran or oil meal purchased, with the result of a large quantity of manure which would greatly enrich the soil and very much add to the products of the farm.

CHAPTER XLIV.

GRASS.

Grass is the pivot upon which farm crops rotate. It is the most valuable and productive crop grown. It feeds all the stock; produces all our meat; feeds the horses, cows, and sheep; produces our milk and butter and cheese; the hides, and wool; and thus contributes more to the sustenance and comfort of mankind than any other farm crop grown. It is a common saying that "grass farmers are the richest farmers;" and it is quite true, because grass is the easiest crop grown and yields the most profitable products. It is of the greatest importance then that grass should be cultivated in the best manner.

Permanent meadows are the most profitable form in which grass can be grown, because once the grass is established it is maintained for many years with very little cost and trouble. In regard to the formation and maintenance of permanent meadows three things are most worthy of notice: the preparation of the land; the choice of varieties of grass; and the treatment necessary for their preservation.

No other crop exacts such a careful preparation of the soil as grass. The most perfect plowing is required to get a smooth level surface; and thorough harrowing, or what is the best, a thorough working with the Acme pulverizing harrow is indispensable. The land should be plowed at least 6 inches deep. If the surface is stony, the stones should be rolled into the furrows and covered at the next turn; the Acme harrow will not disturb them, and they are out of the way of all future work. After the plowing, the furrows are leveled down and pulverized thoroughly, and the working with this implement is continued until the soil is perfectly fine and compact.

A liberal quantity of manure should be plowed in and will be well mixed with the soil by this working, without being torn from its place in the furrows, where it is most wanted and not on the surface. The seed is then sown. Orchard grass is the best single permanent grass for mowing meadows, makes an excellent pasture, and is useful for soiling purposes. $2\frac{1}{2}$ or 3 bushels per acre is required to cover the surface well; but the habit of this grass is to grow in bunches and the thickest sowing will not make a sod. A long experience with this grass has convinced us that it is the best single grass that can be sown, as it will last for 30 years at least in good condition for hay and pasture. It is early in maturity and comes into bloom with red clover, hence a mixture of clover with it is advisable when the object sought is hay and a few years pasture; but for permanent meadow the grass alone is preferable when but one kind is sown.

Mixed grasses produce a thicker herbage than any one kind, and a selection of several kinds of those suited to the soil is desirable. The following are some of the mixtures which have been found useful on the kinds of soils mentioned.

MIXTURE OF GRASSES.

FOR LIGHT DRY SOIL.

Orchard grass.....	10 pounds.
Tall oat grass.....	6 "
Meadow fescue.....	3 "
Creeping fescue.....	3 "
Creeping bent.....	3 "
Perennial rye grass.....	8 "
Timothy.....	3 "
Kentucky blue grass.....	4 "
Total per acre,	40 "

FOR HEAVY SOILS.

Orchard grass.....	10 pounds.
Timothy.....	6 "
Yellow oat grass.....	5 "
Perennial rye grass.....	10 "
Tall fescue.....	4 "
Rough stalked meadow grass....	5 "
Meadow fescue.....	5 "
Total per acre,	45 "

FOR MOIST SOILS.

Timothy.....	6 pounds.
Fowl meadow grass.....	5 "
Red top.....	10 "
Creeping bent.....	5 "
Floating meadow grass.....	5 "
Water meadow grass.....	5 "
Total per acre,	36 "

FOR SHADED PASTURE OR OPEN WOODS.

Kentucky blue grass.....	5 pounds.
Orchard grass.....	5 "
Creeping bent.....	5 "
Red top.....	5 "
Wood meadow grass.....	10 "
Yellow oat grass.....	5 "
Total per acre,	35 "

In localities where Kentucky blue grass thrives naturally, upon limestone soils especially; this variety is unsurpassed, and indeed unequalled for pasture; and one who has seen the verdant meadows of this grass in Kentucky, Missouri, southern Ohio, and Indiana, and parts of Tennessee, will have no doubt of the possibility of making permanent pastures and meadows in our American climate, which has been supposed to be unfavorable for the culture of grass.

For temporary meadows, there are no better varieties than the popular mixture of timothy and clover, which usually remains for two years, being mown once for hay, and used for pasture the next year. 6 lbs. each of seed is the usual quantity, but we have sown a peck, each, of the seed; which is 12 lbs. of timothy and 15 lbs. of clover, on rather poor land with better results than from thinner sowing.

In sowing grass seeds we prefer to sow one-half each way, so as to get the most even covering of the soil. As the seeds are very small and light, deep covering is to be avoided; and usually the soft mellow soil left in small ridges and furrows by the Acme harrow, will furnish sufficient covering by its natural settlement, or by the beating of the first shower; without any special work for the purpose. We much prefer to sow grass and clover seed by themselves and without any crop of grain, fitting the soil specially for the seed as above described, and sowing in August. A pound of turnip seed sown with the grass seed will afford excellent

protection for the young grass, the broad leaves of the turnips giving welcome shade and protection from early frosts, and from the too warm winter's sun; and the roots dying, through the winter, furnish very useful food for the young crop in the spring. But with fall plowing and early sowing in the spring, grass seeds may be sown with safety then, and will often give a crop of hay, or pasture for sheep in the fall.

CHAPTER XLV.

FODDER AND SOILING CROPS.

The cultivation of fodder crops is one of the indispensable methods of the economical use of land and of the feeding of cattle. Cicero observed, in his ancient time, that "the feeding of cattle was the most important part of agriculture." But in these days, when the exigencies of our social conditions call for every effort on the part of every producer to decrease his expenses and increase his income, it is necessary to make the land yield the largest produce of the most nutritious food. It must be a very good acre of meadow, and one of pasture, that will together support one cow for a whole year; but by the culture of fodder crops of the right kind, and the use of the silo for preserving these crops green and succulent through the winter, one acre may be made to support two or three head of cattle the year round; thus practically more than trebling the value of the land, by the increased income from it.

SOILING is by no means a modern practice, for it has been made use of for many centuries. The advantages of it are obvious. It consists in growing green fodder crops, and cutting these for feeding stock in yards or lots, or sheds. There is no waste of food in this way; none is trodden under foot or fouled and made useless; and every pound of manure, both liquid and solid, may be saved. In the South, this practice prevailed long before it was introduced into practice in the North, and cow penning has been used for enriching the land and economizing feed, where the climate, but much more the prevailing system of agriculture, forbids the pasturage of stock to any large extent. The author has practiced this system in his dairy for several years, with the results of bringing up a practically barren farm by degrees, during a few years, into a high state of productiveness. Objection is made by some persons that it is a costly

practice. It is true that it costs more than turning out the stock on to a pasture, but the extra cost is not much, while the income from the land is fully trebled. One boy of 16 years, is able to cut and bring to the barn the feed for 30 cows; and to feed them and keep them clean. * This is all the extra cost, unless one counts the plowing of the land, and the carrying of the manure to it for the growth of the crops. But if this is taken into account, one might as well complain of the cost of milking the extra cows fed, and taking care of the increased product of the milk and butter.

The system is very simple. Feeding sheds and yards are provided for the cattle, with racks for the fodder. Every necessary arrangement is provided for saving all the manure. A field is first sown with clover and grass and another with fall rye; these make the beginning and provide the first feeding in the season, which begins in May, when the rye is ready for cutting. After the rye is used up, the clover is ready and the rye ground is plowed and sown with early sweet corn, which is ready as soon as the clover or orchard grass, or both, have been exhausted. A mower (one horse) is kept in the fields, and as soon as the dew is off the crops, a sufficient supply is cut—at the first—for two days; one days stock is drawn in for the cattle; and the other is left on the ground or in the barn for the next day. The next day, a new supply is cut for the following day, so that a days stock is always kept ahead. For rainy weather, provision is made for a longer supply; if it is thought desirable. This goes on all the summer with perfect regularity; and when one crop comes in, what is left of the preceding one is cured for winter, or put in the silo.

A silo is simply an air tight receptacle; a square deep building of stone, concrete, or plank; which may be made in a cellar, or a mow in the barn; in which the newly cut green fodder is packed away and pressed down tightly under a covering of planks, heavily weighted. The green fodder heats and ferments somewhat; but as the air is excluded it does not mold or decay; but remains discolored to some extent, and makes a very palatable fodder. One acre of

fodder thus preserved has afforded full provision for one cow or ox for 40 months.

Pasturing is a wasteful practice except upon very cheap lands and where labor is scarce. Where land is worth \$50 an acre and upwards, it is a practice that is far from economical unless in a few special cases where partial pasturing at times is desirable. Instead of pasturing, green fodder crops are thus grown, and cut and fed to stock in yards or lots.

For the purposes of winter feeding there are several other crops besides grass, which may be grown very profitably and will yield twice or three times as much as grass will; and besides by choosing the right crops which follow each other as soon as one is cut and used, another becomes ready; so that a succession of food is provided for the stock; while in pasturing, the grass is only in the best condition for a short time. In this way the costly land in the neighborhood of large towns and cities may be worked with more profit than the cheaper farms which are remote from markets. For dairying, this system of growing fodder crops is indispensable to success.

CLOVER is the first fodder crop which demands consideration, both for its value for all purposes for which it is grown, and for its easy culture. The introduction of this plant into agriculture marked an era in the history of the art, for it certainly worked a revolution in its practice. Clover belongs to the leguminous or pod bearing order of plants, of which the pea and bean are the typical examples. It has some special characteristics which should not go unnoticed here. It has a long fusiform or spindle shaped tap root which penetrates deep into the soil, extending sometimes 3 or 4 feet before it passes into the form of fibers. These long roots extend the feeding space of the plant very considerably, and explain the interesting fact that a crop of clover is able to gather from the soil as much nitrogen as 5 crops of wheat; as much potash as 4 crops; and as much lime as 8 crops; and thus bring to the surface and leave in its roots and stubble, so much additional amount of plant food for

the nourishment of succeeding crops. A crop of clover plowed in as a fertilizer adds to the available plant food in the soil as much as 20 loads of farm manure, and the large percentage of nitrogen in its composition makes it equally valuable for the feeding of animals and the production of manure. Its culture is too well known to need any detailed description, but it is perhaps proper to remark here, that the thorough fitting of the soil for the seed is of the greatest importance for its successful growth.

The period of cutting clover for hay is very important, because of the change in its character as it approaches maturity. This change is shown by the following table.

COMPOSITION OF CLOVER HAY.

Red clover hay.	Organic matter.	Protein or flesh formers.	Carb hydrates or fat formers.	Fat.	Crude fiber.
Cut in full blossom.....	77.1	13.4	29.9	3.2	35.8
Cut when ripe.....	77.7	9.4	20.3	2.0	48.0

The very great difference in digestible nutriment is specially noticeable; being 50 per cent. in the nitrogenous matter—the protein—and nearly 50 per cent. in the carbonaceous or fat producing matter, and in the fat. This shows in a most conspicuous manner the more valuable character of clover at its blossoming stage, when it is the most useful for feeding or for a green manure.

Fresh seed only should be sown, and from 6 to 12 lbs. per acre is required, as the land may be more or less fertile; the richer land requiring the least seed. Clover seed should be saved for home use by every farmer. The seed is contained in the aftermath, which is left to grow and blossom and ripen; which it does in September. The clover is then mown and the straw is left on the field in winrows until it is perfectly dry, when it is taken to a suitable place and thrashed, the dry pods separating with great readiness, and the seed being easily freed when the heads are in this dry state. The seed may be partially cleared from the pods, if the straw is thrashed in a machine, and crowded in so as to rub the heads and break up the chaff. This is much helped

by hanging a sack or a board in the rear of the machine, so as to clog the cylinder somewhat and cause a rubbing action, which breaks the pods. The fanning mill will clean the seed sufficiently for home use. As considerable seed remains in the chaff, this should be scattered over pastures and meadows which may be reseeded in this manner.

LUCERN, or alfalfa, is the nearest substitute for clover that we have. It is not however recommended for use where clover will grow; but in the drier regions where clover will not succeed, lucern is a most useful crop, and is exceedingly productive under irrigation. It is mostly used green for feeding cattle and horses, as it makes inferior hay, the stalks being woody and hard, and most of the leaves being lost in the curing. It is a deep rooted plant, and belongs to the same botanical family as clover. The seed used per acre is 12 to 20 lbs. The usual manner of sowing is in drills, 12 inches apart. As much as 80 tons of green fodder has been cut from an acre of this plant, on the rich irrigated fields of the California river bottoms and tulé lands.

RYE is one of the most useful green fodder crops, and is indispensable when soiling is practiced, because it is the first green crop that is ready for cutting in the spring. It is also a valuable green manure crop for the same reason, as it may be plowed under in May and can be followed by corn, or buckwheat, for the same purpose. For green fodder three to five bushels of seed per acre are sown late in August, so as to get the crop well rooted and forward before winter. In the Southern states this crop makes the best of late fall, winter, and spring pasture; and deserves especial notice for this purpose; for in the South, especially, improvement in the culture of farm crops is exceedingly desirable and there is an abounding necessity for it.

FODDER CORN is the most productive of all the crops grown for feeding in a green state. On good land it will yield 40 tons of fresh fodder per acre and on moderately good land 25 tons is a common yield. The author has grown 600 lbs. of evergreen sweet corn to the square rod, which is equal to 48 tons per acre, and the whole crop was

quite equal to the plot cut for weighing. This crop was not cut until the ears had formed and was cut up in a fodder cutter, ears and stalks together, and fed with some bran and corn meal, to dairy cows with a most remarkable increase in the yield of cream and butter.

Corn should never be sown broadcast, as it needs light and air to mature its sap and make a substantial and nutritious growth. The best mode of culture, and that usually practiced by farmers and dairymen who soil their stock, or who preserve their crops by ensilage, is to plant in rows 3 feet apart, and from 6 inches apart—with single plants—to 18 inches—with 4 or 5 plants together. This gives sufficient room for the air and sun light to reach the plants, and for the frequent cultivation of the land. (See article on corn culture in the next chapter.) The seed required for this close planting is about one bushel to the acre.

The early varieties of sweet corn are especially fit for fodder crops. As soon as the fall rye is cut off, or as the strip of the field is cleared, the ground is manured and plowed. Liberal manuring is the secret of large fodder crops. The land is then planted with some early variety of sweet corn, the Narraganset being commonly preferred on account of its longer stalks and larger ears, while it is only a few days later than the earliest. By the middle of July this crop is ready for use, and as a strip of it is removed the ground is at once prepared for another crop; usually evergreen or mammoth sweet corn; which matures for use in September and thus makes the third crop taken from the land in 5 months. With ordinary good culture and manuring, at least 40 or 50 tons of green fodder may thus be taken from one acre of land; which is sufficient to feed ten cows during this period, at the rate of one ton per cow per month or 60 lbs. to the cow per day. This fact which has been proved in continual practice by the author in his dairy, during several years, and also by many other dairy farmers, goes to prove the great advantage of this method of growing crops for the feeding of stock, and the improvement of the soil; a necessary result of the feeding of so much stock.

One point should not be neglected here. This is the advantage gained by the use of the most effective implements for the cultivation of the land, and its rapid preparation for the crops; avoiding loss of time, which might be a serious detriment to the operation. It is only just to acknowledge the help which is afforded by such an implement as the Acme pulverizing harrow, by which an acre of rye or corn stubble may be fitted in the best manner for the next crop in one hour; the soil being thoroughly worked to a depth of 4 or 5 inches without any plowing. In fact the author has cut off a strip of rye of a quarter of an acre for feeding his cows, and within 30 minutes has had it planted with sweet corn, and fertilized; by the use of the Acme harrow and a corn planter with a fertilizer attachment.

Other crops suitable for soiling or feeding either green or dry, are millet; Hungarian grass, which is practically the same as millet; the Southern cow pea; oats and peas mixed together; and sorghum (which must be used half grown or it becomes too hard for use). For these crops the quantity of seed to be used will be found stated in the appendix; the methods of cultivation are simply those suitable for any crop, applying them to the principles described in former chapters, and remembering that to a large extent the soil is only the vehicle by which we convey nutriment to the crops.

CHAPTER XLVI.

GRAIN CROPS.

WHEAT is the most important of the grain crops although it is surpassed in value and quantity by corn. It is the noblest of all farm crops, being the staff of life to the human race, and the daily bread of civilized mankind. It is a product of civilization, and is not found growing wild; indeed its origin is unknown, and is a matter of dispute among persons who are curious about such questions. Consequently it is the most susceptible plant that is grown to the circumstances and conditions of its culture; and hence it varies very much with its locality, climate, soil, and the kind of manure or fertilizers used. The wheats of the Eastern states are entirely changed in character after two or three years of culture in the west, and the grain grown in the dry climate of Colorado, Dakota, and Oregon, differ so much from that grown elsewhere, as to be easily distinguishable even by a photograph. Hence the attempt to change the character of wheat by the introduction of seed from distant localities will fail, excepting temporarily; for the variation caused by special environments will soon change the character of the seed, and any difference which might have existed will soon disappear. Thus the improvement of the grain must come by selection of seed, and by high cultivation; and not by the introduction of foreign grain, however superior its appearance, character, and yield may be. It is most probable that all the different varieties of wheat, or the supposed different varieties, which number hundreds or thousands, are after all nothing more than the product of climatic influences which are paramount in the growth of this grain; for there is nothing permanent in their character, and a change of locality speedily changes the characteristics and reduces or advances them—as the case may be—to a similarity with the native kinds.

The peculiar kind of hard spring wheat, for instance, is a product from the seed of the Scotch Fife, which in its original cool, moist climate, is plump, soft, and filled with starch; by reason of its long season of growth; but in the short summer of Dakota and northern Minnesota, the grain is formed and ripened in a few days, and hence it is small, dark colored, hard, and deficient in starch, but very rich in nitrogen. Some samples afford 18 per cent. of gluten, and this enables the wheat to produce a very stiff flour which absorbs a large quantity of water and produces comparatively more bread than the white, soft, starchy wheats. Thus all the care and culture which may be given to a sample of wheat foreign to any locality, will fail to improve it, or fix its type in its new home; and to grow wheat successfully it must be, at least to some extent, suited to the climate and soil in which it is grown. No doubt the many failures in this respect with new seed, or new varieties, are due to this peculiarity of the grain; and some climates well suited to spring or fall wheat have been condemned as unfit for the growth of one or the other variety, simply because a mistake has been made in the selection of seed.

The yield of wheat is also affected by climate. The average product of Colorado is 22 bushels; of Connecticut 17½ bushels; of Michigan 19 bushels; while the Southern states produce only from 5 to 9 bushels per acre, and Louisiana with its rich soil yields no more than an average of 3¼ bushels to the acre. No doubt some of this deficiency in the yield in the Southern states is due to the wretchedly poor culture; the prevailing mode of cultivation being to sow the seed upon the ground amid the overpowering weeds, and the corn stalks which have been stripped of leaves and topped; and covering it by means of a bull tongue plow by which the ground is merely scratched. Wheat cannot be grown successfully in such a manner as this. On the contrary the very best preparation should be made for it. A crop of 42 bushels per acre has been grown by the author on an oat stubble which was plowed as soon as the oats were removed, and then well harrowed. The working with the

Acme harrow was repeated twice before sowing. 20 loads per acre of good manure was plowed in, and the two workings with the Acme mingled this with the soil. Just before sowing 40 bushels of air slaked lime per acre were spread, after which the seed (the Treadwell variety) was sown at the rate of one bushel per acre, and covered, along with the lime, by the Acme, which was lapped half over the previous bout at each turn. The plants stood out well and grew evenly, with the result mentioned, 13 acres producing 545 bushels of cleaned wheat. Early plowing, when wheat succeeds oats, is indispensable. If left later, the ground becomes hardened by the dry weather, and the plowing is defective. No other crop demands more thorough preparation of the soil, by perfect pulverization and firming by repeated harrowing. Wheat is a shallow rooted plant and a poor forager; hence its food must be prepared for it and placed within its reach. The early plowing, when manure made the previous winter and well decayed is covered in; the frequent workings after that; and the lime; all tend to reduce the manure to its original elements, and to liberate a large quantity of plant food from the soil, and thus provide a rich and copious nourishment for the crop.

Wheat is profitable when 30 bushels per acre can be grown, and that this yield can be secured is unquestionable if the necessary conditions of the soil are provided for it. The author once sowed 3 ounces of wheat upon a square rod of ground in rows 12 inches apart. The ground was hoed once a week from the planting until the spreading plants wholly covered it, which was before the winter set in. In the spring the soil was stirred as much as possible until it could no longer be done. At the harvest the grain was thrashed, and made 34 lbs. which was equal to 90 bushels and 40 lbs. per acre. English farmers by good culture and the use of the hoe in spring have grown from 65 to 70 bushels per acre. Is there any reason why, with equally good culture, American farmers could not produce a similar yield? We think not.

CORN, like wheat, is greatly influenced by climate and

culture. Being a semi-tropical plant it might be supposed that it would flourish best in a Southern climate, and yet the product of Maine and New Hampshire averages more than twice as much as that of all the Southern states, and four times as much as the yield in South Carolina and Georgia, where the soil is quite as rich as in the stony fields and among the granite rocks of northern New England. Southern corn has a very much larger grain than that grown in the North, but the custom of growing single stalks, which prevails in the South, reduces the yield per acre very largely. This method is "a custom that would be more honored in the breach than the observance;" for the author, on his farm in North Carolina, where a part of the year is spent, has grown corn successfully in the Northern manner with 3 stalks to the hill, and has produced a full crop; having 3 ears to each hill.

The large yield of a full crop of corn is due to its longer season of growth and its vigorous rooting. The roots of corn have been found to extend 8 feet in each direction, and in a crop grown by the author which yielded 99 bushels per acre of shelled grain, the roots, when the soil was washed from them by means of a stream of water through a hose, formed a close network completely through the rows, and a mass of fibers enveloped every visible particle of manure. This crop was grown on a heavy clover sod from the previous year, well manured late in the fall and during the winter, and plowed 7 inches deep, late in the spring, when the clover was a foot high; the furrow' slices being lapped in the usual manner at an inclination of about 45 degrees. After the plowing the soil was well worked with the Acme harrow; which did not disturb the sod or the manure, but mixed it with the pulverized soil in the most intimate manner. The seed was planted with a one horse planter in rows $3\frac{1}{2}$ feet apart, dropping 3 or 4 seeds at intervals of 18 inches. The part of the field thus prepared was two acres, and the crop was husked by the bushel. 398 bushels of ears were measured twice, and paid for; and when shelled the produce was 198 bushels of shelled grain. This however is by no

means a surprising yield of this crop. A well known farmer of long Island, N. Y., Mr. Wm. Crozier, has produced more than 100 bushels per acre. Mr. E. S. Carman of New Jersey has grown 140 bushels per acre; the author has made a crop on one-sixth of an acre of 25 bushels and 8 pounds, a farmer in Ohio has grown upon a small plot at the rate of 246 bushels of grain to the acre, and a few farmers boys in New Hampshire, in competition for a prize offered by the State Agricultural Society, grew crops of from 80 to 120 bushels of grain per acre.

Why then is it, that in the virgin soils of Iowa and Nebraska, which team with the richest plant food, no more than an average of 40 bushels per acre is reached? Inadequate culture is the secret of small crops always and everywhere; while thorough tillage of well fed soil ensures the largest yield. Weeds and corn cannot give each a full crop together.

Corn cannot be improved by the importation of seed from distant localities. It is a creature of climate and soil. The best varieties of corn have been produced by constant, careful selection, and thorough culture, for years upon the same farm. One specially productive variety has been grown on the same farm for 80 years; and another has been improved from a yield of 40 bushels per acre up to 80 bushels, by Dr. E. Lewis Sturtevant of Massachusetts, during 10 years of careful selection and culture.

Corn has a bisexual character, being what is known as a monœcious plant; that is one having staminate and pistillate, or male and female flowers, distinct upon the same perfect plant. The tassel is the staminate flower; the silk is the pistillate or female flower. Every farmer at husking time has observed the numerous stalks which have borne only a tassel and have been without ears. These are imperfect plants, and when they are numerous they greatly reduce the yield. These imperfect barren plants, however, serve their purpose as males in impregnating the perfect plants; and according to a natural law which is expressed in the phrase "like always produces like," these plants have the

effect of making the seed which they impregnate, produce plants like themselves; barren male plants; which have no fruit, and are consequently worth nothing except for the stalks and leaves. Hence a most important part of the culture of corn is to remove the flowers from these stalks, and prevent them from exercising their masculine functions and propagating their useless kind. This system should always be pursued when the improvement of corn is attempted. Perseverance in this emasculation of barren plants (by Dr. Sturtevant, above mentioned), has tended to increase the yield of a crop, after a few years, from 40 to 80 bushels of grain per acre; the increase being chiefly due to the entire elimination of barren and earless stalks from the field.

A fatal mistake in the culture of corn, is the use of the plow after the roots have spread across the rows; and this happens when the plants are about 18 inches tall. After that, only the surface should be stirred, but this should be done frequently. For a large yield, this working of the surface should be done weekly, and it is the more necessary as the weather may be drier; the loosening of the soil—as has been explained in a previous chapter—very much increasing the ability of the porous earth to absorb moisture during the night, as it is condensed by the cooling of the air, and by the circulation of the moist air in the mellow earth as the temperature changes.

OATS usually follow corn in the prevalent rotation. The popular notion that oats are not exhaustive of the soil is quite a mistaken one. The whole plant is richer in nitrogen and potash, and nearly as rich in phosphoric acid as wheat; the grain of which only surpasses oats in respect of the quantity of phosphoric acid contained in it. Besides, oats yield actually a larger weight of produce in an average crop than wheat does; hence it takes more from the soil.

This should be considered in regard to its effect upon the soil; for when manure is applied to the crop, the yield is very considerably increased. Ten loads of barn yard manure per acre have increased the yield of a crop of oats to 78 bushels per acre, when with no manure, the yield on another

part of the same field, naturally quite as fertile, was only 52 bushels. The land in this case was sown with clover with the oats and on the manured land the clover was much better than on the other part of the field, which showed that the manure was by no means exhausted by the oats. Oats will succeed well on land that is too moist for wheat or barley, and newly broken sod land usually produces a good crop. When sown on a corn stubble, the land should be plowed in the fall, the same way in which the corn rows ran, so as to cover the stubs completely. For this end the corn should always be cut low and near the ground. In the spring a thorough working with the Acme harrow fits the ground in an excellent manner for the oats. $2\frac{1}{2}$ bushels of seed should be sown per acre, and the Acme harrow covers the seed perfectly and to the proper depth, as well as a drill will. This grain varies considerably in character, weighing from 24 to 55 lbs. per bushel. In a cool moist climate, as that of Scotland or the North of Ireland, oats reach perfection; weighing heavier than any other, and often weighing 55 lbs. per bushel. In America, the best oats are grown in the Northern and Eastern part of Canada; and it is advisable to procure seed from this locality for the purpose of growing a heavier grain for a few years, until the crop deteriorates by reason of the less favorable influences of a warm dry summer. Oats should be sown as early in the spring as possible to get a long growing season. We have had excellent oats from crops sown on ground which was frozen 4 inches below the surface; but having been fall plowed, and being dry above the frozen subsoil, the land was perfectly well fitted by the use of the Acme harrow. This early sowing is of great importance and secures a full yield of heavy grain.

BARLEY is too much neglected as a farm crop; perhaps because its value as a feeding grain for horses and swine is not well known, and its culture exacts more labor in the preparation of the soil. But no farmer should hesitate to grow a crop for the latter reason; when it is one of the axioms of agriculture that the best possible culture of the soil

is not only profitable for the larger crops grown, but that the fertility of the land is permanently improved by it. Farmers know very well that the soil may be injured for many years to come by injudicious culture, as by plowing clay land when it is wet, or by plowing too deeply and burying the fertile surface soil under a covering of raw infertile subsoil; in a corresponding manner, but conversely, the thorough pulverization of the land—which is necessary for the successful growth of barley—improves it for years to come. It is this fact which made the arduous labor of a previously popular summer fallow profitable, by increasing the yield of all the crops which followed it during the whole rotation. It also furnishes a sufficient inducement for farmers to summer fallow the land as a preparation for laying a field down to permanent meadow.

Barley costs no more to cultivate than wheat; but it yields a greater weight per acre of grain, and is worth more in the market or for feeding. Its use for brewing gives it a high value in the market, but we would advocate its culture for other purposes than this, viz. for its value for feeding and for its excellence as a crop to seed down to grass and clover with. Barley weighs from 50 to 64 lbs. per bushel being thus only a little lighter than wheat. The average weight throughout the United States and Canada is 54 lbs. to the bushel.

This grain requires a thoroughly mellow clean soil, and thrives best in a rich medium light loam inclined to clay; although the lightest colored and thinnest skinned grain is grown on sandy loam. 2 bushels of seed is sown per acre early in the spring. It follows a root crop that has been manured and fertilized, admirably; and in the lengthened rotation suggested in a previous chapter, this would be its most appropriate place; clover being sown with it, and oats succeeding the corn and preceding the roots.

RYE is not an important grain crop and yet it is largely grown by farmers who cannot, or do not, make the culture of wheat profitable. The grain is more nutritious than wheat and makes very sweet and palatable bread. When

ground with corn in equal measures it makes the best feed for horses, to be used with cut straw and hay; and if mixed with corn for fattening hogs, it makes a more healthful food than corn alone, adding to the amount of albuminoids of the corn and reducing proportionately its excess of carbonaceous matter. Its culture is exceedingly easy, being the least exacting grain in this respect grown upon farms; and it is not so much injured by heaving out in the winter as wheat is. Notwithstanding its average poor yield, it pays well for good culture. We have grown 45 bushels per acre upon a well cultivated corn stubble, which was prepared without plowing by thorough working with the Acme harrow. The straw is the most valuable of all kinds for feeding, and rye bran is more nutritious than that of wheat, and superior to it for feeding to dairy cows.

BUCKWHEAT deserves more notice and consideration than it receives at the hands of farmers generally. It is a valuable crop when it receives the treatment it deserves. The great need of our agriculture is more feeding crops and this grain is valuable for this use. When ground with corn and rye it is excellent food for horses, cattle, and swine; and the mixed grains unground, are exceedingly well adapted for sheep. This grain requires cool weather to mature the seed and is therefore sown late in the summer; in July in the north, and August in the south. It never fails to yield a paying crop, producing from 20 to 75 bushels per acre according to the richness of the soil and the favorable season. The latter yield was once reached by the author, upon a piece of newly cleared and broken woodland and in a year when the frosts held off until November. The crop comes in at such a time as to make it very convenient. Any piece of rough ground, well broken up, suits it; but good culture before sowing the seed greatly enhances the product. A peck of seed per acre is sufficient. The seed should be well covered and the Acme harrow is beyond a doubt the best implement for covering it. *

PEAS are one of the leguminous family of plants to which clover belongs, and like this plant, have a favorable effect

upon the soil. This effect of peas however is inferior to that of clover because they leave a much less quantity of refuse matter—as roots and stubble—in the soil; but the dense shade afforded by the plants, and the nitrogenous character of what remains upon the soil, of their refuse; leave it in a favorable condition for a succeeding crop. Wheat following peas, usually succeeds much better than it does after oats or corn, or even after a fallow, and this rotation is a favorite one where peas are largely grown, as in Canada, where they make a substitute for corn.

Peas leave the soil very clean and mellow; their dense shade preventing the growth of weeds, and keeping the ground moist. The seed ($1\frac{1}{2}$ bushels per acre) is sown early in the spring, and as it is difficult to cover them with the common spike tooth harrow, it is better to cover them with the plow or the cultivator, or the Acme harrow, which is better than either, and equal to both together. The seed should be covered at least 3 inches deep. In some localities this crop is grown for sale green, in the town or city markets, with much profit. In this case the seed is sown in drills 12 or 20 inches apart; or in two double drills 8 inches apart, with spaces of two feet between each two drills, to give room for working the ground.

This is an excellent feeding crop; the grain and the vines being both exceedingly nutritious, the grain containing $22\frac{1}{2}$ per cent. of albuminoids, and $52\frac{1}{2}$ per cent. of carbonaceous matter. The former consists largely of a nitrogenous substance called legumin, which is almost precisely the same as caseine of milk in composition and character, and so much so, that a very good cheese is made from peas by the Chinese. The straw contains $6\frac{1}{2}$ per cent. of albuminoids, (timothy hay contains $9\frac{1}{2}$ per cent.) and $35\frac{1}{4}$ per cent. of carbonaceous matter; (timothy hay has $48\frac{3}{4}$ per cent. of it).

Cow PEAS are extensively grown in the South for fodder, and for a green manuring crop; and are of much value in both ways. This plant however is not a pea, but a variety of bean; it is however included under the subhead of

peas, as it is better known as a pea. There are several varieties of this plant, but they differ in no material point; and the mode of cultivating and using all of them is the same. A common mode of planting this crop is to drop the seed among the corn at the last working; but it is much more profitable when grown by itself, and treated as well as any other crop. Its culture is the same as that of the common bean, which it resembles in its appearance and manner of growth; the pods however being round and not flat, as those of the bean are.

This crop might be made exceedingly useful to Southern farmers as a fodder or a grain crop; and for plowing under as manure upon the lands exhausted by the culture of tobacco and cotton. When grown for the latter purpose it should be sown early (a bushel of seed to the acre), and turned under when in full blossom; a second crop being immediately sown and turned under in time for sowing wheat.

BEANS are grown in some localities very largely and as a special crop. Several kinds are grown; the marrowfat, the pea bean, or navy bean (this is the most valuable in the market); the red kidney, and the black soup bean. The plant matures quickly, and although exceedingly rich in nutritious matter—a little more so than peas—it is by no means exacting in regard to the fertility of the soil. It belongs to the leguminous family of plants, all of which possess the ability to get a large quantity of nitrogen from some unknown source, and therefore make a good yield upon land upon which other crops would thrive but poorly. The crop is grown in drills 18 inches apart, the seed used being about a bushel and a half to the acre. It might be made to take a valuable place in a rotation of 8 or more crops, as the product is quite salable at very profitable prices, and is also a valuable food for horses, sheep, and swine, when ground with corn. The haulm is also exceedingly nutritious and contains $10\frac{1}{2}$ per cent. of albuminoids in its dry state.

CHAPTER XLVII.

ROOT CROPS.

The culture of root crops is beneficial to the farmer in two ways; one in producing a large quantity of exceedingly nutritious and succulent food for use in the winter, helping to increase the quantity of manure made by feeding an increased number of stock, and thus enriching the soil; as well as greatly helping to keep down weeds and clean the land by the thorough cultivation required. For these reasons, a root crop should always be brought into the rotation to be followed by spring grain, either oats or barley—the latter being preferable—with clover to follow. It has been objected to this that our climate is not well adapted to roots; but this is not true in regard to the best of all the roots, viz: mangels, and sugar beets, for which our warm and dry climate is specially well adapted. The author has grown mangels at the rate of 1200 bushels, or 36 tons per acre; and 800 bushels of sugar beets of the large growing variety known as "Lane's improved," (originated by the Hon. Henry Lane of Burlington, Vermont). This quantity of mangels is sufficient to feed 12 head of cattle, with a daily ration of half a bushel per head, for 200 days, or more than 6 months; that is from November to May; or during the full feeding season. The cost of growing these crops averaged \$60. per acre, including 600 lbs. per acre of Mapes complete manure, and 600 lbs. of salt; costing about \$15. per acre in all. This shows the profit of this crop, for the half bushel of roots was the principal winter feed for cows which were making 10 lbs. of butter each per week, and this feed, upon which the yield of butter chiefly depended, cost only 2½ cents per day. Thus roots are readily seen to be a large factor in the profitable culture of farm crops, and have a place in it which no other crop can fill as well as they.

The soil requires the most thorough preparation for roots. Usually they follow corn. The land should be well plowed in the fall, a liberal quantity of manure being plowed under, and left until the spring, when it is worked with the Acme harrow, or with a cultivator, and laid off in shallow furrows 27 inches apart for the seed; or the seed is sown with a hand drill, on the mellow soil; the drill covering the seed and rolling the ground over it. This leaves the seed rows plainly marked, so that they can be worked before the young plants are above the ground. This is necessary because the successful growth of roots depends chiefly upon the entire absence of weeds and the frequent culture of the land. The method followed by the writer is as follows. After the seed has been sown as above, the rows are worked a week after, by running a hand cultivator along them, the scrapers working on each side of the row, loosening the soil and destroying the young weeds. As soon as the young plants show above the ground, the hand cultivator is spread to 10 inches in width, and is run across the rows; cutting out the surplus plants, and leaving them at this distance apart in bunches in the main rows. The hand cultivator is kept going over the rows and across them, until the young plants are strong; when the bunches are thinned out to single plants and any vacant spaces may be resown or filled by transplanting the surplus plants. After this, the horse hoe is run through the middles, the weeds killed, and the soil worked; and by this time the young plants will need no more hoeing; excepting the hand hoe run crosswise in the 10 inch spaces. The horse hoe is kept going through the main rows until the spread of the leaves prevents it, when the crop is left to take care of itself. The quantity of seed used is 6 lbs. per acre. This is much more than is required, but a large proportion of the seed will fail to grow, and it is cheaper to have full rows, and cut most of the plants out, than to have a short crop or many empty spaces.

The roots are harvested as follows. After the first sharp frosts, the work is done without delay. A workman passes along the row and with a sharp hoe cuts the tops close to

the roots, leaving them in the row to his left. He returns along the row cutting to his right, and leaving the tops with the others. Thus every second space would have a row of tops in it. Another man follows the first and with a blunt hook or a digging fork, takes up the roots and throws two rows into the space beyond the second row; returning, he takes two more rows and throws the roots with the others; thus gathering four rows into one. Thus there will be first a row of tops then a row of roots, and then another row of tops. Next will be an empty space, and then the rows of tops and roots are repeated as before. In loading, the horse and cart (a cart should be kept on every farm where roots are grown) are taken down the empty row, the horse being thus driven through the field without treading on the tops or roots, and the roots are first taken up and carted to the root pit or the cellar, where the cart is tipped and the roots are dumped all at once, without any hand work. The roots are lifted into the cart with the digging forks, which should have curved prongs upon which the roots may be lifted into the cart easily.

POTATOES are a most important crop for those farmers who keep but few stock, and have a near market in some large city or town. The mode of cultivating them is much the same as that practiced for mangels, excepting that the rows are made 3 feet apart, and the cuttings are dropped in the rows from 12 to 16 inches apart. A clover sod plowed under in the fall and well worked with the Acme harrow in the spring, when 10 or 20 loads per acre of fine manure are given, and mixed with the soil by the harrowing, makes an excellent preparation. By the use of machines for planting, a working soon after planting with a smoothing harrow; a good horse hoe to cultivate the rows well and often—not earthing up the rows too much—and a digging machine; this crop can be grown for 30 cents a bushel including all expenses. Artificial fertilizers are preferable for potatoes in place of manure; as the ravages of the injurious wire worm are avoided by their use.

Various opinions are held by good farmers in regard to

the best manner of planting and cutting the seed; some preferring cuttings with but one eye, and others with two or three. We prefer the common method, viz: to choose medium sized well shaped tubers, and cut them by sloping cuts, beginning at the top end, into sets each having two eyes; and dropping two sets together, about 24 inches apart in the rows, which are 3 feet apart. This gives about 7000 hills to the acre. Until the plants are well up, the horse hoe is run both ways; afterwards it is run in the wider rows and set to throw the soil to the plants, so as to make a low broad ridge. This crop is greatly helped by frequent stirring of the soil on the surface until the blossoming is full, and the tops are in the way of further work. 400 bushels per acre is as little as a good farmer should be satisfied with.

TURNIPS are of little value where mangels or beets are grown. Of the varieties in cultivation the ruta-baga, or Swede turnip, is the only one worth growing as it will keep in good condition through the winter. But mangels are more easily grown and are far superior for feeding to all kinds of stock; hence the culture of turnips is not one to be recommended in this country, where good farming prevails.

English farmers grow Swedes largely for feeding them off from the land by sheep; a practice quite impracticable with us.

SWEET POTATOES are a most valuable crop in the South, where other roots are not suitable to the climate. 300 bushels per acre may be grown with good culture; and for feeding to all kinds of stock, these tubers are unsurpassed.

CARROTS AND PARSNIPS are excellent roots for cows, horses, and sheep; but they are no better than mangels, and are not so easily grown, hence are not desirable crops for ordinary farm purposes.

CHAPTER XLVIII.

TEXTILE CROPS.

COTTON is the leading crop of the Southern States, and farmers in the South necessarily pay the most attention to it. It is however, in general, so poorly cultivated, that it scarcely pays for the labor bestowed upon it, and yields no profit. The average yield is no more than 150 lbs. per acre, which brings no more than \$9. in the market; while 500 to 600 lbs. is easily grown by the best farmers, who follow a scientific culture; manuring the soil and working it in accordance with the true principles of culture; and in some cases the yield has reached 1500 or 2000 lbs. to the acre. The system of culture through the cotton region is generally the reverse of economical; and nowhere else is the culture of farm crops pursued upon a less satisfactory method. This system has grown out of the peculiar circumstances of the Southern farmers for many years past; but the changes which have recently occurred have reversed these conditions so as to bring the necessities of the case so nearly to those of other farmers, that the old system is rapidly changing for a more modern one, and the methods of culture pursued elsewhere are being adopted. These are a rotation of crops; the culture of fodder crops and the rearing and feeding of stock; the making and use of manure; and the use of all the most improved implements. The best of the modern plows are fast taking the place of the very imperfect bull tongue; the Acme harrow is coming into use in place of the common wooden or iron spike harrow; and cultivators, mowing machines, grain drills, and reapers, are seen as in other localities. All this must have a favorable result upon the staple crop of the South; reduce the cost of growing and increase the product of it; thus greatly adding to the profit of the Southern farmers, and improve the condition of the Southern States generally.

Cotton is an exhaustive crop. The fiber is almost pure carbon and contains very little that is drawn from the soil. But the seed is exceedingly rich in nitrogen, phosphoric acid, and potash; and thus draws very heavily upon the land. 1000 lbs. of seed contains 35 to 40 lbs. of nitrogen; 20 lbs. of potash; and 30 lbs. of phosphoric acid. As there are 2 pounds of seed produced for every pound of ginned cotton, a crop of 500 lbs. of clean fiber per acre therefore takes from the soil the above quantities of valuable elements, and thus calls for an adequate return of manure or fertilizer.

The large quantity of carbon in this crop may be all derived from the atmosphere, but at the same time it is indispensable for the full exercise of this function of the plant, that it should have the most vigorous development possible; and to secure this the soil should not only be furnished with every other element in abundance, but it should have an adequate supply of carbonaceous matter in the soil.

Hence the same kind of rotation that is practiced where the common sorts of farm crops are grown, will be found valuable to the cotton planter; and the plowing in of green crops, and the use of stable manure, as well as of special artificial fertilizers, will be found necessary for the production of a full yield of cotton.

Cotton is a tropical plant and requires much heat and a hot sun for its successful culture. It also requires a rich soil. The methods of culture practiced by the best farmers in the South are as follows. The land is broken in the fall; usually it is a fallow or newly cleared ground. It is then "bedded" in the spring, and manure is plowed in as the beds are made. The beds are about 3 or 4 feet wide and are raised somewhat in the center. The middle of the bed is then split and a furrow is made in which some compost or fertilizer is dropped, and this is covered lightly with soil. The seed is then sown and covered. A machine for planting seed is in use which saves labor and expense in this work. The great pest of the cotton planter is the prevalent crab grass which has been permitted to seed on the land

until the soil is so thoroughly filled with it, that it is very difficult keep it down. For this reason the most thorough cultivation is required. The horse hoe which may be worked close to the rows is the best implement for this work; but some hand hoeing is required, until the land is rid of the prevailing weeds by thorough culture, for several years.

The continual growth of corn and cotton on the same land, without adequate manuring, has exhausted much of the soil in the cotton growing districts; and the custom of throwing out the land to "old field" until it grows up again with timber, and in the meantime becomes cut up and gullied by the rains, has given an unpleasing appearance to the Southern country. This will no doubt be remedied in course of time, when a more profitable system is introduced; and the culture of farm crops is made a study. No doubt a reasonable and scientific rotation of crops; the culture of wheat; sweet potatoes and fodder crops for the feeding of stock, with the surplus cotton seed; and the production of the requisite manure, clover, and such of the grasses as are adapted for the climate; will in time change the customs of the farmers and the appearance of the country for the better, and add greatly to the wealth and comfort of the people.

FLAX is one of the most valuable of the textile crops, and succeeds best in a cool climate and in rich moist soil. It is largely grown in the west for the seed which is used for the production of linseed oil, but the fiber is really the most valuable part of the plant. This use of it however is greatly curtailed in this country for some reasons, which are difficult to understand, and our supplies of linens are brought from foreign countries. Nevertheless, as there is a profitable demand for the seed, and it is most valuable for feeding to sheep and cattle for fattening, there is a place for this crop upon every well ordered farm in the country.

A clay loam, or rather light rich sod, is the best for this crop. A grass or clover sod suits it admirably. The land is plowed in the spring and well pulverized, and half a bushel of seed per acre is sown. Early sowing is advisable,

and as the thinner seeding gives more branchy stems and yields more seed, the above quantity should not be exceeded, except when the fiber is the object, when double this quantity is used.

HEMP is grown largely in Kentucky and Missouri upon the rich lands, which under a favorable climate yield profitable crops. Its culture is similar to that of flax; excepting that as the seeds are borne upon pistillate or female plants, which are fertilized by other plants which bear the staminate flowers, and produce the pollen, it is necessary to thin out these fruitless plants during the cultivation of the crop so as to give more room to the seeding plants; also to transplant as many as may be required if they are deficient in certain parts of the field.

CHAPTER XLIX.

THE CULTURE OF TOBACCO.

The growth of tobacco has brought not only a great amount of wealth into the country, but by reason of exhaustive culture, it has brought barrenness and temporary ruin upon many a fair field, which might have otherwise been kept in a productive condition. It is an exhaustive crop as is seen by the following analysis of its ash.

COMPOSITION OF TOBACCO.

	<i>Whole plant, (in 1000 parts).</i>	<i>Ash, (in 100 parts).</i>
Water.....	180	
Ash.....	197.5	
Potash.....	54.1	27.4
Soda.....	7.3	3.7
Magnesia.....	20.7	10.5
Lime.....	73.1	37.0
Phosphoric acid.....	7.1	3.6
Sulphuric acid.....	7.7	3.9
Silica.....	19.0	9.6
Chlorine.....	8.8	4.5

Tobacco is the most exhaustive crop grown, as far as regards the mineral elements drawn from the soil. A crop of 1000 lbs. takes up as much mineral matter as 3000 lbs. of hay; as much lime as 10,000 lbs.; as much magnesia as 3000 lbs. and as much phosphoric acid as 2000 lbs. Repeated crops of it therefore soon bring the soil to a condition of exhaustion of its available fertility, and render it barren. Every element of plant growth is taken up by tobacco and the nitrogen is as largely drawn upon as the rest. Its culture therefore is one to be taken up with caution, and every care to supply the soil with adequate food; and although the profit realized from it is very large, this temptation should not lead the farmer to sacrifice the soil for the sake of it. The land is not really a personal inheritance. It is most truly given to mankind to use it for the best interests of the race, and much like the owners life, which he

may think to be his own to do as he pleases with it, but which cannot be wasted and thrown away or destroyed without a breach of divine or human laws; so the land cannot be wasted or destroyed by its owner without the infliction of an injury upon the public, and the breach of a strict moral obligation to use it for the good of mankind. This thought should never be lost sight of by a farmer, and should be an impulse to his efforts to use his land so as to make it most productive to his own comfort and happiness, and to the welfare of his race.

Although tobacco is exceedingly exhaustive it may be grown in a rotation without loss or damage. It will not take more from the soil than can be easily returned to it in the form of a green crop plowed in; a liberal dressing of manure; and artificial fertilizers, consisting of superphosphate of lime; potash salts; (the muriate however is not fitted for this crop and the sulphate only is to be used) and sulphate of magnesia; with blood and flesh fertilizer which is rich in nitrogen. A clover sod plowed under in the fall so that it is well decomposed by the spring, will furnish the nitrogen needed for this crop, and the land will be in an excellent condition for it in other ways. Where this crop is thus brought into a rotation and alternated with other farm crops, there is no reason why its culture may not be made as useful and profitable as that of wheat, clover, or potatoes. The clean culture that is required is certainly very serviceable in preparing the land for other crops.

Tobacco is grown with profit only under systematic and skillful culture. The land is prepared as above described, and the plants are grown in beds and transplanted to the field when the weather is settled and warm. The plant beds are made much in the same way as for cabbages; a piece of rich soil being prepared, and freed from weeds by having a brush pile burned over it. A tablespoonful of seed is sown upon a square rod, and furnishes enough plants for an acre of land. The seed is sown early so as to have the plants ready as soon as the time arrives for transplanting, and these are moved from the beds when the leaves are

as large as a silver dollar. The plants are rather tender; they require fine mellow soil, and to be set out when the ground is moist or just before a rain. The French planters who take special care of this crop, cover each plant with a conical cup made of paper twisted into the desired shape, and which protects the young plants from the sun until they have become well rooted. The plants are protected from frost and cold rains in the seed beds by a covering of brown sheeting spread over a frame surrounding the bed.

As soon as the plants are established in the field, each one receives a small quantity of artificial fertilizer, a mixture of hen manure, wood ashes, and plaster, is excellent for this purpose; the large quantity of sulphuric acid and lime in the ash calls for a corresponding supply of sulphate of lime (plaster), and this is of great use to push the young plants forward. The soil is kept fine and mellow by frequent cultivation during the growth of the crop. The great enemy of the tobacco plant is the larvæ of a sphynx moth, the same which depredates upon tomatoes, a very large light green worm with oblique yellowish stripes upon its sides. This worm will eat large holes in the leaves in a night, and if left unmolested would soon strip the stalks bare and destroy the crop. They are sought out early in the morning and at evening, and destroyed. Turkeys are eager in the search for these worms, and a flock of them kept in a field and fed there, will do good service in ridding the plants of the pest.

Another indispensable and constant labor is the removal of the numerous suckers which grow from the axils of the leaves as soon as they become large. These suckers are to be pinched off as soon as they appear, or they will seriously retard the growth of the leaves. The object of the grower is to get large well shaped perfect leaves; and to secure this end, the plants are pushed into vigorous growth and preserved from whatever may be an injury to them. A profitable crop is not made without great watchfulness and care, and the skill to do the right thing at the right time. The last process in the cultivation is the topping of the

plants. This is done as soon as the flower buds appear. These are pinched off with the small leaves at the top of the stalk. From 8 to 14 leaves are left to grow. The small varieties, especially the bright yellow kinds, or the finer textured wrappers, and the Oronoko and Persian tobacco used for cutting for cigarettes, are topped at 8 or 10 leaves. The larger kinds have 10 to 14 leaves left upon the stalks. After this work has been done the constant care of the planter is exercised in keeping the suckers pinched, and removing any later flower buds which may appear. All this care tends to throw the whole strength of the plant into the leaves, and not only to increase the size, but to improve their texture and substance. At this stage of the plant, the watchfulness of the planter is redoubled, to save the leaves from the worms, and to remove any of them which may become rusted, and the lowest ones which may be in the way of cutting.

When the leaves are fully grown, the ripening stage is watched with care lest the leaves become too ripe. As soon as they begin to turn yellow, the time to cut the plants has arrived. This is done by severing the stalks near the ground and below the lowest leaves with a sharp knife. The stalk is first pierced with the point of the blade and slit for the length of several inches to facilitate the curing. The plants are then strung upon a stout lath until it is full, and the lath and the plants are placed in a rack to be carried to the curing house. This is a substantial building, protected from the weather, but provided with numerous ventilators for admitting or excluding air, when the curing is done without fire heat. When fire heat is made use of, the house is provided with a few ventilators for regulating the temperature, and with a fire place, and flues traversing the lower part of the building, for raising the temperature to a sufficient degree. The tobacco here undergoes a process of drying; after which the curing is completed by bulking the leaves, stripped from the stalk and bound by their pedicels or stems into bundles or bands of a dozen or thereabouts. These bundles are placed in

compact, long piles, and weighted. They then undergo a fermentation in which some heat is developed, and this process brings out the flavor and peculiarities of the leaf. After this has been completed, the leaves are packed in boxes or hogsheads for sale. The price of the finished leaf varies very much, ranging from 3 or 4 cents per pound, up to 75 cents or one dollar, or even higher for the yellow colored and finest varieties. The yield varies from 500 to 1500 lbs. of cured leaf per acre.

THE CULTURE OF HOPS.

CHAPTER L.

SPECIAL CROPS.

HOPS are grown with great profit as a farm crop, when the grower understands the manner of culture, and has sufficient perseverance, persistence, and patience, to withstand the numerous accidents and drawbacks which are met with in this business. These are due to the adversity of the season; the diseases which affect the plant; the insects which infest it; and the extraordinary fluctuations of the market caused by the condition of the growing crop, or the gambling propensities of the dealers who handle it after it leaves the farmers hands; or of the speculators who never see it but yet venture thousands of dollars in attempts to raise or lower the market value of it.

Hops are grown of the best quality on a rich clay loam abounding in limestone, and well supplied with decomposed vegetable matter. They are found growing naturally in swamps or wet soil that is rich in organic matter; but under cultivation will thrive in any soil that is made rich and is well cultivated. They are chiefly grown in central New York; in southern Wisconsin; Oregon; and California; and in these localities are found occasionally in fields of 10, 20, and even up to 100 acres in California. A 5 acre hop field is however as much as the average, for this crop costs a large amount in the preparation and furnishing of the land, and for the drying kilns, and a good deal of labor in its cultivation.

The method of culture is as follows. The land chosen is thoroughly well prepared and is laid out with furrows 7 feet apart each way. At the intersections, a hill is made, and enriched with well decayed manure. At each hill, two or three sets, or root cuttings, are planted, about a foot apart; and in the center of the hill room is left for planting a long stout pole 14 or 16 feet long for the vines to climb.

upon. The first year there is no crop; but the land is planted with potatoes; being of course first plowed and cultivated. The Acme harrow is exceedingly well adapted for the culture of hop fields as it entirely fills the space between the hills and leaves the whole ground worked in the best manner, without tearing out the manure applied to the hills; and when the field is crossed the whole of it is cultivated with far less labor and in a much better manner than with the ordinary horse hoe or harrow. The second year there is half a crop, and a full crop is made the third year. As the hop is a dioecious plant, that is one in which the staminate and pistillate flowers are borne upon different plants, grown from different roots, it is necessary that a certain number of the staminate plants should be grown to provide pollen for fertilizing the pistillate plants, which bear the fruit or perfect hops. The bitter substance known as "lupulin," which is the valuable part of the hops, is deposited among the scales and around the seeds of the pistillate flowers which must be fertilized by the pollen of the staminate plants. The staminate plants are usually set out in every seventh hill each way, thus making one hill to every 48 of the pistillate kind.

Hops are an exacting crop on the soil. The following table giving the analysis of the fruit, and the entire plant, shows this.

COMPOSITION OF HOPS AND THEIR ASH.

In 1000 lbs.	Entire Plant, (dry)	Hops. (dry)	Ash of	
			Entire plant.	Hops.
			(per cent.)	
Water.....	250	120		
Ash.....	74	59.8		
Potash.....	19.4	22.3	26.2	37.3
Soda.....	2.8	1.3	3.8	2.2
Magnesia.....	4.3	2.1	5.8	5.5
Lime.....	11.8	10.1	16.0	16.9
Phosphoric acid	9.0	9.0	12.1	15.1
Sulphuric acid.	3.8	1.6	5.4	2.6
Silica.....	15.9	9.2	21.5	15.4
Sulphur	2.0	4.8	4.6	3.4

The above figures afford a key to the problem of the methods of fertilization of this crop, and explains why certain substances are effective in producing a vigorous growth.

Wool waste for instance, gives an extraordinary result upon this crop, and the effect is explained by the fact that wool is rich in sulphur, and also in nitrogen, which is also largely contained in this crop.

Plaster (sulphate of lime) is also useful, as it supplies both sulphuric acid and lime. But the main reliance for the feeding of the crop is stable manure. This is one of the objectionable features of the business of growing special crops like this, for unless the farmer makes some special and adequate provision for the manure, by the way of feeding some purchased concentrated food with such coarse fodder as he can grow, to his stock, the chances are great that the rest of the farm may be deprived of its share of the manure, and the special crop get a larger portion than can be afforded. The careful farmer, who has the tact and skill to grow these special crops successfully, and is tempted thereto by the large amount of cash which they bring in, will always have a certain amount of stock feeding in this way above indicated, for the purpose of making an extra quantity of manure which can be extended by the addition of such other materials as can be composted with it. A well made compost, in which stable manure; swamp muck (this is especially valuable for this crop); wool waste; butchers offal; tanners waste; such as hair and fleshings, with the lime used in removing the hair, and if possible the ashes from the burning of the tan bark; the sweepings of town and village streets; night soil; and other similar matters, are mixed, and well decomposed; furnishes an excellent basis for the manuring of a hop field. The extra fertilizers are gypsum and plaster; superphosphate of lime; dried flesh and blood; the potash salts; and spent hops from breweries.

This crop is often seriously damaged by mildew which affects the leaves, and stops the growth of the plants; and by the hop louse or aphid which entirely covers the plant on the under side of the leaves, and ruins the crop. The white grub, which eats the roots; and rust which sometimes attacks the leaves, also damage the crop, and seriously reduce the profit of it. Hail, at times, batters the vines and

beats off the fruit; and dry weather at the setting of the cones, decreases the produce. On the other hand, when all the favoring circumstances tend to make a large yield of fine hops, the prices are so low as to render the crop almost wholly unprofitable. Nevertheless, on an average of seasons, the hop grower who well understands his business, gives close attention and care to it, and at the same time has "other eggs in his basket" and does not depend upon this crop alone, always has a satisfactory reward for his labor; and some years, is repaid in a most handsome and profuse manner for his care and skill.

The hops are picked when the yellow, bitter powder—the lupulin, or extractive principle of the flower—appears within the scales, and can be beaten out from them when the flower is dry. The picking is hurried forward as fast as possible, and as the hops are picked they are dried in kilns, upon wire gauze doors under which a large stove is kept heated. When dry, the hops are packed in bags of about 180 to 200 lbs. for sale. As they lose their fragrance and strength by age, they rapidly depreciate by keeping; and a year old hops are of but little value.

The spent hops from the brewery are an excellent manure, when decomposed in a compost, and should never be neglected by farmers or hop growers who can procure them conveniently.

CABBAGES are an excellent feeding crop, especially for sheep, and are largely grown also for sale in the markets of towns and villages. This crop is subject to all the requirements and necessities of a root crop, and can be grown in a rotation in the place of turnips, or ruta bagas, or other roots. As it needs good manuring and clean culture, and also yields a very large quantity of useful fodder or salable produce—24 tons per acre is a fair yield—it is profitably grown between two grain crops. An advantage in this crop is that early potatoes may be taken before it, and thus two crops grown in one season and both are productive and profitable.

The land is planted with the first crop as early as possible, and is cultivated often so as to hurry it through early

in July, when the cabbage plants are ready in the bed for the second crop. The cabbage seed is sown in a bed of rich fine soil in May, and the plants are transplanted when large enough, into another bed, and set 3 inches apart, so as to get large fibrous roots and a stocky growth. As soon as the potatoes are taken up they are sent to market at once and usually bring \$1. or more per bushel; the land is then worked over; the Acme harrow being the best implement for this purpose, fitting an acre an hour in the most perfect manner without any plowing, leveling the ridges, and leaving an even mellow surface ready for the new crop. The potato vines are gathered with a horse rake and carried from the field to the compost heap—which is a most necessary adjunct to every well cultivated farm. A marker, having runners 3 feet apart, is drawn across the harrow marks, making rows in which the plants are set out 2 feet apart in the rows. By taking care to draw the Acme harrow evenly across the field, lapping one-half of the ground at each turn, the distance between the plants in the row can be kept even, after the first row is set out, by observing the course of the cross marks.

No manure is required for the cabbage crop, as a liberal quantity is plowed in for the potatoes; but a dressing of artificial fertilizer, superphosphate of lime, guano, or fine bone dust, is given; being sown upon the land after the working with the harrow. 500 or 600 pounds per acre is generally used. Frequent working with the horse hoe is required; and if the land is as clean of weeds as it should be, no hand hoeing in the rows is needed. With good cultivation, and on good ground, three-fourths of the cabbages will make good, solid, salable heads; and at times, with the best grown and fresh seed, 90 per cent. of the crop will be solid heads, and will sell for \$5. per hundred wholesale. This will amount to over \$300. per acre; a very satisfactory result for a second crop, and paying well for the extra care in the culture that is required. The author has taken 150 bushels of Early Rose potatoes from half an acre early in July; realizing \$150. for the crop; and in November has sold

3200 cabbages from the same half acre, at \$5.50 per hundred; making for the season's income from this half acre \$326.; which was nearly as much as the income from 10 acres of wheat the same year.

The worst enemies to this crop are club foot and the green worm. The former is the larva of a black fly which is akin to the onion fly. The worm is a small white grub which eats into the root and deforms it, causing the cabbage to wilt and become worthless. The remedy is lime, spread on the land before planting, at the rate of 40 bushels per acre. This trouble is never experienced when cabbages are grown upon ground where turnips or cabbages have not been grown for three years. The green worm which is the larva of the white cabbage butterfly—and other species besides this—are all easily kept in subjection by the use of Persian insect powder, or a strong solution of saltpeter scattered over the plants.

ONIONS.—Under special and favorable circumstances the culture of onions may be made extremely profitable. At times the crop brings in as much as \$500. per acre; but at the low prices sometimes prevailing the income from a full product is rarely less than \$300. per acre.

The soil best adapted for this crop is a reclaimed and drained swamp. The black vegetable soil seems to provide precisely the right sort of food and conditions for it, and to give the bulbs the most desirable flavor and mildness. There are a few localities, where this kind of soil prevails, as in the town of Goshen, in Orange County, New York; Berea, in Ohio; Wethersfield, in Connecticut; Kalamazoo, in Michigan; which have become noted for the profitable culture of this crop; and the methods there followed may be imitated elsewhere with advantage.

The low black soil is first drained by means of open ditches to dry the surface sufficiently to enable it to be well cultivated, and no more; for moisture is indispensable to the finest quality of this vegetable. It is then thoroughly grubbed and freed from all obstacles to the most perfect tillage, and plowed and manured or fertilized. For this

crop, the soil is the vehicle for the conveyance of food to the crop, quite as much as for the furnishing of it from its own resources. Hence perfect tillage is indispensable for the proper digestion of the manure in the soil, to fit it for the nutrition of the plants. This point is especially noteworthy; for as has been explained heretofore, plant food is digested in the soil by the chemical action of the atmosphere aided by the finely divided and porous condition of the land; and therefore where high manuring is necessary for the production of any crop, it is equally necessary that the soil should be most thoroughly pulverized. And while this is desirable for any crop, it is indispensable for success with onions.

For this reason onions will grow upon any kind of soil if it is made quite fine, and is filled with manure. "As rich as an onion bed" has thus become a popular byword, but it is a true one, and is justified by the facts. The manure should be fine so that it may be intimately mixed with the soil by harrowing; and no other implement so perfectly does this work as the Acme pulverizing harrow; for its peculiar action in cutting up the soil, smoothing it, and turning it over, mixes the fine manure with it so that these shallow rooted plants can get a full supply of it. This crop needs to have its food near the surface.

The best fertilizers for onions are superphosphate of lime, of which 600 lbs. per acre is generally used; wood ashes, 20 to 40 bushels per acre; salt, 5 or 6 bushels; and night soil composted with earth which is the best of manures, because it is fine, rich in all the required elements of plant food, and rapidly decomposes in the soil. The land thus well prepared and brought to a smooth level surface, is sown with 12 to 20 lbs. of seed per acre. The most popular varieties are the yellow Danvers; white globe; and red Wethersfield; in the order named. The last mentioned is the best keeper; the second is the mildest flavored; and the first is the most prolific and is but slightly inferior to the others in their best points. The seed is sown by a hand drill which drops and covers it and rolls the land over it. This is a convenient method, because it leaves the rows well marked for the early

use of the cultivator which follows the sowing very soon, and before the young plants are visible. The rows are made 12 inches apart.

In a week the seed sower is changed to a hand cultivator, and is run along the rows, straddling them and stirring the soil on both sides, so as to destroy the newly germinating weeds. This work is repeated frequently, not only to kill the weeds, but for the purpose of helping the growth of the crop. When the young plants are well up, they are thinned out with a narrow "onion hoe" to 6 inches apart; some growers leave them no more than 4 inches from each other, and when the soil is very rich, the bulbs may crowd upon each other in the rows. A crop thus grown has measured 800 bushels to the acre and has sold for \$1.25 per bushel.

The rows must be kept clean and free from weeds. This is a special point in the culture of this crop. When the bulbs are of good size, some of the plants will throw up thick hollow seed stems, and these are to be broken down, lest the bulbs stop growing. A light roller or a bundle of brush is drawn over the rows to effect this purpose. When they are ripe the bulbs are taken up with a digging fork or hook, and left in rows upon the ground to dry for two or three days. They are then stored on an upper floor of a dry loft, or in shallow bins, in a building kept for the purpose. Freezing does not injure them, if they are kept frozen by covering them with straw to prevent thawing in a mild spell. Warmth will cause them to sprout and become injured for sale or use.

The worst enemy of the onion grower is the maggot which bores in the bulb when it is small; and the cutworm whose bad habits are well known. Prof. Riley the first entomologist in America, advises the following method of evading these pests.

"As a preventive treat the land early in spring with a mixture of lime and ashes, preferably wood ashes. This mixture should be lightly spread over the land after plowing and harrowed in. If, after the seed is sown, and the plants begin to come up, the worms appear and threaten

damage, employ the poisoned ball system, which, in brief, consist in placing along the rows, at a distance of 15 or 20 feet apart, small bunches of fresh cut grass or other green plant; cabbage leaves answer a good purpose. These bunches of grass or green plant should be previously sprinkled with Paris green or London purple. Should the worms still appear in great numbers by migration from surrounding fields, sprinkle the ground at night, while the worms are at work, with a diluted emulsion of kerosene. A Goshen grower has used pure kerosene for killing the worms, simply blackening, not killing, the onion tips. The free use of pure kerosene may injure the plants, hence an emulsion is recommended as safer and cheaper. The kerosene is emulsified with soap or milk in order that it may readily dilute with water. There is little doubt but that by some spraying of the fields at night with this mixture the worms can be destroyed by wholesale. It should be used most thoroughly at the points in the field where the worms are first noticed at work, and from which they spread to surrounding points."

Some other crops which are found profitable under various local circumstances, are CELERY, which succeeds to perfection upon reclaimed muck swamps and black bottom soil; MUSK AND WATER MELONS, which require a similar culture to that of cabbages; TOMATOES, which are grown in the same manner as potatoes, but require the whole season to mature; and CUCUMBERS, which are in demand for pickling. All these crops may be made very profitable by good culture, and will come conveniently and usefully in a rotation as a fallow and manuring crop; benefiting the soil; destroying weeds; and preparing the land for a succeeding crop.

It is not alone the business of the good farmer to study his art, to practice every known device, and apply every fact he may learn to increase the produce of his land, and yet leave it improved in condition, or at the least no worse for the enlarged products; but it is also his business to choose such crops as he can make most profitable; watching the

course of events; acquainting himself with the requirements of the markets; and thus making his land the means of bringing in the largest money return. The ordinary routine of farming is often too closely adhered to for the best results to the farmer. He may grow vegetables for the markets near by, or for those of distant cities; he may grow fruits, small and large; grow cucumbers and apples, and of the latter make vinegar to pickle the former; he may even manufacture his produce into finished and more salable articles; he may do all this, and yet be a farmer; and the more of this he does the more accomplished and successful farmer he will be.

But the more he knows of the inner secrets of his art and the better he can till his land, the better he can turn all his work to profit and advantage. His crops will be larger, he will choose those which sell the most readily and for the most money; he will work up as much as he can, using his knowledge and skill for the purpose of making his products more profitable. Every producer, of whatever kind of commodities he may have to sell, must study his markets and learn everything possible of the disposition of his wares. Otherwise he is working blindly and in the dark, and to great disadvantage.

So the farmer must not confine himself altogether to his fields and his barns and his crops. His own mind and intelligence offer a broad field and deep rich soil for culture of the most productive and profitable kind. The more he knows, the more he can do; and the more he can make his work and practice meet the necessities of the world which he supplies. How many farmers know what the new process of milling wheat is, and how the wheat he grows is adapted for it? There is 10 cents a bushel difference between the market value of two kinds of wheat of the same grade, simply on account of the adaptability of the one kind for this new process, by which a large quantity of more nutritious flour is procured from the better variety of wheat. There is money in this knowledge.

Again, if the market values of wheats are studied, it will

be found that there is a wider difference still between the qualities of the grain, which vary at least 25 per cent. in the market values. This must bring loss to many farmers, and the loss is more than doubled by the less quantity produced of the poorer grain. Instances might be multiplied without end in which farmers have neglected to cultivate themselves, while they have necessarily failed to cultivate their soil as profitably as they might have done.

When this fact is realized—and it is the hope of the author that the perusal of the pages of this little work may lead to this knowledge—the earnest farmer desiring to succeed in his work to the utmost, will spare no efforts to gain all the information and knowledge he can that relates to the practice of his vocation, so that he may become acquainted fully with all the principles which underlie The Culture of Farm Crops as well as of the best means of disposing of his produce.

THE END.

TABLE II.

NUMBER OF HILLS PER ACRE AT

2½ feet apart.....	6.970
3 feet by 1 foot.....	14.520
3 feet by 2 feet.....	7.260
3 feet by 3 feet.....	4.840
4 feet by 3 feet.....	3.630
4 feet by 4 feet.....	2.722
5 feet by 5 feet.....	1.742
6 feet by 6 feet.....	1.210
7 feet by 7 feet.....	1.000
12 feet by 12 feet.....	302
15 feet by 15 feet.....	194
20 feet by 20 feet.....	109
30 feet by 30 feet.....	48

TABLE III.

WEIGHTS OF A BUSHEL OF

Wheat.....	60 pounds.
Corn.....	56 "
Corn meal.....	48 to 50 "
Barley.....	48 "
Buckwheat.....	48 "
Oats.....	32 "
Rye.....	56 "
Beans	60 "
Onions.....	52 "
Potatoes.....	60 "
Lime.....	80 "
Clover seed.....	60 "
Timothy.....	45 "
Orchard grass.....	13 "

TABLE IV.

A barrel of apples or potatoes.....	180 pounds.
A barrel of flour.....	196 "
A barrel, liquid measure.....	40 gallons.
A bushel contains.....	2150.4 cubic inches. (and is a cylinder 18½ inches diameter and 8 inches deep.)
A U. S. standard gallon contains.....	231 cubic inches.
A box 17¾x15x8 inches holds.....	1 bushel.
A box 14⅓x10x7½ inches holds.....	½ "
A box 18⅓x15x10 inches holds.....	a heaped bushel.

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FIGURE 1.

Fig. 1 shows front coulters passing an obstruction such as stone, knoll, corn stubble, or other rubbish—the rear coulters remain at work in the soil.

This flexibility admits of one bar dropping into furrow, while the other bar is working on a higher level, and it enables the driver with the aid of the tilting lever, to clear the Harrow of rubbish which may accumulate under the coulters.

In other harrows where the gang bars are fastened rigidly together, neither bar will remain on the ground when the other bar is passing an obstruction, nor will either bar drop into a dead furrow or other hollow when the other bar is on a higher level. Neither can rigid bar harrows be cleared of rubbish without the driver leaving his seat and lifts the harrow.

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**New Style "ACME" Harrows, Nos. 10, 11 and 12
have Reversible Coulters, viz:**

When worn out on one end they may be turned "end for end" and in fact are equal in point of durability to two sets of Coulters.

Adjustable Coulters, viz:

The Coulters on this style may be adjusted to cut over more or less of the surface. In summer fallow the Coulters may be adjusted to "overlap" so as to practically clean the ground of weeds, if they have not been allowed to grow up rank. Again on ground where there is loose rubbish, the coulters may be set with less flare, and when thus set the Harrow draws easier.

Two-Wheel Sulky Attachment

—FOR THE—

"A C M E" Pulverizing Harrow, Clod Crusher and Leveler.

Can be attached to or detached from the Harrow in ten minutes. It is arranged so as to regulate the depth of work completely, and can be used in transporting the Harrow on the road.

The Sulky is very valuable in covering grain, and especially so where there is rubbish, such as corn stubble, as by means of the Lever, the Harrow may be instantly raised from the ground so that the rubbish will readily pass out from under the Coulters.

Where the ground is hard, so as to require extra weight on the Harrow to force it into the soil, the entire weight of the Sulky may be put on the Harrow by simply pushing the Lever forward, thus adding about 80 pounds to the weight.

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**"From His Own Experience in Preparing Ground
For Winter Grain,** by the use of the "ACME" Pulverizing Harrow, the writer is quite free to say that had this implement been used instead of the common harrow, the loss of wheat by the hard winter would have been trivial, and that many a single acre which has not returned the seed sown upon it, might easily have made enough grain to have paid the whole cost of this implement."

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PARTS TO REPLACE BROKEN PARTS; the only stipulation being that the farmer demanding such parts shall sign a statement that the breakage occurred in fair usage.

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