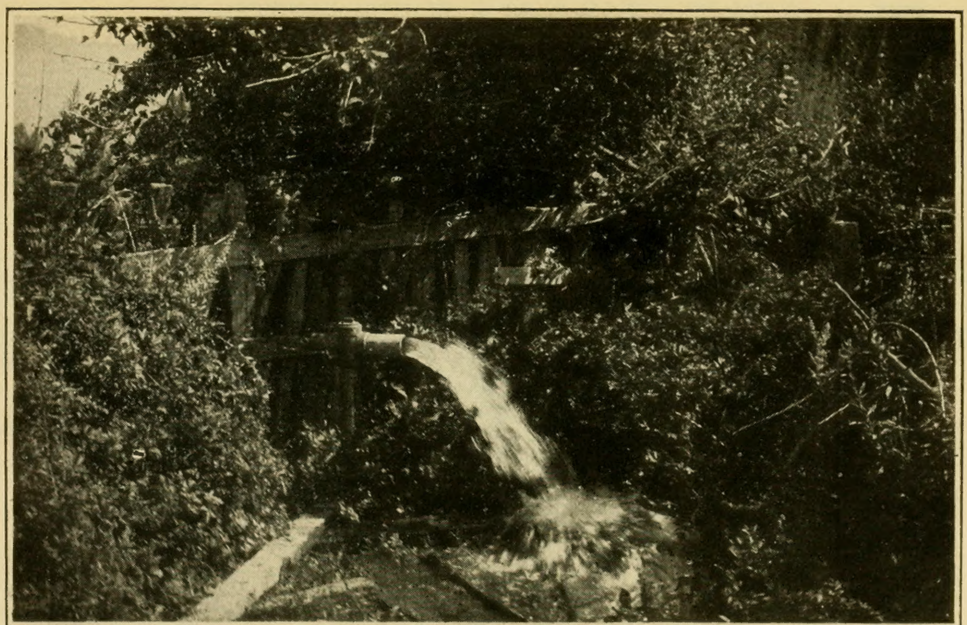

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THE PRIMER OF IRRIGATION

BY

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TO JOHN MCALPINE of Duluth, Minnesota, a man who has devoted years of his life to assisting the toiler and wage-earner, to better their condition, and who is now fighting for a clean administration of The Irrigation Law, this work is affectionately dedicated.

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PREFACE

THE author of this work has had in mind for many years the outlines of a book which would lend aid to those who are beginners in irrigation farming.

After work was commenced on this book it was realized that much more than fifty or even one hundred pages would be necessary to even half-way cover the subject, and before it was completed nearly three hundred pages of type were used.

While much of value could be added, and no doubt a lot could be taken away without serious loss, the author offers it as it is, hoping that its readers may find some profit in its perusal.

D. H. ANDERSON.

Chicago, July 1, 1905.

THE PRIMER OF IRRIGATION.

CHAPTER I.

Soil in General—Its Formation, Characteristics and Uses—Fertility and Sterility.

The mere planting of a seed in the ground is not sufficient to insure its growth, or development into a useful or profitable plant. This fact is well known to everybody, but what is not so well known is, the reason or cause why a seed grows up into a vigorous plant capable of reproducing seed similar to the one from which it sprang, and how it does it.

There are certain elements which are essential to the growth of every plant, the development of every germ, for without them it cannot live; these are heat, light, air and moisture. A few grains of wheat discovered in the coffin of an Egyptian mummy after three or four thousands years' deprivation of the four essential elements, were found inert, that is, they were not alive, neither were they dead, for upon giving them the essentials above referred to, the wheat sprang into life and produced a plentiful supply of grain.

PLANTS ARE LIKE ANIMALS.

Still, notwithstanding the necessity of heat, light, air and moisture, plants cannot flourish without proper food. In this respect plants are similar to animals. Among animals there is no universal specified diet, some eating one kind of food, others another. We see many that eat flesh exclusively, others whose sole diet is insects. Certain animals eat herbs and grass, others grain, and when we reach man we find an animal that will eat anything and everything, hence we call man "omnivorous."

It is the same with plants, some devouring in their fashion a certain kind of food, some another, and so on all along the list. Plants are substantially like animals that possess a stomach, they eat and digest, absorb and assimilate the food they obtain. If the plant is not furnished with its proper food, or if it is prevented from obtaining it, it shrivels, droops, withers and dies just like an animal that starves to death.

There is another striking resemblance between plants and animals, which is the instinct and power to seek food. The plant being a fixture in the soil, cannot of course, "prowl" about in search of food, but it throws out roots, fibres and filaments in every direction, its instincts reaching in the direction of food as surely and with as much certainty as the nose of an animal scents its prey, or the eye of an eagle sees its quarry. Not only does the plant seek food beneath the surface of the earth, but it thrusts shoots, branches and leaves up into the atmosphere for the purpose of extracting nourishment there also.

It is, however, from the soil that plants receive the principal supply of food necessary for their development, hence an acquaintance with its chemical and physical properties is important in helping us to understand the nutritive processes of plants, and the operations of agriculture.

Volumes of books have been written on the general subject of agriculture, but they are more adapted to soils upon which falls sufficient rain to dissolve the salts necessary to produce a crop. In a book devoted to irrigation, the principles of agriculture and the adaptation of the various elements of plant food in the soil, are all the more important as the water employed in irrigation—which is nothing but artificial rain—is absolutely within the control of man, and not dependent upon meteorological uncertainties. One fact should, however, be constantly borne in mind by the practical irrigator, that pure water is absolutely sterile so far as plant food is concerned, and if poured upon a pure soil, which is also sterile, there can be no crop of any sort raised. A remedy for supplying a defect of plant food in irrigating water will be given in detail in another chapter, the scope of this chapter being limited to soils that contain plant food, or are arable, in which case the quality of the water is of secondary importance.

ORIGIN OF ARABLE SOIL.

Arable soil owes its formation to the disintegration of minerals and rocks, brought about by mechanical and chemical agencies. The rock may be said to stand in about the same relation to the arable soil resulting from its disintegration as the wood or vegetable fibre stands to what is called the humus resulting from its decay. To be fertile, however, the soil must contain disintegrated vegetable matter. There is no fertility in a heap of sawdust, nor is there in a heap of powdered rock; indeed, the two might be combined and still remain sterile, it is only after both have been disintegrated by chemical or mechanical action that they become plant foods capable of nourishing and maintaining plant life.

From this it results that soil consists of two grand divisions of elements: inorganic and organic. The inorganic are wholly mineral, they are the products of the chemical action of the metallic, or unmetallic elements of rocks. They existed before plants or animals. Life has not called them into existence, nor created them out of simple elements. Yet these inorganic mineral elements of soil become part of plants, and under the influence of the principle of life they no longer obey chemical laws, but are parts of a living structure. Through the operation of the laws of the life of the plant, these mineral elements become organic and so continue until death comes and decay begins, when they return to their mineral form.

Organic elements are the products of substances once endowed with life. This power influences the elements, recombines them in forms so essentially connected with life that they are, with few exceptions, produced only by a living process. They are the products of living organs, hence termed organic, and when formed, are subject to chemical laws. The number of elements in the inorganic parts of soil is twelve: Oxygen, sulphur, phosphorus, carbon, silicon and the metals: potassium, sodium, calcium, aluminium, magnesium, iron and manganese.

The number of elements in the organic parts of soil does not exceed four: Oxygen, hydrogen, carbon and nitrogen.

The great difference between these two divisions is, that while the inorganic elements are combinations of two elementary substances, the organic are combinations of three or four elements, but never less than two. These three elements, however, are variously combined with the other elements to form salts which enter into the great body of vegetable products. in fact they are continually changing, the mere change of one element, or its abstraction forming a new product. It is this susceptibility to change, and the constant assumption of new forms by vegetable products which is the foundation of tillage, and the essence of the knowledge of irrigation.

HOW PLANTS FEED.

We do not know and we may not understand what life is, nor how plants grow, but it is a knowledge which comes to the most superficial observer, that all plants feed upon various substances their roots find in the soil, which substances are called "salts," and they are prepared for the uses of the plant by the action of organic matter on the inorganic or vice versa. That is to say, vegetable matter combines with decomposed rocks or minerals and forms a plant food without which the plant cannot live. We know as a fact that the silicates or rock elements and minerals or metallic salts compose all the earthy ingredients of soil, and are always found in plants, the ashes of any burned vegetable or plant showing this. But these silicates and salts do not make fertility in soil. Fertility depends on the presence in the soil of matter which has already formed a part of a living structure, organic substances in fact. It is this matter which causes constant chemical changes in which lies the very essence of fertility. To make this quite clear, it will be sufficient to refer to the fertility in the valley of the Nile in Egypt caused by the overflow of the river and the deposits, upon the silicates and minerals or metallic salts, which in plain language means the sands of the desert, of a layer of mud containing decomposed vegetable or organic matter. The consequence is, chemical action takes place and a rich harvest follows. The result would be the same in our arid plains where the soil contains all the ingredients necessary to plant life, but the element of moisture to dissolve and unite them is absent. Here, irrigation creates fertility. The oxygen and the hydrogen in the water supplies the soil with the elements it lacks to manufacture plant food.

There is a curious, not to say mysterious, fact connected with the transformation of the organic and inorganic elements in the soil into plant food, and that is, the chemical change does not take place except through the intervention or agency of the living plant itself. It is life that is necessary to the process and this life of the plant gives life to the inert elements around it. The mere presence of a living plant gives to the elements power to enter into new combinations, and then these combinations occur in obedience only to the well-known, established, eternal laws of chemical affinity.

If, on a dry day, a wheat or barley plant is carefully pulled up from a loose soil, a cylinder of earthy particles will be seen to adhere like a sheath around every root fibre. This will be also noticed in the case of every plant. It is from these earthy particles that the plant derives the phosphoric acid, potash, silicic acid, and all the other metallic salts, as well as ammonia. The little cylinders are the laboratories in which nature prepares the food absorbed by the plant, and this food is prepared or drawn from the earth immediately contiguous to the plant and its roots. This demonstrates the importance of the mechanical tillage of the ground. Cultivated plants receive their food principally from the earthy particles with which the roots are in direct contact, out of a solution forming around the roots themselves. All nutritive substances lying beyond the immediate reach of the roots, though effective as food, are not available for the use of the plants, hence the necessity of constant tillage, cultivation of the soil, to bring the nutrition in contact with the roots.

FORMATION AND USE OF EARTH SALTS.

A plant is not, like an animal, endowed with special organs to dissolve the food and make it ready for absorption; this preparation of the nutriment is assigned to the fruitful earth itself, which in this respect discharges the functions performed by the stomach and intestines of animals. The arable soil decomposes all salts of potash, of ammonia, and the soluble phosphates, and the potash, ammonia, and phosphoric acid always take the same form in the soil, no matter from what salt they are derived.

It is essential that these "salts," as they are called, should be understood, for without them there can be no fertility. Unless these "salts" exist in a soil in certain quantities the organic elements, or what are known as "humic acids," are insoluble and cannot be absorbed into the plant through its roots, and so there can be no fruit or vegetable. Yet there is such a thing as an excess of these same salts, and then there is barrenness. A common illustration of which may be seen in what are termed "alkali lands," which will be treated in detail in another chapter.

To simplify an acquaintance with these various salts, we shall divide them into three general classes depending upon the acids formed from them, all of them nutritious to plants.

First—Carbonates.
Second—Nitrates.
Third—Phosphates.

The carbonates compose a very large portion of the salts used in agriculture, and include limestone, marble, shells. These salts are set loose from the rock, that is the decomposed rock already alluded to, by the action of the living plant, and their business is to dissolve, or render soluble, the organic matter in the soil, so that the plant may absorb it through its roots. When there is an excess of these salts, or of lime or alkali, the organic matter is rendered insoluble, that is, the plant cannot absorb it, and then the soil is barren. There are, however, certain plants known as "gross feeders," which flourish in such soils, but of them more will be said in another chapter.

The second class of nourishing salts is the nitrates, and includes saltpeter, nitrate of potash, nitrate of soda, and all composts of lime, alkali and animal matter. This class of salts produces ammonia which hastens the decay or decomposition of the organic matter, and prepares it for absorption by the plant. All the nitrates act under the influence of the growing plant and yield nitrogen which is essential to its life, indeed, if there are any salts which can be called vegetable foods, they are the nitrates, and they hold the very first place among salts in agriculture.

The third class of plant nourishing salts is the phosphates. They are found in bones, liquid manure, and in certain rocky formations which are abundant in the United States, and ground up, are largely used upon land to add to its fertility and increase the supply of plant food.

The phosphates act much like the nitrates, their acid forming a constituent of the plant.

The proper, proportionate quantity of all these salts in the soil, is generally in the order already given; the carbonates in the greater quantity, the nitrates in less quantity, and the phosphates least. The quantity of any salt which may be used to advantage, however, will depend upon the demands or necessity of the plant which will show for itself the salt proper for its well being and perfection.

To still further simplify the idea of the use and operation of these salts and their necessity, it will be well for the reader to again imagine a similarity between the plant and an animal. The stomach of the animal secretes, or produces, gastric juice and other acids which come from practically similar salts, by the action of which the organic matter—the meat and vegetables—put into the stomach, are digested and distributed to nourish every part of the body. If there were no gastric juice, or other acids formed from the salts of the body, the organic matter put into the stomach could never become food, and the body, left without nourishment, would starve and die.

So it is substantially with plants. The main difference being that the plant has no stomach within itself, but it requires food just the same as the animal, and if it does not receive it, it starves and dies. By the active principle of life in the plant as in the animal, the salts of the soil are brought into the presence of each other to form acids which act upon the organic matter in the soil, or the humus, in very much the same manner as the gastric juice and other acids of the animal stomach, convert it into prepared food, so to speak, and the plant absorbs it, is nourished by it and grows to maturity.

SILICATES AS ESSENTIAL TO FERTILITY.

There is one important prevailing element in all soil which can neither be overlooked nor ignored, in fact, its power of fertility is unlimited; we refer to the silicates. Salts are spoken of as the inorganic substances acting upon humus or organic matter to produce nourishing foods that can be absorbed by the plant, but behind these salts, there is another substance which really constitutes the framework of the plant structure, the bony framework of the plant, the sinew of the soil.

Silex, or silica, which is the earth of flints, is, in its pure state, a perfectly white, insipid, tasteless powder. Glass pulverized is an illustration, so also is a sand heap. But earth of flints, sand heaps, are barren and worthless, as much so as a peat bog, but put the two together, and there is astonishing fertility. This silica unites readily with the mineral substances or bases, forming what are called "neutral salts," to which is given the name "silicates." Thus we have the silicate of soda, of potash, of lime, of magnesia, of alumina, of iron and of manganese, a class which forms the great bulk of all rock and soil.

The action of the silicates is simple and easily understood. When humus, or decomposed organic matter —manure for instance—is mixed with silica, that is added to a common sand heap, there is an immediate decomposition of the silicate of potash, which we have said is a neutral salt, and it becomes an active salt of potash which dissolves the humus, or organic matter and fits it for plant food. So the same process goes on with the other silicates as the various plants growing in the soil may demand for their nourishment. They are converted into active salts, which are capable of dissolving organic matter, whereas, as neutral, inactive salts or silicates, they are powerless to act.

Were it not for these silicates, the various active salts and acids would lose their virtue, but as it happens, the silicates hold them in a firm grip, intact, until the action of plant life demanding food, sets them free to aid in preparing plant food.

The base, or fixed element of the earth called silex, or silica—keep in mind a sand heap and it will be easy to remember—is "silicon." It is pure rock crystal, common quartz, agate, calcedony and cornelian. All these are silicon acidified by oxygen, and hence called silicic acid. It is this which forms, with potash, the hard coat of the polishing rush, the outer covering of the stalks of grasses. It is the stiff backbone of cornstalks which stand sturdily against the blast. Wheat, rye, oats, barley, owe their support to this silica, and where grain is said to "lodge" during a heavy storm, the trouble may be traced to a deficiency of silica in the soil. It cases the bamboo and the rattan with an armor of flint so hard that from it sparks may be struck. Entering into the composition of all soil, and hard and unyielding as it appears, forming not only the solid rock, but the delicate flower, combining with the metals of soil whose gradual decomposition is the birth of fertility, silica, or the sand heap, may well be likened to the bony structure or framework of the animal.

The next chapter on particular soils will give more in detail, the component elements which enter into their composition, and present a series of tabulated analyses showing proportions favorable to the growth of various products.

CHAPTER II.

Particular Soils, and Their Adaptation to Varieties of Plants.

Although this book is intended to apply exclusively to irrigation, that is, the artificial application of water to lands deprived of a sufficient rain fall to raise a crop, such as the arid and semi-arid lands, which constitute so vast a portion of our western country, yet, as all arable or fertile soils in whatever part of the world they may be, must contain certain elements necessary to plant life, an inquiry into the specific nature of soils will supply whatever information may be needed to till irrigable lands, as successfully as those where a rain fall may be depended upon to raise a crop. It is even possible that such information may be of greater practical value, because the elements in the soil and the crop itself, are under better control and management when the ncessary water is in an irrigating ditch, than when it is in a cloud beyond control.

As a matter of fact, there is very little difference in soils as such, wherever they may exist. All of them are capable of producing some variety of plant life, unless absolutely barren on account of the absence of plant food, as the Desert of Sahara, for instance, or by reason of an excess of the elements essential to plant life, as our so-called "alkali lands." But, when it comes to the comparative quantities of organic and inorganic elements to be found in all soils, there is a vast difference, particularly when crops of a certain kind are to be successfully raised.

It was stated in the last chapter that soil consists of inorganic and organic elements. The inorganic material being decomposed rocks and minerals; to be more precise, such as were never endowed with life, and the organic material consisting of decomposed vegetable matter, which once possessed some form of life, both of which elements are absolutely necessary to grow any kind of plant.

A little experiment, which any one can perform, will make this clear to the reader. When any vegetable substance is heated to redness in the open air, no matter whether it be a peach or a potato, a strawberry or a squash, a handful of straw or a beautiful rose, the whole of the so-called organic elements, which are carbon, hydrogen, oxygen, and nitrogen, are burned away and disappear, but there remains behind an "ash" composed of potash, soda, lime, magnesia, iron, etc., which does not burn, and which, in most cases, does not undergo any diminution when exposed to a much greater heat. It is this "ash" which constitutes the inorganic portion of plants.

The predominance of certain of these substances, which, it was stated in the last chapter, are absorbed from the soil by the operation of plant life, is what enables agriculturists to give certain names to various kinds of soils, which names, however, are of very little practical importance, except to enable a farmer to specify which of them are best adapted to the varieties of plants he desires to raise.

So far as these inorganic substances are concerned, they must exist in the soil in such quantities as easily to yield to the plant, so much of each one as the kind of plant specifically requires. If they be rare, the plant sickens and dies just the same as does an animal when deprived of its necessary food. The same thing will happen if the organic food supplied the plant by the vegetable matter in the soil be wholly withdrawn. It should be noted, however, that a plant will sometimes substitute one inorganic element for another, if it does not find exactly what it requires, as soda for potash, the tendency of every plant being to grow to perfection if it possibly can do so. This matter will be treated at length in the chapter on "Plant Foods."

The following table of the essential inorganic elements found in soils will prove useful and well worth study. The first column gives the scientific, technical name of the elementary bodies; the second column the elements or substances they combine with, and the third column contains the result of the combinations, that is, the various substances ready to form salts which enter into the life of the plant.

Elementary Body	Combines with	Forming
Chlorine.	Metals	Chlorides.
Iodine	Metals	Iodides.
Sulphur	Metals	Sulphurets.
Sulphur	Hydrogen	Sulphuretted Hydrogen.
Sulphur	Oxygen	Sulphuric Acid.
Phosphorus	Oxygen	Phosphoric Acid.
Potassium	Oxygen	Potash.
Potassium	Chlorine	Chloride of Potassium.
Sodium	Oxygen	Soda.
Sodium	Chlorine	Chloride of Sodium, or Common salt.
Calcium	Chlorine	Chloride of Calcium.
Calcium	Oxygen	Lime.
Magnesium	Oxygen	Magnesia.
Aluminum	Oxygen	Alumina.
Silicon	Oxygen	Silica.
Iron and Manganese	Oxygen	Oxides.
	Sulphur	Sulphurets.

All the above elementary substances, except sulphur, exist only in a state of combination with other substances, principally oxygen, and are found only in the soil, in no combination are they generally diffused through the atmosphere, so as to be capable of entering into the life of the plant through the leaves, or those portions above the ground. Hence, they must be taken up by the roots of plants, for which reason they are said to be the necessary constituents of a soil in which plants are expected to grow.

The enormous quantity of inorganic matter in soil may be estimated by a simple calculation. Out of five hundred samples of soil gathered from different parts of the world, the average weight of a cubic foot, wet, has been found to be 126.6 pounds. Now, let us ascertain how many pounds of mineral, or metallic salts exist in an acre of soil, say eight inches deep, the usual tilled depth, or surface soil; of the subsoil, we shall speak later on. We shall give the chemical analysis of an ordinary alluvial, or river bottom soil, such as is common in the western lands. The first column gives the name of the mineral, and the figures in the second column the parts of the mineral in an agreed one hundred parts, and the third column the weight of each substance in the surface soil eight inches deep:

Elementary bodies and their combinations	Percentage	Weight in pounds
Silica and fine sand	87.143	3,203,781+
Alumina	5.666	208,308+
Oxides of Iron	2.220	81,617+
Oxide of Magnesia	0.360	13,235+
Lime	0.564	20,735+
Magnesia	0.312	11,470+
Potash combined with Silica	0.120	4,411+
Soda combined with Silica	0.025	919+
Phosphoric Acid combined with Lime and Oxide of Iron	0.060	2,205+
Sulphuric Acid in Gypsum	0.027	992+
Chlorine in common Salt	0.036	1,323+
Carbonic Acid united to the Lime	0.080	2,941+
Humic Acid	1.304	47,941+
Insoluble Humus	1.072	39,411+
Organic substances containing Nitrogen	1.011	37,169+
Total Inorganic and Organic substances	100.	3,676,464

It should be remembered that these immense quantities are contained in only eight inches of top soil, and that twelve inches, or one foot of soil, which is about the depth before reaching the subsoil, would contain a total of inorganic and organic matter equal to 5,514,696 pounds, or 2,757 and one-third tons.

The calculation is made by multiplying 43,560, the number of square feet in an acre, by 126.6. pounds, the estimated average weight of one cubic foot of wet soil, which gives the weight of one acre twelve inches deep. Then dividing by twelve, we get the weight of an acre one inch deep. To ascertain the weight of eight inches, we have only to multiply by eight inches, and again multiply by the number of parts of any organic or inorganic matter to ascertain the exact weight of that particular matter in the acre, thus:

43,560x126.6=5,514,696 pounds per acre one foot deep.

5,514,696÷12=459,558 pounds per acre one inch deep.

459,558x0.120=551.46960 pounds of Potash in one inch acre.

551.46960x8=4,411 pounds of Potash in acre eight inches deep.

Five right hand figures must be cut off, three for the decimal places and two more because the calculation is based on a percentage of one hundred parts.

The average weight of a cubic foot of dry soil, according to the foregoing estimate, based upon the tests taken in the cases of five hundred soils collected from various places on the globe, is 94.58 pounds, which will make the dry soil acre eight inches deep weigh 2,715,792 pounds, a difference in weight between wet and dry soils of 960,672 pounds per acre eight inches deep, which, of course, represents the weight of water.

This information will prove of value in considering the question of applying water to the soil. As a rule, the proportions of inorganic and organic matter remain about the same, except that the application of water by irrigation adds to the quantity in soluble matter carried to the soil, which is greater in the case of irrigation than when rain is depended upon, humus and salts in solution being carried in the ditch water.

ORGANIC MATTER IN THE SOIL.

By referring back to the test table of a specimen soil, it will be noticed that the first twelve substances are "inorganic," and the three last "organic." It will also be noticed that the proportion of inorganic matter is vastly greater than that of the organic. It is necessary that this should be so, for the organic matter is the "active" principle, the dynamic force, and the inorganic matter the "passive" principle. If the proportions were reversed, the inorganic matter would react upon and destroy itself, and as it could not be replaced very well, there would soon be an end to the growth of plants. Hence, nature provides a store-house of raw material, so to speak, to be utilized in the manufacture of plant food, and it is practically inexhaustible, the subsoil, for an unlimited depth, containing all the ingredients necessary to restore the top soil should it become jaded and unresponsive to the demands of cultivation and fertility, if the farmer will take the trouble to dig down after them and bring them to the surface.

Moreover, the inorganic elements in the soil are permanent. They are insoluble except when acted upon by the acids formed through the chemical action of the organic matter, and the vital force exercised by the growing plant.

In the table of specimen soil, given on another page, the percentage of inorganic matter passes 95 per centum, while the organic matter is about three and one-half per cent. Yet that particular soil is a fertile one, in which it is possible to produce a good crop of any kind of plant. It is only an analysis, it is true, and a chemical analysis is not always to be depended upon, because there are so many unknown and mysterious applications of the laws of nature, but there are many things to be said in favor of ascertaining what ingredients the soil does contain, approximately, if not with rigorous exactitude. It gives the practical farmer valuable information in the form of suggestions for the improvement of the soil. It enables him to remedy the defects in his land by the application of substances it needs, and, what is equally of value, it enables him to avoid adding to the soil what he knows it already contains, and will put him upon the search for substances it does need. Moreover, an analysis will indicate to the farmer whether a certain soil is capable or not of producing a good, profitable crop of certain plants, and save him from losing his time, labor, and money by planting a crop which can not grow to perfection because of some defect in plant food necessary to plant life. In other words, the farmer will know what to do with his land without guessing, or trying expensive experiments. This is not "Book farming," it is common sense.

The reader has already discovered that the inorganic elements consist of decomposed rocks and minerals, which have assumed a variety of forms by combining with one another, and now he has reached a point which is the foundation of plant life, being that other essential in all soils, the organic elements, which must exist in a greater or less proportion. This organic matter consists of decayed animal and vegetable substances, sometimes in brown or black fibrous particles, many of which, on close examination, show something of the original structure of the objects from which they have been derived; sometimes forming only a brown powder intermixed with the mineral matters of the soil, sometimes entirely void of color and soluble in water. In soils which appear to consist of pure sand, clay, or chalk, organic matter in this latter form may often be detected in considerable quantities.

In the table already given, the percentage of Humic acid, Insoluble Humus, and organic substances containing Nitrogen, is given as 3.387 per centum, a very small quantity apparently, but really amounting to 124,521 pounds or 62¼ tons, in a top layer of soil eight inches deep, covering one acre of land. A quantity sufficient to supply crops with essential matter for plant food during many years without manuring.

This vegetable matter is the result of vegetable decomposition, a decay which means fermentation ending in putrefaction, a purely chemical process. Whence it is said: Growth is a living process; death, or decay, a chemical process. Putrefaction is the silent and onward march of decay, its goal being humic acid, which in its turn produces life. The saying of that great physician of the past centuries, Paracelsus, may be aptly quoted here: "Putrefaction is the first step to life." Everything travels in a circle in the vegetable as well as in the animal kingdom: The egg, or germ must first putrefy to produce an animal, and the seed, or plant germ, must first putrefy before there can be any living plant.

It has been said that various names have been given soils, according to the predominating mineral of which they are composed, but in reality, there are only three great varieties of soil: sand, clay and loam, the latter being a mixture of granite sand and clay. The great distinctions in the scale of soils, may be said to be sand and clay, all other varieties proceeding from mixtures of these with each other. Now, the sand may be siliceous, or calcareous, that is, composed of silicates or lime. By clay is meant the common clay abounding everywhere, and composed of about thirty-six parts of Alumina, 68 parts of Silica, Oxide of Iron, and Salts of Lime, and Alkalies, 6 parts. A sandy clay soil is clay and sand, equal parts; clay loam is three fourths clay and one fourth sand; peat soil is nearly all humus, which we have seen is vegetable matter decomposed, decayed or putrefied; garden, or vegetable mold is eight per cent humus, the rest being silica, and the other mineral substances; arable land is three per cent humus. There are, in addition to these varieties of soil, several special varieties which are fortunately not general, and therefore, need not be more than referred to. They are those peculiar conditions found in the "black waxy," "bad lands," "hard pan," upon which, nothing short of dynamite will make any impression so far as discovered, and the "tules," which are common to California, but are extraordinarily fertile when reclaimed, being similar to peat bogs without the disadvantages of the latter, and that are known as "swamp" or "marsh lands." When it comes to "desert lands" in the sense of the Acts of Congress, they lack only water to make them as fertile as any lands in the world. They will be treated in the chapter on Arid and Semi-Arid Lands.

Aside from the chemical composition of soils, what equally concerns the farmer is their physical characteristics. These may be enumerated under the terms cold, hot, wet and dry land. And these are dependent upon weight, color, consistency, and power to retain water. The relation of the soil to consistency makes it light or heavy; its relation to heat and moisture makes it hot or cold, dry or wet.

Taking the varieties already specified, sand is always the heaviest part of soil, whether dry or wet; clay is among the lightest parts, though humus has the least absolute weight. To calculate more closely: a cubic foot of sand weighs, in a common damp state, 141 pounds; clay weighs 115 pounds, and humus, 81 pounds, and garden or vegetable mould and arable soil weigh from 102 to 119 pounds. The more humus compound soil contains, the lighter it is.

The power of a soil to retain heat is nearly in proportion to the absolute weight. The greater the mass in a given bulk, the greater is this power. Hence, sand retains heat longest, three times longer than humus, and half as long again as clay. This is the reason for the dryness and heat of sandy plains. Sand, clay and peat are to each other as 1, 2, 3 in their power of retaining heat.

But while the capacity of soil to retain heat depends on the absolute weight, the power to be warmed, which is a very important physical characteristic, depends upon four circumstances: color, dampness, materials, and fourth the angle at which the sun's rays fall upon it.

The blacker the color, the easier warmed. In this respect, white sand and gray differ almost fifty per cent in the degree of heat acquired in a given time. As peat and humus are of a black, or dark brown color, they easily become warm soils when dry, for secondly, dampness modifies the influence of color, so that a dry, light-colored soil will become hotter sooner than a dark wet one. As long as evaporation goes on, a difference of ten or twelve degrees will be found between a dry and a wet soil of the same color. Thirdly, the different materials of which soils are composed exert but very little influence on their power of being heated by the sun's rays. Indeed, if sand, clay, peat, garden mould, all equally dry, are sprinkled with chalk, making their surfaces all of a color, and then exposed to the sun's rays, the difference in their temperature will be found to be inconsiderable.

Fourthly, the angle at which the sun's rays fall on the land, has much t do with its heat. The more perpendicular the rays, the greater the heat. The effect is less in proportion as these rays, by falling more slanting, spread their light out over a greater surface. This point is so well understood that it is not necessary to dwell any longer upon it, further than to add, that there are localities where every degree of heat diminishes the prospect of a good crop, particularly in hot regions, and the circumstance should be taken advantage of to obviate the danger of loss. A northern exposure or an eastern exposure, or a crop on a slope may sometimes realize more benefit than if this knowledge were disregarded.

The relation of soil to moisture and gas, particularly moisture, is of great importance in the case of irrigation. All soil, except pure siliceous sand, absorbs moisture, but in different degrees. Humus possesses the greatest powers of absorption, and no variety of humus equals in its absorptive power, that from animal manure, except those heavily charged arid and semi-arid lands, in which fibrous roots and vegetable matter form a large part of the elements they contain. The others rank in the following order: Garden mould, clay, loam, sandy clay, arable soil. They all become saturated with moisture by a few days' exposure.

It is a very interesting question: Does soil give up this absorbed water speedily and equally? Is its power of retaining water equal? There is no more important question to the irrigator. As a general fact, it may be stated, that the soil which absorbs fastest and most, evaporates slowest and least. Humus evaporates least in a given time. The power of evaporation is modified by the consistency of the soil; by a different degree of looseness and compactness of soil. Garden mould, for instance, dries faster than clay. As it has already been shown, that the power of being warmed is much modified by moisture, so the power of a soil to retain water makes the distinction of a hot or cold, wet or dry soil.

Connected with this power of absorbing moisture, is the very important relation of soil to gas. All soils absorb oxygen gas when damp, never when dry. Humus has this power in the highest degree, however, whether it be wet or dry. Clay comes next, frozen earths not at all. A moderate temperature increases the absorption. Here are the consequences of this absorptive power.

When earths absorb oxygen, they give it up unchanged. But when humus absorbs oxygen, one portion of that combines with its carbon, producing carbonic acid, which decomposes silicates, and a second portion of the oxygen combines with the hydrogen of the humus and produces water. Hence, in a dry season well manured soils, or those abounding in humus, suffer very little.

The evaporation from an acre of fresh-ploughed land is equal to 950 pounds per hour; this is the greatest for the first and second days, ceases about the fifth day, and begins again by hoeing, while, at the same time, the unbroken ground affords no trace of moisture. This evaporation is equal to that which follows after copious rains. These are highly practical facts, and teach the necessity of frequent stirring of the soil in the dry season. Where manure or humus is lying in the soil, the evaporation from an acre equals 5,000 pounds per hour. At 2,000 pounds of water per hour, the evaporation would amount in 92 days, that is, a growing season, to 2,208,000 pounds, an enormous quantity of water, too much to be permitted, however beneficial that evaporation may be. It is true that this evaporation is charged with carbonic acid, and acts on the silicates, eliminates alkalies, waters and feeds plants, but where irrigation is practiced, the evaporation is carried on with as good an effect beneath a mulch of finely pulverized soil through which it penetrates, if the land is properly prepared for and tilled after the application of water. This is a subject which demands careful study, so that the laws of nature may be as rigorously enforced when man takes them under his control, otherwise, there will always be failure. How to enforce those laws without doing violence to the principles which underlie them, is matter which will be fully treated in future chapters.

In concluding this chapter, it is deemed proper to call the attention of the reader to this maxim which should never be forgotten: It is not the plants grown in a soil that exhaust it, but those removed from it. It is an undeniable fact, that the growth of plants in any soil is beneficial, inasmuch as it brings into play the forces of nature which are in constant motion toward increase through fertility. For ages, the great prairies of the West, and also the so-called "arid, and semi-arid" lands have been storing up humus which now needs but the application of water to convert them into lands that will laugh with rich harvests. Plant life has, for centuries, sprung into existence, reached maturity, and decayed, going back into the soil, with no hand to remove it. The consequence is, all these lands are rich in salts and humus, and it is left for the man with the ditch to add moisture, open the soil and admit oxygen to the seeds he plants, so that they shall be fed up to perfection and enable him to reap a glorious harvest.

The laws of nature are the same in this regard as to the man who looks to the heavens for his inconstant rainfall. There is for him to consider in the lands under ditch, that all soil has four important functions to perform, which are:

First.—It upholds the plant, affording it a sure and safe anchorage.

Second.—It absorbs water, air and heat to promote its growth. These are the mechanical and physical functions of the soil.

Third.—It contains and supplies to the plant both organic and inorganic food as its wants require; and

Fourth.—It is a workshop in which, by the aid of air and moisture, chemical changes are continually going on; by which changes these several kinds of foods are prepared for admission into the living roots.

These are its chemical functions. They all are the law and the gospel of agriculture, and all the operations of the farmer are intended to aid the soil in the performance of one or the other of these functions.

CHAPTER III.

Semi-Arid and Arid Lands—Their Origin and Peculiarities.

From a general chemical point of view there is very little difference between the soils elsewhere on the surface of the globe, and those in the vast empire in the United States west of the 100th meridian. The soil possesses the identical organic elements already specified in the table given in the second chapter; the same organic substances abound; the processes of plant life are similar, and the same plant foods are essential to the welfare of crops. Still, there is a difference apparent to every man who thrusts a spade into the ground, plants a seed, and attempts to coax the soil to produce a harvest.

A bird's eye view of the entire region impresses the observer with the appalling sense of a vast, barren desert, a few oases, here and there, where widely separated streams and springs exist, but in the main it is an illimitable ocean, a desolate plain, with occasional straggling clumps of scant coarse grass, sage brush, artemisia, chemisal, greasewood, scrub oak, cactus and other sparse vegetation, kept alive by the scant snows of winter followed by dreary, hot, rainless summers, or by inadequate winter rains succeeded by a tropical dry season. This is the general aspect of the semi-arid lands.

Beyond them, except in the North, there is no winter, no seasons, nothing but a pitiless cloudless sky, tropical heat, unmitigated by moisture, with an atmosphere so dry and desiccating that animal matter exposed to its oxygen dries, or oxidizes and becomes reduced to an odorless powder, the toughest substance soon presenting the appearance of a moth-eaten garment. This is the aspect of the arid lands. Some say there are a hundred millions of acres of both kinds of land west of the 100th degree of longitude, others claim a hundred and fifty millions of acres, but the author suspects a still greater measurement.

Notwithstanding all these discouraging features, there is no land in the world that possesses greater fertility, greater capacity for plant growth, and that will so amply and so richly repay the labor of him who puts his hand to the plow and blinds his eyes to the hideous scenic features, until he has created an oasis of his own, in the midst of which he may sit in peace, plenty and content, beneath his own vine and fig tree, in a cooling breeze, sipping the pure cold water from his own olla hanging in the shade, while over, beyond him, sizzling in the hot sands of the so-called desert, eggs may poach in the intense heat, and not even an insect find energy enough to emit a single buzz.

By and by, a neighbor comes, sees the oasis and the near by sands, wonders if he can accomplish as much, tries it, and is surprised to find how easily it is done. Then comes another neighbor, and another, and still more, who push the desert farther off, until there is no desert as far as the eye can reach, nothing visible but rich harvests, fat kine, and plenty. The very atmosphere has changed; the rainfall is slightly increased, where rain and moisture had been strangers from a time far beyond the memory of man, the dews of heaven begin to fall and restore to the parched soil a portion of the moisture stolen from it by the greedy sun. It is a desert reclaimed, semi-arid and arid lands wrenched from the grasp of ages of barrenness and in the struggle forced to perspire plenty, comfort, and wealth. Is the picture overdrawn? The reader has but to look around to perceive the truth of it; it is a moving picture constantly before the eyes of him who turns them in the right direction.

There are men still living who remember when all that vast domain was considered as a desert, and indicated on the maps of long ago, as "The Great American Desert," even the Government regarding it as a desert not worth offering the public, or so poor and worthless as not to be worthy of protecting against marauders.

It has been said that from a general chemical standpoint, there is no difference in the soil which offers so mournful and dreary a prospect as our semi-arid and arid lands, and that found anywhere else on the globe. In their physical characteristics, however, a vast difference is presented to the eye, but that difference is not to the disadvantage of the desert, for when we come to investigate, even carelessly, we discover a greater richness of inorganic and organic matter than in any other region on the earth. For ages the land has been exposed to the lixiviating action of rain water, in greater or less quantities—for it must be taken as true that at some period in the misty past all these lands were exposed to the wash of rains—without losing their fertility. As year after year and age after age rolled away, greater or less vegetation grew to maturity, and, unharvested, returned back into the soil to further enrich it, and hence it became richer and richer, for it must be remembered, that the fertility of the ground is not diminished by plants growing therein; it is not until they are removed from the ground that the soil gradually loses its fertility. Neither was there any impairment by their utilization as pasture grounds for countless herds of wild and domesticated animals, for those, during ages of pasturage, returned to the soil the elements most suitable for plant life.

GENERAL CHARACTERISTICS.

Inasmuch as this book is devoted to irrigation, it will be understood in all cases, that the lands and soils referred to in it belong to that class known as "arid," or "semi-arid," or, as they are commonly called, "desert lands," as contradistinguished from those soils which produce crops through the instrumentality of rain. This is often said to be raising crops by "natural means," but it by no means follows that growing crops by irrigation implies "unnatural" means, the latter method being equally as natural as the former, the forces of nature being equally at the command and disposal of the farmer. Nature works along lines laid down by general laws, and man makes a special application of them for his own uses and purposes. He drains the land when the rain fall is too abundant, and when it is insufficient, or fails altogether, he irrigates it. He follows the laws of nature in both cases, wthout altering, straining, or violating them, indeed, he could not if he would.

Comparing the entire vast area of arable desert lands of the great West with the lands within the rain belt, the soil relations between the various localities are substantially the same. There are good and there are bad lands, lands that are fertile and others that are sterile; here we find soils which will grow luxuriant crops, there we see soils that are not worth even an experiment.

To realize this properly the reader must divest his mind of the idea of immensity that amazes, and often disheartens him; this idea eliminated, the only thought that should dominate his mind, if he contemplates practical success, is, how to abolish the actual differences and arrive at practical uniformity in agricultural results. He thinks of the pioneers who went into the forests with their axes and laboriously felled trees and extracted stumps with infinite labor, to prepare a clearing, in the soil of which he might plant his sparse crops, and wait years before establishing any sort of home. Perhaps he remembers how a bog or marsh had to be drained, and the years it required to "sweeten" the soil before it could be utilized. He does not fully realize that in the desert his land is ready for his muscles, for his seed, and for his crop; he does not dream that he does not have to grow old before carving out a comfortable home as he had to do in the old days, back in what he is pleased to call "God's country," and that out in the desert he may have a home and plenty while still young enough to enjoy them.

The climatic differences are too much in favor of the desert to desire alteration, but the diametrically opposite methods of controlling the soil are difficult to be appreciated, though they are never baffling. They are no greater than elsewhere, but they are opposed by preconceived opinions, perhaps, rooted prejudices, and are, therefore, apparetly more serious. There are illimitable treeless regions, covered or patched with stunted vegetation, that receive little or no moisture at all from the clouds, and a soil parched, even burned by the hot sun. Yet the scientists have discovered and classified 197 different species of plants that love the desert soil and flourish in it. Many of them suitable for animal food, all of them indicating some quality in or under the soil as plainly as if they were labeled.

Thus, greasewood, or "creosote bush," indicates less than 0.4 per cent of alkali in the soil; salt grass and foxtail mean that there is plenty of moisture at the surface of the ground and consequently, the presence of free ground water not far below the surface; shad scale indicates dry land with less than 0.4 per cent of salt; rabbit bush flourishes on sandy soil comparatively free from salts, and will seldom grow under any other conditions; sweet clover and foxtail indicate wet land and less than four per cent of salts, though sweet clover will grow in six per cent alkali soil and produce a fairly good crop for forage if harvested very early.

So it is with the color of the soil. Indications are ever present of the dominant characteristics of the ground. Red soils always indicate iron in the form of an oxide; black soils mean carbonate of soda, an alkali ruinous to vegetation; white soils or gray mean soda in sulphate salt form, also deleterious to plants when more than one or two per cent; gray or brown and black cracked or checked soil with vegetation, signifies adobe, while barren, dark or light colored soil so hard that dynamite is more suitable for its tillage than a plow, is "hardpan," the former indicating a soil retentive of moisture, the latter indicating that moisture is somewhere beneath.

Another peculiarity of desert land soils is the frequent occurrence in the soil when plowed or dug up, of innumerable small roots or rooty fibers. They are, indeed, vegetable remains, but through lack of moisture, they have not fermented into humus, though it may be said that they have practically "oxydized" without losing any of their nitrogenous elements. It is well for the desert soil where this organic matter exists, that these rooty fibers have not fermented, for the inorganic matter, the alkalies and other mineral and metallic salts would have speedily devoured the product and left nothing for plants to feed upon. The reader has already been informed that both organic and inorganic elements are essential to plant life, and that the inorganic elements—the substances given in the table in the second chapter and their combinations into salts, are largely in excess of the organic elements. The same principle holds good in the case of desert soils—it is not a theory but a practical fact—that organic matter added to the inorganic means life; their separation, death. Hence, it is clear, that the addition or presence of organic matter and nitrogen, added to the mass of inorganic substances in the soil, tempers the latter and lessens its natural tendency to do harm. In the case of an alkali soil, vegetable matter and nitrogenous substances lessen the deleterious effects of the alkali, although it may not reduce the percentage of the salts. Whence, also, the presence of masses of coarse or fine vegetable fibers in the soil is evidence of either the absence of an excess of alkali, or that it is under control and innocuous to vegetation. Perhaps the reader may see in this a way to get rid of the alkali in soils and render them fertile. If he does, he will not be far wrong in his idea, as we shall see presently.

LACK OF WATER.

There are two conditions which are the bane of all desert lands, whether arid or semi-arid: Lack of water and the presence, in excess, of alkalis. We shall devote space here to some general remarks on both conditions, leaving it to subsequent chapters to enter more into details. The chapters on "Alkali Soils," "The Relations of Water to the Soil," and that on "Cultivation," will give more particulars, though at this point it may be necessary to include matter which will be repeated elsewhere, or presented from a different viewpoint. This, however, should not be deprecated as a fault, but extolled as a benefit, for the subject is of so much vital importance that it can not be repeated too often, lest it be forgotten.

There must be a water table at some point below every soil, at a less or greater depth. This may be accepted as a fact without going into geology to prove it. Such subsoil water originates in a variety of sources, through percolations from above, underground streams coming from great distances, from springs that have their original sources in some nearby hill or mountain land, by seepage from rivers, brooks, or streams, from an irrigating ditch, or pond, and from the artificial surface application, or through sub-irrigation. Although the action of the earth's gravity pulls or draws water downward as it does every other object heavier than the atmosphere, the constant natural tendency of the water beneath the surface is to rise to the surface and evaporate.

It is this rise of the water table to the surface that causes more alarm than any other process of nature in the arid and semi-arid regions, particularly in the arid regions where all water must be applied artificially. The reason is obvious. The subsoil water contains in solution whatever soluble salts it may come in contact with, and reaching the surface, evaporates, leaving behind a deposit of the salts as crystals. Constant deep cultivation also has a tendency to bring up the water table with alkaline solutions, for we have already seen that the subsoil contains in reserve as much mineral matter and salts as the surface soil. And this is so whether the land is in the arid regions or in the rain belt, the disadvantage of the desert land being that the proportion of organic matter is not high enough to maintain an equilibrium of plant food consumption. Still, this is not an incurable disadvantage, for when the labor and expense of draining, mixing, tempering, and reducing soils in the rain belt is compared with the trifling care and attention devoted to desert land soils to render them continuously fertile, the wonder is that they produce any crops at all, so slight is the effort to make them yield.

It is not uncommon to fill the subsoil with water from irrigating ditches, by putting into it all the supply obtainable during the flood season, thus bringing the water table sufficiently near the surface to supply the crops by capillary action. This brings the ground water within three or four feet of the surface, which is well enough for alfalfa and gross feeding plants, but is bad for trees, vines, and more delicate plants. In arid regions where irrigation is the only means of bringing moisture to the soil the water table may be a hundred or more feet below the surface and can not rise on account of impenetrable strata of rock or hardpan. But in that case the irrigation water creates a new water table, the excess of the irrigating water sinking down until it meets an impervious stratum of rock or hardpan, and there it accumulates, becomes stationary, dissolves out the earth salts and when the surface soil dries out or is deeply cultivated begins coming to the surface by capillary action, every subsequent additional saturation of the soil from the irrigating ditch increasing the area and zone of the artificial water table. When that happens, and it does happen in desert lands sooner than it takes to clear the ground of trees and stumps in the rain belt, drainage becomes of vital importance, second to irrigation itself.

In semi-arid regions, where there is some rain fall, though inadequate, the amount of rainfall, whatever it may be, has washed the alkali out of the surface soil down into the water table, and the surface soil is freer from the deleterious material, which in the arid soils even prevents the seeds from germinating and obtaining a foothold strong enough to resist it, for when a plant has outgrown its infancy, and developed its first true leaves, it will require a most extraordinary quantity of deleterious material to destroy it. It refuses to absorb what it does not need and does not require, and unless wholly overpowered by the solutions in the water that surrounds it, it will grow up to be something more or less perfect.

It is said that six or eight inches of rain will mature a crop in the semi-arid region with proper cultivation. It matters little whether it be wheat or barley if the grain be sown very thin to allow more room for stooling. Six inches will grow it to fodder and eight inches will cause it to head out fairly well. An instance has been called to the attention of the author, where ten inches produced two crops without irrigation.

A fair crop of potatoes was grown in and removed from the fibrous, red clayey soil in April. The land lay on a side hill, about in the center, the summit of which had been roughly plowed to gather as much rain as possible so as to utilize the seepage for the potatoes. Immediately after the removal of the potatoes the land was plowed deep, and moisture still showing, it was carefully cultivated. Corn, of the variety known as "white Mexican," was then dibbled in and left to its fate. From the time of its planting, until harvested, not a drop of water was put on the land by way of irrigation, and only about an inch of rain in "Scotch mists" fell upon the surface. The corn came up in four days and grew strong and vigorous. The soil was plowed deep about every ten days, fully turned over and followed with the cultivator and harrow, until it became so soft and powdery that it was difficult to walk in it. It was also hoed frequently, not a weed being permitted to appear, and the soil stirred deep and drawn well up over the roots. The land measured about an acre. The corn grew to full maturity without a single set back, or twisting of a leaf. The stalks measured an average of nine feet and each bore from two to four perfect ears of plump kernels, and made good roasting ears, and when harvested in the middle of June, the ground still showed some moisture.

Instances of this particular kind are abundant in every locality in the arid and semi-arid regions. They are nothing but experiments, or rather accidents, and prove nothing that can be of general utility. They show, however, what may be done by careful cultivation with a small amount of water husbanded to the last drop. There was not a particle of alkali in the soil above referred to, and it was very retentive of moisture. It emphasizes what the author contends, and what scientific investigation places beyond the pale of denial, that cultivation and moisture are what may be considered essentials, and not water in its liquid form. To borrow a word from another profession: we are dealing with the homœopathy of agriculture, and advocating water triturations provided they accomplish the purpose of growing a profitable crop, where drastic doses will ruin.

In every case, however, the supply of water diminished by evaporation must be restored either by irrigation or by rain fall, and the requisite amount must be continuous and not intermittent; that is, the plant must be kept growing.

If it were not for the fact that water is a solvent of the salts necessary to plant life, and as a medium for conveying them in a state of solution to the plants, there would be no necessity for water, and plants could grow in an absolutely dry and rainless region without irrigation.

It should be borne in mind that it is not so much "wetness" that plants require, as a medium for dissolving the earthy salts and vegetable acids, so that the two may find their affinities and form the various chemical combinations which are necessary to make the plant. When that has been accomplished all the rest is surplus, waste, useless expenditure of the forces of nature, deleterious to plants by over feeding them, and injurious to the soil by washing its reserve elements out altogether, or driving them down into the subsoil beyond the reach of the plant roots, or forcing them to combine in excessive quantities which leach out, or crystallize on the surface and accumulate in masses that prevent the germination of seeds.

More will be said upon this important subject in the chapter on "The Relations of Water to the Soil," the second bane of desert land, "alkali," being next in order.

CHAPTER IV.

ALKALI SOILS; THEIR NATURE, TREATMENT AND RECLAMATION.

The "alkalis," as they are called, are common to all soils wherever they may be found on the globe; they belong to earth and are part of its essential constituents.

Originally, they were brought or carried into the soil along with the other elements which form its inorganic bulk (as has been explained in Chapter II), by the pulverization of rocks and minerals, the deposition of inorganic sediment held in solution by water, by glacial action, by seepage from rivers, and numerous other ways.

These elements, if unacted upon, would forever remain in an insoluble, inert condition, incapable of exerting any influence upon each other, or of performing any functions whatever; in which case, however, there could not be any plant life of any kind. But nature comes in and begins action upon these elements and changes their form so that they may become capable of aiding in the production of plants by furnishing them with the food to make them grow and ripen their fruit or seed.

First, we have the atmosphere, or air, which, however arid the region, contains oxygen in a very large proportion, and this oxygen attacks the inorganic elements, transforming them into various substances, or rather fits them to be acted upon by other substances so that they may become useful or otherwise. Thus, oxygen acts upon potash, soda, lime and magnesia to form what are known as "alkaline bases," that is, the foundations for the "salts," which are beneficial in moderate quantities but injurious in excess. The forces of nature are always at work, regardless of the quantity of the product; certain laws are followed, and these laws keep on operating in certain unvarying ways, according to a fixed program, which is never changed unless man comes in and compels a change. The following table will enable the reader to understand in a general way how nature works upon the elements in the soil through oxygen:

OXYGEN

Unites with Potassium and forms Potash.
Unites with Sodium and forms Soda.
Unites with Calcium and forms Lime.
Unites with Magnesium and forms Magnesia.

The oxygen acts upon the above four metals just as it does on iron exposed to the air, when it forms the familiarly known "rust," which is technically called "oxide of iron." So the potash, soda, lime and magnesia are really the earth oxides, the four of them being "alkaline bases," that is, the foundations upon which to compound all the various kinds of alkalis.

These "oxides," or "bases," in themselves, would be of very little use or harm while in that state, but the oxygen in the air and everywhere else attacks the other essential elements in the soil as well as the potash, soda, lime and magnesia, that is, the silicon, carbon, sulphur and phosphorus, but instead of converting them into oxides, or alkaline bases, turns them into "acids." The following table will explain:

OXYGEN

Unites with Silicon and forms Silicic Acid.
Unites with Carbon and forms Carbonic Acid.
Unites with Sulphur and forms Sulphuric Acid.
Unites with Phosphorus and forms Phosphoric Acid.

Here is where the whole trouble about alkali soils begins, for these acids mentioned in the last table, which may be called mineral, or metalic, acids, have a great affinity for the alkaline bases mentioned in the first table, and greedily seize upon them, forming "salts," as they are commonly called. When these mineral acids attack the alkaline bases, this is what happens:

Silicic Acid froms Silicate of Potash, Soda, Lime and Magnesia.

Carbonic Acid forms Carbonate of Potash, Soda, Lime and Magnesia.

Sulphuric Acid forms Sulphate of Potash, Soda, Lime and Magnesia.

Phosphoric Acid forms Phosphate of Potash, Soda, Lime and Magnesia.

It is the carbonate of soda, or what is commonly called "sal soda," which makes "black alkali land," and sulphate of soda, or "Glauber salt," which constitutes "white alkali land." There are numerous other salts formed by combining the alkaline bases and the mineral acids, but sufficient are given here to make the principle clear; to enumerate the others would require a volume, and complicate too much the idea sought to be conveyed in this book. Moreover, their action is the same as the sodas, though in a much less harmful degree.

So far, water has been kept in the background, as unnecessary to the formation of these salts, but when water is brought in the distribution of these alkaline salts is largely aided, for the alkalis are extremely soluble in water, the latter taking up nearly its own weight of the salts. When this happens, the alkalis are carried wherever the water penetrates, and when it comes to the surface it evaporates into the atmosphere, but leaves the alkali salts behind to accumulate, until the soil is ruined for purposes of vegetation unless they are removed, or got rid of in some way and the soil thus "reclaimed," as it is called.

In this inorganic matter, plant life is impossible. As has already been said, organic matter in combination with the inorganic matter, is essential to plants of any kind, and here originates a phenomenon as common as the continual process of the formation of alkalis by combinations with the mineral, or metallic, acids, as above specified. Organic matter also combines to form acids which are called "vegetable acids," and they also readily combine with the alkaline bases, the result of which is mutual destruction. This will be understood from a simple experiment that any reader can try.

Vinegar is the most commonly known vegetable acid, the technical name of which is "acetic acid," it being formed during the germination of seeds in the ground, as will be explained in the chapter on Plant Foods. The plant forms it within its tissues and then rejects it for the purpose of permitting it to continue dissolving the earthy substances with which it is in contact. It is also formed artificially for domestic use. Now this vinegar is the natural enemy of the alkalis. When poured upon any of the alkalis of potash, soda, or magnesia, it causes a hissing or effervescence. When this ceases, there is left neither an alkali nor acid, both have disappeared, and their substances are totally changed into something else, a new salt called an "acetate," which is neither one thing or the other; they have mutually destroyed each other.

These acetates are not noxious to plants, and appear to be freely created by the plant itself during the process of developing acetic acid, which is essential for the purpose of transforming starch into sugar, whether of the cane or grape variety, and for laying the foundation of woody fiber and cellular tissues, all of which, alkali tends to prevent if in excess. It is well known from actual experience that sugar bearing plants, such as sorghum, sugar beets, and trees of abundant starch and woody fiber will flourish luxuriantly in alkali soils that will not even permit the germination of cereals, or alfalfa. The reason why this is so is not far to seek, and when well understood the partial reclamation of alkali lands, even under adverse conditions, may be attained, and wholly so where the conditions are opposed to the accumulations of alkali from artificial sources.

DANGEROUS PERCENTAGE OF ALKALI.

There is much controversy about the dangerous amount of alkalis in arable soils, but the entire question may be resolved into four divisions:

First—Soils naturally so heavily charged with alkali as to be worthless.

Second—Soils in which the alkali is increased by fortuitous or artificial means.

Third—Alkali soils suitable for general crops.

Fourth—Alkali soils adapted only to certain special classes of plants.

The sodas are the most dangerous of the alkalis, both the carbonate, or "sal soda," which is the cause of "black alkali land," and the sulphate, or "Glauber salts," which is the deposit on most of the "white alkali lands," because they are so very easily soluble in water, whereas the sulphate of lime, or "gypsum," and all the other sulphates, and the phosphates, are very much less soluble in water. The consequence is, the soda alkalis are always shifting their location, always following the water, because the latter takes them up greedily whenever they are brought in contact, whether on the surface or in the subsoil, or under the influence of seepage which carries the alkalis from a higher to a lower level. The tendency of water when in motion, or flowing, is first downward, it leaches, or percolates through the soil, but after it has become stationary, that is, when it does not find an outlet through drainage, either natural or artificial, it begins an upward movement toward the surface through capillary action, and carries with it the alkalis it contains in solution, evaporates and leaves the salts on the surface. It is not difficult to understand how the alkalis accumulate in the soil, the difficulty begins when the attempt is made to remove them and fit the soil for plant life.

As the amount of alkali deposited in the soil increases, the number of species or varieties of plants decreases. Where soils are charged with an excess of alkalis by fortuitous or artificial means, the reader will understand that the excess has been added to the natural supply by the flooding of rains, or by irrigation. The alkali has not been washed out of the soil by the water, it has been carried into it by water charged with the soluble salts, directly, or by seepage from irrigating ditches. In either case, deep cultivation, surface, or sub-drainage, will tend to restore the soil to its normal condition. Moreover, it is not difficult to wash out of the soil the elements necessary to plant life through the application of water, and, inasmuch as the alkalis are more soluble than any of the plant foods, it should be less difficult to eliminate the former by the same process that carried them into the soil, intelligently applied.

One per cent of alkali salts in an average soil one foot deep equals 40,946 pounds dry, and 55,146 pounds wet, too great a quantity for the successful growth of cereals, although the soil may be very rich in all the other plant foods, which is generally the case in all alkali soils, and this percentage will prevent the growth of trees, bushes, vines and root crops in general. Sometimes the alkali is near the surface, in the first two inches of it; indeed, the tendency of the alkalis is toward the surface, in this case the one per cent of alkali would mean a weight of the salts in a foot deep acre of only about 6,824 pounds dry, or 9,191 pounds wet, a quantity not in excess if distributed uniformly through the soil. But lying at the immediate surface, the cereal grains cannot germinate, or if they do the young and tender plants perish from thirst, literally, the alkalis absorbing all the water around them, although there may be plenty of untainted water in the subsoil, in which case deep plowing and turning the soil over will furnish a top soil in which the seeds may germinate and reach a growth able to resist the alkali turned under. In fact, the roots of the plants will reach beyond the alkali, for the latter will then have again sought the surface, where it can do no harm.

Alfalfa, for instance, will grow in a moderately alkaline soil, because the long tap roots penetrate to the subsoil depths, where there is less alkali. Moreover, the thick growth and luxuriant foliage shade the ground and prevent evaporation, which is the handmaid of alkali deposits.

All soils showing less than one-fifth of one per cent of alkali salts, that is, less than 9,000 pounds to the foot acre dry, or 12,000 pounds wet, may be considered safe for all kinds of crops, and there will never be any danger from excess of alkalis, so long as good water is used and the land well drained and cultivated. When the alkali goes beyond one-fifth to two-fifths per cent, general crops fail, as a rule, and spots begin to show when cultivated. And when the alkali reaches four-tenths and six-tenths of one per cent, while general crops will not grow, sweet clover and the common run of fleshy, scented and sugary plants will grow and produce large crops, but must be harvested early in the case of forage plants, as has already been said, else they will become bitter and uneatable.

There are, as has been said, about 197 species of plants which possess a great affinity for alkali and will luxuriate in masses of it where all other vegetation fails to gain a foothold. Thus, greasewood, or creosote bush, will flourish in a soil containing 194,760 pounds of alkali salts per acre one foot deep, which is more than four per cent of alkali. Scrub salt bush will grow in soil containing 78,240 pounds per acre, equal to about one and one-half per cent. Samphire luxuriates in soil containing 306,000 pounds of alkali per acre, or about six per cent. Wheat, however, will not grow where the soil contains a total of 20,520 pounds of the sulphates, carbonates, chlorides and nitrates of soda and potash per acre one foot deep, which is less than one-half of one per cent of the weight of the soil.

ATTEMPTS AT RECLAMATION.

It is impossible to establish any rule or set of rules for the adaptation of alkali lands to profitable crops. The natural growth of numerous varieties and species of plants on strong alkalis is of very little moment to the farmer, his main inquiry being: How shall I get rid of the excess of alkali? The whole object of cultivating the soil is to compel it to produce something useful as well as profitable, otherwise it is labor lost to put a plow in the ground. But in the arid and semiarid lands the soil may be exceedingly fertile for general crops, and after cultivation and irrigation may become so impregnated with alkali as to lose that fertility in spite of the quantities of essential plant food still in the soil.

Where this calamity overtakes the farmer he can not very well wander about and take up a new location on fresh land and again go through the same experience. He must remain rooted to the soil, so to speak, and use all the information he can gather to restore his land to its normal condition, or so much of it as has gone wrong. It is a well-known saying: "All signs fail in dry weather," and there are several others equally as apt. Some say: "It is useless to pray for rain with the wind from the wrong quarter," or, "It is a dry moon, and the horns up won't let the water out." In the case of alkali soils there are no apt sayings, but there ought to be one, and a very good one seems to be: "Alkali laughs at the established methods of cultivating the soil."

When crops begin to look "sick," and black or white patches appear here and there, the reason is not far to seek: alkali is at work. The subsoil may be alkaline; there may be a stratum of hard pan which prevents the water with its solution of alkalis from leaching down through beyond the reach of the roots; the irrigation water may contain a large percentage of alkali in solution, and, coming to the surface, carry its alkali along with it; there may be an irrigation ditch above and beyond, or a stream, or reservoir, from which the water seeps and comes up wherever it can find an outlet. In all these cases, and there are many others, except where the soil is naturally strongly alkaline, he looks for the cause, and he finds it in fortuitous or accidental additions of alkali. Excess of alkali has been carried into the soil, and he first stops any further arrivals. The beginning of a remedy is the same in the case of a thousand or more acres as in the case of but one, there is merely a difference in extent of operations. Then the alkali having got into the soil, he quite naturally thinks that it may be got out in the same way it got in. This is true as to methods. It drains or seeps in; let it drain and seep out. It came to the surface with the water through capillary action, therefore let that capillary action be stopped or impeded. The water from the subsoil evaporating at the surface left the alkalis behind to interfere with plant life, hence, if that evaporation be prevented or reduced, there will be no more, or, at least, less surface deposits.

Without stopping to consider drainage, which requires a chapter of its own, there are two conditions or processes which are keys that nearly fit the situation: cultivation and rotation of crops.

Cultivation serves a double purpose; that of breaking up the uniform capillary spaces in the soil and preventing the rise of the water from the subsoil to the surface, and that of covering the ground with a layer of dry soil, or a mulch, that prevents evaporation. Indeed, there are cases where frequent cultivation, or stirring up of the soil, have reduced the accumulations of alkali to one-third the amount on uncultivated land. As to its preventing evaporation, every farmer is too well acquainted with the effect of cultivation as a conservative of the moisture in the soil not to know this thoroughly.

The incorporation of organic matter in the soil, such as stable manure, leaves, straw, plowing under a crop of weeds, or green manure, tends to break up the capillary pores in the soil and retard the upward movement of the subsoil water. But this retarding process is much greater if this organic matter is spread over the ground in a uniform layer or mulch. This method alone has saved many an orchard when an adjoining one in the same kind of soil was perishing from an excess of alkali.

It should not be forgotten that it is water that dissolves the alkalis, not moisture. For which reason the water in the subsoil must be kept below the surface at least three, four, five and six feet, according to the soil and the crops. It is the standing water below the surface which soaks up the salts, and they must be drained away until the water table will not send up water, but moisture only, a sort of subsoil evaporation, to coin an expression, the water coming up as wet vapor, or merely wetness, leaving its salts behind, they being unable to follow unless held in solution.

As soon as water from rain or irrigation begins to fill the soil, the standing water below with its alkalis in solution commences to rise, but by keeping this subsoil water at a depth of five or six feet, and thus allowing an easy movement of moisture through the land, the work of reclamation is easily attained. Here is where the rotation of crops may be called upon to aid. The farmer has been growing wheat, barley, small fruits, corn, etc., and the soil has become so impregnated with alkali as to prevent the growth of any more similar crops. Now when he is leaching the alkalis out of the soil he plants gross feeders, plants that have an affinity for alkali. Sorghum and sugar beets are recommended for correctives of alkali soils, but there are many other plants that may be used for the same purpose, such as asparagus, onions, sweet clover, and among the fruits, pears, figs, pomegranates and date palms, all of which withstand the action of alkalis which would kill cereals and small fruits.

The reason is that all sugar-producing plants require large quantities of alkali, particularly the carbonates, for starch is produced by the decomposition of carbonic acid, which the plant breathes in through its leaves, and takes up from the soil through its roots. Now, taking the carbon out of the alkalis renders them innocous, just the same as does vinegar or acetic acid, which is also always forming in plants that produce sugar. Not to be misunderstood, it may be well to say here that this starch is transformed into sugar, woody fiber and cellular tissue. When it comes to raising 20 to 40 tons of sugar beets per acre, carrying 17 to 22 per cent of sugar, and reflect that 100 parts of the green syrup of sugar beets carbonated show 9.18 per cent of alkali ashes, and that the leaves and root fibers will show nearly as much more, it is a simple sum in arithmetic to demonstrate that it will not take many such crops to remove the alkalis, and make it necessary to add more voluntarily as a fertilizer. Indeed, in non-alkali soils it is necessary to add alkalis as fertilizers in cultivating beets. Within two or three years the alkali-devouring plants will have removed so much of the alkali from the soil that barley and wheat can be introduced, and afterward a good stand of alfalfa secured. All of these attempts at reclamation are, in the opinion of the author, equivalent to a rotation of crops, since they benefit and strengthen the soil by taking away elements that certain plants do not require, as well as add those which they need.

The following general rules to follow in reclaiming alkali soil may be considered as a recapitulation of what has been said in this chapter, and in all the authorities on the subject:

First—Insure good and rapid drainage to a depth of three or four feet, in which case flooding the land with water is a simple and sure method of washing out the alkali.

Second—Plow deep; say, twelve inches.

Third—Furrow land and plant sorghum in the bottom of the furrows. Irrigate heavily, and gradually cultivate down the ridges to uniformity.

Fourth—After two years in sorghum (or sugar beets, etc.)—deeply plowed each year and cultivated frequently—plant barley. Have the surface of the ground well leveled, and flood heavily before planting.

Fifth—Seed to any desired crop, for if the land is at all porous a stand of any ordinary crop can be secured, except in the worst spots.

What has been said with reference to the black and white alkalis, is applicable to the other alkali salts, the chlorides (common salt, etc.), nitrates, muriates, etc., most of which are beneficial and necessary to plants in reasonable quantities, but deleterious and destructive in excess, but, we repeat, not so dangerous as the sodas.

The processes of chemical transformations are always going on in nature, and every soil, together with the plants or crops growing upon it, constitute a vast laboratory, in which materials of an almost infinite variety are in a constant state of manufacture, and by acquiring even a superficial knowledge of what nature is doing and trying to do, man will be better able to divert nature in his direction to his profit. Nature is perfectly willing that this should be done, and if she is diverted from her purposes and does too much or too little, it is because the man behind the plow is looking the other way.

Adobe soils and the hardpans have been reserved for another chapter, as having a closer relation to drainage, water, and cultivation, than to arid lands. Adobe is a peculiar kind of clay of several varieties, and the hardpans, though sometimes arable, in general resemble the cement plaster which has been found unimpaired in the pyramids and temples of Egypt after thousands of years' exposure to the elements.

It is reasonable to suppose that plants which will grow in heavily charged alkali soils, do so because they have an affinity for the alkaline salts, and take up large quantities of them. Whence it is clear that, by continually growing, cutting and removing this "alkali vegetation," the excess salts in the soil will be gradually eliminated, and thus the soil be fitted for the growth of other desired plants. This is the law and the gospel in the case of the commonly known "salt meadows," of which there are estimated to be in the United States over one hundred thousand square miles. The attempt to reclaim these lands in this manner has proved successful in Germany and Holland, and has passed beyond the mere experimental stage in the United States. Wherefore the query: Is not the same law applicable to the overcharged alkali lands of the arid and semi-arid regions?

CHAPTER V.

RELATIONS OF WATER TO THE SOIL.

When a small portion of soil is thoroughly dried and then spread out on a sheet of paper in the open air it will gradually drink in watery vapor from the atmosphere and thus increase its weight to a perceptible degree. In hot climates and during dry seasons this property of absorption in the soil is of great importance restoring, as it does, to the thirsty ground, and bringing within reach of plants, a part of the moisture they have so copiously exhaled during the day. Different soils possess this property in unequal degrees. During a night of twelve hours, for it is at night that watery vapor is deposited on the ground (evaporation from the soil occurring during the day), 1,000 pounds of perfectly dry soil will absorb the following quantities of moisture in pounds.

Quartz sand	0
Calcareous sand	2
Loamy soil	21
Clay loams	25
Pure clay	27

Peaty soils and those rich in vegetable matters will absorb a much larger quantity from the atmosphere, sometimes becoming "wet" two inches deep, a surprising quantity of water when the weight of it on an acre of ground is calculated. The weight of dry and wet soils has already been given, and the difference between the two will, of course, show the quantity in weight of the moisture or water absorbed. The average weight of dry soils is about 94 pounds, the average ordinary wet weight is 126 pounds, the difference, being 32 pounds, represents the average weight of water per cubic foot. Now, multiplying 43,560 square feet in the acre by 32, gives 1,393,920 pounds to the acre one foot deep. and dividing by 12 to ascertain the weight of one inch, we have 116,160 pounds, or about 58 tons of water falling on an acre of ground in the shape of dew in a single night. Of course that quantity represents the highest possible absorptive quality in a heavily charged vegetable soil. Other soils would receive a less quantity as will be readily understood, but there is enough to be equivalent to quite a smart shower and worth encouraging.

In what are known as "dry" climates there is always some moisture in the atmosphere which is deposited upon the soil, for wherever there are oxygen and hydrogen there must be moisture. But the quantities vary in climates as much as they do in soils. Where there is evaporation from the soil moisture during the day there is also a re-absorption of moisture by the soil at night and, with this fact in mind, it may be laid down as an axiom: The tendency of water is to evaporate from the soil into the atmosphere during the day and to fall back upon the soil during the night. To reduce the idea to an axiom: A dry soil has an affinity for a moist atmosphere, and a dry atmosphere loves a moist soil.

SATURATION AND POWER TO RETAIN MOISTURE.

The rain falls and is drunk in by the thirsty soil; the dew descends and is absorbed, and the waters of irrigation poured upon the ground quickly disappear. But after much water falls upon the earth the latter becomes saturated, can hold no more, and the surplus runs off the surface or sinks down through until it reaches the water table. This happens more speedily in some soils than in others. Thus, 100 pounds of dry soils, as here specified, will hold the quantity of water set opposite their respective names without dripping or running off.

Quartz sand	25 pounds
Calcareous sand	29 pounds
Loamy soil	40 pounds
Clay loam	50 pounds
Pure clay	70 pounds

But dry, peaty soils and adobe will absorb a much larger proportion before becoming saturated to the dripping point; sometimes such soils will absorb their own weight of water. Arable soils generally will hold from forty to seventy per cent of their weight of water.

This power of retaining water renders such a soil valuable in dry climates. But the more water the soil contains in its pores the greater the evaporation and the colder it is likely to be. Indeed, evaporation is a source of cold, sometimes to so great a degree that ice will be formed. In very hot regions in India where ice is inacessible it is customary to place small, shallow saucers filled with water on the ground after nightfall, and they are gathered in the morning before sunrise, the water being converted into ice by the rapid evaporation from the soil during the night. Our modern ice machines owe their efficacy for making ice to the rapid evaporation of ammonia under pressure. Ether, chloroform, alcohol, and numerous other substances, produce a sensation of cold when rubbed on the skin, which is not due to anything in those substances, but wholly to their rapid evaporation or volatility. The presence of a saturation of water in the soil, however, excludes the air in a great degree and thus is injurious to plants, whose roots must have air as well as moisture, hence the necesity for drainage where there is a liability to saturation.

Unless rain or dew is falling or the air is saturated with moisture, watery vapor is constantly arising from the surface of the earth. The fields, after the heaviest rains and floods, gradually become dry, and this takes place more rapidly in some fields or parts of fields than in others, in fact, wet and dry patches of ground may be seen on the same field, indicating a heavy or light soil. Generally speaking, those soils capable of containing the largest portion of the rain that falls also retains it with greater obstinacy and require a longer time to dry. The same thing happens when the land is irrigated. Thus, sand will become as dry in one hour as pure clay in three, or peat in four hours.

There is one fact every irrigator should constantly bear in mind and that is: Water saturation of the soil is never necessary to plant life; it is, in fact, positively injurious except in the case of acquatic plants. A long time ago men, seeing rice growing luxuriantly in swamps, imagined that plant would not grow anywhere else, and, accordingly, rice culture meant a swamp. But it was discovered that rice would grow better and produce a larger and richer crop in arable soil generally, and now it is cultivated with astonishing success the same as wheat, barley, or any other cereal, except for a short period of flooding.

Nature, through heavy rains and other water sources, converts the soil into a storage reservoir by establishing a water table beneath the surface from which the water vaporizing up constantly moistens the growing stratum of the soil, decomposes and dissolves the salts which are necessary to plant life, and is itself decomposed by the principle of life in the plant and its elements, oxygen, hydrogen, and nitrogen, utilized in the interior of the plant itself. Where there is no natural supply of water for this storage purpose irrigation must copy nature and provide one, or at least furnish an adequate supply of moisture for solvent purposes. When that has been done everything has been done that should be done.

A familiar illustration of the action of moisture may be witnessed in the slaking of lime in the open air without the direct application of water. The same transformation takes place in the case of all the other soluble mineral salts when in the presence of moisture. This transformation effected, the plant thrives, and, to give it an excess of dissolving liquid is to float off the material needed by the plant and thus deprive it of its nourishment. It is like feeding an infant on thin, weak soup instead of nourishing bouillon and expecting it to thrive.

EVAPORATION FROM PLANTS.

The tendency of plants is to exhale or perspire moisture as well as the soil. The flow of the sap is constant from the roots to the leaves to receive oxygen and carbonic acid and back again to the roots; like the circulation of the blood in animals it travels in a circuit. When the sap reaches the leaves it parts with a portion of its water, and in some plants the quantity is very considerable. An experiment with a sunflower, three and one-half feet high, disclosed the fact that its leaves lost during twelve hours of one day, 30, and of another, 20 ounces of water, while during a warm night, without dew, it lost only three ounces, and, on a dewy night, lost none.

All this evaporation or exhalation of water from the leaves of plants is supplied by the moisture in the soil, for plants generally do not drink in water through their leaves but through their roots, and when the escape of water from the leaves is more rapid than the supply from the roots the leaves droop, dry and wither, because then they are drawing from their sap, living, so to speak, upon their own blood. This evaporation in the plant is similar to the perspiration constantly exuding from the skins of healthy animals and it has added to it the mechanical evaporation which takes place on the surface of all moist bodies when exposed to hot or dry air. There can be no growth or health without it, hence, it is often beneficial to wash or spray the leaves of plants and trees to remove the dust or other clogging material that has accumulated upon the leaves and "stopped perspiration." To stop this leaf evaporation is to kill the plant as surely as was killed the boy in the Roman pageant. His entire body was covered with a thick coating of gum arabic, on which was laid a layer of gold leaf, the intention being to have him pose as a golden statue. He died in a few hours and it was not until the cause of his sudden death was investigated by scientific men that it was discovered that the closing of the pores of the skin, thereby preventing evaporation from its surface, was the cause. On dry, dusty soils, where there is none, or very little rainfall, the accumulation of dew during the night is generally sufficient to "trickle" along the leaves and carry down the dust and other accumulations on the leaves which interfere with evaporation. Sometimes the plant, as if aware that there is a stoppage in its circulation, will throw out fresh, new leaves to cure the defect, but this is done at the expense of the root, tuber, or fruit.

The amount of loss due to natural and mechanical evaporation from plants, of course, differs very greatly in the various species of plants depending, in a great measure, on the special structure of the leaf, whether fine or coarse meshed, large or small, lean or fleshy, the natural perspiration, however, always exceeding the mechanical. Both processes, moreover, are more rapid under the influence of a warm, dry atmosphere aided by the direct rays of the sun.

As showing the quantity of evaporation an experiment was tried with an acre of maple trees containing 640 trees. The calculation is not positively exact, but it is worth accepting as a basis for other experiments on crops of all kinds and may come somewhere near enabling the irrigator to determine the quantity of water to be applied to the soil, whether there is a water table within the reach of the surface or none at all.

The evaporation was assumed to take place only during a day of twelve hours and each of the 640 trees was estimated as carrying 21,192 leaves. From an estimate based on the quantity of evaporation from one tree containing the number of leaves above specified, which were carefully counted, the 640 trees evaporated from their leaves in twelve hours 3,875 gallons of water, or 31,000 pounds. During ninety-two twelve-hour days, the life of the maple leaf, the evaporation would amount to 2,852,000 pounds. During that period the rainfall was 8.333 inches or 43.8 pounds to every square foot of surface, equal, per acre of 43,560 square feet, to 1,890,504 pounds. The evaporation from the leaves of the trees, therefore, exceeded that of the actual fall of rain by nearly one million pounds. Whence did the surplus come? Evidently from the water stored in the water table and drawn up by the action of the roots of the trees. Where there is no water table or ground water and the soil is dry "all the way down," it is necessary to create one by irrigation and this is not so difficult as might be imagined, for we must consider that in the case of maple trees the roots may reach down into the subsoil for fifty feet, and in the case of ordinary fruits, vegetables, and cereals, a water table at that depth would be wholly unnecessary even if generally impracticable. Soil saturation at any depth beyond four feet with unlimited surface cultivation is sufficient, although in the case of vines and trees it should be much deeper.

The above experiment with the maple trees although, perhaps, of no practical value on account of its uncertainty, being more or less guess, demonstrates two things, when there is also taken into consideration the quantity of sap in plants and the amount of salts held in solution in it.

First—How easily a soil may be exhausted by cutting and removing plants and crops therefrom.

Second—As a direct corollary, through its diametric opposite, it shows how easily alkaline salts may be removed from the soil by cutting and removing the plants and crops. These alkali-consuming plants hold large quantities of the earth salts in their sap in solution, the carbonates, sulphates, the sodas, and potash, literally taken up out of the soil. Of course, when removed a certain amount of alkali is removed with them. This has been the experience with the "salt meadows" in Germany and Holland, and in the United States, as has been already noted, and, in a small way, with the alkali lands of the West where the experiment has been made.

CAPILLARY POWER OF SOIL.

When water is poured into the saucer or sole of a flower-pot filled with earth the soil gradually sucks it up and becomes moist even to the surface. This is what is known as "capillary action," and exists in all porous bodies to a greater or less extent. A sponge is a well-known instance of this power, and if the small end of a piece of hard chalk be held in water the entire mass soon becomes saturated. The experiment with the flower-pot, however, represents the action in the soil, the water from beneath—that contained in the sub-soil—is gradually sucked up to the surface. It is one of the operations of the laws of nature which maintains all things in constant motion to preserve their life and vitality, for, if permitted to remain at rest without motion, they sicken and die, afterward putrefying as happens even with water which becomes stagnant, that is, ceases to be in motion.

In climates where there is winter, or even a moderate degree of cold weather, this capillary action ceases and the tendency of the water is to "soak" downward, and it is not until warm weather that capillary action begins and the water commences "soaking" upward toward the surface. In a warm, or hot climate, this action is constant and it also takes place whenever the soil is parched or dry.

This suspension of capillary action in winter, or cold weather, furnishes a strong point in favor of winter irrigation, which really takes the place of the autumn and spring rains, and of the snow that slowly melts and its waters carried down into the soil to the water table ready to begin an upward movement when the weather becomes warm and the surface soil dry.

The dryer the soil and the hotter the atmosphere, the more rapid is the rising of the water to the surface by capillary attraction, and. as the water ascends, it carries along with it the saline matters dissolved by it and, reaching the surface, evaporates, leaving the salts it carried behind. It is this capillary action which has incrusted our own lands with alkalis of all kinds; it is the same in India, Egypt, South Africa, and elsewhere. On the arid plains of Peru, and on extensive tracts in South Africa, alkali deposits, several feet in thickness, are sometimes met with, all of which are caused by the capillary action of water bringing up to the surface the salts in the subsoil. So it is that the enormous beds of nitrate of soda in Peru and those of the carbonate of soda in Colombia were created; and in our own black and white alkali and sodium bad lands capillary action may be blamed for their condition. It must not be forgotten that wherever there is seepage there is also capillary action, for that power is exercised in every direction. It does not matter which end of the sponge or piece of chalk is held to the water, both become saturated. It may be said that capillary action is a violation of the law of gravity, or, rather, is a law of itself acting independently.

This tendency of water to ascend to the surface of the earth is not the same in all soils. It is less rapid in stiff clays and more rapid in sandy and open, porous soils generally, and it is of especial importance in relation to the position of the water table in the soil when considered as a source of water supply or shallow rooting plants. Gravity draws the water downward toward a water table, and in a dry subsoil it is capillary attraction that impels it down. But when the water in the surface soil is less than that below an upward movement begins as though nature were desirous of maintaining an equilibrium which, scientifically speaking, it always does, or attempts to do. However, there is a zone of capillary action, a space between the water table and the surface, in which moisture rises and with it carries food substances to the roots of plants. Where the water itself rises it means more than capillary attraction, it means a rise of the water table through additions from some new water supply or saturation of the soil, in which case plants are injured vitally and drainage must come to the rescue. It is the rise of the water table that is to be feared in irrigation. The reason is because the rise of alkaline solutions is greater than in the case of pure water. Thus, a 50 per cent solution of sodium chloride (common salt) and sodium sulphate will rise faster than pure water, and a much stronger concentration of soda carbonate will rise still faster. Hence the necessity of preventing soil saturation and the maintaining of a zone of capillary action, in which the roots of plants may be fed by material furnished through that action when they would be killed if saturation were permitted to overcome it.

A few practical ideas may be gathered from the foregoing which are worth considering:

First—It is evident that deep plowing will enable the rainfall or the irrigation water to penetrate deeper into the soil, in which case it will remain longer and the effects of a small quantity of rain may extend over a period long enough to mature a crop where half as much again would show nothing.

Second—To be effective and beneficial to vegetation the water in the subsoil must be in constant motion. When water ceases to flow in the subsoil streams, or when capillary action is entirely suspended, the water becomes stagnant, ceases to imbibe oxygen, nitrogen and carbonic acid, and practically rots, causing vegetation within its influence also to decay. Running water coming from the clouds or irrigating ditch enters the soil charged with gaseous matters above specified, mixed in their proper proportions, and carries along with it various dissolved inorganic substances which are not permitted to be deposited out of it while it is in motion. Hence, to derive the full benefit of the water, the land must be drained even where irrigation is practiced, so that the surplus water, after irrigation is stopped, may find a ready outlet. If there should be no surplus, no harm is done by drainage facilities; on the contrary, the tendency of all drainage is to open the soil below and "draw" the moisture from above as well as to carry off the surplus water in a soaked subsoil if there be one. Drainage does not carry off moisture, but only the surplus water; capillary attraction will always hold the moisture.

Third—Whenever sufficient water is added to the soil to compensate for loss by evaporation from soil and plant, the business of the irrigator is accomplished. To keep on adding, to soak the soil continually, would be to injure vegetation as much as by furnishing too little water, as it is only by keeping the surface soil loose and finely pulverized—the deeper the better—that evaporation from the soil may be retarded.

As to the quality of the water the more impure it is, particularly in organic matter, the better it is for vegetation. There is no more impure water in the world than that of the river Nile, yet it gives fertility and produces luxuriant vegetation where there would be barrenness and sterility were it pure. The exception in the case of irrigating alkali lands would be water heavily charged with alkali salts, this kind of water being one of the causes of deleterious alkali deposits.

THE SOIL AND THE ATMOSPHERE.

The oxygen of the atmosphere is essential to the germination of the seed and to the growth of the plant. The whole plant must have air, the roots as well as the leaves, therefore it is of consequence that this oxygen should have access to every part of the soil and thus to all the roots. This can only be effected by working the land and rendering it sufficiently porous.

Some soils absorb oxygen faster and in greater quantities than others. Clays absorb more than sandy soils, and vegetable molds or peats more than clay. It depends, however, upon their condition as to porosity, and also upon their chemical constitution. If the clay contains iron or manganese in the state of oxides these latter will naturally absorb oxygen in large quantities for the purpose of combining with it, having a great affinity therefor, while a soil containing much decaying vegetable matter will also drink in large quantities of oxygen to aid the natural decomposition constantly going on.

In addition to absorbing oxygen and nitrogen, of which the air principally consists, the soil also absorbs carbonic acid and portions of other vapors floating in it whether ammonia or nitric acid. This absorption of atmospheric elements and gases of every kind occurs most easily and in greater abundance when the soil is in a moist state. Hence it is that the fall of rains and the descent of dew, or the application of irrigation water, favors this absorption in dry seasons and in dry climates; it will also be greatest in those soils which have the power of most readily extracting watery vapor from the air during the absence of the sun. It must be clear from this that the influence of dews and gentle showers reaches much farther than the surface of the soil, watery vapor following the atmosphere down deep into the soil, penetrating as deep as the porous nature of the soil will permit it. Some say that, under proper conditions as to cultivation, the soil will gain in dew at night nearly as much as it loses by evaporation during the day. It appears reasonable enough to suppose that the atmosphere, under a pressure of fifteen pounds to the square inch, will penetrate to any depth and carry with it whatever of moisture and gases it contains.

THE SOIL AND THE SUN.

In addition to the chemical effect of sunlight upon plants the rays of the sun beating down upon the earth impart to the soil a degree of heat much higher than that of the surrounding atmosphere. Sometimes this soil heat rises from 110 degrees to 150 and more, while the air in the shade is between 70 and 80 degrees, a quantity of heat most favorable to rapid growth. The relations between the heat of the sun and the color of the soil is of little importance where sunlight abounds, although in some locations it is of considerable importance. This has already been alluded to and all that need be said here is that the dark-colored soils, the black and the brownish reds, absorb the heat of the sun more rapidly than the light-colored, for which reason, as to warmth, the dark soils more rapidly promote vegetation than the others.

As to the power of retaining heat it is interesting to note that sandy soils cool more slowly than clay, and clay more slowly than peaty soils, or those rich in vegetable matter. Vegetable mold will cool as much in one hour as a clay in two, or a sandy soil in three hours. That is, after the sun sets the sandy soil will be three hours in cooling, the clay two, and the soil rich in vegetable matter, one hour. It is also interesting to note that on those soils which cool the soonest dew will first begin to be deposited.

Man possesses very little power over the relations between the soil and heat other than growing plants whose abundance of leaves and luxuriant growth will shade the ground, prevent, or retard evaporation, and enable the soil to maintain a uniform heat, or mixing sand with less heat-retaining soils. These matters are of more importance in kitchen garden culture than in the fields; but there are deep valleys among the mountains where the sun rises about 9 a. m. and sets about 3 p. m., and in these, there being so little scope for the sun's rays and the soil being cool for a much longer period than it is warmed by the sun, the power of retaining heat would render one soil more valuable and favorable to plant growth than a soil less retentive.

CHAPTER VI.

PLANT FOODS — THEIR NATURE — DISTRIBUTION AND EFFECTS IN GENERAL.

There are four substances which are essential to all plant food; without them few plants could live, and what is surprising, they form a very large portion of every plant in one form or another. These substances are: Carbon, Oxygen, Hydrogen and Nitrogen. We shall take them up in rotation and briefly explain their origin, nature and action.

CARBON.

Carbon is generally known under the form of coal, any kind of coal, but for experimental purposes it is usually wood charcoal that is considered the nearest approach to pure carbon, there being none except the diamond which can be called actually pure or crystallized carbon. As wood charcoal, it is derived from willow, pine, box, and several other woods, burned under cover so as to prevent free access of air, and its manufacture is of great commercial importance, kilns for its creation existing in thousands of places throughout the United States, where forests abound and wood is in plenty. It should be borne in mind that this carbon, or wood charcoal, is an essential element of the plant, inasmuch as it comes out of it by burning. Moreover it is all manufactured in the plant, extracted as part of its food from the soil, or the air.

Heated in air, charcoal, or carbon, as we shall call it hereafter, burns with little flame, and is slowly consumed, leaving only a white ash, the rest of the carbon disappearing in the air. It is not lost, however, for by the burning it is converted into a gas which goes by the name of "carbonic acid," which ascends and mingles with the atmosphere, to be again absorbed by plants to manufacture more carbon, or rather a fresh supply of charcoal. This carbonic acid gas is deadly, speedily causing death if breathed.

Carbon is light and porous and floats on water, but plumbago, or black lead, and the diamond, which are only other forms of carbon, are heavy and dense. Both black lead and the diamond when burned in the air at a high temperature, leave only a very little white ash, the rest being converted into carbonic acid and disappearing in the air like the common charcoal.

Of this carbon, all vegetable substances contain a very large proportion. It forms from 40 to 50 per centum by weight of all parts of dried plants cultivated for the food of animals or man, and the part it performs in the economy of nature is therefore very important.

Light, porous charcoals possess several notable properties in plant culture:

First—they absorb into their pores large quantities of gaseous substances and vapors which exist in the atmosphere. Thus: They absorb over ninety times their bulk of ammonia; fifty-five times their bulk of sulphuretted hydrogen; nine times their bulk of oxygen; nearly twice their bulk of hydrogen, and absorb sufficient aqueous vapor to increase their weight from ten to twenty per centum.

Second—They separate from water, decayed animal matters and coloring substances which it may hold in solution. In the soil they absorb from rain, or flowing water, organized matters of various kinds, and yield them up to the plants growing near to contribute to their growth.

Third—They absorb disagreeable odors and keep animal and vegetable matter sweet when in contact with it. For which reason vegetable substances containing much water, like potatoes, turnips, etc., are better preserved by the aid of a quantity of charcoal.

Fourth—They extract from water a portion of the saline substances, or salts, it may happen to have in solution, and allow it to escape in a less impure form. The decayed (half carbonized) roots of grass, which have been long subjected to irrigation, may act in one or all of these ways, on the more or less impure water with which they are irrigated, and thus gradually arrest and collect the materials fitted to promote the growth of the coming crop.

OXYGEN.

We know oxygen only in its gaseous or aeriform state, although it may be liquefied, and even converted into a solid form under the name of "liquid air." As a gas it is invisible and possesses neither color, taste, nor smell. When inhaled in a pure state it is stimulating and exciting to the vital functions, but used in excess it causes death. Plants refuse to grow in pure oxygen gas and speedily perish.

It exists in the atmosphere in the proportion of 21 per centum of the bulk of the latter, and in this state and proportion it is necessary to the existence of animals and plants, and to permit combustion everywhere on the globe. The amount of it in water will surprise many readers, for every nine pounds of water contains eight pounds of oxygen. A knowledge of this fact will cause the full value of water as an essential to plant growth to be appreciated; moreover, water possesses the power of absorbing still more oxygen from the atmosphere than it contains naturally. Thus, water will absorb from three and one-half to six and one-half parts of oxygen to one hundred parts of water. Rain, spring and river waters always contain an additional proportion of oxygen which they have absorbed from the atmosphere. This is taken up in the soil, for, as the water trickles through the soil it surrenders the oxygen to the plants with which it comes in contact, and ministers to their growth and nourishment in various ways to be hereafter explained.

But the quantitiy of oxygen stored in solid rocks is still more remarkable. Nearly one-half of the rocks which compose the crust of the earth, of every solid substance we see around us, of the soils which are daily cultivated, and much more than one-half of the weight of living plants and animals, consist of this elementary body, oxygen, known to us only as an invisible, imponderable, unperceivable gas.

HYDROGEN.

Hydrogen is also known to us in the state of gas, and like oxygen is without color, taste, or smell. It is unknown in a free or simple state, although chemists have succeeded in obtaining it in small quantities, and is not so abundant as either carbon or oxygen. It forms a small percentage of the weight of animal and vegetable substances, and constitutes only one-ninth of the weight of water. With the exception of coal and mineral oils known as "hydro-carbons," it is not a constituent of any of the large mineral masses of the globe.

It does not support life, and animals and plants introduced into it speedily die. It is the lightest of all known substances, being fourteen and one-half times lighter than air. Water absorbs it in very small quantities, one hundred gallons of water taking up no more than one and one-half gallons of it.

NITROGEN.

This substance is likewise known only in a state of gas. It exists in the atmosphere in the proportion of seventy-nine per centum of its entire bulk, and is without color, taste, or smell. It is lighter than atmospheric air in the proportion of ninety-seven and one-half to one hundred, and is deadly in its pure state to both animals and plants. It is essential in the atmosphere we breathe, moderating the combustion which would ensue if the air were pure oxygen, and forms a part of many animal and some vegetable substances, but does not enter, except in small proportions, into mineral masses. It is less abundant than any of the so-called organic elements, but it performs certain most important functions in reference to the growth of plants. Spring and rain water absorb it as they do oxygen, from the atmosphere, and bear it in solution to the roots of plants, one hundred parts of water dissolving about one and one-half to four per centum of the gas.

PROPORTIONS OF THE FOREGOING ELEMENTS IN PLANTS.

Although the substances of plants are composed mainly of the above organic elements, they exist in very different proportions. This will appear from the following table of "dried" plants, taking one thousand parts by weight as the standard:

	Oats.	Clover seed.	Grass, hay.	Peas.	Wheat.	Potatoes.
Carbon	507	494	458	465	455	441
Hydrogen ...	64	58	50	61	57	58
Oxygen	367	350	387	401	431	439
Nitrogen	22	70	15	42	34	12
Ash	40	28	90	31	23	50
	1,000	1,000	1,000	1,000	1,000	1,000

The above proportions are slightly variable, but the figures given represent nearly the relative weights in which these elementary elements enter into forms of vegetable matter. Herbaceous plants generally leave more ash, that is, inorganic matter, the wood of trees and the different parts of plants yielding unequal quantities.

HOW ORGANIC ELEMENTS COMBINE TO FORM PLANT FOODS.

Carbon being a solid, and insoluble in water, can not be taken up through the pores of the roots of plants, the only parts with which it can come in contact. Hydrogen, in its simple state, forms no part of the food of plants because it does not exist in the atmosphere or in the soil in any appreciable quantities. Oxygen exists in the atmosphere in the gaseous state and may be inhaled by the leaves of plants. Nitrogen may be absorbed by the leaves of living plants, but in a quantity so small as to escape detection. Horeover, oxygen and nitrogen being soluble in water to a slight degree, may also be absorbed in small quantities along with the water taken in through the pores of the roots.

But this absorption by the plant is insufficient to maintain its life and growth. It must have a liberal supply of food in which the four elements specified form a large percentage. Now, this food can only be obtained, or manufactured, by the four organic elements entering into mutual combinations to form what are known as "chemical compounds." It is these chemical compounds which find their way into the interior of the plant, into its very substance, and then the plant grows and reaches maturity, provided these chemical combinations are continued during its period of existence.

It must be borne in mind that the atmosphere diffuses itself everywhere. It makes its way into every pore of the soil, carrying with it its oxygen, carbonic acid and other substances it may be charged with, to the dead vegetable matter and to every living root. Its action is double: Playing among the leaves and branches, and fondling the roots by mingling with the soil. It is the workman, and its tools are its gases, and with them it manufactures out of the raw material it finds in the soil—that is, the silica, the sulphur, and other inorganic substances, and the decayed organic matter—chemical combinations which the plant seizes, appropriates and digests.

CHEMICAL COMBINATIONS.

When common table salt and water are mixed the salt dissolves and disappears. By evaporating the water it is possible to recover the salt in the same form and condition as it was at first. This is called a "mechanical combination," with which chemistry has nothing to do, and which would not, in the economy of nature, be sufficient as a plant food, although such combinations and solutions are absorbed by the plant—they do not feed it!

But when limestone is put into a kiln and burned it is changed into an entirely different substance, which is called "quicklime." The limestone is decomposed by the burning, the carbonic acid mixed with lime is driven off by the heat, and lime remains.

So when sulphur is burned in the air it is all converted into a white vapor of an unpleasant odor, which is finally absorbed by the atmosphere and disappears. This is also a chemical decomposition, in which the sulphur is combined with the oxygen of the atmosphere.

To cite another illustration, it may be said that water itself is a chemical compound of the two elementary bodies, oxygen and hydrogen.

None of these latter are mixtures like the mixture of salt and water, but elementary bodies united to form new substances, which, as has been said, are called "chemical compounds," and it is through these chemical combinations that all plants and fruits possess their various peculiarities.

The number of compounds which the four organic elements form with each other is practically unlimited, but of them, a very few only minister to the growth and nourishment of plants. Of these water, carbonic acid, ammonia, and nitric acid are the most important. These compounds we shall take up in their order, a knowledge of all of them being of essential importance in agriculture.

WATER.

The following are the three qualities of water important to plant life:

First—A solvent power.

Second—An affinity for certain solid substances.

Third—An affinity for its own elements.

First—Water possesses the power of absorbing the several gases of which the atmosphere is composed, and carries them to the roots of plants whence they are taken into the circulation.

It dissolves many solid inorganic substances, earthy and saline, and conveys them in a fluid form to thé roots of plants, which enables them to ascend with the sap. It also takes up substances of organic origin, such as portions of decayed animal and vegetable matter, and likewise brings them within reach of the roots.

When warm the solvent powers of water over solid substances is very much increased, a fact which accounts for the luxuriant vegetation in the tropical and semi-tropical regions, and in what are known as "warm soils."

Second—Water exhibits a remarkable affinity for solid substances. A familiar instance is mixing water with quick lime. The lime heats, cracks, swells, and finally becomes a white powder. This is familiarly known as "slaking" lime. When thoroughly slaked, the lime will be found to be one-third heavier than before. Every three tons of lime, therefore, absorb one ton of water; hence, if four tons of slaked lime is put upon land one ton of water is also mixed in the soil.

Water has an affinity for clay, the hottest summer seldom robbing the clay of its water, enough being retained to keep wheat green and flourishing when plants on lighter soils are drooping and burning up.

An affinity for water causes vegetable matter to combine chemically with it, but in the case of a porous soil the water is merely "drunk in" mechanically and it is retained unchanged in the pores of the soil, whence it may be evaporated out, as related in the last chapter, but not where there has been a chemical transformation. This is a fact that should be remembered in applying mixtures of vegetable matter to the soil by way of fertilization. A mere mechanical mixture is of little effect; there must be a chemical transformation provided for. And it should also not be forgotten that water itself is capable of a chemical change whereby its qualities are preserved and retained much longer, indeed, than if merely poured upon the soil as a mechanical attempt to assist plant growth.

Third—Water possesses an affinity for its own elements, and this fact exercises a material influence on the growth and production of all vegetable substances. In the interior of plants, as in animals, water undergoes continual decomposition and re-composition. In its fluid state it finds its way into every vessel and every tissue. In this situation the water yields its oxygen to one portion of the plant and its hydrogen to another portion, wherever either is needed, and, in like manner, the oxygen and the hydrogen resume their combination as water and cling together until a new chemical change is needed. To comprehend this better the reader has only to observe the effects of water on his own system, for, as between plants and animals, the transmutations of oxygen and hydrogen, conveyed into the system by means of water, are practically identical.

We shall have more to say upon this subject in the chapter on the advantages of irrigation.

CARBONIC ACID.

Carbonic acid, as has been said, is the gas from burned charcoal, or carbon. It has an acid taste and smell, is soluble in water, and reddens vegetable blues. Water dissolves more than its own bulk of this gas. It is one-half heavier than atmospheric air, and is deadly in its effects. Yet it is the principal food of plants, being absorbed by the leaves and roots in large quantities, hence its presence in the atmosphere is necessary to plant growth, though the proportion is small.

Carbonic acid unites with potash, soda and lime, forming compounds known as "carbonates." Thus pearlash is carbonate of potash; the common soda of the shops is carbonate of soda, and limestone, or chalk, is carbonate of lime. The common carbonate of lime, in its various forms of chalk, limestone, or marble, is insoluble in pure water, but it dissolves readily in water containing carbonic acid. We know that water absorbs a quantity of carbonic acid from the atmosphere, and hence as it trickles through the soils containing limestone, etc., it dissolves a portion of the earth and carries it in its progress to the roots of the plants, where the earthy solution is used directly or indirectly to promote vegetable growth.

As to its absorption by water, a reference to a common glass of soda water will be sufficient to make this clear.

Some plants manufacture their own acids out of the carbonic acid—distinctive acids—for instance, oxalic acid, which is found in the leaves and stems of the common sorrel (oxalis). It is an acid not found in the soil and may be obtained from sugar, starch and even from wood by various chemical processes, principally by the use of nitric acid. To detail all the uses to which carbonic acid may be put would be going deep into chemistry, which is beyond the scope of this book. However, vegetable acids will be referred to in the next chapter.

AMMONIA.

Ammonia is a compound of hydrogen and nitrogen, and performs a very important part in the process of vegetation. It promotes not only the rapidity and luxuriance of vegetation, but exercises a powerful control over the functions of vegetable life. It possesses several special properties which bear upon the preparation of plant food.

First—It has a powerful affinity for acid substances, and unites with them in the soil, forming saline compounds or "salts," which are more or less essential to vegetable life.

Second—It possesses a very strong affinity for the acids of potash, soda, lime and magnesia. When mixed with these acids the acid in the salt of ammonia (sal ammoniac) for instance, is taken up by the potash, etc., and the ammonia is set free in a gaseous state. This is the effect of lime dressing on a soil rich in animal and vegetable matter; it decomposes the salts, particularly those of ammonia.

Third—The salts which ammonia forms with the acids are all very soluble in water, and thus ammonia is brought down to the roots of plants for their use.

Fourth.—In the state of carbonate it decomposes gypsum, forming carbonate of lime (chalk) and sulphate of ammonia, both of which are peculiarly favorable to vegetation.

Fifth—The presence of ammonia in a soil containing animal and vegetable matter in a decaying state causes this matter to attract oxygen from the air with great rapidity and in abundance, the result being that organic acid compounds are formed which combine with the ammonia to form ammoniacal salts. On the decomposition of these latter salts by the action of lime or other of the affinities above mentioned, the organic acids separated from them are always further advanced toward the state in which they become fit for plant foods.

Sixth—The most important property of ammonia is the ease with which its salts undergo decomposition, either in the air, in the soil, or in the interior of plants, a peculiarity which is possessed by water, as has been said. In the interior of the plant ammonia separates into its constituent elements as freely as water. The hydrogen it contains in so large a quantity is always ready to separate itself from the nitrogen, and so, in concert with the other organic elements introduced into the plant through the roots or the leaves, it aids in producing the different solid bodies of which the several parts of the plant are made up. The nitrogen also becomes fixed, that is, "permanent" in the colored petals of the flowers, in the seeds, and in other parts of the plant it passes off in the form of new compounds, in the insensible form of perspiration, or in perfumed exhalations of the plant.

NITRIC ACID.

This acid consists of nitrogen combined with oxygen, and never occurs in nature in a free state, but is found in many semi-tropical regions in combination with potash, soda and lime, in what are known as "nitrates." They are all, like the salts of ammonia, very soluble in water, those of soda, lime and magnesia attracting moisture from the air, and in a damp atmosphere gradually assume a liquid form. Saltpeter is a compound of nitric acid with potash (nitrate of potash), and it may sometimes be used as an influential agent in promoting vegetation. Like the acid itself, these nitrates, when present in large quantities, are destructive of vegetation, and are frequently the cause, in arid and semi-arid regions, of utter barrenness, the nitrous incrustations accumulating upon the surface of the soil. In small quantities, however, they exercise an important and salutary influence on the rapidity of growth.

CHAPTER VII.

PLANT FOODS—CEREALS—FORAGE PLANTS—FRUITS—VEGETABLES—ROOT CROPS.

Plants of every variety are very hearty feeders as a rule; in fact, if a plant be furnished with unlimited quantities of its proper food, and the environments of soil and climate are favorable, it will increase its bulk to enormous dimensions; the case is the same with fruits.

Sir Humphrey Davy introduced plants of mint into weak solutions of sugar, gum, jelly, etc., and found that they grew vigorously in all of them. He then watered separate spots of grass with the same several solutions, and with common water, and found that those watered with the solutions throve more luxuriantly than those treated with ordinary water. From this it may be reasonably inferred that different organic substances are taken into the circulation of plants and then converted by them into its own substance, or acts as food and nourishes the plant. Of course, it will be understand that by "plant foods" are meant whatever material tends to make the plant grow to maturity.

We have learned that plants absorb carbon in the shape of carbonic acid, and the part ammonia plays in the plant economy. Indeed, ammonia is actually present in the juices of many plants, for example: in beet roots, birch and maple trees, etc. In tobacco leaves and elder flowers it is combined with acid substances. It is also an element in the perfume of flowers, whence the value of barn yard manure to supply that element.

Nitric acid is invariably present in common, well known plants, in combination with potash, soda, lime, and magnesia (nitrates). It is always contained in the juices of the tobacco plant and the sunflower. The common nettle contains it and it is present in barley in the form of nitrate of soda.

Like ammonia, nitric acid exerts a powerful influence on growing crops, whether of corn or grass. Apied to young grass or sprouting shoots of grain, it hastens and increases their growth and occasions a larger production of grain, and this grain is richer in gluten, and therefore more nutritious in quality.

As showing the power of a plant to select its own food: if a bean and a grain of wheat be grown side by side, the stalk of the wheat plant will contain silica and that of the bean none. The plant intelligence, or instinct, so to speak, knows what it wants or needs, and it takes what it requires, rejecting everything else. Plants have also the power to reject through their roots such substances as are unfit to contribute to their support, or which would be hurtful to them if retained in their system. Knobs, excrescences and exudations may often be seen on the roots, stems, and even the leaves of plants, which many think are due to the ravages of some insect, but which are nothing more than the natural effort of the plant to get rid of some obnoxious or harmful substance in its system. When the plant's blood is out of order its nature attempts to cure it by forcing the dangerous substance or matter to the surface, as does the animal system under like circumstances.

Even the germinating seed is a chemical laboratory, inasmuch as it gives off acetic acid, or vinegar, which dissolves the inorganic material in its vicinity and returns with it in a condition to build up and nourish the plant.

The chemical compounds produced by the juices of all plants may be said to be innumerable. Most of them are in such small quantities that it would scarcely be worth while to consider them, but some are of a highly remedial quality, as quinine from Peruvian bark, morphine from the opium of the poppy, salicine from the willow, etc. All the cultivated grains and roots contain starch in large quantities, and the juices of trees, grasses and roots contain sugar in surprising quantities. The flour of grain contains sugar and two other substances in small quantities, namely: gluten and vegetable albumen, which are important nutritive substances. Sugar is also present in the juices of fruits, but is associated with various acids (sour) substances, which disappear altogether, or are changed into sugar as the fruit ripens.

WOODY FIBER, OR LIGNIN.

To manufacture the foregoing chemical compounds nature requires a huge structure, an enormous space when compared with the product turned out. More than one has wondered why a monstrous oak should produce so ridiculously small a fruit as an acorn, and a weak pumpkin vine one so enormous. The philosopher in the fable complained of this irregularity of nature as he lay under an oak. But when a small acorn fell upon his head he changed his mind. Now, all this huge structure, the body of the plant, is as carefully manufactured as the delicate savory fruit, and out of the same ingredients, practically. The bulky part of the plant, the bone and sinew, so to speak, is the woody fiber, or lignin.

When a piece of wood is cut in small portions and cooked in water and alcohol until nothing more can be dissolved out of it there remains a white, fibrous mass to which is given the name woody fiber, or lignin. It has neither taste nor smell, and it is insoluble. Strange to say, two of its chemical constituents are the same as water, being oxygen and hydrogen, with an equal quantity of carbon added.

Under the microscope this woody fiber appears to consist of what is called "cellular" matter, the true woody fiber, and a coating for strengthening purposes, called "incrusting" matter. This cellular matter is composed of oxygen and hydrogen in the proportions to form water, but it is difficult to separate them to determine the elementary construction, but we shall see that they demand a certain food and are intended for an important purpose.

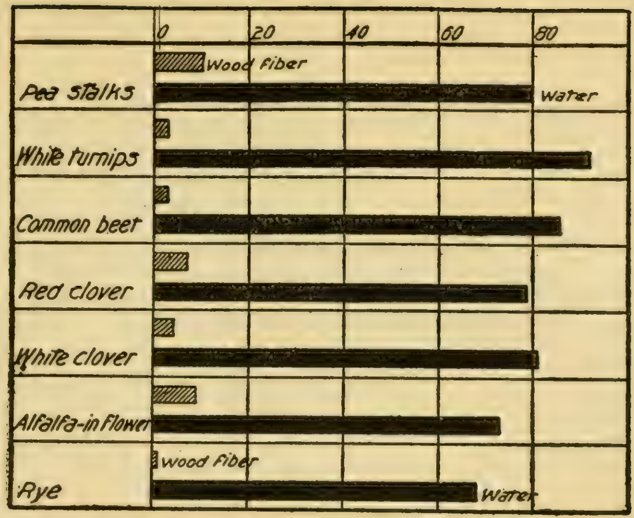
The woody fiber sometimes constitutes a large proportion of the plant, and sometimes it is very small. In grasses and corn growing plants, it forms nearly one-half of the weight, but in roots and in plants used for food it is very small in the first stages of their growth. The following table gives the percentage of woody fiber in a few common plants while in a green state.

Name of plant.	Per cent of woody fiber.	Water.
Pea stalks	10.33	80.0
White turnips	3.0	92.0
Common beet	3.0	86.0
Red clover	7.0	79.0
White clover	4.5	81.0
Alfalfa—in flower	9.0	73.0
Rye	1.0	68.0

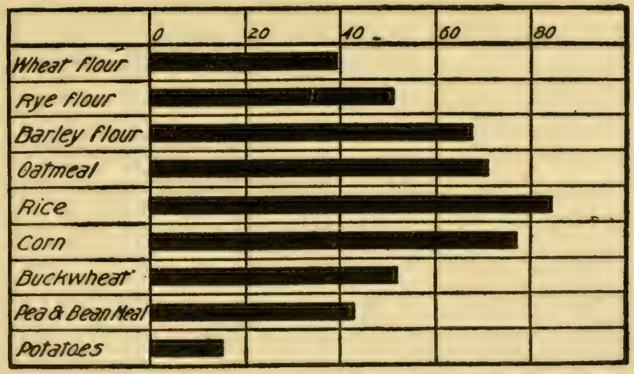
STARCH.

Next to woody fiber, starch is the most abundant product of vegetation. By whatever names the various kinds of starch are called: wheat starch, sago, potato starch, arrow root, tapioca, cassava, etc., they are all alike in their chemical constitution. They will keep for any length of time when dry and in a dry place, without any change. They are insoluble in cold water or alcohol, but dissolve readily in boiling water, giving a solution which becomes a jelly when cold. In a cold solution of iodine they assume a blue color.

The constituents of starch are carbon, oxygen, and hydrogen, with less carbon and more oxygen than woody fiber and about the same quantity of hydrogen.



PER CENT OF WOOD FIBER AND WATER IN A FEW COMMON PLANTS Page 82.



Per Cent of Starch in 100 Pounds of Different Grains—Page 83.

That starch constitutes a large portion of the weight of grains and roots usually grown for food the following table will show, one hundred pounds being the quantity upon which to base the percentage:

Name of plant.	Percentage of starch.
Wheat flour	39.77
Rye flour	50.61
Barley flour	67.70
Oatmeal	70.80
Rice	84.85
Corn	77.80
Buckwheat	52.0
Pea and bean meal	43.0
Potatoes	15.0

In roots abounding in sugar, as the beet, turnip, and carrot, only two or three per centum of starch can be detected. It is found deposited among the woody fiber of certain trees, as in that of the willow, and in the inner bark of others, as the beech and the pine. This is the reason why the branch of a willow takes root and sprouts readily, and why the inner bark of certain trees are used for food in times of famine.

GUM.

Many varieties of gum occur in nature, all of them insoluble in alcohol, but become jelly in hot or cold water, and give a glutinous solution which may be used as an adhesive paste. Gum Arabic, or Senegal, is the best known. It is produced largely from the acacia, which grows in Asia, Africa, California and in the warm regions of America generally. It exudes from the twigs and stems of these trees, and forms round, transparent drops, or "tears." May of our fruit trees also produce it in smaller quantities, such as the apple, plum and cherry. It is present in the malva, or althea, and in the common marsh mallow, and exists in flax, rape, and numerous other seeds, which, treated with boiling water give mucilaginous solutions.

All the vegetable gums possess the same chemical constituents of carbon, oxygen, and hydrogen, in nearly the same proportions as woody fiber and starch.

SUGARS.

All sugars may be classified according to four prominent varieties: Cane, grape, manna and glucose.

First—Cane sugar is so called from the sweet substance obtained from sugar cane. It is also found in many trees, plants and roots. The juice of the maple tree may be boiled down into sugar, and in the Caucasus the juice of the walnut tree is extracted for the same purpose.

It is also present in the juice of the beet, turnip and carrot. Sugar beet cultivation is assuming enormous proportions in the United States, as well as in Europe. Carrot juice is boiled down into a tasteless jelly and when flavored with any fruit flavors passes for genuine fruit jelly.

It is further present in the unripe grains of corn, at the base of the flowers of many grasses and in clovers when in blossom.

Pure cane sugar, free from water, consists of the following elements, estimated in percentages:

Carbon, 44.92; oxygen, 48.97; hydrogen, 6.11; almost identical with starch.

Second—Grape sugar. This sugar is so called from a peculiar species of sugar existing in the dried grape or raisin, which has the appearance of small, round, or grape shaped grains. It gives sweetness to the gooseberry, currant, apple, pear, plum, apricot, and most other fruits. It is also the sweet substance of the chestnut, of the brewer's wort, and of all fermented liquors, and it is the sugar of honey when the latter thickens and granulates, or "sugars."

It is less soluble in water than cane sugar, and less sweet, two parts of cane sugar imparting as much sweetness as five parts of grape sugar, at which ratio forty pounds of cane sugar would equal 100 pounds of grape sugar. Its chemical constituents are, in percentages: Carbon, 40.47; oxygen, 52.94; hydrogen, 6.59. Likewise nearly the same as starch.

As a test to distinguish cane sugar from grape sugar: Heat a solution of both and put in each a little caustic potash. The cane sugar will be unchanged, while the grape sugar will be blanckened and precipitated to the bottom of the vessel.

MANNA SUGAR, ETC.

Manna sugar occurs less abundantly in the juices of certain plants than cane or grape sugar. It exudes from a species of ash tree which grows in Sicily, Italy, Syria and Arabia. It is the product and main portion of an edible lichen, or moss, very common in Asia Minor. This curious lichen is found in small, round, dark colored masses, from the size of a pea to that of a hazel nut or filbert, and is speckled with small white spots. The wind carries it everywhere, and it takes root wherever it happens to fall. It can only be gathered early in the morning as it soon decomposes, or corrupts. The natives gather it from the ground in large quantities and make it into bread. This is said to be what constituted the "rain of manna" which fed the Israelites during their wanderings in the desert, and it derives its name from that circumstance.

Manna sugar is found in the juice of the larch tree and in the common garden celery. In the mushroom a colorless variety is found. To add two other varieties of sugar, the black sugar of liquorice root and sugar of milk may be mentioned.

GLUCOSE.

The name of this sugar means "sweet," a sweet principle, or element. It occurs in nature very abundantly, as in ripe grapes, and in honey, and it is manufactured in large quantities from starch by the action of heat and acids. It is only about one-half as sweet as cane sugar. It is sometimes called "dextrose," "grape sugar," and "starch sugar." What is known to the trade as "glucose," is the uncrystallizable residue in the manufacture of glucose proper, and it contains some dextrose, maltose, dextrine, etc. Its profusion and ease of manufacture makes it a cheap adulteration for syrups, in beers, and in all forms of cheap candies. The test for it is the same as that given to distinguish between cane and grape sugar.

All the elements in the foregoing sugars are similar in their chemical constitution, and what is still more remarkable about them, is the fact that they may be transformed one into the other, that is: Woody fiber may be changed into starch by heat, sulphuric acid, or caustic potash; the starch thus produced may be further transformed, first, into gum, and then into grape sugar by the prolonged action of dilute sulphuric acid and moderate heat. When cane sugar is digested (heated) with dilute sulphuric acid, tartaric acid (acid of grapes), and other vegetable acids, it is rapidly converted into grape sugar. When sugar occurs in the juice of any plant or fruit, in connection with an acid, it is always grape sugar, because cane sugar can not exist in combination with an acid, but is gradually transformed into grape sugar. This is the reason why fruits ferment so readily, and why, even when preserved with cane sugar, the latter is slowly changed into grape sugar and then fermentation ensues, and the preserved fruit "spoils."

GLUTEN, VEGETABLE ALBUMEN AND DIASTASE.

These substances are the nitrogenous elements in plants.

Gluten is a soft, tenacious and elastic substance, which can be drawn out into long strings. It has little color, taste, or smell, and is scarcely diminished in bulk by washing either in hot or cold water. It is a product of grain flour, left after washing dough in a fine sieve, and allowing the milky, soluble substance to pass off. The percentage of gluten in various grains is as follows:

Wheat	8 to 35 per centum.
Rye	9 to 13 per centum.
Barley	3 to 6 per centum.
Oats	2 to 5 per centum.

Dried in the air it diminishes in bulk, and hardens into a brittle, transparent yellow substances resembling corn, or glue. It is insoluble in water, but dissolves readily in vinegar, alcohol, and in solutions of caustic potash, or common soda.

Vegetable albumen, is practically the same as the white of eggs. It has neither color, taste, nor smell, is insoluble in water or alcohol, but dissolves in vinegar, and in caustic potash, and soda. When dry it is brittle and opaque. It is found in the seeds of plants in small quantities, and in grain in the following percentages:

Wheat	.75 to 1.50
Rye	2.0 to 3.75
Barley	.10 to .50
Oats	.20 to .50

It occurs largely, moreover, in the fresh juices of plants, in cabbage leaves, turnips and numerous others. When these juices are heated, the albumen coagulates and is readily separated.

Gluten and vegetable albumen are as closely related to each other as sugar and starch. They consist of the same elements united together in the same proportions, and are capable of similar mutual transformations. The following table will show the percentages in which the reader will notice that nitrogen is an element which does not exist in starch or sugar:

Carbon	54.76
Oxygen	20.06
Hydrogen	7.06
Nitrogen	18.12

When exposed to the air in a moist state both these substances decompose and emit a very disagreeable odor, giving off, among other compounds, ammonia and vinegar. Both of them exercise an important influence over the nourishing properties of the different kinds of foods, as we shall see in a subsequent chapter.

DIASTASE.

This substance may be manufactured from newly malted barley, or from any grain or tuber when germinated. It is not found in the seed, but is manufactured during the process of germination by the seed itself, or its decomposition, and it remains with the seed until the first true leaves of the plant have expanded, and then it disappears. Its functions, therefore, are to aid in the sprouting of the seed, and that accomplished, and there being no further use for it, it disappears. The reason for this is as follows:

Diastase possesses the power of converting starch into grape sugar. First, it forms out of starch a gummy substance known as dextrine, in common use as adhesive paste, and then converts it into grape sugar. Now, the starch in the seed is the food of the future germ, prepared and ready to minister to its wants whenever heat and moisture come together to awaken it into life. But starch is insoluble in water and could not, therefore, accompany the fluid sap when it begins to circulate. For which reason, nature forms diastase at the point when the germ first issues, or sprouts from its bed of food. There it transforms the starch into soluble sugar, so that the young vessels can take it up and carry it to the point of growth. When the little plant is able to provide for itself, and select its own food out of the soil and air, it becomes independent of the diastase and the latter is no longer wanted. Weaning a child will give the reader the idea.

VEGETABLE ACIDS.

There is another class of compound substances which play an important part in the development of plant foods and the perfection of growth. They are known as the vegetable acids, and it is due to them that plants possess a taste and flavor, every plant having its own peculiar acid. They are usually classified into five species and enter into combination with all of the substances heretofore referred to. They are:

Acetic acid (vinegar), tartaric acid (acid of wine), citric acid (acid of lemons), malic acid (acid of apples), and oxalic acid (acid of sorrel). Acetic acid is the most extensively diffused and the most largely produced of all the organic acids. It is formed wherever there is a natural or artificial fermentation of vegetable substances. It easily dissolves lime, magnesia, alumina, and other mineral substances, forming salts known as "acetates," which are all soluble in water, and may, therefore, be absorbed by the root pores of plants. It is an acid common in everything, and may be manufactured from wood, alcohol, cane sugar and from the juice of apples, or by any vegetable fermentation, the process of fermentation throwing off carbonic acid and forming vinegar.

Tartaric acid finds lodgment in a variety of plants. The grape and the tamarind owe their sourness to it, and it exists also in the mulberry, berries of the sumach, in the sorrels, and in the roots of the dandelion. It is deposited on the sides of wine vats, and when purified and compounded with potash, it becomes the familiar "cream of tartar," which is known to every housewife. In the grape it is converted into sugar during the ripening of the fruit.

Citric acid gives sourness to the lemon, lime, orange, grape fruit, shaddock and other members of the citrus family. It is the acid in the cranberry, and in numerous small fruits such as the huckleberry, wild cherry, currant, gooseberry, strawberry, and the fruit of the hawthorn. In combination with lime, it exists in the tubers, and with potash, it is found in the Jerusalem artichoke.

Malic acid is the chief acid in apples, peaches, plums, pears, elderberries, the fruit of the mountain ash. It is combined with citric acid in the small fruits above mentioned, and in the grape and American agave it is associated with tartaric acid. It has exactly the same chemical constitution as citric acid, and the two bear the same relation to each other as starch, gum and sugar. They undergo numerous transformations in the interior of plants, and are the cause of the various flavors possessed by fruits and vegetables.

Oxalic acid has poisonous qualities, but an agreeable taste. It occurs in combination with potash in the sorrels, in garden rhubarb, and in the juices of many lichens, or mosses. Those mosses which cover the sides of rocks and the trunks of trees sometimes contain half their weight of this acid in combination with lime.

This chapter is, of course, one step farther in advance of the one immediately preceding, and the facts stated are intended to lead on up to a complete, practical knowledge of the forces of nature operating in the soil and within the plant to attain perfection. Nothing but the bare essentials, the mere outlines, have been given so far; to attempt to enter into all the details would be to write an entire volume, the reading of which might prove tiresome and unproductive of anything practical. All that it is desired to do in these preliminary chapters is to furnish the reader with sufficient elementary knowledge to enable him to go farther on his own account and to infer what the soil needs for the cultivation of plants; how that soil is to be cultivated, and how the element of water is to be applied to it in order to increase its productiveness and his profit. This is the true preliminary to irrigation, as we imagine, for it would convey no information to suggest the pouring of water on the soil, and drenching plants and crops with it, unless the intelligence is prepared to understand why that should be done, and all the details and consequences laid before the reason and common sense.

So far, the reader ought to have a comparatively clear idea of the chemical constitutions of the substances which enter into the soil, and from the soil into the plants, but there still remains the question: How do the substances necessary to plant life get into the condition of plant food? This question will be answered in the next chapter.

CHAPTER VIII.

HOW PLANT FOOD IS TRANSFORMED INTO PLANTS.

The growth of plants from the seed to the harvest, or fall of the leaf, may be divided into four periods, during each of which they live on different foods and expend their energies in the production of different substances.

This is important to be well understood, for plants can not be dieted like animals, they need certain provisions at certain periods of their growth, and if not supplied with them the result is failure, or a sparse crop. A farmer feeds his chickens egg-producing food, his cows milk-generating fodder and mash, and his cattle fat-making provender. He might as well deprive his animals of their necessary stimulating food and expect them to go on laying eggs, furnishing milk and growing fat, as to expect his crops to succeed without providing them with the requisite material to arrive at perfection. But, to proceed.

These four periods in the life of plants are:

First—The period of germination, that is, from the sprouting of the seed to the formation of the first perfect leaf and root.

Second—From the unfolding of the first true leaves to the flower.

Third—From the flower to the ripening of the fruit or seed.

Fourth—From the ripening of the fruit, or seed, to the fall of the leaf and the return of the following spring.

Of course, in anuual plants, when the seed or fruit is ripe or harvested, there are no more duties or functions to perform, hence the plants die, having accomplished the object of their existence. But in the case of perennial plants, there are important things to be done in order to prepare them for the new growth of the ensuing spring.

PERIOD OF GERMINATION.

1. To sprout at all, a seed must be placed in a sufficiently moist situation. No circulation can take place, no motion among the particles of the matter composing the seed, until it has been amply supplied with water. Indeed, food can not be conveyed through its growing organs unless a constant supply of fluid be furnished the infant plant and its first tender rootlets. This does not mean drenching the immature plant with water, but supplying it with moisture. A child needs feeding just as much as an adult, but not to the same extent, and over-feeding kills the young plant as quickly as the young animal. The reason is plain, if the reader remembers what was said in the last chapter, in which it was specified that water is a chemical compound of oxygen and hydrogen. In this state it is too strong a food for the young plant, and "drowns" it out, as the saying is. But in a state of moisture, the chemical nature of the water is altered somewhat and becomes available to the juices in the seed, whereby the germ is enabled to grow and fulfill its mission without meeting with a premature death. It is water that is the parent of moisture and without water, of course, there can be no moisture. Nevertheless, throughout this entire book, it is moisture that will be insisted upon; when plants have that, the whole object of irrigation will be accomplished, unless it be the intention to grow aquatic plants.

Now, this moisture must be constant during the entire life of the plant, not liberal one day with the next day dry, and so on, alternately, as some say may happen in the case of pork for the purpose of making alternate layers of fat and lean in the bacon, but not in the case of vegetation.

2. A certain degree of warmth is necessary to

germination. This warmth varies with the seed, some seeds, those containing much starch, for instance, requiring more, and slow germinating seeds less. What is needed is not too early a planting and protection against any inclemency of the weather from frost or cold rains, and not too late a planting in locations where there are no winter or spring frosts, to avoid too great a heat from the sun, which is as dangerous to tender plants as frost. "Warmth" is a sufficiently descriptive word to make the meaning clear.

3. Seeds refuse to germinate if entirely excluded from the air, even where there is plenty of moisture. Hence, in a damp soil, seeds will not show any signs of life for a long time, and yet when turned up near the surface within reach of the air, they speedily sprout. The starch in the grain intended to feed the germ will not dissolve in water, so it happens that the farmer, sometimes, in ditching or digging a well, throws up earth that has lain many feet below the surface for years, perhaps ages, the length of time makes no difference, from which sprout plants of unknown varieties. They have never lost their vitality. The "oat hills" in the southern part of California are familiar examples. Year after year a good crop of oats springs up without planting, cultivating the surface being sufficient to bring the buried grain within reach of the air. It is said that the old Padres originally sowed this grain broadcast wherever they went, taking a sack of it on their horses, and as they traveled along cast handfuls of it in the most favorable spots. This grain grew to maturity year after year, going back to the soil unharvested, there being nobody to gather it. The civil and criminal records of the southern California courts are full of lawsuits and murders growing out of struggles to obtain and retain possession of these "oat hills."

A friend for whose accuracy there is abundant evidence, cites a case that happened to him personally in a small valley in the semi-arid region. Wanting water he began sinking a well and went down one hundred feet before reaching moist ground. That ground was a soft black loam, and desiring to keep it for a top dressing, he laid it aside for future use. Not long afterward seeds began sprouting all over it and, helping the sprouts with a little water to keep the soil moist, he raised a thick crop of fine sweet clover. The seeds had never been planted by the hand of man, for the formation of the soil indicated that it might have been in the same condition since the Deluge.

4. Generally speaking, light is injurious to germination, wherefore, the seeds must be covered with soil, and yet not so deep as to be beyond the reach of air. Sowing grain broadcast leaves much of it exposed to the light, and even after harrowing, it does not germinate, being food for birds and drying up or burning up in the sun. In light, porous soils, it is common, however, to sow broadcast and then plow under, afterward harrowing lightly. It is also common in the arid and semi-arid regions to plow the grain in "dry" in the summer or dry months, and when the rains come in the autumn, or say, in November and December, the grain sprouts in a few days.

The reason why light is prejudicial to germination and why atmospheric air is necessary is because during germination seeds absorb oxygen gas and give off carbonic acid, and they can not sprout unless oxygen gas is within their reach, the only place where they can obtain it being from the atmosphere. In the sunshine the leaves of plants give off oxygen gas and absorb carbonic acid, while in the dark the reverse takes place. Hence, if seeds are exposed to the sunlight, they give up oxygen which they need and absorb carbonic acid, which kills them.

5. During germination, acetic acid (vinegar) and diastase are produced, as mentioned in the last pre-

ceding chapter, whereby the insoluble starch is converted into sugar, which is soluble and can be absorbed as food by the youthful plant.

6. The tender young shoot which ascends from the seed consists of a mass of organs or vessels, which gradually increase in length, sometimes "unroll" into the first true leaves. The vessels of this first shoot do not consist of unmixed woody fiber, that is not formed until after the first leaves are fully developed. In the meantime the young root is making its way down into the soil, seeking a storehouse of nourishment upon which it can draw when the sugar of the seed shall all have been consumed.

These phenomena are brought about in the following manner: The seed absorbs oxygen and gives off carbonic acid. This transforms a portion of the starch into acetic acid, which aids the diastase to transform the insoluble starch into soluble sugar, or food that can be taken up into the plant. It also dissolves the lime in the soil contiguous to it, and returns into the plant, carrying the lime or other dissolved earthy substances with it. The seed imbibes moisture from the soil, and this dissolves the "sugary starch," so to speak, and it all goes into the circulation, and the plant is enabled to grow and develop its first leaves. It is like a baby fed on milk.

When the true leaves have expanded, woody fiber begins to make its appearance, which can be readily understood by attempting to break the plant stalk, a thing easily done before the first leaves appear, but not so easily afterward. The sugar in the sap is now converted into woody fiber, the root drawing up food from the soil, and the leaf drinking oxygen and carbonic acid from the atmosphere. The moisture must still be constant, for the root can not absorb food unless the latter is properly dissolved.

FROM THE FIRST LEAVES TO THE FLOWER.

The plant now enters upon a new stage of existence, deriving its sustenance from the air and the soil. The roots descend and the stem shoots up, and while they consist essentially of the same chemical substances as before, they are no longer formed at the expense of the starch in the seed, and the chemical changes of which they are the result are entirely different.

Here is where the farmer will make a fatal mistake if he relaxes his vigilance. The whole energy of the plant is directed toward one single goal, that of preparing for the flower which is the forerunner of the fruit. What the flower is, that will be the fruit.

The leaf absorbs carbonic acid in the sunshine and gives off oxygen in equal bulk, and the growth of the plant is intimately connected with this absorption of carbonic acid, because it is in the light of the sun that plants increase in size. Now, by this function of the leaf, carbon is added to the plant, but it is added in the presence of the water of the sap and is thus enabled by uniting with it to form any one of those numerous compounds which may be represented by carbon and water, and of which, as was shown in the last chapter, the solid parts of plants are principally made up. This period may be called the period of "plant building," the plant utilizing every material that will bring it up to the condition of flowering.

The sap flows upward from the roots, through which have been received the silica, potash, soda, phosphorous, etc., in solution, and reaching the leaves, meets the carbonic acid flowing in through the myriad of mouths in the leaves, and then flows along back downward to the roots, depositing, as it descends, the starch, woody fiber, etc., which have been formed by the action of the carbonic acid. Thus the sap circulates round and round like the circulation of blood in the veins of an animal, except that its heart is not a central organ, but an attraction of affinities among the substances which enter into plant life, affinities constantly pursuing each other through the veins or capillaries of the plant, and forming unions, the products of which add to the growth of the plant and enable it to accomplish its destiny.

During this ante-flowering period there are produced in the plant not only woody fiber, but other compounds which play an important part in a subsequent stage of its existence; one of these, the most important, is oxalic acid, which has already been alluded to. This acid seems to be formed at this period to aid in perfecting the future fruits that will follow the flower. What is curious about these various acids now formed is that many of the plants are sour in the morning, tasteless during the middle of the day, and bitter in the evening. The reason is, during the day these plants have been accumulating oxygen from the atmosphere to form acids, but as the day advances this oxygen is given off, carbonic acid is imbibed and the acids decomposed. Hence the sourness disappears, but the materials are in the plant ready for use when required—the acid storehouse is filling against the day of need.

In the case of wheat, barley and other grains, the chief energy of the plant, previous to flowering, is expended in the production of the woody fiber of its stem or stalk, and growing branches, drawing up from the soil for that purpose the various ingredients they require from among the inorganic elements, which unite with the vegetable acids in the sap and form compounds which are essential to the perfection of the grain or seed. In the first stage of its growth the starch of the seed is transformed into gum, and then sugar; in its second stage, when the leaves are expanded, the starch is transformed into woody fiber.

FROM THE FLOWER TO THE RIPENING OF THE FRUIT.

The sap has now become sweet and milky, indicating sugar and starch. These during the third period are gradually transformed in the sap into starch, a process exactly the reverse, or contrary of that in the first and second periods. The opening of the flower from the swollen bud is the first step taken by the plant to produce the seed by which its species is to be perpetuated. At this period a new series of chemical changes commence in the plant.

1. The flower leaves absorb oxygen and emit carbonic acid all the time, both by day and by night.

2. They also emit pure nitrogen gas.

3. The juices of the plant cease to be sweet, even in the maple, sugar cane, and beet; the sugar becomes less abundant when the plant has begun to blossom. A change not difficult to understand when it is considered that nature is at work preparing to perfect the seed or fruit, and is not working for commercial interests. The structure of the plant is now of no consequence, and ceases to be of any importance. The imbibing of oxygen, which is the parent of all acids, is intended to convert the sugar into material for the seed, or fruit, the wheat or the peach, the strawberry or the squash.

The husk of grain bearing grasses, corn, wheat, oats, etc., is filled at first with a milky fluid which becomes gradually sweeter and more dense, or thicker, and finally consolidates into a mixture of starch and gluten, such as may be extracted from the grain as has already been said.

The fleshy envelopes of many plants, at first, tasteless, become sour and finally sweet, except in the lime, lemon and tamarind, in which the acid remains sensible to the taste when the seed has become perfectly ripe.

Fruits, when green, act upon the air like green leaves and twigs, that is, they imbibe oxygen and give off carbonic acid, but as they approach maturity they also absorb or retain oxygen gas. The same absorption of oxygen takes place when unripe fruits are plucked and left to ripen in the air, as is common in the case of tomatoes, oranges, lemons, and bananas. After a time, however, they begin throwing off carbonic acid and then they ferment, spoil or rot.

RIPENING OF THE FRUIT.

In the case of pulpy fruits, such as the grape, lemon, orange, apple, peach, plum, etc., when unripe and tasteless, they consist of the same substances as the leaf, a woody fiber filled with tasteless sap, and tinged with the green coloring matter of the plant. For a time, the young fruit performs the functions of the leaf, that is, it absorbs carbonic acid and gives off oxygen, thus extracting from the atmosphere a portion of the food by which its growth is promoted and its size is gradually increased. Remember what has been heretofore said about carbon constituting the bulk of the plant.

By and by, however, the fruit becomes sour to the taste, and this sourness rapidly increases, while at the same time it gives less oxygen than before, the retaining of the oxygen being, as has been said, the cause of the sourness, the oxygen converting the sugar into tartaric acid and water. The grape is an illustration, though the same thing happens in fruits abounding in the other vegetable acids.

This formation of acid proceeds for a certain time, the fruit becoming sourer and sourer. Then the sharp sourness begins to diminish, sugar is formed, and the fruit ripens. The acid, however, rarely disappears entirely, even in the sweetest fruits, until they begin to decay.

During the ripening of the fruit, the woody or cellular fiber gradually diminishes and is converted into sugar. This will be noticed in several kinds of fruits, particularly winter pears, which are uneatable when actually ripened on the tree, but become ripe, long after plucking, by continuing to absorb oxygen, which converts the woody fiber, or cellular tissue, into sugar, which is not difficult to understand, as woody fiber is very similar to sugar in its chemical constitution.

It should be noted that the entire forces of the plant are concentrated upon the seed, the element, or agent of reproduction, the pulp of the most delicious fruit, the kernel of the sweetest nut being nothing but protective envelopes and food supplies for the germ when the time and opportunity shall arrive for germination. So that the object of the plant in making so many transformations is not fruit, but seed.

FROM THE FALL OF THE LEAF TO THE FOLLOWING SPRING.

When the seed is fully ripe the functions of annual plants are ended. There is no longer any necessity for absorbing and decomposing carbonic acid; the leaves, therefore, begin to take in only oxygen, with the result that they are burned up, so to speak, and they become yellow, or parti-colored; the roots decline to take in any more food from the soil, and the whole plant prepares for its death and its burial in the soil by becoming resolved into the organic and inorganic elements from which it sprang, and of which it was originally compounded.

But of trees and perennial plants, a further labor is required. The ripened seed having been disposed of, there are incipient young buds to be provided for, buds which are to shoot out from the stem and branches on the ensuing spring. These buds are so many young plants for which a store of food must be laid away in the inner bark of the tree, or in the wood of the shrub itself.

The sap continues to flow rapidly until the leaves wither and fall, and then the food of the plant is converted partly into woody fiber and partly into starch. It has been shown how these substances are converted into food by chemical changes, or transformations, and these changes do not cease so long as the sap continues to move. Even in the depth of winter the sap slowly and secretly stores up starchy matter, in readiness, like the starch in the seed, to furnish food to the young buds when they shall awaken in the spring from their winter sleep. It is the same process as in the case of a seed planted in the ground.

RAPIDITY OF GROWTH.

It has been shown that from carbonic acid and water, the plant can extract all the elements of which its most bulky parts consist, and can build them up in numerous ways. But the rapidity with which the plant can perform this building up is almost incredible.

Wheat will shoot up several inches in three days, barley six inches in that time, and a vine twig will grow about two feet in three days. Cucumbers have been known to attain a length of twenty-four inches in six days, and a bamboo has increased its height nine feet in less than thirty days.

The rapid growth of vegetation in semi-tropical arid and semi-arid regions is phenomenal. A young eucalyptus tree has been known to grow thirty feet in a single season, and wheat or barley three inches high three days after planting is not uncommon. Potatoes (solanum tuberosum) have run up to fifteen pounds in weight before the plant had time to blossom, in fact, it never did blossom.

Three-pound onions, eighty-pound watermelons, and five-hundred-pound squash are not rarities, and I have been told of a field of corn, of the white Mexican variety, that grew fourteen feet with four perfect ears of corn to the stalk with only twelve inches of rain. As for sweet potatoes, or yams, thirty pounds weight do not occasion surprise, and beets after two years' growth are often as large as nail kegs, all woody fiber, of course, and unfit for food.

It is true that such examples are mere experiments, indeed they may be called specimens of "freak" vegetation, and rarely mean perfection of quality, but they indicate the ability of the plant to rapidly assimilate from the soil and air large, even excessive, quantities of the elements it needs, or fancies, provided they exist in abundance, and they demonstrate that the farmer has it within his power to convert this enormous productive energy into "quality" of product by regulating it through adequacy of moisture and cultivation without excess.

In the foregoing chapters nothing but the mere outlines of the chemistry of agriculture have been given. Even to do that it was necessary to concentrate a mass of matter from a multitude of books, lectures, personal experiences of successful farmers, and from other sources, to reach simplicity and clearness. The books are full of never-ending disputes over theories, doctrines and scientific experiments, relating to plants and the soil, and it was thought best to eliminate all those disputes and present the operations of nature with regard to the soil and plants in as simple a manner as possible.

There are many things mysterious in nature which science has not yet been able to explain, and which practical experience accepts without inquiring into reasons or causes. Why do early potatoes often reach maturity and the vines die down before the latter have a chance to blossom? What is the answer to the problem of seedless fruits, such as oranges, lemons, grapes, etc.? Why do certain plants revert to originals which have few traits in common, like the tomato, for instance? Why do not the seeds of plants always produce the same variety? We know that the laws of chemistry are practically immutable, though their manifestations may be irregular. What has been written, it is hoped, will be of some benefit toward preparing for the practical part of this book, which will occupy the subsequent chapters.

CHAPTER IX.

PREPARATION OF SOIL FOR PLANTING.

One great object of cultivating or tilling the soil is to break up and loosen the earth, in order that the air may have free access to the dead vegetable matter in it, as well as to the living roots which spread and descend to considerable depth beneath its surface.

If it be desirable to have a luxuriant vegetation upon a given field of land, that is, a good crop, one must either select such kinds of seed as will grow in it, or which are fitted to the kind of soil in which they are planted, or change the nature of the soil so as to adapt it to the crop it is desirable to raise.

It is not denied that plants will grow in any soil that contains the general elements essential to their existence, but when the quantity and quality of the crop are considered as of importance, it is useless to "guess," for only partial satisfaction will result, and often entire failure, which is usually attributed to the elements or to the wrath of Providence.

Farming for profit means that the farmer knows every foot of his land and the nature of the soil; what it will grow and what it needs. A lack of this knowledge is farming for luck, and is equivalent to gambling with the eyes shut. There is less labor and twice the profit in harvesting forty bushels of wheat on an acre of properly cultivated soil than forty bushels on two acres roughly tilled. The case is the same with any sort of crop, and this is so plain that it seems absurd to mention it, yet it is forgotten in numerous cases of farmers, who go more on quantity of acreage than perfection of cultivation and increase of crop. It is not extensive farming that pays so well as concentrated farming. A man with one hundred acres well in hand is better off than another with five hundred acres of struggling crops. Wholesaling in any business is more expensive and the returns less than in retailing, and every farmer knows, perhaps by bitter experience, that everything about a farm is attended with expense, if not always in cash money, then in a draft upon his future strength and vitality. Irrigation, however, promises to be a cure for rambling farming, by compelling concentration. Why spread water over one hundred acres to raise a sparse crop when the same or much less water will secure a fine, luxuriant crop on twenty-five acres? When a single grain of wheat may be made to stool out into sixty plants, is not that better than when it stools out into only twenty? The former shows health, vigor, and productiveness, the latter mediocrity. The one means a syndicate, the other a home.

The new beginner, the small farmer, reads accounts of the great farming schemes, the thousands and thousands of acres which run bank accounts into five and six figures. He dreams of gang plows, steam plows, combined harvesters and reapers, his fat cattle upon a thousand hills, and he swells himself up like the toad in the fable to equal the ox, and bursts in his effort. Let the reader desirous of gaining a competency through farming, acquire a home before he is worn out in the struggle, before his patient wife sinks beneath the sod in the effort, and his children grow up into cowboys, rustlers and desperadoes, imitate nobody, read none of the glowing accounts of successful great farmers without at the same time understanding that all such began, as a rule, on enormous capital, took a magnificent ranch through the early demise of a worn-out ancestor, through a mortgage foreclosure of some "imitator," or raises himself to grandeur upon the cheap labor of his fellowmen. Let him take the soil and treat it as the foundation for a home, for plenty, and the other things will come to him.

It was said in a former chapter that plants are like animals, in that to grow to perfection they must be properly managed and fed. A half-starved hog produces poor bacon, a chaff-fed horse has little energy, the wool of a starveling sheep is coarse and wiry, and even a human being, limited in his diet or restricted in nourishment, possesses a flabby, shriveled brain and a weak physical energy. Men say of animals: prune, cultivate, select, feed; of men: prune, cultivate, feed, and wherefore not say the same of plants and the soil: prune, cultivate, feed? Herein is the whole science of preparing the soil for cultivation, the heredity of plants, their atavism, their environments, the survival of the fittest, and whatever else may be said of animals and humanity. But to return to the great vegetable kingdom.

All of our practical writers agree, and the everyday farmer knows by his personal experience, that as the systems of roots, branches and leaves are very different in different vegetables, so they flourish most in different soils. The plants which have bulbous roots require a looser and a lighter soil than such as have fibrous roots, and the plants possessing only short fibrous radicles demand a firmer soil than such as have tap roots or extreme lateral roots. But it may be considered as a truism that shallow cultivation of the soil always produces minimum crops, whereas maximum harvests are gleaned by deep plowing whatever may be the plant.

It is always a question of the ability of the roots to reach out after food and their exposure to air. To comprehend this fully it should be considered that there is about as much of the plant under ground as above it, and the experienced farmer can always tell by the growth of his crop above ground whether the roots are doing well under ground, if the growth is not in accordance with the natural progress of the plant, there is some obstacle below the surface which can be removed by cultivation, the loosening up of the soil to a sufficient depth. How quickly growing corn revives and takes a new lease upon life after deep cultivation between the rows! Not shallow cultivating, or scratching over the surface, but 'deep plowing.' Level with a shallow cultivator afterward, of course, then hoe and see the stalks shoot up. It is some trouble, certainly, but do you not depend upon a good crop to make money, and to obtain a home? It is also a trouble to raise a child, but when it grows up straight, is not the labor more amply repaid than when it grows up crooked and stunted?

The character of the cultivation, however, depends upon the condition of the subsoil. Where that is hard or packed, it must be broken through, and up, to permit root penetration. Frequently, not to say generally, there is moisture beneath the hard, packed sub-soil, and by breaking through the moisture finds its way up and "slakes" the hard pan or other resistant subsoil. There is also a difference in cultivation between the soils of the arid and the humid regions, differences which are atmospheric and also in the quantity of the organic elements which will be made apparent as we go along.

It seems unnecessary to repeat so simple a thing when it should be as plain as day, that plants possess an instinct that does not fall far short of the marvelous. For instance, in the arid regions the plant sends its roots down deep and out in every direction after the moisture which it apparently knows it can not get at the surface or near it, whereas, in the humid regions, the roots spread out more, because they apparently know that the moisture is near the surface and they do not have to toil so hard to make their way down deep. Anyone practicing surface irrigation will know that the roots of plants which have a habit of penetrating deep into the soil, grow along the surface, because the moisture is there. Plants always adopt the easiest method of obtaining food.

Now why do plants travel after moisture and not after dry soil? It is not water plants need, nor is it moisture, but it is food. They know that there is food material in the dry soils, but it is not in a fit condition to be absorbed, whereas, moisture prepares the food for them, hence they refrain from pursuing the raw material and expend their energies in seeking the manufactured product. Let a garden patch which has been kept moist, and in which the roots congregate, be allowed to dry, and another patch that has been dry and away from which the roots turn, be moistened, and the plants will grow away from their former hunting ground and in the direction of the new one. This is common observation. A beet root has been known to travel sixteen feet in the direction of a well where it knew it could get a drink, although plants, as a rule, are not drinkers but feeders of the most pronounced Epicurean type.

In the arid and semi-arid regions it is better to provide for a deep burrowing of the roots, because when they frequent the surface, they are liable to suffer from drought, or surface dryness. In this the reader will find an argument in favor of sub-irrigation.

Upon this instinct of roots to seek their proper food in moist soil, depends the measurement of soil tillage, whether deep or shallow, and by "shallow" is not meant a mere surface scratching, but a good wholesome upheaval of the soil from a depth of eight to twelve inches, thence on up to eighteen if the subsoil be in question. Where the subsoil is not hard packed, then as deep as the subsoil; if packed it should be broken up. But where the subsoil is open and porous there is less need of deep plowing; on the contrary, it may be necesary to pack the bottom of the furrow, which is accomplished by a plow attachment known as a "packer," so arranged as to follow the plow and press down the earth at the bottom of the furrow; a useful contrivance where irrigation is practiced, inasmuch as it tends to prevent the leaching of the irrigation water down into the porous subsoil, where the water is run into the furrows.

It can not be too strongly impressed upon the reader that the soil must be so cultivated that it will retain moisture without permitting it to leach beyond the reach of the roots, and at the same time so broken up and pulverized that the roots may easily penetrate. Let this be the axiom constantly in mind: Give the plant roots room to spread. Upon this depends the perfection of the plant. "Stunts" are always caused by too little root room, the plant languishing because they are unable to reach moisture by reason of obstacles in the soil. If there is any moisture in the soil the plant will get it if it be given an opportunity.

Let us assume that we have a parcel of land in which it is purposed to grow plants without the application of manure. It does not matter whether it be virgin soil or one that has already grown a crop of any kind; the first thing to be done to this land is to improve the soil, that is, prepare it for vegetation. This may be done in seven ways:

First—By cultivation, or, more properly speaking, pulverization of the soil, by plowing and other mechanical means of reducing its consistency.

Second—By mechanical consolidation.

Third—By exposure to the atmosphere; that is, "fallowing."

Fourth—By alteration of its constituent parts.

Fifth—By changing its condition in respect to water.

Sixth—By changing its position in respect to atmospheric influences.

Seventh—By a change in the kinds of plants cultivated, or "rotation of crops."

PLOWING AND PULVERIZING.

All these different methods of preparing the soil means practically the same thing—the breaking up of the soil, which must be done constantly if a good crop in quantity and quality be desirable.

By reason of their chemical elements the tendency of all soils is to concrete; that is, to run together into a sort of more or less hard cement, a tendency enhanced by the growing of crops and the application of water, or either. Thus, sand without consistency and quicklime without coherence, when mixed together with water, produce a hard cement or plaster, which may be crushed and pulverized before it can become again manageable. In soil the chemical agencies of nature are constantly at work to produce the same result; hence cultivation to break up a tendency which is adverse to the growth of plants and free root penetration.

The very first object of cultivation is to give scope to the roots of plants to spread in every direction, for without abundance of roots no plant can become vigorous, whatever may be the richness of the soil in which it is placed. The quantity of food taken from the soil does not depend alone upon the quantity in the soil, but on the number of absorbing root fibres. The more the soil is pulverized the more the fibres are increased, the more food is obtained, and the more vigorous the plant becomes. Any house plant growing in an earthenware pot will demonstrate this. The roots grow down and then, finding an obstruction, begin growing round and round in search of food, until the entire pot is filled with root fibres, even forcing out the soil to find room, and when they have grown to the limit of their confined space, the plant stops growing and becomes sickly.

This cultivation or stirring up of the soil for root expansion is not only essentially precious to planting, or sowing, but highly beneficial afterward, during the progress of vegetation; and when practiced in the spaces between the plants it also operates as a method of root-pruning, by which the extended fibres are cut off, or shortened, thereby causing them to throw out numerous other fibres whereby the mouths or pores of the plants are greatly increased, and their food capacity enhanced. It is very much like fattening animals for market by encouraging their consumption of fattening food.

Cultivation renders capillary attraction more uniform, this peculiarity of the soil being greater when the particles of earth are finely divided. Thus, gravels and sands scarcely retain water at all, while clays, not opened by pulverization or other means of breaking them up, either do not readily absorb water, or when exposed to long action, they retain too much of it. In the arid regions deep cultivation is essential to admit moisture from the atmosphere, as for example, the dews of night. In irrigated sections deep and thorough cultivation checks evaporation and reduces the accumulation of alkali salts to a minimum, besides saving water.

Heat is tempered by deep cultivation, which is a great desideratum in the arid and semi-arid regions, the layer of pulverized soil serving the purpose of shade or mulch, and the evaporation retarded, the moisture acquires a uniform temperature. This seems to be a small matter in plant growth, but practical experience has demonstrated that it is an important part of the general combination of practices which result in successful agriculture.

Whenever the soil is opened, turned over and otherwise prepared for planting, a portion of the atmospheric air is buried in the soil and this air so confined, is decomposed by the moisture retained in the earthy matters. Ammonia is formed by the union of the hydrogen of the water with the nitrogen of the atmosphere, and nitre by the union of oxygen and nitrogen. So also, the oxygen of the air may unite with the carbon contained in the soil and from carbonic acid gas. Heat is given out during all these chemical processes. As a rule farmers do not pay much attention to these simple facts, but the plants he is growing do, and they are more or less benefited as they are permitted to take advantage of these laws of nature, or prevented.

The depth of cultivation must depend upon the nature of the soil and the variety of plant grown in it. The subsoil, also, is not to be disregarded. Rich clayey soils can hardly be cultivated too deep, and even in sands, unless the subsoil contains alkali in dangerous quantities, or other plant poisons, deep cultivation should be practiced. When the roots are deep they are less liable to be injured by excessive water or drought; the radicles are shot forth into every part of the soil, the space from which nourishment is to be drawn being extended over a much greater extent than when the seed is superficially inserted in the soil.

In this respect cultivation should be attended with a thorough mixture of the soil by turning it over and over. Plowing, of course, accomplishes this result in a great measure, but the difference of gravity between the organic and the inorganic matters in the earth, has a tendency to separate them, for which reason light or shallow stirring of the soil is of little or no use practically, because it leaves the surface of the soil too light and spongy and the lower part too compact and earthy. Even where the plant roots are near the surface cultivation with a plow and a complete turning over of the soil is much better than the mere scratching of the surface, for there, as has been said, it is equivalent to root pruning.

In a former chapter reference is made to the fact that plant roots consume all the food in their neighborhood, and this furnishes another obvious reason for deep cultivation, otherwise the roots of a new crop reaching out for nourishment find an empty cupboard.

Some soils, however, require the opposite of pulverization and demand mechanical consolidation. This will be understood in the case of spongy peats and light, dusty sands. A proper degree of adhesiveness is best given loose soils by the addition of earthy matters in which they are deficient, perhaps the bringing up of a heavier and more consistent subsoil will accomplish the purpose. Rolling and treading, however, are simple methods, but in that case the soil must be dry, and the operation must not be carried too far, or so far as to concrete the earth, which is its constant tendency, as has been observed.

A peat bog drained and rolled will sooner become covered with grass than one equally well drained but left to itself. Drifting sands, however, may well be rolled when wet, and by repeating the process after rains or floodings, they will in time acquire a surface of grass or herbage. Light soils should always be rolled, and the seeds should be "tread in" when planted, a pat with the hoe not being sufficient, as in the case of heavier soils, unless the seeds be very small.

Exposure to the atmosphere, speaking with reference to soils, means "lying fallow," the only benefit of which, and sometimes it is not a small one, is to expose insects and their eggs, weeds and their seeds, to destruction. In climates where there are severe winters and hard frosts, a hard, lumpy soil becomes pulverized by the action of the frost, and soils that have become soured, sodden and baked by the tread of cattle or other cause in wet weather, are more rapidly sweetened and restored to friability by exposure to the hot sun of summer, than by the frosts of winter. Some maintain that the only benefit of fallow, that is, turning up the soil roughly to the atmosphere, is to free the soil from the roots of weeds. There is nothing, indeed, in the idea that the land "needs a rest," for if properly cultivated, soil will keep on producing as long as there are any elements capable of feeding plants. The idea originated in ancient times when lack of help to till the entire farm, or a deficient supply of manure, compelled the suspension of cultivation on certain parcels or fields.

It is certain that what is called an "exhausted soil" obtains no renewing material from the atmosphere.

To alter a soil is to add or subtract the ingredients which are lacking, or which exist in excess. The so-called "alkali soils" are an illustration of excessive ingredients, and any sterile, sandy or gravelly soil may be regarded as one representing a deficiency of food producing elements. In case of sterility, the only remedy is to add the ingredients lacking, or convert sterile material into fertile ones by chemical means. Thus: where in sterile soil, on washing it, there is found the salts of iron or acid matters, the application of quick-lime will ameliorate it, and in a soil of apparently good texture, but sterile on account of the sulphate of iron, a top dressing of lime will afford a remedy by converting the sulphate into a manure.

If there be an excess of calcareous matter in the soil it may be remedied by the application of sand or clay. Too much sand is improved by clay, marl, or vegetable matter, and light sands are benefited by a dressing of peats, and peats improved by adding sand. The labor of thus improving the texture or constitution of the soil is more than repaid by the requirement of less manure, in fact, accretions in the way of new soil are a natural manuring and insure the fertility of the soil, where manure might be doubtful on account of its adding an excess of organic matter, which is equally as deleterious to plant growth as too much inorganic matter. An equal number of tons of sand, clay, marl, or other natural soil, as of manure, will often tend to greater productiveness than from the addition of manure. When there is an excess or superabundance of soil material, the problem of its removal is much more difficult and serious, the reclamation of alkali lands abundantly demonstrating this. Ordinary sand and gravel may be plowed under, scraped from the surface, or partly washed off by flooding, particularly where the lay of the land is sloping. In the case of alkali, as has already been said, drainage, or exhaustion of the soil by the cultivation of gross feeding plants seems to be the reasonable remedy; at all events it proves effectual.

Burning over the soil was an ancient method, one used by the Romans to alter the constituents of the soil, the object being to render the soil less compact, less tenacious, and less retentive of moisture by destroying the elements that tend toward holding it in a concrete consistency.

It is practiced in the United States for the same purpose, but in the vast areas of the boundless West, where a man is not limited to a small acreage of the soil, it is not regarded as worth the labor, although it might in many instances be beneficial. The soils improved by burning are all such as contain too much dead vegetable fiber, by the burning of which they lose from one-third to one-half of their weight. So stiff clays, adobes, hardpans, and marls are improved by burning. But in the case of coarse sands, or where the elements of the soil are properly balanced, burning is detrimental, and the same is the case in silicious sandy soils after they have once been brought into cultivation.

As to changing the condition of lands in respect to water, the subject belongs to irrigation, but it may be said here in passing, the land should be cultivated, having in mind the flowing of water, whether from irrigation or rain, so as to avoid the accumulation of stagnant water, which is injurious to all classes of useful plants. When the surface soil is properly constituted and rests on a subsoil moderately porous, both will hold water by capillary attraction, and what is not so retained will sink into the substrata by its gravity; but when the subsoil is retentive, it will resist the percolation of water to the strata below and thus accumulate in the surface soil, and, making the latter "soggy," will cause disease to the plants. Hence the origin of surface draining, that is, laying land in ridges or beds, or intersecting it with small, open gutters, a very good practice where irrigating water is used, for into them the water may be turned and then plowed over, left to come up to the surface where the plant roots can reach it. The alteration of land by water will be treated in detail in its proper place under the head of "Irrigation."

We have already referred to the effect of the sun's rays on land, and add here that in cultivating, there is one advantage in ridging lands and making the ridges run north and south, for on such surfaces the rays of the morning sun will take effect sooner on the east side, and those of the afternoon on the west side, while at mid-day the sun's elevation will compensate for the obliquity of its rays to both sides of the ridge. In gardening there is much advantage in observing this method of cultivation, for the reason that much earlier crops may be produced than on a level ground. Thus, sloping beds for winter crops may be made southeast and northwest, with their slope to the south, at an angle of forty degrees, and as steep on the north side as the mass of earth can be got to stand. On the south slope of such ground of course the crops will be earlier than on level ground. There is little advantage of this sloping, however, unless perfection of garden produce is desirable, although the advantage of sloping is a diminution of evaporation and also a ready natural drainage.

Although rotation of crops will be treated in a special chapter, the subject has a bearing upon cultivation, or treatment of the soil, since the necessity for a rotation of crops seems to grow out of a diminution of certain plant foods desirable to certain plants, and there are many species of plants which require particular substances to bring their seeds or fruits to perfection. It may be that these particular substances are in the soil but beyond the reach of the plant. In that case it is clear that a thorough mixing of the elements of the soil will bring the appropriate food within reach of the plant, or, if that can not be done, then the planting of some other crop, and permitting it to return back into the soil, will afford the required food for the desired plant. In this place, cultivation and thorough mixing is advised. In the proper chapter the whole subject will be treated in detail.

The following are some of the root and soil peculiarities of well known plants:

Wheat—Has feeble roots at surface, but strong tap roots penetrating deep into the soil. Stiff soil.

Oats—Next to wheat, will stand stiff soil, but the plant throws out in the superficial layer of soil a number of fine feeders in lateral directions, and hence the top soil should be light and open.

Barley—It throws out a network of fine, short root fibers of no great depth and requires a light, open loam.

Peas—Require a loose soil, with little cohesion, and spread soft root fibers deep.

Beans—Ramify strong, woody roots in all directions, even in a heavy and compact soil.

Clover—Grass seeds and small seeds generally put forth at first feeble roots of small extent, and require so much the greater care in preparing the soil to insure their healthy growth. The pressure of a layer of earth a half to one inch thick suffices to prevent germination. Such seeds require only just as much earth to cover them as will retain the needful moisture for germination.

Turnips, potatoes, etc.—The nature of these fleshy and tuberous roots clearly point out the part of the soil from which they draw their chief supply of food. Potatoes are found in the topmost layers of soil, whereas the roots of beets, turnips, parsnips, etc., send their ramifications deep into the subsoil, and will succeed best in a loose soil of great depth. Still they grow well in heavy and compact soil properly prepared for their reception.

As to the length of roots it has been found that alfalfa will grow roots thirty feet, flax five feet, clover above six feet, etc., and beets have been known to send out a long, tapering root sixteen feet along the surface, an instance of which has been already noted.

It is on the root that the farmer should bestow his whole care. Over that which grows from it he has no control, except perhaps in the way of pruning or bud "pinching," as in the case of tobacco, melons, fruits, etc.

CHAPTER X.

LAYING OUT OF THE LAND—METHOD OF PLANTING.

Generally speaking every farmer has his land under his eye and knows what to do with particular portions of the ground. He will plant wheat in this field, barley over yonder, further along he expects to have a patch of rye.

In the case of vegetables he follows the same practice and plants his cabbages, his beets, turnips, etc., wherever the fancy moves him. It is a haphazard manner of farming, and to it may be attributed failures which have been ascribed to the elements. From what has been heretofore said it must be apparent that there is something in soil and in the manner of planting which it would be well to heed; indeed, which must be heeded if success be desired and a crop assured. True, plants will grow if the seed be thrust in the ground; that is, after a fashion; and so will an animal grow if kept alive after a fashion, but the produce in both cases will be scrub.

The time is coming, if it has not already arrived, when farmers will be able to produce as much from half an acre of ground as from an acre, and better crops. Too much land is as great a bar to success as too little, for in the former case there is too much trusting to luck, whereas in utilizing nature for the purpose of wresting products from the bosom of the earth there is not the smallest element of luck; it is all pure science, knowledge, ability, etc. A man with the trifling commercial business keeps an account of stock, his books show just what he has on hand, his sales and purchases. His inventory shows where his varieties of goods are located on his shelves. But when it comes to a farm, which is never a small business, no books are kept, no account of stock taken, and the location of his crops are retained in his mind's eye. More than that, quality is little regarded, the varieties of soil are not considered, and plants requiring one kind of soil are fed on a kind they do not flourish in. This is the common rule.

Take any tract of land, large or small, and when the crop is growing there will always be spots where the plants are thin, sparse and sickly. Failure of proper cultivation? Not at all; nothing but failure to properly lay out the land so as to know what it is suitable for. The pollen of a sickly plant spreads as far as that of a good healthy one, and poor results are attributed to poor seed, etc., when a little care and forethought might have made the crop uniform and the results satisfactory.

This is preparatory to the subject of laying out the land, for upon doing that properly depends the success it is always desirable to attain in every species of farming for profit. If profit be not the desideratum, then why go to the trouble and labor of farming?

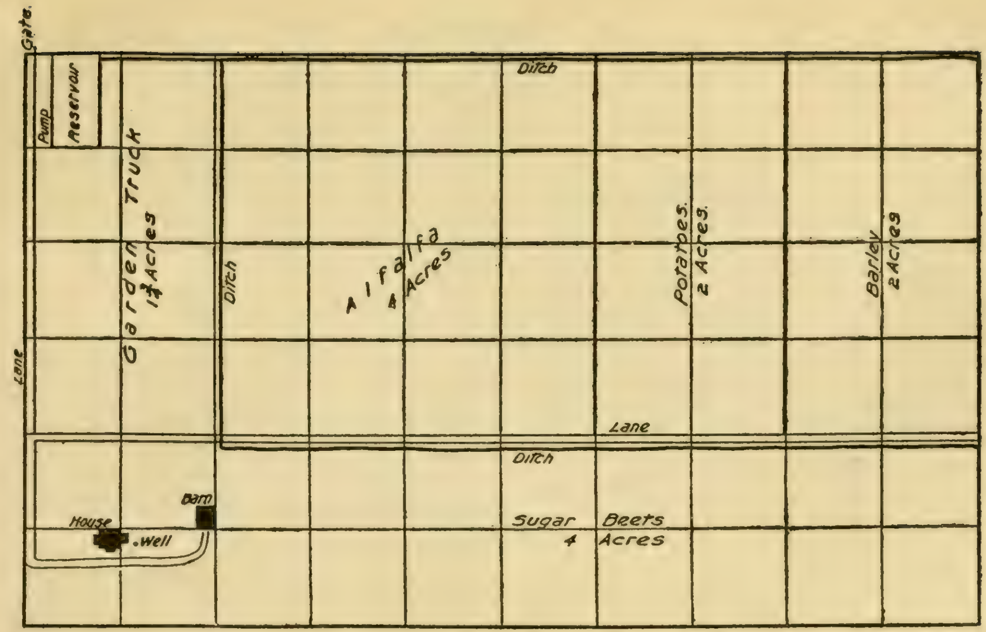
The proper laying out of the land is always of great importance, and where irrigation is practiced it is of the highest importance. Water runs down hill and it also soaks into the soil seeking the water table, and this water table is always receiving additions through the constant or periodical application of irrigation water, and rises to do damage.

Hence, drainage is to be considered as well as the slope of the land. The first thing to be done is to prepare an outline of the land, its boundaries. If a square tract the matter will be easy, for any sized square may be laid down upon paper and then measured off into acres or parts of acres to suit the convenience. A map of one's land is a necessity nowadays, and it is not difficult to prepare one. It is the farmer's diagram of the location of his stock, equivalent to the shelves in a store of merchandise. It tells him the location of his crops, the nature of the soil, his ditches and all their ramifications, and if anything goes wrong he can immediately put his finger on the point of trouble and go at once to correct it.

To prepare a map of the land measurements must be taken, and these measurements are expressed in tables universally adopted and can therefore always be relied upon as uniform. To begin with, an acre of land, whatever its shape, contains exactly 43,560 square feet, and after an outline has been traced upon paper, lines may be drawn from side to side and these lines crossed by other lines drawn from top to bottom. The map will then be covered with little squares which may be any part of an inch in size, but representing a given quantity of land; say one inch square on the paper represents an acre of ground; then if you have a farm of 100 acres your map will be ten inches square, if the land is a square, but whatever the shape of the land it will contain exactly 100 square inches. Not a very large map, but very convenient, for on it may be expressed the exact location of crops, even to a small cabbage patch, ditches, farm buildings, orchards, vines, etc., etc. Of course any scale to the acre may be selected instead of one inch. If the farm is large then make the scale one-half inch to the acre or even less, or if small make the scale two inches or more, to allow of the least details.

If it is desirable to make an accurate estimate of the amount of land in different fields under cultivation, the following table will be of assistance:

10x 16	rods equals 1 A.	70x 69.5	yards equals 1 A.
8x 20	rods equals 1 A.	220x198	feet equals 1 A.
5x 32	rods equals 1 A.	440x 99	feet equals 1 A.
4x 40	rods equals 1 A.	110x369	feet equals 1 A.
5x968	yards equals 1 A.	60x726	feet equals 1 A.
10x484	yards equals 1 A.	120x363	feet equals 1 A.



Showing Method of Making Map of Land—Page 122.

20x242	yards equals 1 A.	240x181.5	feet equals 1 A.
40x121	yards equals 1 A.	200x108.9	feet equals 1 A.
80x 60.5	yards equals 1 A.	100x145.2	feet equals 1 A.

100x108.9	feet	equals ¼ A.
25x100	feet	equals .0574 A.
25x110	feet	equals .0631 A.
25x120	feet	equals .0688 A.
25x125	feet	equals .0717 A.
25x150	feet	equals .109 A.
2178	sq. feet	squals .05 A.
4356	sq. feet	equals .10 A.
6534	sq. feet	equals .15 A.
8712	sq. feet	equals .20 A.
10890	sq. feet	equals .25 A.
13068	sq. feet	equals .30 A.
15246	sq. feet	equals .35 A.
17424	sq. feet	equals .40 A.
19603	sq. feet	equals .45 A.
21780	sq. feet	equals .50 A.
32670	sq. feet	equals .75 A.
34848	sq. feet	equals .80 A.

In measuring land there are three distinct operations to be performed: Taking the dimensions of the tract; delineating or laying down the same on a map, and calculating the area or superficial contents. All the tables applicable to land measurements will be found in the Appendix, to which the reader is referred.

For ordinary purposes a knotted cord or tape-line may be used. In measuring a simple figure, as a square field, nothing is necessary but to measure the length and the breadth, which, multiplied together, will give the superficial area. Where fields are irregular shaped, it is necessary to adopt some standard guiding form, and from that measure the different angles, so as to be able, from the dimensions taken, either to calculate the contents at once, or to lay down the form of the field on paper according to the scale adopted, and from that ascertain its dimensions and calculate its contents.

The simplest and most accurate mode of ascertaining the contents of all irregular figures is to throw them into triangles, and this method is usually employed whether a small piece of irregular shaped land is to be measured or a vast extent of territory. To find the contents of a triangle all that is necessary is to multiply half the perpendicular by the base. And this regardless of the shape of the triangle. In measuring land in this manner, and by a little calculation, every foot of land can easily be represented on paper.

TAKING THE LEVEL.

After the land is accurately measured, or measured satisfactorily to its owner, taking the level of its surface is the next thing in order, and in this there can not be too much care taken, particularly where irrigation is practiced. Upon it depends the proper flow of water in ditches, the flooding of land and adequate drainage.

To explain it will be necessary to be a little abstruse, but the idea will be readily grasped by thinking. The earth is a sphere, that is, "round," and all places on its surface, whether a ten-acre tract or one of ten thousand, are said to be "level" when they are equally distant from the center of the earth, and "out of level" when their distances from that center are not equal.

Now, because the earth is a sphere, or round, every level line drawn upon its surface from one point to another, must be a curve and part of the earth's circumference, assuming it to be perfectly smooth, or at least parallel with it.

The common methods of leveling are sufficient for irrigation on an ordinary tract of land, but for long canals and ditches miles in extent, the leveling must be in accordance with the curved level line to correspond with the surface of the earth equi-distant from its surface. The usual instrument for leveling is the road or mason's level with telescope and compass, the latter to get the bearings. For ditching purposes a "plumb-bob" level, a two-legged contrivance open like the letter A with a line fastened at the top and terminating in a pear, or "top" shaped piece of lead. In the exact center of the bar across the A is marked a notch, and when the point of the "bob" is at that center notch, the line is level. Illustrations of this and other contrivances for leveling land will be found elsewhere, and referred to in the synoptical index so as to be easily found.

To continue the level line a series of poles are necessary. These are so placed that the one nearest the eye conceals all the rest. To allow for inequalities of surface, a notch is cut in the starting pole, or at the point where the level line begins, and that point must be level with it all along the line. A small spirit level held to each pole, and the eye will demonstrate the exact level line for all practical purposes. This method is sufficient for small areas, to lay the level of a ditch, or its laterals, but in large tracts, of course, a surveyor should be called in. Every farmer with a hundred acres to level can easily do the whole surveying himself by following this apparently crude method, and be as accurate in his leveling as a professional surveyor.

Where there are curved lines to be drawn on irregular surfaces, a hill or a knoll, for instance, being in the way of a straight line, the mariner's compass may be brought into use to ascertain bearings, and a series of straight lines drawn which will make skeletons for the curves. In fact, it is no trick at all to draw a level line around a hill, or curve a ditch in the shape of a letter S or Z, by this simple method. All these measurements should be traced on the map, for even if not used immediately they will prove useful when necessary to ditch, or irrigate.

The following table showing various grades per mile will be useful as a basis of calculation in drawing the level lines for ditches or general irrigation purposes:

1 foot in 15	is 352	feet per mile
1 foot in 20	is 264	feet per mile
1 foot in 25	is 211	feet per mile
1 foot in 30	is 176	feet per mile
1 foot in 35	is 151	feet per mile
1 foot in 40	is 132	feet per mile
1 foot in 50	is 106	feet per mile
1 foot in 100	is 53	feet per mile
1 foot in 125	is 42	feet per mile

Any desired grade or "flow" can be calculated by remembering that there are 5,280 feet in a mile. By dividing 5,280 feet by the number of feet in length of the ditch, the grade or "fall" will be the result, estimating one foot as the desired fall or flow of the water in the ditch, and the desired fall or flow may be regulated when drawing the level line by notching the poles used in leveling.

ELEMENTARY INFORMATION.

To make this land leveling business clear to the mind of the elementary reader, let it be supposed that he desires to run a ditch from one point to another. He has the letter A-shaped plumb-bob leveler, half a dozen poles ten feet or so in length, and a carpenter's spirit level. With these he is prepared to run practically level lines all over a hundred-acre tract of land.

At the starting point ascertain the "plumb" point, that is, the spot over which hangs the lead bob exactly in the middle of the cross-bar of the A, then plant a pole, and at the height of the eye, say five feet, cut a plainly visible notch, or make any kind of a mark that can be seen from a distance. This is the standard of the entire ditch.

Next, take another pole, your A level, and the spirit level, and walk along the proposed line of ditch any convenient distance to a point. Four rods or so are not too far, less if there are obstructions to level around. Lay the A level over the selected point and ascertain the exact level of point two, as it may be called. Now place the spirit level against the pole about the height of the eye, and look along its top just as if "sighting" a gun. Slide it up and down, if necessary, until you find the notch in the first pole, with the "bubble" in the spirit level exactly in the center, and make a notch or mark in pole number two where the top of the spirit level touches it.

A calculation is easily made, for the notch on pole one is five feet from the surface of the ground, and by measuring the height from the ground of the notch in pole number two, any variation will mean that another level point must be selected, or that there must be some grading or digging.

The second level point having been established, proceed with the third pole in the same manner, comparing it with the second pole, carefully noting the figures on paper, and so continue until the work is completed. Laterals may be run in the same manner, and the entire parcel of land gone over, the results in figures showing the slope or lay of the land for every purpose. This leveling, if carefully and completely done, will show numerous grades, or slopes in the same parcel or tract of land, and the knowledge of this is extremely valuable; in fact, necessary for irrigation purposes, whether ditching or flooding. It is often a very intricate matter to irrigate every portion of a given field uniformly, and failure to do so always results in lack of uniformity in any crop sought to be grown upon it, there being too much water on some parts and not enough on others. It will be understood that the waste of water and the loss in crop must exceed by far the expense of leveling the land in every direction. The chapter on irrigation will give details of flowing water on irregular surfaces, and reference to the synoptical index will point out comprehensive illustrations.

Before concluding this portion of the chapter on "Laying Out of Land," it is proper to add by way of information, that on July 28, 1866, the Congress of the United States legalized what is known as the "metric" or French system of measurements, and provided that "It shall be recognized in the construction of contracts * * * * as establishing in terms of the weights and measures now in use in the United States, the equivalents of the weights and measures in common use."

That portion of the "French" system relating to land measurement is given here, in case any farmer should fancy it in preference to the "English" system, which has always been used:

MEASURES OF LENGTH.

Metric Denominations and Values.	Equivalents in Denominations in Use.
Myriametre....10,000 metres.	6.2137 miles.
Kilometre......1,000 metres.	0.62137 mile, or 3,280 ft. 10 in
Hectometre......100 metres.	328 feet 1 inch.
Dekametre........10 metres.	393.7 inches.
Metre...............1 metre.	39.37 inches.
Decimetre....1-10 of a metre.	3.937 inches.
Centimetre..1-100 of a metre.	0.3937 inch.
Millimetre...1-1000 of a metre.	0.0394 inch.

MEASURES OF SURFACE.

Metric Denominations and Values.	Equivalents in Denominations in Use.
Hectare....10,000 sq. metres.	2.471 acres.
Are...........100 sq. metres.	119.6 sq. yards.
Centare..........1 sq. metre.	1,550 sq. inches.

This metrical, or decimal, system is not in common, everyday use; on the contrary, it is rarely found except in Government reports.

The matter of fencing should not be omitted in this place, and so estimated quantities in the convenient barbed wire fencing are here given. The table gives an estimate of the number of pounds of barbed wire required to fence the space or distance mentioned, with one, two or three lines of wire, based upon each pound of wire measuring one rod ($16\frac{1}{2}$ feet):

	Pounds.	Pounds.	Pounds.
1 side of a square mile.	320	640	900
1 rod in length........	1	2	3
100 rods in length.......	100	200	300
100 feet in length........	6 1/16	12 1/8	18 3/16

METHODS OF PLANTING.

It must not be supposed that this part of the present chapter will exhaust the subject of methods of planting. The subject is too large and important to be treated in one place, and it is therefore distributed in other chapters to follow. But it is all important to consider the nature of the plant which it is purposed to grow, and plant the seed in such manner that it will have room to grow and develop its seed or fruit. If the previous chapters have been carefully read the reader will remember that great stress was laid upon the fact that all plants are great feeders, and that they are so by instinct, and to attempt to compel them to abstain from their proper food, or limit their food supply on the ground of economy or indifference, or upon the supposition that they will grow anyhow, is to reduce the product of that plant proportionately. It is always a losing plan to restrict the food of plants, for that means stunting their growth.

Now, whether the seed be sown broadcast, planted in drills, or the young plant transplanted, care must be taken that the roots have space to spread, or reach out for the required food. If they have not then they rob each other and fail to produce as desired. Plants are cannibalistic in their customs and must not be humored in the slightest degree.

There is a curious fact about the growth of plants which may not be out of place here, inasmuch as it will prove an addition to the reader's information concerning the peculiarities of the plant kingdom: Experiment has demonstrated that the smallest seeds, even, say the mustard or radish, sown in an absolutely sterile soil will produce plants in which all the organs are developed, but their weight after months does not amount to much more than that of the original seed. The plants remain delicate, and appear reduced or dwarfed in all dimensions. They may, however, grow, flower and even bear seed, which only requires a fertile soil to produce again a plant of natural size.

In planting without providing room for the plant to feed, or sowing, or planting too many of its fellows in too close proximity, the soil is rendered sterile by over-consumption, and the plants starve or fail to produce adequate crops. This well known fact, together with the application of the experiment above cited, will explain why, in rows of plants, there are spots where the plants do not grow to perfection so far as producing is concerned. They grow, it is true, but they are dwarfs.

There is another thing to be considered also in this connection, which is that plants are not all robust or healthy in the same degree. One may be so situated as to its environments as to be able to develop more quickly than its neighbors, in which case it will "crowd out" its neighbors, or absorb their food, which means the same thing. Just as when two humans sleep in the same bed, the healthy and vigorous one will absorb the vitality of the weaker one, a well attested circumstance in medical annals.

Experience has demonstrated beyond controversy that there is as much of a plant under ground as above it, whether that plant be a tree or a cabbage, and hence it is not difficult to gauge the proper distances in planting, if perfection of growth be the desideratum. Few, however, pay the slightest attention to this fact, and hesitate to "prick out" the superfluous plants in the radish or lettuce bed, and the consequence is they wonder why their neighbor grows such fine cabbages when they have the same soil and bestow the same care upon them. They do not give them the same care; the neighbor is economical, for he thins out his rows and gives the remaining plants room to grow. This means quality as well as perfection.

A Chinese gardener will grow vegetables so close together that they will touch, and anyone watching him will suppose that the thinning out process is not essential. But it is in his case as well as in all other cases, the only difference being, the Chinaman knowing very well that his plants will not grow if crowded together, and that they must be thinned out. But he knows the reason, and that reason is that they must have food in sufficient quantities, so he gives it to them and makes up for lack of space by supplying food. This is why the Chinaman can be seen always dosing his plants with liquid fertilizers. He never rests, but is always at work "forcing" his vegetables to grow. Anyone can do the same, but the average American farmer, with his acres of land to the Celestial's square feet, does not deem it necessary to crowd his plants. Moreover, to speak truly, forced plants are never as substantial as those grown naturally, and this ought to be a sufficient reason for so planting that every individual plant may be surrounded by its own storehouse without encroaching upon the preserves of its neighbors.

The following table will assist the farmer in planting seed, bearing in mind always that the plant is as large under ground as above it, whether it be a tree or a cabbage. The distances are in feet, basing the calculation as 43,560 square feet to the acre:

Distances Apart.	No. of Plants.	Distances Apart.	No. of Plants.
1 x1	43,560	7x 8	888
1½x1½	19,360	8x 8	680
2 x 1	21,780	9x 9	537
2 x2	10,890	10x10	435
2½x2½	6,969	11x11	360
3 x1	14,520	12x12	302
3 x2	7,260	13x13	357
3 x3	4,840	14x14	222
3½x3½	3,555	15x15	193
4 x1	10,890	16x16	170
4 x2	5,445	17x17	150
4 x3	3,630	18x18	134
4 x4	2,722	19x19	120
4½x4½	2,151	20x20	108
5 x1	8,712	24x24	75
5 x2	4,356	25x25	69
5 x3	2,904	27x27	59
5 x4	2,178	30x30	48
5 x5	1,742	40x40	27
5½x5½	1,417	50x50	17
6 x6	1,210	60x60	12
6½x6½	1,031	66x66	10

To round out the above calculation, the following table of the quantity of seeds required in planting is added:

	Seeds, Per Oz.	Length of Drill, Per Oz.	Vitality, Years.
Asparagus	1,000 to 1,200	50 feet	4 to 6
Beet	1,200 to 1,500	100 feet	6 to 8
Carrot	20,000 to 24,000	200 feet	1 to 3
Cabbage	8,000 to 12,000	Transplant	4 to 6
Cauliflower	8,000 to 12,000	Transplant	4 to 6
Celery	50,000 to 60,000	Transplant	3 to 5
Egg plant	5,000 to 6,000	Transplant	5 to 6
Endive	20,000 to 24,000	Transplant	8 to 10
Lettuce	25,000 to 30,000	400 feet	5 to 6
Okra	500 to 600	50 feet	5 to 6
Onion	7,000 to 8,000	200 feet	1 to 2
Parsnip	5,000 to 6,000	200 feet	1 to 2

Radish	3,000 to 4,000	100 feet	4 to 5
Salsify	2,500 to 3,000	100 feet	4 to 5
Spinach	2,000 to 3,000	100 feet	4 to 5
Tomato	About 20,000	Transplant	4 to 5
Turnip	8,000 to 12,000	200 feet	6 to 7

The quantity of seed for the space specified in the second column of the latter table is much too great, but it is the conventional quantity and is given as the maximum. In our garden culture all of the common plants mentioned are susceptible to transplanting with good results, even the onion; but, of course, in field culture chopping out with a hoe is the most advisable method to pursue in thinning.

CHAPTER XI.

LAYING OUT LAND FOR IRRIGATION.

If the author had his way about it, he would have the land on each side of every main or large supply ditch sloped down gently for at least one hundred and fifty feet, and on that slope he would plant peas, beans, corn, and melons and raise a good profitable crop without any or with very little furrow or surface irrigation. The seepage water would answer the purpose of sub-irrigation, or infiltration, as will be explained in another chapter. This water aided by deep cultivation and pulverization of the soil would be sufficient to gratify his most ardent hopes.

At the bottom of each slope would be established an open ditch or covered drainage system, and the surplus water caught and utilized for surface or furrow irrigation on the plat below. The land on the ditch slope would be plowed and cultivated parallel with the ditch line, and at right angles to it on the plat below the slope.

This system of laying out the land is equivalent to terracing but more convenient and natural, withal, less expensive, for the ditches can be arranged to suit the slopes of the land rather than the reverse. Should the land be sufficient in quantity to make it worth while and the topography permit, a series of slopes could be provided for and every drop of the usually wasted seepage water utilized. It is very pretty to the eye and looks very nice and regular on paper, but the author believes that although the ditches run everywhere in the most profuse irregularity and ugliness, destructive even of the refinement required of landscape art, yet there is nothing more beautiful to his eye than a luxuriant crop of profitable plants. Experiment and settled practice has demonstrated the utility and value of this system all over the world. Corn, beans, peas, peppers, onions, even small fruits and crawling berry vines growing to perfect maturity without a drop of water from the clouds or by artificial application, and as to the quality—well, they are imported into this country from Europe and the American epicure pays three times as much for them as for home productions because he finds them better suited to his palate. Every housewife knows that her window plants flourish and grow luxuriantly by keeping the "saucer" of the flower pot filled with water without any surface wetting at all.

The system is as old as Egypt and Babylon, and it is adapted to small farms and is an obviously economical system of increasing the duty of water without increasing its quantity, and it is more conducive to the perfection of plant growth and life than "over-dosing."

DITCH-BANK IRRIGATION.

The system last referred to is really what may be called "ditch-bank irrigation." The object of it, of course, is to use the water that seeps or percolates from the banks of a raised ditch, which is sufficient to moisten the slope of the bank and the soil for some distance outward from the base. We find that this system was in favor with the old Spanish settlers, who opened a ditch from a stream on a grade so slight that a very slow flow would result. The land on each side of this ditch was thus moistened and almost every variety of vegetables and small fruits were raised without other irrigation.

To accomplish the purpose, the land is deeply plowed, turning under a good covering of manure, then harrow thoroughly until the soil is evenly settled. After this the land is ready for the elevated ditch from which the seepage water is to be obtained. This is done by throwing back a few furrows to form a ridge which shall be high enough to command the land under it. The ridge is shaped evenly and the surface raked over, a hoe being used to mark out a narrow ditch. When the water is turned in the course of the water may be regulated with a hoe and by a little cutting and filling, so that the water will run evenly along the entire length of the ridge.

In less than a week the soil along the ridge will be in a suitable condition to receive whatever seed or plant it is desired to grow; indeed, there will be as much space along the base of the ridge as there is on its slope which will be sufficiently moist. If the ground is not too porous, the water will percolate slowly and evenly and moisten the soil without cropping out at the surface anywhere. By thrusting the hand into the soil it will be found that the percolating water is within an inch of the surface, but never quite reaches it, due probably to surface evaporation. As will be noticed in the case of sand, the surface may be dry but water-soaked an inch or so below.

The number of ridges may be multiplied to suit the quantity of surface it is desirable to irrigate in that fashion, and they may be made large enough to control a quarter or half an acre. Even though the land at the base is perfectly flat, the water flows down the slope and spreads out along the levels. Should the land be sloping generally, the overflow from the first or highest ditch may be troughed to a lower one and so on indefinitely. Wooden troughs of four-inch stuff nailed together in the form of a V, with two or three cross-cleets at the top to prevent warping, are very serviceable, and being about sixteen feet in length, comparatively light, and therefore easy to handle, may be made to reach any desired distance by overlapping. Or, the overflow from a series of these ridge ditches may be collected into one ditch and carried to small fruits or joined with a larger stream. The simplicity of the arrangement, though requiring some labor at

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first in establishing the proper grade, fairly compensates for that work and care, for during the rest of the season the irrigation is automatic, that is, it goes on uninterruptedly and without any assistance. All the repairs needed will be a few strokes of the hoe, a trifle of raking, and the land will always be ready for any kind of crop or succession of crops. Care should be taken not to puddle the bottom or sides of the ridge ditches, as in case of a reservoir. On the contrary the water should occasionally be shut off and the ditch raked up to open the soil, for the object of these ditches is not to store or hold water, but to enable the water to seep or leach out into the soil.

There is never any danger of the soil becoming soggy, for the quantity of water is small, regulated to suit the demands of the plants, and to allow for a slight evaporation.

DEPRESSED BEDS.

Growing out of the ditch-bank irrigation is the depressed or sunken bed system, which is quite similar, the water being fed from ridge ditches, but instead of percolation the water is run directly over and upon the soil after the manner of flooding. The land is not sloped but is flat, or level, a small flow, however, being desirable rather than objectionable. It is adapted to very light and unretentive soils and for shallow rooting plants like strawberries.

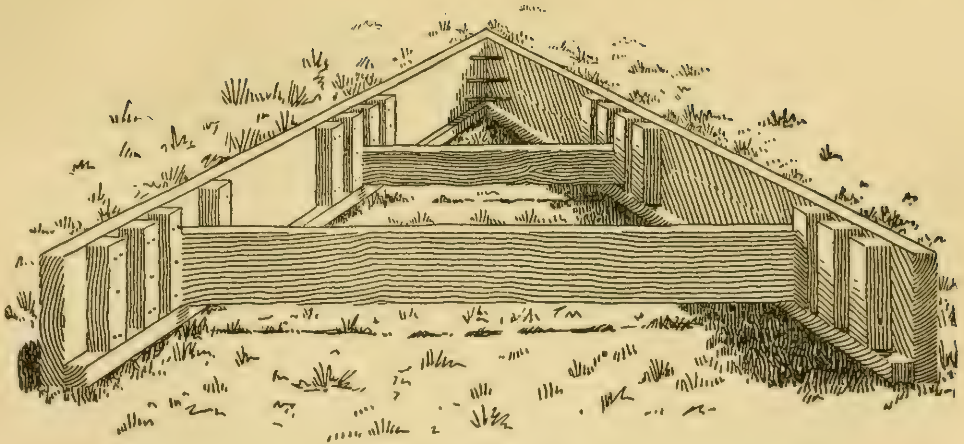
The land is laid out in rectangular checks, or any other desired form, and around the sides of the checks are elevated ridges upon the top of which are laid ditches in which the water flows slowly and quietly. The water is admitted to the checks from several points at the same time and distributes itself over the surface uniformly, slowly soaking into the soil.

In the hot summer months when it is desirable to maintain the growth of shallow rooted plants, it is an admirable system, and is enhanced in its effects by spreading over the soil a mulch of rotten straw, or coarse manure under which, protected from the sun, the water slowly spreads with very little evaporation. It possesses more beneficial aspects than mulching and sprinkling, for the reason that the water is retarded by the presence of the mulch from reaching the roots of the plants, where it is needed, and evaporation is much more rapid.

For the hot, dry season, where there is no danger of over-saturating the soil, the depressed bed is available for all kinds of vegetables, small fruits and flowers, the use of it showing marvelous results.

The system is in common use in Europe, where the heat is not excessive, and where a light sandy soil is under cultivation. It is the system adopted by the market gardeners in the sand hills south of the city of San Francisco, where the vegetable gardeners have transformed large areas of apparently worthless land into terraces, and on these have arranged depressed beds in which enormous quantities of succulent vegetables are grown for the city market. The water is raised by windmills and pumps from wells sunk in low spots, and delivered to small flumes which run from the windmill towers to the opposite hillsides. The water is flowed upon the highest terrace and conveyed thence by means of troughs and small ridge ditches from terrace to terrace and all the beds filled.

In all cases of surface or ditch irrigation the land must be laid out to suit the flow of the water, which is necessarily down hill, so to speak. If the land is not smooth on a level or slope, it must be leveled or graded by means of a scraper or other device for removing uneven portions and hillocks. If the land is too uneven to be irrigated uniformly, then sub-irrigation is the only remedy, or piping water to the tops of the ridges, or by establishing a reservoir on the highest spot, and thence running ditches in every direction



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after tracing or laying out the courses with the leveler as related in another and previous chapter.

As much care must be taken proportionately in field culture as in the case of small kitchen gardens, the principle being the same.

To put land in shape to irrigate it should first be plowed as deep as possible and then cut into beds of a larger or smaller size, depending upon the quantity of land to be irrigated and the amount of water at the disposal of the farmer. This may be done by means of a drag constructed in the shape of the letter A, from eight to twelve feet and more at the bottom, running to a point at the top. The land is dragged by drawing the A-shaped contrivance point first across the field from side to side. The wide spreading ends of the drag gather in the loose earth, clods and other rough material and heap them up behind in the shape of a ridge. These beds may be made from sixteen to eighty feet wide and ten to forty rods long; it all depends upon the quantity of water at hand to fill them.

After the field has been laid off into beds, the ground between the ridges must be leveled if uneven or humpy, and for this purpose a scraper will be serviceable. By it the humps should be scraped into the low places, and then a harrow may be used and the leveling process finished with a board leveler, well weighted down. This is nothing more than a strong thick plank weighted with stones and dragged back and forth over the beds until they are in a perfect condition to receive water uniformly upon the surface. The ends of the beds should come up close to the main ditch, or to the large lateral ditch, so that the water can be turned on in full volume. These beds may be irrigated one after the other by flooding, or by furrow irrigation. Indeed, there is no limit to the manner of irrigating, the great desideratum being to spread the water uniformly over the entire bed. It will be perceived that the system is similar to that of the smaller depressed bed-irrigation, except that the ridge ditches are not used, the ridges around the large beds being used to retain the water and to mark out the land in such shape and sized plats as to correspond with the quantity of water on hand. The flow of water must be sufficient so that it will rapidly cover the bed, and if that is deficient then the beds must be made smaller, otherwise the plants at the upper end of the bed will flourish and produce well, whereas those at the lower end will be sickly and produce little if anything. This often happens in the case of corn, potatoes, etc., when the water runs either too rapidly or too slowly into the furrows. The slope of the land should be such as to provide a quick rush of water all along the line, and its standing in the furrows to slowly soak into the soil. For this purpose the source of the water supply must be considerably higher than the land to be irrigated, and the quantity delivered large enough to fill quickly. Too slow a flow and too small a quantity will soak the upper end of the bed and give the lower part too little.

One important thing to be guarded against in laying out the land for irrigation is to avoid the washing out of the soil by the action of the flowing water. Inasmuch as the land irrigated is always under cultivation and loosely put together after the action of the plow, it is very easily washed into gullies, and every gully means a lessening of fertility. There is not so much danger in this respect when the land is covered with a heavy crop and flooded, because then, the plants will retard the rush of water and prevent damage by washing. But in furrow irrigation, the furrow soon may become a deep gully which the plow and cultivator can not remove, and every subsequent application of water will enlarge. To obviate this it is good farming to make the furrows short by damming with a quantity of earth, and when one furrow—the first one—is well filled, remove the temporary dam and let the water flow down into another short furrow. This will be the opening up of a succession of reservoirs which, being small, will not be liable to cause any damage, and will permit a speedy watering of the entire row of plants.

CHAPTER XII.

THE USE OF WELLS, STREAMS, DITCHES AND RESERVOIRS TO DISPOSE OF THE TREMENDOUS SUPPLY OF WATER.

Statistics show that the mean annual rainfall of the world is thirty-six inches, which is about 50,000,000 cubic feet per square mile of the earth's surface per annum, a quantity of water which is amazing when reduced to gallons so as to bring it more readily within the average comprehension.

A gallon of water, United States standard, weighs eight and one-third pounds and contains 231 cubic inches. As there are 17 28 cubic inches in a cubic foot, a simple calculation will show that the annual rainfall on every tract of land equal to 640 acres amounts to 374,026,000 gallons, or, reducing it to weight, 1,558,442 tons of water, being about 2,435 tons per acre. It will, of course, be understood that all this water is not equally distributed, but it all falls upon the earth somewhere and is taken up by the soil in the same proportionate amount as by the oceans and seas. The calculation might be made more accurate by assuming that the surface of the earth is about one-third land and two-thirds water, and that, therefore, only one-third of this enormous quantity of water is taken up by the land, but we are dealing with averages and the record must stand as written.

This tremendous supply of water must be disposed of by nature in some adequate manner, for if allowed to stand and accumulate the earth would soon be submerged. Fortunately, Dame Nature disposes of it, except when an inundation somewhere sweeps away towns and country, showing that she herself is overburdened with the supply. The rain falls and is carried off the land so far as the surplus that is not drunk in by the ever-thirsty soil is concerned, by means of brooks, rivulets, streams, rivers and mighty waterways into the ocean for transformation by evaporation into more rain. A large portion of it remaining on the land also evaporates, that is, transformed into vapor, which hangs in the atmosphere, invisible except to touch, when the weather is "damp," as is said, or gathers into clouds which empty their contents back upon the earth. So far, the action of evaporation and rainfall is equal and the equilibrium or eternal balance of nature is maintained.

SURFACE WATER.

But an enormous portion of the fallen rain does not return into the atmosphere, whence it came, to repeat its beneficial and grateful performance; it penetrates into the soil, percolates through a myriad of pores, cracks and crannies, until it accumulates beneath the surface of the earth, sometimes at immense depths, and forms subterranean streams and reservoirs. Sometimes, when the soil is unyielding, the percolating water does not attain the dignity of a subterranean stream or reservoir, but is held in the grasp of the soil above some impervious or impenetrable stratum of rock or hard pan, and becomes what is known as "surface water," a water table which throws off moisture to be carried to the surface by capillary attraction.

It is a maxim in physics, "nature abhors a vacuum," and so whenever there is a vacant place the water fills it, and thus there is a never ending supply of water from rain or melting snow which is practically rain in another form. The fact that there are rainless, arid regions does not alter the fact, for somewhere beyond them in the mountains is the supply of water the rainless belt should receive, and it sinks beneath the arid lands waiting to be drawn up to the surface by the ingenuity of man, it being prevented from doing so of its own accord by insurmountable obstacles in the soil.

The method of reaching these subterranean deposits of water, underground reservoirs and water tables, is by what is commonly called "a well." When a well is dug down into the water table or surface water, say from four to six feet in diameter or any other size deemed adequate to insure a good supply of water, and from ten to 100 feet in depth, and curbed with stone or mitred plank, and a windlass and bucket arranged at the top, or a common suction pump, a certain amount of water supply is assured. For domestic purposes, perhaps to irrigate a small garden patch, where labor is of little consideration, a well with the above pumping apparatus will serve, but few farmers will rest content with this ancient system of procuring a water supply, and if anyone aspires to cultivate the soil and irrigate he must largely extend his plant.

QUANTITY OF WATER NEEDED.

To estimate the quantity of water that the irrigation farmer must provide, it is necessary to go into a few details as to the quantity required to raise a crop. That quantity he must have or go out of business.

To irrigate a few acres successfully it may be necessary to have a supply of water running up into the hundreds of thousands of gallons. Taking rainfall as the standard of water needed to grow a crop, we find that one inch of rain on an acre of ground is equivalent to 27,154 gallons, and for the purposes of irrigation, that is, to give the ground a good wetting, at least two inches of water are necessary, more being required in some localities.

Professor King has made the following estimate of the quantity of water required during the growing season in various localities:

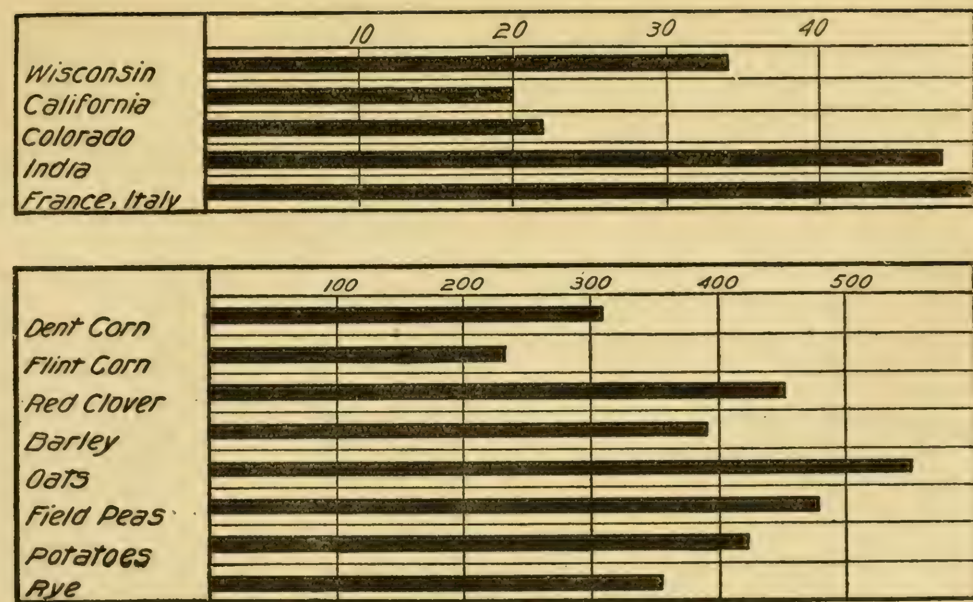


DIAGRAM SHOWING POUNDS OF WATER TO EACH POUND OF CERTAIN CROPS REQUIRED FOR PRODUCTION—
Page 145.

Wisconsin	34 inches per acre
California	7½ to 20 inches per acre
Colorado	22 inches per acre
India	48 inches per acre
France and Italy........	50 inches per acre

To still further go into the details of the quantity of water required to grow a crop to maturity, Professor King gives the following table of amounts of water necessary to produce the certain plants dry:

	Pounds of Water to Each Pound Dry Product.
Dent corn	309
Flint corn	233
Red clover	452
Barley	392
Oats	552
Field peas	477
Potatoes	422
Rye	353

This enormous quantity of water which must be provided for the needs of plants is not an alarming amount when it is considered that it may be obtained very cheaply by modern machinery where the water supply is adequate and a proper arrangement of ditches and reservoirs is made to economize it, the universal tendency being always toward waste.

WHERE OPEN WELLS ARE A SUCCESS.

Ordinary open wells are more successful in clay and stone than in sand, there being far less liability of the water running out, the bottom of the well being a retaining reservoir, which may be greatly enlarged by tunneling out to any safe distance into the water table or water stratum. Where the water stratum is in sand it is better to use screen points, that is, tubing with perforated ends, which admit the water but keep out the sand. Several of these screen points may be run down into the water-bearing sand stratum at a sufficient distance to prevent one robbing the other, and all be connected with a suction pipe. Experience tells that these screens should be run down to the bottom of the water-carrying sand if possible, and that in any event they should be sized according to the depth of the strata.

To accomplish this purpose successfully in wells an open well large enough for two men to work in should be sunk down to the sand and curbed to prevent caving. Then by driving ordinary gas piping as a casing for the screens and boring with a common auger, the screens may be lowered to any depth, or if the water-bearing sand is very deep a succession of screens may be put down on top of each other to enlarge the water supply.

Assuming the water supply to be adequate for the purposes of reasonable irrigation from a well, the next question is how to raise the water in the most economical manner. Economy is wealth in irrigation more than in any other business. Horace Greeley boasted that he raised the finest potatoes in the country, but they cost him about $2.50 each, and his milk cost him the same price as the finest imported champagne wine.

WINDMILL IRRIGATION.

Aside from human muscle and ox or horse-power drawing water in the ancient fashion, and still practiced in Asia, the simplest and least expensive method of raising water is by windmill. A sixteen-foot windmill connected with a storage reservoir will raise water enough to irrigate fully ten acres. But the windmill could not deliver the amount of water demanded if the supply were used at the same time as the pumping, hence the necessity of constructing a reservoir in which to store the water. With this reservoir the windmill may be made to pump constantly and provide a supply of water against the time of need. One with a capacity of several millions of gallons may be constructed without great expense, as will be described on another page.

Instead of a windmill, a centrifugal pump may be used which will raise water to a height of about fifty feet at a cost of less than 30 cents per million gallons. These pumps are geared to be operated either by steam or gasoline engines. Where there is plenty of fuel or coal is accessible, steam power is advisable, but where fuel is scarce or expensive the use of gasoline is naturally more economical.

In central Asia, which includes Persia and the surrounding countries, the water of the brooks and mountain streams seeps through the porous conglomerate formation and disappears deep in the earth, forming subterranean streams. Owing to the nature of the soil, canals and ditches would not be of much utility, and hence recourse is had to a system of irrigation by means of a group of deep wells dug at the base of the mountains. These wells are connected together by underground galleries which terminate in a large well, which answers the purpose of a reservoir. Along down the valley some distance from the large well are established a series of dry cisterns about 150 feet apart, the bottoms of which are lower than that of the well reservoir. The depth of these cisterns diminishes gradually until the last one is reached, the depth of which may not exceed eighteen inches.

All of these wells and cisterns are connected together by galleries large enough for a man to pass through in a stooping position. This arrangement of wells and cisterns with their connecting galleries is sufficient to supply an open canal which carries water to the valley, the whole length of the irrigating system ranging from two to thirty miles. Direct conduits and piping have been used, but discarded owing to the tremendous depth of the wells and the fact that the water is seepage water, not collecting fast enough to be piped. Sometimes water is run into these subterranean reservoirs and the water supply thereby augmented largely.

This system of connecting a number of wells with tunnels or galleries has been tried in the United States and has proved satisfactory in providing an increased water supply by means of an underground reservoir. Deep cisterns have also been tried for the same purpose, but the most common practice is to run a tunnel or gallery out from the bottom of a single well, in fact several of them, if the formation will permit. If sunk on high ground a flow of water may be secured from below by piping, otherwise pumping must be resorted to, which is the case when the wells are very deep.

All the rising subterranean waters are essentially artesian, whatever the depth of the bore of well which strikes the vein.

An artesian well is nothing more than one branch, end or leg of a tube or pipe, the other end, or intake, of which is at a greater or less elevation above the outlet. The fact that such wells are so called from the city of Artois, in France, where deep flowing or spouting wells were first sunk or bored, has nothing to do with the characteristics of the water supply, provided it rise in the well, flows over the mouth or spouts up into the air. In such cases it is evident that the water is not what is usually called surface, seepage or drainage water, although there is very little difference.

The value of the artesian well, which is bored deep into the earth, lies in the fact that its elevated source is constantly being replenished with a supply of water greater than that used for irrigation or other purposes. In the case of water from a saturated soil, or water that has percolated down through porous ground through cracks and crannies to find reservoirs, the supply depends upon the amount of rainfall or seepage. In ordinary wells, to draw water by constant pumping for adequate irrigation is to soon exhaust the stored supply, or ground water, there being no source to replenish it.

But in the case of artesian wells in the arid regions the source of the subterranean water which rises, flows over the mouth or spouts up into the air, is in a region where the precipitation of water in the form of rain or snow is much greater than can be utilized, or the underlying water plane is supplied from the perennial flow of large rivers or streams fed from a never-failing watershed.

It is essential to artesian water that it be confined under pressure beneath a cover. All water in porous soils, if the pores are to be filled to saturation, must rest upon a floor of practically impervious material. Underground water has a slow motion on account of the resistance of friction, and accumulates, assuming a nearly horizontal position along its upper surface, as it does in an open pond or reservoir. This is its nature. Now, if an overlying impervious bed has an inclination steeper than the inclination of this water plane, its dip may bring it into contact with the water. Down grade from the line of meeting of the water plane with the under surface of the more steeply inclined impervious cover, the conditions of confinement under pressure exist, and beyond this line of contact or meeting the ground water will be artesian—that is, when it finds an outlet it will rise, seeking to attain the portion or level its surface would have were it not for the obstacle in the shape of the overhanging rock or impervious bed in its way.

When this impervious covering is perforated by boring a well, the question whether there will result a flowing well, or a mere rise to some higher level within the bore hole, will depend on what the level of the ground surface may be. If at that point the ground surface happens to be above the grade plane of the confined underground water, there can not be a flowing well.

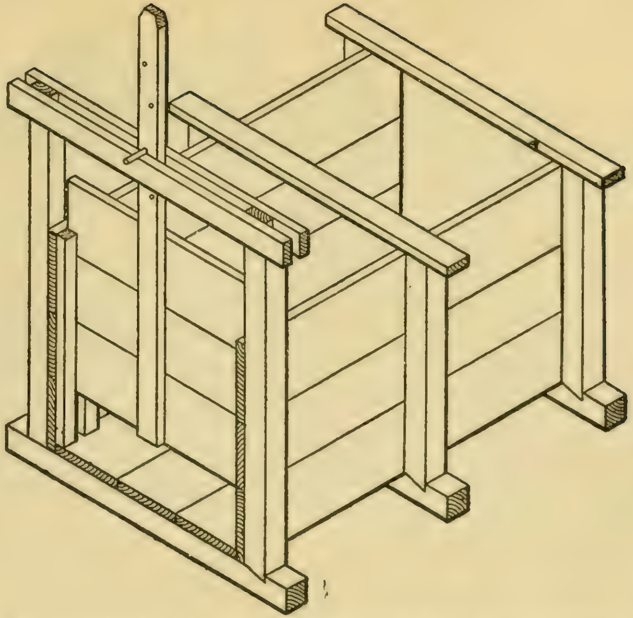
TAKING WATER FROM STREAMS AND RIVERS.

There are four varieties of natural water courses, the waters of which, when used for the purpose of irrigation, require different machinery or appliances to control.

First—The slow current, to control the water of which all that is necessary is a simple sluice gate that may be opened or closed by any contrivance which can be raised or lowered or moved to and fro sideways to admit or stop the flow of water or regulate its quantity. At a point above the level of the land to be irrigated a three-sided box is sunk, the bottom of which is below the regular surface of the water and the top above the surface of the leveled bank.

The end toward the water is fitted between two uprights on each side of the box, which form grooves to permit the slide to be moved or pushed down to control the supply of water. Or, the "gate," as it is proper to call the sliding end of the box, may be in two parts hinged at each side and swinging open in the middle like the gates of a transportation canal, care being taken to have the two wings of the gate open up stream so that the pressure of the water will not throw them open automatically.

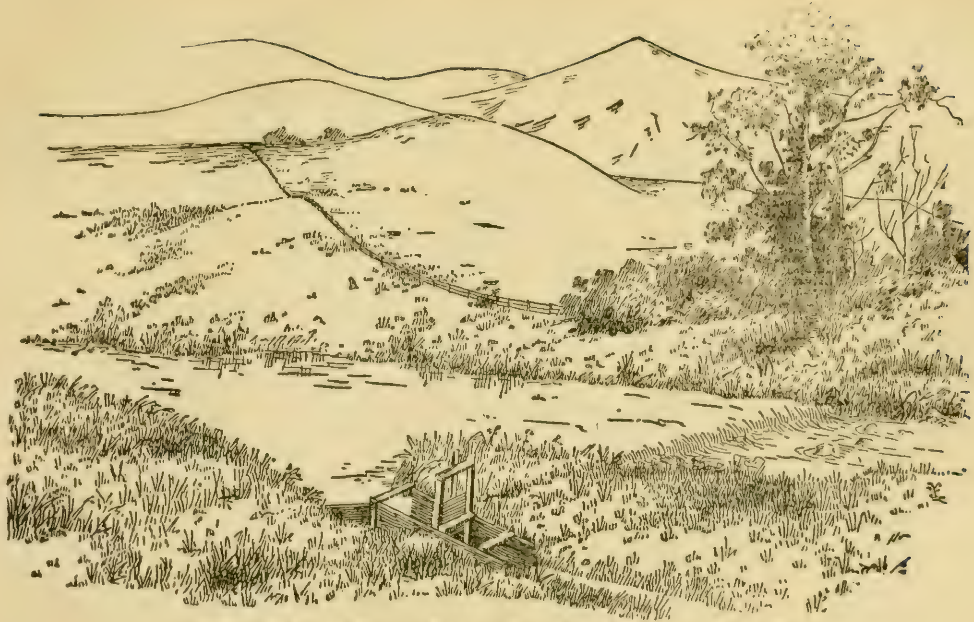
These two simple principles of an intake and shutoff gate is the basis of all contrivances for admitting water from a slow moving stream, whether the land to be irrigated consist of 100 or 1,000 acres. There are many varieties of them, some in iron and steel and constructed of massive masonry to accommodate an



Box for Admitting Water tc Ditch From Stream With Slow Current—Page 150.

FURROW IRRIGATION—Page 151.

Dam in Dry River—Page 151.



Diverting From a Small Stream With Rapid Current—Page 151.

enormous flow of water, but all of them are substantially based upon the idea given above.

Second—Rapid current streams, or mountain torrents, require a dam to reduce the current before it enters the water gate, or else the latter would be soon torn out or undermined by the swirl of the waters. This is the object of the dam: to create a smooth, placid sheet of water, similar to the surface of a pond or reservoir, and from it admit water in through the water gate. This dam, if the current is very swift, may be constructed at right angles with the bank, that is, straight out into the stream. This will form a breakwater, a quiet harbor, so to speak, and the water wil become still inside of it.

Third—Dry rivers. Dry river beds are common everywhere in the arid and semi-arid regions. They are often alluded to as "rivers with their bottom on top," being dry nearly always except during the rainy season, when a greater or less body of water flows in their channel, according to the quantity of rainfall within reach of the watershed which supplies them.

Although surface-dry for eight or nine months of every year, there is in most cases an underground supply of water sufficient to supply an enormous quantity of water by sinking cribbed reservoirs and pumping. For the ordinary purposes of irrigation these streams must be dammed to create a reservoir which will retain the water when it flows, and back it up high enough to reach the head gates of the irrigating ditches along its banks. These streams are not always as peaceable as they seem, for they are often converted into raging torrents that carry away every obstacle in their path. Hence the damming of them requires the highest engineering skill and the most substantial material to dam up the water, for no one can tell whether the stream will run a small quantity of water or inundate the country around about.

An arroyo is the Spanish for a small cut or opening between low hills, and refers to a small stream or rivulet that sometimes flows through it. These water courses are not streams, properly speaking, but rather waterways, for they have no subterranean or underground water, and what does flow in or through them is adventitious or accidental, depending upon the quantity of rainfall.

These arroyos are quite common in all hilly land in the West and Southwest, and sometimes reach the dignity of mountain torrents, but in a few days they run dry and the water is lost. Much of this water may be saved for irrigating purposes in a variety of ways. Damming is not advisable generally, for the dry stream may become an irresistable torrent and sweep everything out of its path. A partial or wing dam in most cases will hold the water for several weeks, perhaps three months, and permit it to slowly seep down into the soil for the benefit of the land below, or, where the lay of the land on the hillsides is favorable, running deep furrows parallel with the slope will restrain the water from flowing too rapidly down the watershed, and thus also permit it to seep slowly into the soil, and if followed up will eventually result in creating a water table into which shallow wells may be sunk for pumping purposes.

Where the land is sloping below a hill or series of hills deep furrowing with a sidehill plow at intervals of say six feet from the top to the bottom of the hill with a succession of rough furrows at the bottom will save up or store enough water to irrigate by infiltration many acres of land for corn, potatoes, melons and vines generally. Experiments demonstrate that this process will equal two irrigations of an inch each, and by careful, constant cultivation a good crop of corn or potatoes, even melons, peas and beans, may be grown without any irrigation, the subsoil being moist and kept so by deep tillage while the crop is growing.

Varieties of head gates, the direct drawing af water from rivers and streams and damming are not given, for the reason that such appliances are not within the control of the individual irrigation farmer, but are under the management of the State, the federal Government or of water companies. The idea is all that is necessary in this article, and from the idea given the farmer may apply the principle to ditches and reservoirs over which he has control on his own land.

CHAPTER XIII.

THE SCIENCE AND ART OF IRRIGATION.

The main object of irrigation should always be borne in mind; that is: nature having withheld from plants the moisture necessary to their growth, it becomes necessary to supply the omission. When that object has been attained, the work of the irrigator ends, and to continue farther would be detrimental to the soil, and injurious to plants instead of beneficial.

Given a certain tract of land, and a water supply, the question which confronts the irrigation farmer is: How shall the water be applied to the best advantage? It must occur to him that there can not be one fixed, rigid system of applying water to the soil, for he can perceive by looking about him that there are widely different varieties of plants, and opposite conditions of soil which preclude a uniform system of irrigation.

Scientific writers, and practical men, those who have studied the subject from the earliest ages, and in every country, have suggested more than a dozen different systems, but practical irrigators of modern times, men who have acquired experience by practical experiments, some of them costly, in our sixteen arid and sub-humid States, have settled upon four distinct systems of irrigation as amply sufficient for every condition of soil and climate, for economically supplying plants and soil with life-giving moisture.

Let the reader recall what has already been said on the subject in previous chapters, that except in the case of aquatic plants, it is not water or rather wetness that is essential to the perfection of plant life, but moisture. True, it is from water that moisture is derived, but when water is converted into moisture it is no longer water, but plant food. When a man eats meat and vegetables, he is not eating oxygen, hydrogen, nitrogen, carbonic acid, and the like, he is eating, however, combinations of those chemical substances, combinations which he, himself, can not create by devouring the chemicals themselves in an original state. To attempt to do so would be his speedy death, notwithstanding the theories concerning the value of dieting on certain artificial chemical combinations known as "health foods."

Water is poured into or upon the soil; gravity draws it downward; the particles of earth seize upon what they require, and the surplus water continues to descend until it reaches a water table, or is carried off through drainage appliances. Then capillary action begins, and the moisture ascends, and it and the nutritive elements it has gathered from the soil is seized upon by the roots of plants and devoured, that is absorbed, and the plant grows and waxes perfect upon the meat with which it is fed.

The four systems of irrigation referred to are as follows:

First—FLOWING, or ditch irrigation, where the water is run over the land through ditches or furrows intersecting the land to be watered.

Second—FLOODING, where the water is made to cover the land entirely at any desired depth, and is either allowed to remain stagnant, or stationary, or possesses a slight current.

Third—INFILTRATION, or seepage, in which the water is carried to the roots of plants by means of open ditches, or through subterranean waterways, in which case it is termed SUB-IRRIGATION.

Fourth—ASPERSION, or sprinkling, in which the water is applied in a shower, or as an imitation rain. Watering with a common garden sprinkling pot, or rubber hose, will give an idea of this system.

The first of these systems constitutes irrigation in the strict sense of the word, wherever water is utilized as a fertilizer of the soil, or an agent of humidity or moisture. The latter system relates to watering small garden plants, and flowers, and is commonly applied by means of some sprikling apparatus suitable to the size of the garden patch, and the quantity of water to be applied. It is not serviceable in hot dry regions and seasons because of rapid evaporation which makes it less economical than the others.

The choice of these systems, excluding the last, is subordinated to the nature of the soil, and topography, or "lay" of the land, the species of plants and the kind of culture, the quality and level of the water, and particularly to the disposable volume of the latter. In fact, two principles based upon the volume, or quantity of irrigating waters, regulate their use: The utilization of the maximum quantity of water obtainable to irrigate a given surface, or an increase of the irrigable surface to correspond with the maximum quantity of water.

The first principle is applicable to the sub-humid sections where there is a certain amount of rainfall in the winter months with dry summers, or a "dry season," like the Pacific Coast States, New Mexico, Arizona, and portions of Texas, or snow in winter as in Colorado, Wyoming, and the other northerly States.

In these localities, the rain and snow store in the soil a greater or less volume of water, which serves not only to fertilize it, but to keep it in a condition which will enable vegetation to either continue to grow without stopping, or to sprout in the early spring without preliminary irrigation.

In the warmer regions, however, there are dry belts, where the rainfall is so slight as to be unserviceable to perfect a crop, and in these belts little will grow without irrigation. To these localities may be applied the second principle.

Between these limits, principles, or conditions, are grouped numerous variations in plant growth, in aid of which irrigation supplies the means of rationally utilizing water for crop growing purposes. These variations will be taken up under the explanation of the four systems alluded to.

FLOWING, DITCH AND FURROW IRRIGATION.

On a naked tract of inclined, or sloping land, water follows the heaviest grade with an increasing speed or flow. When the same tract is covered with growing plants, the flow of water is retarded by the resistance of the plants, until an equilibrium is established, which requires more or less time according to the steepness of the grade and the character of the plants, and then the water flows with a uniform velocity, the same as if the land were naked. When that equilibrium has been reached, reason tells the irrigator to stop the water supply or the surface will be cut into gullies.

When the grade is very slight, the water, being unable to attain sufficient velocity, is lost in the soil before it can cover the entire tract.

In the former case, the zone of irrigation must be narrowed, and in the second, the lateral or distributing ditches must be brought closer together. When the surface soil is undulating, or irregular, the water spreads out unevenly, in which case the distributing laterals must be brought still closer together, and arranged to correspond with the irregularities to avoid gullying.

Flowing is adapted to land the slope or grade of which is between four and two per cent per running yard. On steeper grades, irrigation is effected more economically by arranging a series of levels or plateaus.

On feeble grades, the quantity of water increases by accumulation and remains longer in a stagnant condition, but in general, by this system of irrigation the water is more fully aerated and its fertilizing power increased.

On large fields, water flowing over steep grades being more rapid, the ditches or water furrows should be more numerous, to enable the soil to gather from the water whatever fertilizing material it holds in suspension.

Where the grade is very slight, drainage may be necessary to carry off an excess of water. After cultivation is always necessary as soon as the soil is in a suitable condition, from twelve to twenty-four hours being sufficient time according to the climatic conditions of heat and cold.

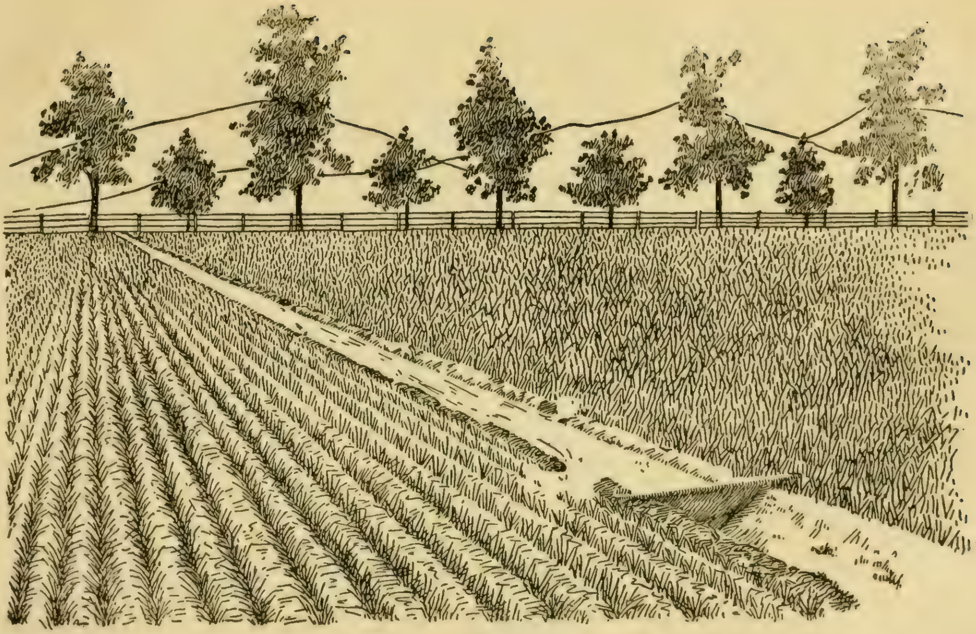
In all cases of ditch and furrow irrigation, it must be remembered that the less the number of distributing ditches or furrows, the less the quantity of water turned into the soil.

IRRIGATION BY FLOODING.

(*Submersion.*)

In the system of irrigation by flowing, whatever method be adopted, running water over the land, or drawing it from ditches through furrows, the best conditions for utilizing water are realized, that is to say, so far as movement, aeration, double use, and facility of distribution are concerned. It is possible to avoid direct contact of the water with plants, thus retaining essential atmospheric influences, and also regulating the temperature of soil and vegetation. In this latter case, it is reasonable to suppose that even in the arid, hot regions, the application of cold water direct from a mountain stream, or surface well, would check vegetation, an effect which is always deleterious to all growing crops.

But there are circumstances when flooding or submersion of the soil is not only convenient but more beneficial, inasmuch as it supplies the soil with moisture to a greater depth, thus furnishing deep rooted plants with food material. Reference to alfalfa will make this clear.



IRRIGATION BY FLOODING—Page 158.

Irrigation by flooding is simply submerging a given tract of land, by covering it with a sheet of water more or less deep, and allowing it to remain upon it a certain time, to "soak" into the soil before drawing it off to use on some other tract.

On flat or level ground, preparations for submersion are simple and easy. It suffices to smooth the surface by reducing knolls and filling cavities or hollows by means of a plow, cultivator, or road scraper, and then throwing up ridges of earth or dikes around the edge of the tract to retain the water.

It is an essentially economical method of irrigation, and is adapted to land and plants which do not require continuous or periodical applications of water. Its advantages are that it irrigates uniformly; utilizes all the water applied, it being absorbed except the small fraction lost by evaporation. Again, it tends to enrich the soil more than any other system by giving the various organic and inorganic solutions suspended in the water time to be deposited upon and carried into the soil. Lastly, it insures the destruction of insects and their larvae injurious to plants.

Opposed to its advantages are the following defects:

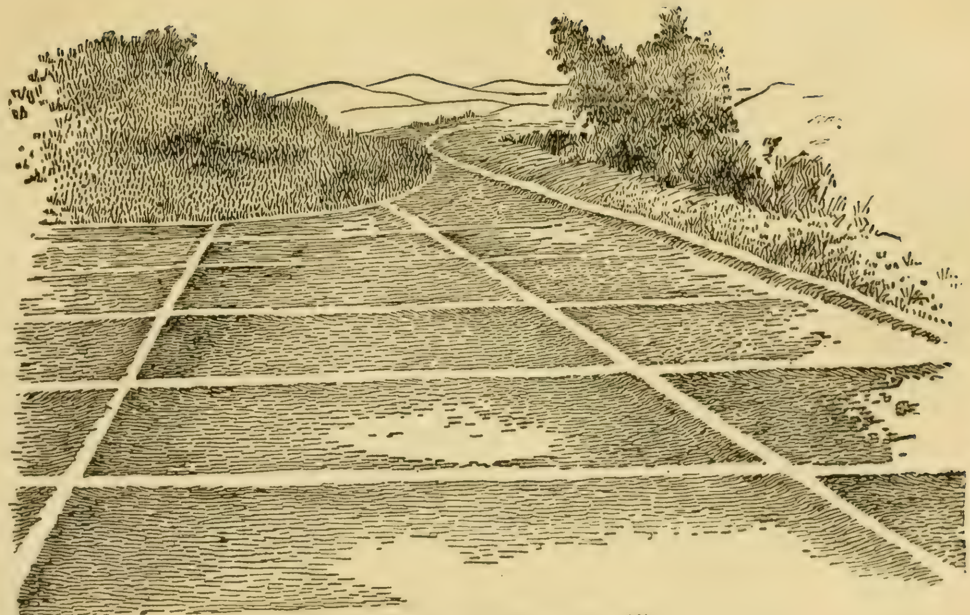
The plants are submerged either totally or partially, and the essential atmospheric influences suspended; the surface of the land is cut into dikes which interfere with adequate cultivation, and the consumption of water is much greater in a given time than when the water is flowed upon the land. Exceptions might be made to include alfalfa, sugar beets, and heavy root crops—gross feeders—the proper flooding of which could not be detrimental, but on the contrary beneficial. It is, moreover, essential in rice culture, and highly beneficial in vegetable gardens, fruit culture and in vineyards.

NATURAL SUBMERSION.

Irrigation by flooding, though produced by artificial means, is effected by the operations of nature in many regions of great fertility and abundant harvests. Countries of immense extent are fertilized by periodical, or rather annual submersions without which the soil would be absolutely barren.

Such countries are Egypt, which is fertilized by the regular flooding of the river Nile; the llamas, pampas, and steppes of South America, which are boundless natural pastures, maintained by the periodical overflow of numberless streams and rivers, and whose fertility and plant growth could not be perpetuated by artificial irrigation through ditches, because of the absence of grade to allow flowing. In the zone bounded by the dikes and river bed of the Rhone, between Avignon and the sea, in France, the lands are submerged through their whole extent during the winter months. Cereals, alfalfa, vines, fruit trees and vegetables grow to perfection without other fertilization and with very little cultivation. The damages from these annual inundations, though not slight, are regarded as of little consequence when compared with the benefits derived from them.

Other regions might be specified if it were necessary to advocate the benefits of land flooding. We might go back into the misty ages of antiquity and point to the wonderfully fertile regions around the Euphrates and Tigris, and depict the glories of ancient dynasties that reached the pinnacle of earthly greatness through the fertilizing of land by flooding, and show how those powerful dynasties crumbled into dust when the lands were no longer thus fertilized, but this is intended to be a practical work with barely enough sentiment to make it readable.



LAND LAID OUT IN BASINS—Page 161.

ARTIFICIAL FLOODING.

It is possible for man to imitate or copy nature, even to surpass nature, for he can control his water supply, whereas that of nature is uncontrollable to a great extent and destructive—a combination of utility and damage.

There are two methods of artificial flooding or submersion of land:

If the irrigation water provided for ditch or flowing is not all exhausted by that process, it is run upon land especially prepared for submersion, and allowed to remain upon it stagnant for a certain length of time, longer in winter than in summer, until it is all absorbed. Or, when there is at hand a greater quantity of water than is needed for ditch purposes, it is allowed to flow over the tops of the dikes, in proportion as fresh water is added, and then the water becomes flowing water to be utilized upon a series of submergible fields.

In the first case, that of stagnant or still water charged with mud or other fertilizing material and food supplies, the matter is deposited upon the soil, which, in the case of sandy soil, or light loams, fertilizes and consolidates them into consistency.

In the second case, where the climate is frosty in winter, plant life in the soil is protected; mud and soluble materials are deposited in less quantities, and the atmosphere, or oxygen in the soil is not completely intercepted for the benefit of weeds and deleterious plants.

LAYING OUT THE LAND.

The best arrangement of a tract of land designed for submersion, is to divide it into sections, or basins, by means of dikes or ridges, which may be thrown up by the plow. Each section, fed by the ditch, retains its water, the same being allowed to run into it laterally until it stops, and becomes stationary or stagnant. In this way the humidity in the soil is equalized or rendered uniform.

On large level tracts, or where the subsoil is impervious, the sections or basins may be enlarged. In that case the flow into the basins should be hastened so that every portion of the basin be covered simultaneously, otherwise the humidity would not be uniform. The only limit to the size or extent of these basins is the supply of water and the facilities for flowing it upon the soil. Several openings may be made from the distributing ditch to hasten the process, and the length of time the water is to remain upon the soil is gauged by its permeability. The soil should not be saturated unless a system of drainage is provided. This can only be determined by testing the soil after the water has been run off or is all taken up. If sodden, there is too much, if after a few hours it will not pack in the hand, it is ample. If the quantity of the flow of water justify it, a number of basins may be submerged simultaneously by openings made through the ridges or dikes.

Submersion without dividing the land into basins causes a great loss of water. During the daytime it is possible to regulate the flow of water, and with a plow, furrows may be run in various directions, or a hoe is often sufficient to direct the water uniformly over the surface. But at night, it is not so easy to control the course of the flow, particularly on large tracts of land. Night irrigation of this kind is practised, but the crop appears luxuriant in spots, which shows lack of uniformity in the application of the water.

As to the size of these basins to be submerged, the lay of the land and the water supply must be the guides. There are irrigated lands with submerged basins from the extent of a small garden patch up to a hundred-acre tract in alfalfa.

In extensive tracts, particularly cereals, beets, etc., flowing and ditch irrigation would be speedier and more economical than submersion, and in many cases more advantageous, particularly in the case of shallow rooted plants. Thus flowing is preferable in the case of barley, but submersion would be beneficial in the case of peas, the former spreading out its roots near the surface, and the latter thrusting them down deep into the soil. So, potatoes will not stand submersion, but beets can scarcely be drowned out. In rice culture, as has been said, submersion is essential.

Should the land have a slope or grade impossible to level, care must be taken to provide a lower dike sufficiently high to overcome the height at the top where the water supply enters, for in such case, the water at the top of the grade would barely cover the soil, but flow over the top of the lower dike and thus become flowing water and not stagnant or stationary.

Professor Schwerz, in his treatise on practical agriculture, thus refers to the advantages and the disadvantages of submersion:

"By inundating the soil it is easy to shield a field from any unfavorable temperature (heat or cold).

"The preparations for inundation are generally inexpensive. The food elements held in solution by the water have ample time to be deposited upon the soil. Insects injurious to vegetation, and which are not destroyed by ordinary irrigation, are totally destroyed, and the same may be said of noxious weeds in arid soils.

"On the other hand, many serviceable plants are drowned by prolonged inundations; herbs are rendered less hardy to changes of temperature, and hay and forage plants generally are of inferior quality. Inundation is deleterious at the flowering period of plants, though they can be irrigated beneficially in other modes. Finally, to inundate a large field rapidly throughout its entire extent is to consume an enormous amount of irrigation water."

From these considerations, the scientist draws the conclusion that, "The choice between inundation and ordinary irrigation must lie in favor of that ordinary irrigation, although in turfy, tough soils, or one very porous, inundation is more advantageous."

CHAPTER XIV.

THE SCIENCE AND ART OF IRRIGATION—INFILTRATION OR SEEPAGE.

Irrigation by infiltration or seepage is effected, following the configuration of the soil, by means of flowing, or sleeping water seeping or soaking into the soil from ditches, canals, or other waterways at or beneath the surface of the land. The water spreads, soaks, seeps out fanlike into the soil from the sides and bottom of the ditch or canal, and descends in pursuance of the law of gravity, or ascends in accordance with the law of capillary motion toward the surface, where it evaporates unless its course is stopped by breaking up the soil.

Water descending by the force of gravity continues on until it meets with what is commonly called "ground water," with which it mingles. If it does not encounter ground water, or a water table, it expends its energy by descending as far as it can as water, then it is converted into moisture and begins making its way to the surface through capillary motion. Infiltration rests upon the principle of the permeability of the soil, and hence, this method of irrigation is not always so beneficial as those which have been already mentioned, for it consumes a large quantity of water without supplying the soil with a uniform humidity. There is this exception, however; when the flowing water in the trench, ditch, or underground conveyance reaches the intended root zone and there spreads out or seeps into soil where it can be directly utilized. This is one of the advantages of sub-irrigation, a system which can not be ignored for many reasons.

SUB-IRRIGATION.

Sub-irrigation is a variety of infiltration which possesses many advantages over surface irrigation where wastage of water is an object to be avoided. By this system, land too elevated to be reached through other means is transformed into fertility. In the case of hill land it is admirable for cereals, and also on lands where weeds abound. It lends an invaluable aid to special plant cultures, such as grapes, olives, oranges and citrus fruits generally, and in gardening. It enables steep lands to be cut into terraces which irrigation water could not reach or in which it could not penetrate to a sufficient depth. In addition to these advantages, the application of underground water to arid or waste land covered with gravel or sand, permits the propagation and cultivation of productive plants which would otherwise perish through dryness of subsoil. Finally, a well arranged system of sub-irrigation operates as a drainage system, and thus a double purpose is served.

The nature of the soil is of more importance than the configuration of the land in sub-irrigation. In this respect, hard, impenetrable soils, and those too open and porous should be avoided for general infiltration purposes. Experience alone is able to guide the irrigator in establishing any system of deep ditches, the main point to be attained is always to provide for moistening the soil uniformly.

FURROW IRRIGATION.

Applied to cultivated land, furrow irrigation is allied to infiltration. Running water into furrows between the rows of plants and then cultivating over is a very common method of irrigation by infiltration, and is suitable for all shallow rooted plants, corn, potatoes, and tubers generally. The after cultivation by which the surface soil is pulverized, forms a mulch which retains the moisture below for a long period. It is also adopted on a large scale in orchards, vineyards, and nurseries; for small fruits, vegetable and flower gardens, wherever, in fact, deep irrigation or sub-irrigation, flooding, or flowing would be useless, or inefficient. It is well to provide that the water or surface wet be prevented from spreading as far as the stalks or bodies of the plants, for that means rotting, restricting it to the service of the roots. This renders this method of irrigation more efficacious than direct irrigation for the reason that the humidity is imprisoned around the roots where it is needed and evaporation retarded.

It is in the kitchen garden that infiltration attains marvelous results, particularly in the culture of root plants. In fact, it is the only system of irrigation which enables plants to obtain the greatest quantity of nutritive elements from a given surface. The soil is never at rest, and where the climate is favorable, one crop after another may be grown all the year around, and even in climates where the farmer is satisfied with one crop each season he may easily raise two. It is the equivalent to hothouse culture so far as growth is concerned, but the plants possess a quality unknown to forced cultivation.

WINTER IRRIGATION.

Infiltration or sub-irrigation is an admirable system for what is known as "winter irrigation," when the water supply is more abundant than is the case in the dry or growing season in humid climates. Water is run into the underground conduits to fill the soil with moisture, and then by the further storing up of the water in excess, surface irrigation becomes practicable when it comes to planting, and plants are supplied with moisture until their first true leaves are formed, by which time their roots are in moisture laden soil and they grow to maturity with very little after irrigation, unless shallow rooted, in which case surface irrigation is always necessary.

There are three atmospheric and meteorological conditions which should be considered under the name of winter: In the arid and semi-arid regions of the South and Southwest and on the Pacific slope, where the Kuro Siwa or Japanese ocean current creates a perpetual spring climate, what is known as the winter season is the growing period generally for cereals and garden products—it is the "wet season." If there be any rainfall at all it begins about November and ends in April. Sometimes the rainfall is not more than five or ten inches, perhaps fifteen inches, an amount so small to a farmer in the humid regions that he would not venture to move a plow, but eight inches is considered sufficient to raise a reasonable crop without irrigation, provided there is constant cultivation. In such regions every drop of water is utilized and care taken to prevent evaporation.

In such a climate the farmer dry plants, that is, he puts his seed into the ground when the latter is as dry as powder, plowing it up previously or plowing his seed under. There being no moisture of course it does not sprout, but lies in the soil as safely as in his barn bin. But when the first rain comes, perhaps only half an inch, his seed is up in a few days, and then begins cultivation to prevent evaporation. This is continued during the entire season, after every shower, large or small, so that his crop matures very well on eight inches of water from the clouds, aided, however, by dews and mists, which, as has been said in a former chapter, is quite considerable.

Here winter irrigation is of the most incalculable benefit for the deciduous plants which spring into life in March and April, small fruits, orchards and the like, for it fills the soil with moisture, and when a trifle of surface irrigation is added the plants continue growing with profusion and produce profitable crops.

In the totally arid regions where there is no rainfall at all, nothing but aggravation mists, or heavy, foggy dews, nothing can be grown without irrigation of some kind, and experience has demonstrated that surface irrigation can not very well be performed unless there is an ocean of water at hand to be wasted in evaporation, for the climate is usually hot. Now, if the soil can be moistened by infiltration through subterranean conduits, that moisture will remain in the soil for an indefinite period and may be added to by subsequent irrigations. The fact is, that this system of sub-irrigation furnishes an artificial water table which provides capillary attraction something upon which to operate.

The same results may be attained by running water into deep open furrows, care being taken to cultivate over immediately, and then infiltration or seepage will begin operating, and whatever excess there may be will find its way into the soil in all directions, from a higher field to a lower one, and from one slope to another, for instance.

The second climatic condition is where the region is cold and frosty, precluding winter growth, and without very much snow or other precipitated moisture. Here sub-irrigation prepares the soil for spring cultivation, and sufficient water is retained for surface irrigation when needed. It should be observed that constant and deep soil cultivation is as much necessary in such a region as in an arid or semi-arid one, the rule being that the roots of plants must be provided with adequate moisture regardless of surface conditions.

The third condition of climate is where the rains and snows of winter are comparatively heavy, equal to the rainfall in the sub-humid sections, but the cold is too great to permit any sort of plant life. In such case winter irrigation is as much of a necessity as in the arid and semi-arid regions because the necessities are the same. There is a cessation of water precipitation in the spring of the year, or else the precipitation during the growing season is not sufficient to mature a crop, hence there must be water enough stored up in the soil to meet the coming drought.

IRRIGATION BY SPRINKLING.

Water sprinkling is practically artificial rain in a small way. In an arid climate it is of trifling advantage unless other means of irrigating are employed, or unless there is a thick growth of vegetation which shades the ground, or "mats," as in the case of strawberries, etc. It is adapted to garden culture, however, and in horticultural cultivation generally it is of the highest excellence. Where water can be conveyed in pipes, with hydrants placed at intervals to admit of hose attachments, there is no better system of irrigation, though in this, as in all others, the soil must be kept open to retard evaporation, otherwise constant applications of water are necessary to keep plants growing.

Where water is not obtainable from pipes and hydrants, a tank on a two wheeled cart, with a projecting sprinkler is commonly used. In ordinary vegetable gardens hand sprinklers are used, the water being run into a convenient reservoir, which may be a barrel sunk into the ground, and the water dipped out. With one or with one sprinkler in each hand, the irrigator walks along the rows, slowly sprinkling the plants with water until it runs off the ground as in a rainfall. Many plants are benefited by this system of irrigation. Flowers, small bush fruits, strawberries, and even trees, the spraying of water upon which washes the leaves and freshens them, or as it is sometimes expressed, "gives them a drink."

In market gardens in proximity to cities, hydrant water is plentiful and this is used for sprinkling or any desired system of irrigation. Lawns are watered by means of a rubber hose with all sorts of attachments intended to scatter the water over the largest space. Where windmills are in use and elevated tanks common, all the advantages of hydrant water may be secured at small expense, and the same is the case where the farmer is so fortunate as to have an elevated acre or two of ground in which to dig a catch reservoir. There are some doubts as to the proper time during the day to irrigate crops or plants by sprinkling. Some contend that the evening or the early morning is the best time while others, again, contend that it does not make any difference. It does make a difference, when one stops to think. In the early morning the water is chilled after the hours of the night, and when water is applied after sundown it becomes cold and where the water is colder than the plant it is not beneficial, but stops growth. To recur again to the everlasting Chinaman, whose ideas are founded on centuries of success in growing anything he attempts, he can be seen religiously pouring water on his plants, even the most delicate, while the hot sun is shining down upon them with a burning heat. One looks in vain for the plants to droop and wither under such treatment, for they keep on growing vigorously and luxuriantly under the influence of the heat and the watery vapor engendered by the heat of the sun.

There can be no doubt that by the constant or regular application of water to the soil, in quantities to equal evaporation, the ground will be maintained in a moist condition favorable to plant growth. Moreover, there is always less water required for a second application than for a first one, and the quantity diminishes with each application, until a modicum of water will be reached and a profitable crop raised economically. Where there is no water in the subsoil, or at least none attainable by capillary motion, irrigation creates an artificial one which may be drawn upon by aeration of the soil by deep cultivation. Where there is a water table already within serviceable distance of the surface, irrigation may be so regulated as to keep the soil open and aerated by the flowing of water through it, and when that object has been attained, the labor of irrigation will have been reduced to an economical minimum and production astonishingly increased.

We shall have more to say on the subject of sub-irrigation in a special chapter devoted to the system.

CHAPTER XV.

SUB-IRRIGATION—DRAINAGE.

Infiltration, or seepage, as a method of irrigation is included in this chapter because it is practically sub-irrigation.

The drainage here referred to is that system of carrying off the surplus or excess of water through underground conveyances, when the same is connected with a system of sub-irrigation. Drainage proper will furnish matter for a special chapter on the subject.

Irrigation by infiltration, or seepage, is effected through following the configuration of the land, by means of flowing or sleeping water seeping through or into the soil from ditches, canals, or pipes, uncovered or covered, but located below the surface of the ground. The water spreads out, seeps or soaks out from the conveyance fan-like into the soil from the sides and bottom of the ditch, canal or pipe, and, following the law of gravity, descends or ascends in accordance with the law of capillary attraction.

Infiltration rests upon the principle of the permeability of the soil, and hence, this method of irrigation is not always as beneficial as those already mentioned, for the reason that it consumes a large quantity of water without supplying the soil with a uniform humidity.

Unless, however, and here are two occasions when infiltration is more economical and beneficial: When the water in the trench, or ditch, or underground conveyance is running water, and when it reaches the roots of the plants intended without spreading out where it can not be utilized.

The advantages of underground or sub-irrigation are too numerous to be ignored. By this system, land too elevated to be reached by water through other means may be transformed into fertile tracts. In the case of hill land it is admirable for cereals, and also on lands where weeds abound. It lends an invaluable aid to a series of special cultures, such as grapes, olives, oranges and citrus fruits generally, likewise in gardening. It enables steep land to be cut into terraces which irrigation water generally could not penetrate to a sufficient depth. In addition to these advantages, the application of underground water on arid or waste land covered with sand or gravel, permits the propagation and cultivation of profitable productive plants which would otherwise perish through dryness of sub-soil. Finally, a well arranged system of sub-irrigation operates as a drainage system as well as for irrigation.

The nature of the soil is more important than the configuration of the ground in sub-irrigation. In this respect, hard impenetrable soils should be avoided for irrigation by infiltration. Experience alone can guide the irrigator in establishing his system of deep ditches, the main point being always to provide for moistening the soil uniformly.

Furrow irrigation applied to cultivated land is similar to infiltration. Running water into furrows and then cultivating the soil over them is a very common method of irrigating by infiltration, and it is suitable for shallow rooted plants, corn, and tubers generally. The pulverized earth forms a mulch which obviates rapid evaporation and enables the water to seep into the soil in every direction before drying out. It is also adopted on a large scale in orchards, vineyards, nurseries, for small fruits and in flower and vegetable gardens where deep irrigation or sub-irrigation proper would not be effective. In all such methods of irrigation it is well to provide that the water or surface wetness be prevented from extending as far as the plant proper, and restrict it to the service of the roots. It is considered more efficacious than direct irrigation, for the reason that the humidity is imprisoned around the roots and evaporation is perceptibly retarded.

It is in the kitchen garden, applied to the culture of root plants, that irrigation by infiltration attains marvelous results. It is the only system of irrigation that enables plants to obtain the greatest quantity of nutritive matter from a given surface. The soil is never at rest; one crop may immediately succeed another, growth continuing all the year around without interruption. It is, in the hot arid regions, equivalent to hothouse culture, so far as luxuriance of growth is concerned, but the crops possess a quality of excellence unknown to forced culture.

SUBTERRANEAN CONDUITS.

Although infiltration is sub-irrigation, many persons limit the system of sub-irrigation to the conveyance of water through underground pipes, tiles or conduits. This method of irrigation is very ancient in its application to special cultures, or to utilize liquid fertilizers. When the volume of water is limited, the soil too porous for surface applications, the method of applying water to the roots of plants through subterranean conduits is very successful in its results, but only, let it be said, for very profitable plants. In general, the great expense attendant upon the installation of a system of underground conduits has prevented the common use of this system of irrigation, ordinary infiltration as above described having been found satisfactory.

But the constant pouring of water upon the soil in many of the older irrigated districts in the arid region, has resulted in creating a water table near the surface, so near in fact that formerly fertile tracts of land have been converted into swamps. Hence, drainage has become a problem necessary to be solved if fertile lands and profitable orchards are to be saved from destruction, and it is gradually dawning upon the minds of irrigators that where there is a system of sub-irrigation there is also a system of drainage ready at hand.

The writer advances the proposition founded on long experience in other countries of similar soil, climate and meteorology as the arid and semi-arid lands of the west, that sub-irrigation and drainage may well go together, and that if tiling or other media be so arranged in underground conduits, they will serve a double purpose, one highly economical and productive of good results. The conditions, indeed, are identical. The water passing through the drain pipes is surplus water, which may quite naturally be used over again as is the surplus water from a surface ditch, or that from overflowed land.

Nearly a hundred years ago the scientist Fellenberg put in at the agricultural establishment of Hofwyl, near the city of Berne, a system of sub-irrigation through subterranean conduits, for the purpose of moistening the fields in dry periods, when the spongy soil of the gardens commenced to dry and crack, and when the turf was not sufficiently packed to permit surface irrigation.

These underground conduits were so arranged as to serve two purposes: to carry off drainage water, or to retain it for moistening the soil. To accomplish this end the pipes were cut at fixed points by a mass of clay which was traversed by a drain which served as a communication between the ends of the conduit, and which could be closed by means of a movable plug or valve. To cause the water to ascend or flow into the soil, it sufficed to stop or plug up the tubing below the point to be irrigated, and the water flowing through the drain rose to its level and flowed into ground by infiltration.

The idea was approved in England, and in 1839 Fellenberg's system was adopted, and irrigation by infiltration came into common use, largely, however, for the purpose of flowing liquid manures through pipes to fertilize the sub-soil of arable land. The system was afterward enlarged and developed into a system of sub-irrigation where surface irrigation could not be practiced. It was carried to the United States and is now quite common where water is scarce, and in orchards, vineyards and for deep rooted plants generally.

SUB-IRRIGATION AND DRAINAGE COMBINED.

In every properly arranged system of irrigation the ditches or other conveyers of water are equivalent to open drains devised for the purpose of flowing water from the surface along lines and in directions carefully surveyed.

According to the common understanding, drainage means carrying off an excess of water from swamps and cold, over-moist soils for the purpose of reclaiming them, or converting them into fertile fields. But since irrigation plays so important a part in farm economy and profitable plant culture, indeed, since it has become an absolutely essential element of success in the arid and sub-humid regions of the United States, and is gaining ground in the humid regions, it has been discovered through costly experience that drainage and irrigation are inseparable systems.

Originally, the pioneer farmer on arid and semi-arid lands, finding none at all or very little water or even moisture in the sub-soil, disregarded drainage if he ever even thought of such a thing, and went on pouring water upon the soil and into it faster than it could evaporate.

The surplus accumulated little by little, until after a few years he discovered that his vines, trees and even small fruits were beginning to die at the tops. Investigation disclosed the curious fact in an arid region, that there was too much water in the soil; that a water table had formed, in some cases within two and four feet of the surface, and that no means of drainage having been provided, this water table was constantly rising, and in the course of a very few years his land would become a valueless swamp. A ridiculous thing in a rainless region, but one that was quite common.

Again, the advent of an enormous ditch or canal was hailed with joy. It meant water, and water in the arid regions, it must be confessed, means everything. As years went on, the water in the canal was insidiously working its way through the sub-soil by infiltration or seepage and dissolving the deleterious alkalis in the soil through which it passed, carried the solution down to the low lying lands, saturated them and evaporating, left a whitened soil dead, so far as useful vegetation was concerned. Quite naturally there was much consternation, and various remedies were thought of. Beets and sorghum, and other gross feeding plans, were recommended as alkali destroyers. Then ditches were dug to carry off the seepage water from the bottom lands or to prevent further infiltration from the canals. An unconscious recognition of the necessity for drains.

Still the insidious infiltration went on, and by and by barren black or white patches began to appear higher up the sloping land, until seepage water became the bane of the irrigation farmer. Then came the idea of cementing the great ditches to prevent seepage, a good policy where water is to be transported long distances but if all ditches were cemented there would be no infiltration and many lands would revert to an arid condition and pioneering would have to begin over again. The great aim of converting arid lands into fertile, moistened soil would be defeated if seepage or infiltration were to be stopped entirely.

Out of this condition grew the idea of drainage systems which it was supposed would more or less obviate the alkali trouble, but this also deprived the land of seepage water from canals and ditches in which the water was good irrigating water, and so wasted it.

Scientists came to the rescue and gave the patent opinion that the good water became bad by associating with the deleterious elements in the soil, picking them up in solution and earrying them along down to the lower levels, and then backing up, on the principle that it is the nature of water to seek its own level, carried up the deadly ingredients to the surface, and there abandoned them in a cowardly fashion and evaporated, leaving alkali and other impurities behind to destroy vegetation, ruin fertility.

But this did not dishearten the farmer, for if one tract of land ceased to be productive by reason of an excess of alkali deposits, he selected a virgin tract out of his numerous broad acres and went on as before. But now he is confronted with the alkali fiend on all sides in certain regions and seeks a remedy against it. The demand now is for small farms, every foot of which may be made productive, and be more profitable than a large ranch cultivated in patches.

Years, nay, ages ago, in other arid regions than those of the United States, the same difficulties encountered by the western irrigation farmer were experienced and sought to be overcome by means of drainage. It was soon discovered that by drainage alone, the vegetating stratum above the drain pipes no longer presented its natural cohesion, but dried and cracked into fissures to such an extent that surface irrigating water cut gullies into the soil through which it rapidly disappeared on its way to the drains to be wasted or to obstruct the drain pipes. These inconveniences were grave in the case of small irrigating ditches, but were aggravated when the main supply ditch or canal crossed the line of drains. A remedy was sought by giving the drains a steeper incline to create a strong, rapid current through the pipes, or by using light conduits with vertical wells or tubing at certain fixed points, up which the excess water might rise and thus regulate the flow, or again by isolating the drains and the irrigating ditches.

In drained fields two experiments were tried:

First. The drains were buried only about four inches below the turf, and the surplus water allowed to spread out through open joints of the tiles, or through openings expressly made for the purpose, within reach of the roots, whereas, in drainage exclusively, the drains operated contrariwise by drawing the water away from the roots. By this method none of the land was overlooked and irrigation could be effected at any time, and liquid fertilizers could be introduced whenever desirable. The pipes were easily laid in an ordinary furrow opened by a plow, and could be multiplied economically to any extent.

Second. The second process was to lay a certain number of drains along the line of the steepest grade and connect them with a transverse collecting pipe or conduit, in the center of which was arranged a vertical tube or well of wood or tile, up which the water ascended and flowed over into a main ditch from which the surface could be irrigated in the usual manner. Each transverse collecting drain corresponded with a principal flowing ditch, and to suspend irrigation all that was necessary was to throw open the front or end of each discharge drain where it entered the transverse collecting drain.

The vertical tubes or wells were vent holes provided with sluices which could be worked from the top in any desired convenient manner, whenever it was desired to drain without irrigation or irrigate without draining, or whether it was desired to hold the water at a given level in the soil to furnish seepage water or irrigate by infiltration.

The principle of these methods is identical with that of ordinary irrigation, which, after all is said, is the seepage or filtration of water from above down through the soil, and the absorption by the soil of the elements held in suspension or solution by the water. Carbonic acid is disengaged by flowing over the surface, is partially decomposed by the plants and absorbed by them, and the remainder passes into the soil. Oxygen, after subjecting what it reaches to the phenomena of combustion, which explains the fertilizing effects of irrigation, is less abundant in water filtered through the soil than in that which flows over the surface, while, on the contrary, carbonic and sulphuric acids increase in quantity. By seepage or infiltration from below upward, mineral matters, lime, chalk, potash, etc., are not precipitated mechanically, but deposited in the sub-soil unless the water be saturated, which is too often the case in the alkali lands, but which is more or less obviated by combining this system of drainage with irrigation. At all events it reduces the quantity of the deposit of deleterious mineral salts to a minimum. In addition to that desideratum it is possible to wash the alkali out of the soil by permitting the saturated water to drain off and carry with it the alkali in the sub-soil or near the surface, top washing of course carrying the surface alkali down within reach of the drains. It is like cleansing a sponge of its impurities. Dip an impure sponge in a basin of pure water and squeeze. The water becomes impregnated with the impurities of the sponge. Throw away that water and fill the basin with clear water and dip in it the sponge and squeeze as before. By and by the water running from the sponge is clear, showing that the latter contains no more impurities.

If it be true, as the majority of the scientists maintain, that the use of irrigating water is all the more beneficial when vegetation is most flourishing and luxuriant, and that the nutritive elements in the soil are directly absorbed by the roots, it is apparent that the oxydizing and purifying action of drainage combined with irrigation must be the means of supplying vegetation with the necessary plant food, either through the infiltration of the water into the region of the roots or by intermittent flowing over the surface from the vent wells.

The system is quite simple, expense alone being probably the only disadvantage, but even then, if the land must be drained, the laying of tiles, if with a view of also irrigating, will divide the expense.

By an arrangement of valves or plugs managed from the vertical vent wells, the pipes are closed at the point where irrigation is desired. Then, the water flowing through the drains is stopped at the closed valve, escapes through the loose joints of the tiles, and if permitted, will make its way to the surface. When one section has been sufficiently irrigated in this manner, the valve is opened, and another one further down is closed, and the soil in that section irrigated in the same manner. To drain without irrigating, all the underground valves are opened and the water flows through the secondary drains into the main, or transverse collecting drain, to be carried off entirely or into a reservoir for further use unless too alkaline.

To wash the soil, repeat the process of irrigation and drainage several times successively until tests show a weak solution.

This system of irrigation and drainage may be adapted to any condition of soil, or to any topography. Indeed, the principle of the siphon may be connected with it. Regard, of course, must be had to the nature of the plants to be irrigated when it comes to regulating the depth at which the tiles are to be placed, or the height to which the water is to be permitted to ascend in the soil. Where the land is flat the tiles may be laid on a light grade, the source of the water supply above the tiles regulating the velocity of the current of water and the height to which it can be raised in the soil. In such cases, a fifty or a hundred-acre tract may be sub-irrigated by infiltration until it is in a fit condition to cultivate for any crop without any flowing over the surface. In sloping land the pipes should be laid parallel with the slope to insure uniformity of distribution, at, say, four feet below the surface for ordinary culture, with transverse collecting pipes at intervals, so as to lay out the land in sections, each one of which may be irrigated in turn. Practically, the system means the creation of an artificial water table managed at will.

A query arises here: Will not the water rising in an upper section of land through the drain pipes also descend to the section below at the same time in obedience to the law of gravity?

The answer is that water as such certainly will descend and much faster than it rises. But moisture will not. In irrigating the upper section of a tract of land through drain pipes, the water is under pressure which overcomes gravity. Again, the soil will absorb the water as fast as it rises and not until it is saturated will it give any of it up, and then the surplus will begin to flow downward, but when that moment arrives the irrigator opens the valve and removes the pressure, suffers the saturated land to drain off and moisture alone is left, which, as has been said, does not drain downward, but ascends toward the surface in obedience to the law of capillary attraction.

SURFACE, SUB-IRRIGATION AND DRAINAGE COMBINED.

It is possible to combine surface, sub-irrigation and drainage by the same system of underground conduits or tiles, and for that reason drainage should always be arranged with a view of making a treble use of it.

The line of irrigation is always along the line of drainage, which is evident from the fact that drainage is nothing more than disposing of the excess water that flows through the soil. There is no other way for it to reach the drain tiles except through the soil, and this is true whether the soil is arid or a swamp. The flow of irrigation water is necessarily in the same direction as the drainage water, and hence it is economy to combine them.

If the water source is high enough above the field to be irrigated or drained, a sufficiently large reservoir or retaining ditch should be provided. From this, what may be called the "velocity water," is to be supplied. That is, the water naturally flowing downward toward the drain pipes can not rise to the surface except by seepage or infiltration, and then only when the lower drain courses are closed at their intersection with the transverse collecting drain. But water let in from an elevated source, unites with the drainage water and forces it to the surface or to any desired height, even above the surface if necessary or required.

Now, by closing the exits of the drain tiles at any point, the water may be forced up through the vertical vent wells or tubes and allowed to flow into distributing ditches through which any part of the land may be surface irrigated, and a double use of the drainage system be effected. It is a convenient and profitable mode of irrigating small, shallow rooted plants, strawberries, for instance, and the tubers like potatoes that will not stand water soaking. Likewise it is adapted to the kitchen garden and floriculture.

It is an admirable system for what is termed "winter irrigation," where the water supply is more abundant in the winter months than in the dry season. Sub-irrigation is practiced to fill the soil with moisture, and then by storing the water, surface irrigation becomes practicable when planting time arrives, and when plants show their first true leaves. By that time their roots are in moist soil and they grow to maturity with very little after irrigation unless shallow rooted.

There are three classes or conditions of atmosphere or meteorological conditions existing in the great west, however, which should be understood whenever mention is made of "winter."

In the arid and semi-arid regions of the south and southwest, and on the Pacific slope where the Kuro Siwa or Japanese ocean current creates a perpetual spring climate, what is known as winter is the growing period for cereals and garden products. In these localities the seasons are commonly divided into "wet season" and "dry season," winter as it is known elsewhere being unknown. If there be any rainfall at all, it usually begins in October or November and ends in April. Sometimes the rainfall for the season ranges from four inches to ten, sometimes reaching fourteen inches, the latter quantity being sufficient to raise a fair crop of grain without irrigation, but in the case of corn and vegetables constant cultivation is required.

In these regions winter irrigation is beneficial for deciduous plants, which overcome their winter sleep and spring into life in March or April, small fruits, orchards and the like, for it fills the soil with moisture at a greater depth than the rainfall can reach, and when a trifle of surface irrigation is added, they grow and produce profitably.

In the absolutely arid regions where there is an absence of rain, or less than five inches, frequently assuming the form of what is known as a "Scotch mist," nothing can be grown in the way of profitable plants without irrigation of some kind. Now, if the sub-soil can be charged with moisture it will be retained for a long period if the surface soil be kept open and highly pulverized to serve as a mulch, and with a little irrigation it will perform wonders of plant growth. Moreover, by constant infiltration, an artificial water table will finally be created which will become perpetual with periodical additions. In irrigation there is always more water put into the soil than is necessary for plant growth, and the excess water, allowing for evaporation, must flow down into the subterranean receptacles. If there be a sloping field above, then it will perform the duty of a storage reservoir for the lower one, and the escaping water may be caught and utilized as has been already described.

The second climatic condition to be observed is where the region is cold and frosty in winter, but without much snow or other precipitated moisture. Here, winter sub-irrigation prepares the soil for spring cultivation, and sufficient water is retained for surface irrigation when needed to enable plants to start. Colorado and western Kansas, with portions of western Nebraska and eastern Wyoming, are illustrations.

The third condition is where the snows of winter are very heavy, equal to the rainfall in humid regions, but the summers are dry. Northern Utah, Montana, Idaho, Nevada and the Dakotas may be placed in this category. In such regions, winter irrigation and drainage go together naturally. The soil is aerated, maintained in a friable, tillable condition, and almost as soon as spring opens plowing and planting may begin. The soil is charged with water which, if excessive, must be drained off, and if insufficient, the drainage pipes are closed and a uniform saturation induced.

Chapter XVI.

SUPPLEMENTAL IRRIGATION.

When the subject of irrigation is broached one immediately thinks of an arid region or one in which the ordinary rainfall is inadequate to raise a crop to maturity or to raise one sufficiently profitable. In such regions irrigation is practiced all the time, from the planting of the seed to the maturity of the plant, and even afterward it is necessary to again irrigate for the purpose of fitting the soil for cultivation for the planting of another crop. The rainfall is totally disregarded. Irrigation is a necessity.

But in the humid regions where there is an adequate rainfall, or at least from thirty to forty inches of rain precipitated upon the soil during the year, irrigation has until quite recently in this country been looked upon very much in the light of an unnecessary luxury, a refinement of agriculture suitable for gentleman farming and not to be encouraged when it comes to general farming. The idea of irrigating in the humid regions is growing stronger, however, and it will not be long before irrigation will be as common in Massachusetts and New York as in Arizona. Indeed, it must come to that or the humid States will be compelled to go entirely out of the business of crop raising, for the productions of the soil in the irrigated regions are so enormous that the humid or rain farmer will not be able to compete. This irrigating in the humid regions where there is an abundant annual rainfall is what is termed "supplemental irrigation," inasmuch as it supplements the rainfall or makes good its deficiencies and uneven distribution during the periods of the year of the growing season.

Supplemental irrigation, though quite recent in the United States and even now looked upon with disfavor, has been practiced in Europe for centuries where the rainfall is sufficient to raise crops without irrigation, as in our humid regions. Germany, France, Italy and the British Isles have practiced it with profit and success, and to fail to irrigate is to be guilty of bad husbandry and careless of profits.

To state the proposition of supplemental irrigation broadly, it removes the element of chance in all farming that depends solely upon the water precipitated from the clouds naturally. No farmer guesses at his seed, but selects the best variety with the greatest care, even experimenting with a small quantity before trusting his entire harvest to the probability of failure. So also does he choose his implements, his stock, and he prepares his soil in the most approved and certain manner, but when he considers the probabilities of the element favoring him with bountiful returns he shuts his eyes and draws for trumps when he might have the winning cards in his own hands by the exercise of his common sense.

There are times when the skies are as brass and the earth like a burning furnace, then his hopes are blasted and he grieves. There are also times when the rain comes just right and the earth laughs with a harvest. Then the farmer rejoices and says: "We have had a good crop." But if he will stop to consider and look back a few years, go over his ledger of balances, he will discover that in the space of five years, for instance, he has had three bad crops and only two good ones. Why? The only answer is: There was not rain enough to mature the crops; there were several dry spells right in the growing season when the plants were seriously injured and no amount of after rainfall —nay, a deluge—could restore them their lost vitality.

It is not the desire of the author to argue in favor of supplementary irrigation in the humid regions, for that is bound to come to the wise farmers, but there are many who may not yet be assured of the necessity of it, or to whom the knowledge of it has not yet come, and to whom he will only say: How much better it would be if a farmer could plant with the certainty that every crop would be uniformly abundant, and that, too year after year without a single break.

He can accomplish this by simply utilizing the surplus water which he watches go to waste without raising a hand to stop it or to store it up against the time of dire need. It rains, says the rain farmer, therefore why pour more water on the soil? True, but there is a story to tell which will illustrate that sort of argument better than pages of theory. It is an old one to the middle-aged, perhaps threadbare, but new in this connection, for which reason it will bear repeating. This is the story, or, rather, anecdote:

A stranger once traveling through Arkansas one fine day came across a rain farmer sitting in the sunshine at the door of his cabin fiddling away for dear life on a cracked fiddle. Dismounting, the traveler passed the compliments of the season and looked around to take in the situation. It happened that a large hole in the roof of the cabin caught his eye.

"Why do you not mend the hole in your roof?" inquired the stranger.

"'Tain't wuth while, stranger; 'tain't a-rainin'."

"Well, when it rains you will have to mend it," said the stranger, sarcastically.

"Dunno about thet, mister; it mought be too wet to fix when it are a-rainin'."

It seems strange to unaccustomed eyes to see an irrigation farmer of the far west pouring water on his soil with the rain falling in torrents.

A Bostonian who was passing through the Sacramento valley in California in a comfortable Pullman car during a heavy rain noticed a farmer busily engaged in irrigating his land without noticing the downpour.

"Just look at that fool watering his land when it is raining so hard."

"He's no fool," said his companion, who happened to know something about irrigation, "but a wise man. He knows that the effects of the rain will last about three days, but that the irrigation water is good for two weeks."

IRRIGATING IN A HUMID REGION.

The experience of Dr. Clarke Gapen, at one time superintendent of the Illinois Eastern Hospital for the Insane, may do much toward clearing away any doubts the reader may entertain as to the wisdom of irrigating in a humid region. Says the doctor:

"For two years the garden crops on about ninety acres of land were almost a total failure, the loss not only depriving the inmates of the institution of fresh vegetables, but it was a financial loss. In the spring of the third year I suggested to the Board of Trustees the extension of our water mains into the garden and into certain lands which it was proposed to use for garden purposes, consisting of about 150 acres. This was agreed to, and we proceeded to lay about 4,000 feet of water mains out into the farm. As there was some delay in completing the work, our irrigation was not begun until some time in June. We had in the meantime, however, planted a portion of the land in fruit trees and berries, and the remainder was planted in vegetables. As soon as the pipe laying was completed the water was turned on and irrigation of the entire tract begun.

"The following results show the profit of the undertaking:

Beets, 4 acres, 1,960 bu. at 30c............	$ 588.00
Cabbage, 15 acres, 1,498 bbls. at $1........	1,498.00

Cauliflower, 3 acres, 81 bbls. at $1.50......	121.00
Cucumber, ¾ acre, 184 bu. at 60c.........	110.00
Lettuce, ¾ acre, 101 bbls. at $1...........	101.00
Water and musk melons, 7 acres, 16,000 at 3c	148.00
Onions, 3 acres, 245 bbls. at 75c...........	183.75
Peas, 5 acres, 250 bu. at $1.25.............	323.75
Radishes, 3 acres, 304 bbls. at $2..........	608.00
Tomatoes, 6 acres, 1,360 bu. at 30c.........	408.00
Turnips, 15 acres, 3,000 bu. at 30c.........	910.50
Potatoes, 25 acres, 3,000 bu. at 30c........	900.00
Greens, 2 1-3 acres, 500 bu. at 25c..........	125.00
Rhubarb, ½ acre, 261 bbls. at 50c..........	130.00
Total for 90½ acres	$6,478.40
Total for 1 acre	73.57

"While it is conceded that this does not show an excessively large yield, it must be borne in mind that is far greater than the average yield in the regions round about during the same season, and that irrigation was begun very late in the season. Moreover, the ground was newly broken and had never before been used for vegetables.

"The cost of laying the pipe was about $1,500, or, say, $10 per acre. The land before the pipes were laid would have been regarded for agricultural purposes as at a high price at $100 per acre; it now has a producing value to the institution of $500 per acre.

TWO METHODS OF APPLYING WATER.

"In applying the water at the hospital we used only two methods—the ditch and the flowing. In both cases the water was conveyed in large ditches meandering in conformity with the contour of the ground, running often by very circuitous routes to the desired points. There it was diverted into furrows made by what is called 'middle breakers,' or double mold board plow between the rows of corn, potatoes, cabbage or whatever the plant; or by the flooding method it was spread out over a leveled space ten to fifteen feet in width, with ridges six to eight inches high, thrown up to separate these spaces from each other, and occasional cross-ridges if the slope of the ground was steep. We kept the slope of the land constantly in mind and we found it always best to always begin at the lowest point and work up or backward. In irrigating the orchard we ran a furrow on each side of each row of trees and allowed the water to run slowly throughout its length. For orchard purposes we find two irrigations sufficient, one early in the spring and the other just as the fruit begins to ripen. As the trees grow the irrigating furrow is run farther and farther away from the trees."

Dr. Gapen is of the opinion that irrigation has a much larger future in those portions of the country where the rainfall is reasonably large than even in the dry regions, because there is a larger supply of water which can be utilized and, of course, can be utilized to a greater extent. Long continued experiments in the direction of supplemental irrigation have indeed demonstrated beyond any doubt that crops may be doubled and quadrupled. The irrigation system adopted at the institution of which Dr. Gapen is superintendent required from 100,000 to 200,000 gallons of water per acre during the growing season. He estimated that at least two inches of rainfal were necessary for even a light irrigation, approximately 55,000 gallons, being at the rate of 27,154 gallons of water for one inch of rain, and that to give two good wettings to the soil at least 220,000 gallons, or about eight inches, should be given each acre. This was modified to about 100,000 gallons per acre for each wetting. More water, however, could be used to advantage, for the reason that in humid regions a 70 per cent saturation by bulk will give the best results.

As to the expense of the supplemental irrigation at the Illinois institution, above referred to, it cost $3.00 per 1,000,000 gallons to deliver the water at the point required. At this rate the cost of delivering 100,000 gallons, the amount necessary to irrigate one acre, was only 60 cents per acre for two good wettings. This expense was much greater than that incurred by ordinary pumping or lifting, for the reason that there was maintained a pressure of fifty pounds, which required high pressure pumps. The piping was the best grade of cast iron pipe, laid entirely below the frost line, using three, four and six-inch pipe, which cost from 20 to 30 cents per foot.

With a farm located on the bank of a stream, or with an inexhaustible well, it is not difficult to understand that the expense would be much less. The fact remains, however, that with the most expensive appliances supplemental irrigation is productive of double profits, and therefore it is a system not to be rejected without at least a trial of its merits.

Chapter XVII.

QUANTITY OF WATER TO RAISE CROPS.

(The Duty of Water.)

The amount of transpiration through the leaves of plants will furnish an approximation of the quantity of water needed by them before they can attain perfect maturity. That amount of water in the shape of moisture they must have, and if they can not obtain it by natural means, through rainfall, ground water, capillary action, dew, or moisture from the atmosphere, it must be supplied by artificial means through irrigation, else the farmer may as well retire from business, unless he admires a useless expenditure of labor year after year.

It is alleged by men of the highest scientific standing, men who have made irrigation agriculture a profound study, and have performed a multitude of practical experiments to demonstrate the verity of their proposition that about forty inches of water whether rainfall, or evenly distributed artificially, is the proper and essential quantity to successfully grow a crop from the planting to the harvest. Some claim that a lesser quantity will be sufficient. Thus, Professor King found that he could use 34 inches for the growing season in Wisconsin. In California from 7½ to 20 inches will answer the purpose; in Colorado, 22 inches; in India 48 inches are necessary, and 50 inches in France and Italy. All these calculations are based upon the quantity required per acre during the growing period of a crop, which is estimated at about 80 or 90 days.

It is well for the reader to grasp the immensity of such volumes of water, and to enable him to do so, a few mathematical facts will not be out of place.

One inch of water covering an acre of ground, equals 27,154 gallons, or 1,086,160 gallons per acre for the season upon the basis of a supposed total of forty inches. The weight of this amount of water at 8 1-3 pounds standard U. S. weight to the gallon, is nearly 4,526 tons. Weight will be used instead of measure in order to make comparisons.

Let us take potatoes as an illustration, and on them base a simple calculation. According to the laws of most of the States, a bushel of potatoes weighs sixty pounds avoirdupois. At the rate of three hundred bushels per acre, which is a very large yield to the acre, the weight will reach 18,000 pounds, or nine tons.

In the case of sugar beets, the production runs all the way from fifteen to thirty-five tons per acre.

Now, it has been calculated that potatoes and beets contain from 80 to 90 per cent of their weight in water, or its equivalent, and at 90 per cent, to give them the benefit of the largest possible quantity of fluidity, an acre of potatoes would contain about 8½ tons of water, and an acre of beets about 32 tons.

It is impossible to believe that this small quantity of vegetable extract required the distillation in the plant of 4,526 tons of water in ninety days, and the fact is that it does not. In a former chapter it is said that moisture, or water in the shape of moisture, is taken into the plant by way of the roots, and after being utilized in the economy of the plant, it is discharged through the medium of the leaves; that is to say, transpired through the stomata or mouths of the leaves. Indeed, there is no other way by which water can enter into the plant. It is a solvent for plant food, and the plant having absorbed the food, rejects the water by transpiration.

The reader will find in Chapter V an experiment made by Professor Williams of Vermont with an acre of forest containing 640 trees averaging 8½ inches in diameter and 30 feet in height, having an average of 21,192 leaves on each tree to transpire water during ninety-two days.

It was discovered by careful experiment that such an acreage of trees drew from the soil and evaporated, or transpired by way of the tree leaves, 2,852,000 pounds of water during ninety-two days, or 1,426 tons, the evaporation or transpiration being calculated as going on twelve hours per day, inasmuch as it is almost imperceptible at night. This leaves a very large balance of the 4,526 tons unconsumed by the trees, and even assuming that the leaves transpired water during twenty-four hours there would still be 1,674 tons to the good unutilized by vegetation.

Carrying the calculation still further, let it be assumed that the evaporation from the soil was 1,000 pounds per hour and that such evaporation occurred every hour of the twenty-four, and there would be still remaining unutilized for any known purpose 570 tons of water. There would remain a much larger quantity, for the estimate of evaporation could not exist in a forest, and not under any circumstances at night. Moreover, evaporation from a freshly plowed soil does not reach 1,000 pounds per hour, even without vegetation to retard it.

Recurring to the sunflower experiment (Chapter V). An acre of sunflowers three and a half feet high, estimating 10,000 of them to the acre, which would be crowding them, with their great broad leaves, would transpire during twelve hours every day for ninety days 810 tons of water drawn from the soil. It will be perceived that the 4,526 tons of irrigating water or rainfall are still practically intact, and it may occur to the mind of the ordinary reader that forty inches is altogether too much water to put on or into the soil for any profitable or needed purpose. If not, what becomes of it? It is not utilized by vegetation of any sort. Even sugar cane, which possesses an insatiable thirst, would repudiate such gluttony.

The fact is, about three-fourths of this water is wasted—fed to run-off, seepage and drainage. It is put into the soil to kill the plants eventually instead of nourishing and giving them life.

Government experts say that out of a possible forty inches of rainfall 50 per cent of it is lost in running off or out of the land, and 25 per cent disappears through evaporation. If this is correct, then there are left ten inches to be utilized by the crop, whatever it may be, and according to our calculation that amount is ample for plant growth from the planting to the harvest if irrigation is practiced as it should be.

There is this to be also considered, that rainfall does not mean a precipitation of a certain number of inches of water during the growing season when needed more than at any other time, whereas irrigation does mean that very thing. Taking four months of the year as the growing period, that is to say, May, June, July and August, where summer is the seedtime and harvest, or January, February, March and April on the Pacific Coast and semi-tropical regions, the mean monthly precipitation of water at forty inches per annum would be one-twelfth of the annual supply, or three and one-third inches, a total for the entire growing period of thirteen and one-third inches.

When it comes to crop requirements averages are to be disregarded, but assuming it to be true that the forty inches of rainfall are evenly distributed during the growing season, as above specified, then a crop can be grown to maturity on thirteen and one-third inches; indeed, it can not be imagined that the entire annual rainfall is precipitated upon the soil during the four months specified unless rice culture be contemplated. With thirteen and one-third inches of water distributed through the growing season the soil receives 1,508 tons of water per acre, which, by referring to the cases of the forest and the sunflowers above given, will more than satisfy the requirements of those plants; in fact, nearly two acres of sunflowers can be amply provided for.

Now, what becomes of the remaining twenty-six and two-thirds inches of the assumed forty inches? The 3,018 tons of water on our acre? In the opinion of the writer that water has gone down to raise the ground water uncomfortably close to the root zone, where it will do damage, has run off or drained off. It is certainly wasted unless the excess is intended to irrigate several more acres further down some slope, or is to be pumped out from wells and used over again. In that case, why put so much water on the soil if agriculture be the object and not the water supply business?

It is not safe, however, to rely upon thirteen and one-third inches of rainfall during the growing season. Farmers know to their cost that then the rain possesses a very retiring disposition, and the skies are brazen for long periods, long enough, sometimes, to either ruin the crops or to stunt them and produce only a small percentage of what was expected from their early start and growth. In other words, the growing season is also the season of drouths, except in those regions where winter is the growing season, there being no frosts to retard vegetation. Yet, strange to say, even with all the uncertainties of summer moisture good crops are sometimes grown and that on a small percentage of the annual rainfall. With irrigation supplying the deficiency of rainfall there is a certainty of a good, profitable crop every year.

What has been said thus far relates to land which contains natural moisture or a water table, a supply of water which is brought up to the surface by capillary action or by accretions from heavy rains, and where the soil is wet enough to require a system of drainage to carry off the surplus. It is easy to perceive that under such conditions plants will draw moisture from below by means of their tap roots and thus supply themselves with plant food to make up for any deficiency of precipitation. Where those conditions prevail, irrigation becomes supplemental and is not only useful but essential in the humid regions to overcome the possible damage likely to occur during the period of drouths. To dose the soil with water having a water table near enough the surface for the tap roots of plants to reach would be a waste and of no benefit to plant life, as will be readily believed when it is understood that too much water is as detrimental to plant life as too little.

Where there is moisture in the subsoil, and even a modicum of rainfall during the summer months, the author would suggest that if the deficiency amounts to six inches, or four inches, or thirteen inches, such deficiency be made good by an artificial application of water at regular intervals, one surely just at the period of flowering and the last one just before the ripening of the fruit, or at the period when they are said to be "in the milk." At that time a chemical transformation is taking place in the economy of the plant, and it must be supplied with the material to continue it, else it will shrivel and die of old age before ripening.

The same observations may be adapted to those semi-arid regions where the frosts of winter prevent the existence of plant life, and the rainless summers demand irrigation as necessary to raise a crop of any kind. There are fall rains and winter snows, and by keeping the ground open to their reception the moisture can be retained for a long enough period to start the infant plant well on its way in the spring, but after the first true leaves are formed irrigation must begin and continue during the growing period, for there is no rainfall to be depended upon as an aid to agriculture. Under such conditions plants do not require any more moisture than in any other region, and hence it is stated as a broad proposition that the same quantity of moisture that will raise a crop in the humid regions will also raise one in the semi-arid districts, where winter is a bar to winter growth.

In what are designated as "arid and semi-arid" regions, with a semi-tropical climate, although there is very little rainfall, it is surprising how far the small precipitation will go toward maturing a crop without the assistance of artificial applications of water. Five inches will raise a crop planted in dry ground before the rains come, and by careful and continual cultivation of the ground that crop will be profitable enough to make it worth while to plant. In favorable soil one inch of water will wet the ground down about eighteen inches or two feet, and the first rain penetrating to the seed that has been plowed under "dry" will cause it to sprout within three or four days. From that time on until the crop matures, in March or April, if the rain begins in December or January, the farmer cultivates plants that can be cultivated and harrows his wheat and barley to keep the soil open as much as possible. There may not be any moisture in the subsoil—on the contrary it may be as "dry as a bone" for a hundred feet down—but the crop grows, and with few inches of rain it reaches maturity. Of course, it is not luxuriant vegetation, nor is the wheat and barley as high as a man's head. But it produces enough for his stock and his vegetables, unless sugar beets and deep-rooting plants furnish him with a good supply. Some of these "dry farmers" say they are satisfied with eight inches of rainfall and consider fourteen inches a "wash out." In such regions the summer months, from May to November, and sometimes into December, the skies are cloudless and not a particle of rain falls. Then irrigation is an absolute necessity, and it is practiced so as to continue the growing season all the year round and to produce a succession of crops without any cessation. There is undoubtedly more evaporation from the soil than in the humid regions, but that is diminished by deep cultivation and pulverization of the soil. Plants, however, do not require any more moisture than in any other region, and when the quantity consumed by the plant during its period of growth is carefully gauged that is the amount of water to give the soil, with about 25 per cent added to the account of evaporation.

After all is said the quantity of water to be given the soil artificially is governed, in a great measure, by the nature of the soil. In Chapter V, "Relations of Water to the Soil," this subject is treated and the reader is referred to that chapter for the facts and figures. There is one axiomatic proposition which is here repeated in this connection because it is the key to the whole matter: "The more water the soil contains in its pores the greater the evaporation." Plants are like the human body—gorge it, even with the most nourishing foods, and it becomes sick; give it too little to keep up its system and it becomes anæmic. With just enough, an equilibrium is maintained and health is secured as a matter of course. This idea is what the author seeks to convey in calling attention to the fact that what a plant needs is the amount of provision to make for it; all beyond that is superfluous, a waste of material, not productive of any beneficial results.

CHAPTER XVIII.

MEASUREMENT OF WATER.

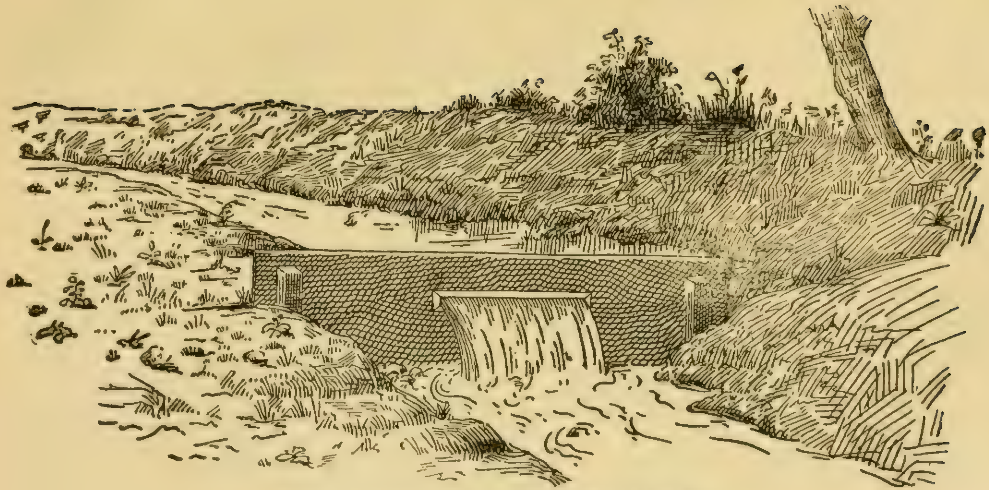
If we fill a gallon measure with water we know that we have 231 cubic inches of water which weighs eight and one-third pounds. That is the United States standard. We also know, because it is easy to measure it, that a cubic foot of water weighs sixty-two and one-half pounds and measures 1,728 cubic inches, equal to seven and one-half gallons.

When it comes to measure water for irrigation purposes it is difficult to ascertain the exact quantity measured, owing to arbitrary standards of what the measure should be. Besides that, the various States and countries are not agreed upon a universal standard of measurement, so that when one reads of fifty inches being required to raise a crop, his measurement may mean a much less number of inches if measured according to some other standard. Ten thousand gallons of water by accurate measurement may be run into a reservoir, and in twenty-four hours or less that number of gallons will be materially reduced, but the loss can be accurately estimated, and so can the exact quantity run out of it for any purpose be measured almost to a drop. But in the case of taking water from a running or flowing stream or ditch, various difficulties stand in the way of accurate measurement.

In measuring water from streams, ditches and running or flowing water, generally three standards, or "units of measure" as they are called, have been agreed upon. They are the inch, the cubic foot per second, and the acre-foot.

THE INCH.

The "inch" as a unit of water measurement originated with the placer miners of the West and was



MEASURING STREAM BY MINERS INCH—Page 202.

adopted by irrigators when water came to be used upon the land for the growing of crops. It is the volume of water which will flow through an inch-square opening or orifice with a certain other volume of water over and above it to give it what is known as "pressure." Both the opening as to size and the depth of water above it are regulated by the laws of some of the States, and in many localities it is regulated by custom—that is, by agreement. The definition given in the laws of Colorado will furnish an idea of what constitutes an inch:

"Water sold by the inch shall be measured as follows, to-wit: Every inch shall be considered equal to an inch-square orifice under a five-inch pressure, and a five-inch pressure shall be from the top of the orifice of the box put into the banks of the ditch to the surface of the water."

Of course, this opening may be larger than one inch square; for instance, six inches, or twelve inches, but in that case the inch will become multiplied into as many inches as there are inches in the opening. At six inches the volume of water would be thirty-six inches, and at twelve inches there would be delivered 144 inches of water. A simple and usual way to measure the inch and retain the pressure is to make the opening one inch wide and any number of inches long—a slot, so to speak; over this slot is arranged a sliding board that can be moved back and forth any number of inches of actual measurement with a carpenter's rule. By this device there will always be the required volume of water, or pressure, above the inch orifice.

Many irrigators roughly measure the quantity of water delivered from a ditch, or canal, by calculating the number of square inches in a cross section of the ditch and calling the result so many inches of water, but this is not a safe rule to follow, for pressure and the velocity of the stream of water are not taken into consideration, and they make a vast difference sometimes in the quantity of water delivered. The orifice measurement under pressure is the most accurate and gives better satisfaction.

The inch, however, as a standard of measurement, or unit, is of very little use except for the measurement of small quantities of water. It may be adapted to the distribution of water from small main ditches or their laterals.

CUBIC FOOT PER SECOND OR "SECOND-FOOT."

Owing to the inconveniences of the "inch" as a unit of measurement, and the limitation on the mechanical device for measuring it, the cubic foot per second or "second-foot" has been adopted as better adapted to the measurement of both large and small quantities of water; indeed, it is made the legal unit in most of the arid States and Territories in water contracts and for defining the amounts appropriated from streams. But although made the unit of measurement it is used in connection with the inch—that is, a cubic foot per second is distributed to farmers according to the number of inches it is supposed to contain. This is fixed by law and the following table will show the variations in the number of inches contained in a cubic foot per second:

In California, Idaho, Nevada and Utah fifty miners' inches equal one cubic foot per second, measured under a four-inch pressure from the center of the orifice.

In Arizona and Montana forty miners' inches equal one cubic foot per second, measured under a six-inch pressure from the top of the orifice.

In Colorado 38.4 miners' inches equal one cubic foot per second, measured under a five-inch pressure from the top of the orifice.

A second-foot is a cubic foot which passes a given point in a ditch or canal in one second of time, and to measure the number of second feet it is only necessary to multiply the number of seconds of time by the cubic feet of the stream to ascertain the total quantity of water. To make this clearer, let the reader imagine a small stream filling a square conduit or box one foot wide and one foot deep. This gives a stream the face or sectional area of which is one square foot. Now, if the water runs through this conduit or box at the speed of one foot per second of time, that will measure exactly one cubic foot per second, or one second-foot. If the water moves at a higher speed, as, for example five linear feet per second, the volume will be five cubic feet per second. If the conduit or stream is five feet wide and twenty feet deep, the area of its face is 100 square feet, and the water flowing one foot per second will give a volume of 100 cubic feet per second or second-feet; if it runs two feet per second, then the volume will be 200 cubic feet per second of time.

In measuring the flow of a stream it will be understood from the foregoing that the width, depth and speed or velocity are calculated. Streams, however, are very irregular in their measurements and the velocity of the water is not fixed. For instance, the water flows more rapidly in the center or where it is deep; along the shore where it is shallow the friction against the bank and bottom retard it quite perceptibly. Moreover, the water flows more rapidly below the surface than at the surface. In such case it is estimated that the place of the greatest motion is about one-third of the distance beneath the surface, this being the locality where the water is least impeded by friction.

It is manifestly impossible for one to stand at the delivery point of the water, watch in hand, and calculate the number of second-feet that flow, hence a simple way of measuring the whole stream is quite common. A line, say 100 feet, is laid off along the bank and each end of the line is marked by a stake. Then a light float —a chip will answer the purpose—is cast into the stream above the upper stake and the exact time it passes is noted, and also the exact time it passes the lower stake. If the float requires twenty seconds to travel between the two stakes, then the velocity of the water is assumed to be five feet per second. Other floats are necessary, for the stream runs with unequal velocity, but the average speed together with the average measurement is taken as the basis of a calculation and the number of second-feet determined from that. Thus, if the width averages twenty feet, the depth four feet, the cross sectional area is eighty square feet. Then, if the rate of flow is two feet per second, we have a volume of 160 second-feet.

THE ACRE-FOOT.

The preceding water measurements are restricted to flowing water for irrigating purposes. There are numerous methods of measuring the volume of water more accurately than in the case of the chip, and it may be said that by means of submerged floats, current meters with electrical attachments, and other contrivances and calculations based upon scientific principles, very little water will escape the notice of the company who has it for sale, and the farmer may be sure of receiving all he is entitled to for his land. By and by it will be possible for the irrigation farmer to estimate exactly the quantity of water required by his plants, and that amount he will be able to give them with accuracy and without any waste or excess.

It is becoming the practice to store unused water during the periods when there is an abundant supply—that is, to lay aside in reservoirs enough to meet any possible contingency of drought or insufficient supply when most needed. The standard of measurement of water stored in reservoirs, the unit of quantity, is designated as "an acre-foot"; that is, an amount of water which will cover one acre of ground, or 43,560 square feet to a depth of one foot. This will give, of course, 43,560 cubic feet, or 325,851 gallons. One cubic foot per second flowing constantly for twenty-four hours equals nearly two acre-feet, and from this it is not difficult to convert cubic feet per second into acre-feet and estimate the quantity of water to be stored in reservoirs for the use and requirements of crops. The reservoirs themselves may also be measured in the same manner as a tank, but allowance must be made for evaporation and absorption.

To further explain the technical units of measurements into quantities, the following table is given:

One second-foot equals 450 gallons per minute.

One cubic foot equals 7.5 gallons.

One second-foot equals two acre-feet in twenty-four hours flowing constantly.

One hundred California inches equal four acre-feet in twenty-four hours.

One hundred Colorado inches equal five and one-sixth acre-feet in twenty-four hours.

One Colorado inch equals 17,000 gallons in twenty-four hours.

One second-foot equals fifty-nine and one-half acre-feet in thirty days.

Two acre-feet equal one second-foot per day, or .0333 second-feet in thirty days.

One million gallons equal 3.069 acre-feet.

Taking water from streams and ditches open to the atmosphere and its changes, rapid evaporation, seepage and absorption, is always attended with an enormous waste, the consequence being that the farmer never knows and no man can tell him whether he is giving his crops the quantity of water they absolutely require. He can not tell how much of the water applied to the soil is utilized by the crops, or is carried off by drainage, seepage, infiltration to some portion of the land where it is not needed and generally lost for useful purposes. He knows, however, that so much water is measured out to him and that he pays for the amount that runs through the head gate, whether it is of any practical use to him or not. The returns from his crops do not represent as much as he hoped, for the expense takes away a very large slice of his profits. His water tax may represent one-third of his receipts, and though he may be well aware that he never received the water he pays for—that is, it never was utilized by his crops—there is no way out of his embarrassment, he must pay or quit. His farm belongs to him—that is, he has the deed to it—but he is paying rent on it all the time.

Chapter XIX.

PUMPS AND IRRIGATION MACHINERY.

In Chapter XII is given a calculation of the amount of water precipitated upon the earth's surface and carried into the soil. The amount is enormous, and if not carried off in the variety of ways mentioned would soon reduce the surface of the globe to an uninhabitable morass. Moreover, if the annual precipitations were uniform in all places there would not be any necessity for irrigation or anxiety about drouths and an insufficient water supply.

We know it to be a fact that all this tremendous annual mass of water poured from the clouds upon the land, or at least a great percentage of it, is carried into the soil, where it filters and seeps down by the force of gravity as far as it can, or until it encounters some obstruction, and if it can not run, seep or drain off back into surface conveyances it remains stationary, waiting for an exit.

The water from rivers and streams is a very small quantity compared with the quantity beneath the surface. It is, in fact, the "run-off" from rain, snow or saturations of the soil that is utilized in ditch and canal irrigation, and that run-off varies in amount from a flood to a thread-like, meandering stream, which is an aggravation as a source of irrigation water. Of course, there are exceptions in large streams, the great waterways of the country, some of them the main arteries of commerce and apparently inexhaustible in water supply.

We have not, however, reached the full limit of land cultivation by irrigation, and when the vast regions yet unreclaimed, but the most fertile in the world, shall have been put under water, or, rather, be ready for water, as a scientist recently observed, "Where is that water to be got?" The fact is that it would require the services of several Mississippis to supply the demand, and even then in a dry season there would be a deficiency. It was owing to the fact that there was not surface water enough, and that the reclamation of arid and semi-arid lands had, apparently, come to a standstill, that the Government has interested itself in the subject of reclamation by irrigation and turned its attention to the construction of gigantic dams, reservoirs and the sinking of wells to secure an adequate volume of water for the purpose of building an empire of fruitfulness in what has always been considered an unfertile and dreary desert.

That there is an abundance of water beneath the surface of the earth is beyond controversy. There is not a desert spot on the globe which, lurking down below its burnt exterior, does not contain natural reservoirs of water in abundance. Even the midst of Sahara is beginning to blossom like a rose with water brought from beneath its sands with very little trouble, and in our own country the great American desert is becoming a vast green pasture and orchard of thriving trees and vines through a little scratching of the surface to obtain the life-giving moisture that never fails to be where it is wanted.

All this leads to the subject of wells, but as that matter has been gone over in a fairly full manner, and as this book is not intended to be scientific or technical, but a primer of irrigation, the methods of digging wells, their variety and history may very well be omitted and this chapter limited to the means of extracting the water from them.

PUMPS.

The only suitably economical method of raising water from a lower to a higher level, as from a well, is by means of a pump. When pumps were first invented or used it is difficult to say, and, moreover, it is of very little moment to know the exact date or the inventor's name. It is quite certain that if he were able to return today and view the innumerable varieties of them, and their tremendous capacity, he would not be able to recognize the principles he sought to put in a practical form.

SUCTION PUMPS.

The ordinary pump is the suction pump, constructed upon the principle that water will fill a vacuum to the height of 33.9 feet vertically at sea level. The piston of this pump fits tight in a smooth cylinder and has a small valve in its upper end which opens upward. The piston is lowered as far as the piston rod will permit, the valve opening to allow it to descend easily. Then the piston is lifted up by means of a level to the full length of the piston rod, the valve this time being closed. By repeating this up and down motion a vacuum is created in the cylinder of the pump—that is, the atmosphere is extracted—and if there is any water it begins to come up and can be made to overflow through a spout placed at the surface. Now, water can not be "sucked" up in this manner more than 33.9 feet in a perfect vacuum, and as a perfect vacuum, that is a reservoir absolutely free from atmospheric air, the estimated height at sea level to which water can be drawn by means of a suction pump does not exceed twenty-eight feet.

The altitude above the sea level and various atmospheric conditions reduce this suction lift materially. for instance: 1,500 feet above sea level the suction lift is 25 feet; 1,500 to 2,000 feet, 24½ feet; 3,000 feet, 23 feet; 4,000 feet, 22 feet; 5,000 feet, 21 feet; 6,000 feet, 20½ feet; 7,000 feet, 20 feet; 8,000 feet, 19 feet; 9,000 feet, 18 feet; 10,000 feet, which is as high as pumping for irrigating water will probably go, water can be sucked up only 17 feet. Some engineers say that 20 per cent less would be a factor of safety in putting in a pump.

These pumps can do a great deal of work if kept constantly at it. Take a suction, single-acting pump that is, one with only one cylinder, having a cylinder five inches in diameter, and a six-inch length of stroke, and it will deliver one-half a gallon per stroke. The faster the man who works the pump makes the strokes, the more water the pump will deliver. At ten strokes per minute, which may be called "leisurely," he would be able to raise 300 gallons an hour, and by doubling the diameter of the pipe or cylinder, he would increase the capacity of the pump four times and deliver two gallons per stroke. By using horse power such an ordinary pump may be made to raise six times as much water, and with a longer lift, one of ten feet, one horse power, an ordinary pump is able to raise 200 gallons per minute, an amount sufficient to give an acre of ground half an inch of water in ten hours.

WINDMILLS.

Animal power is not commensurate with irrigation on anything but a very small scale, as for a small kitchen garden with a few small fruits. Other power must be brought into requisition to attain profit in gardening or general agriculture, where irrigation is practiced. The most common and economical power, though variable at times, is the wind. It is utilized by means of a windmill, which may very properly be called a "wind engine."

The origin of windmills, like that of numerous other things of benefit to mankind is lost in the obscurity of time. About the twelfth century they came into practical use in Holland for the purpose of draining and grinding grain. This mill was of a very unique

WIND MILL AND TANK FOR HOUSE AND GARDEN USE—Page 212.

construction, with a shaft called the wind shaft, which carried four arms or whips on which long, rectangular sails were spread. The whip carrying the sail was often thirty to eighty feet long, so that the tips of the sails described a circle sixty to eighty feet in diameter. These sails came down close to the ground, and every one who has read the adventures of Don Quixote will not be surprised that his encounter with the windmill on the supposition that it was a cruel giant ended disastrously.

There is now at Lawrence, Kan., the ruins of what is said to be the first windmill of this type erected in the United States. It was erected by an English company at an expense of $10,000 upon the Holland plan. Since that time the windmill has become a thing of beauty and power, and for cheapness it is within the reach of every farmer, and is one of the most economical aids to irrigation that can be devised.

It is indeed the simplest appliance for raising water known, and as showing the capacity of a first-class modern windmill, the following table is submitted as founded on experience and positive guarantee. The "size" mentioned in the first column means the diameter of the wheel, and the "lift" expressed at the top of the columns refers to the distance of the piston to the point of delivery:

Size	.120,106	2.75	80,070	1.84	49,742	1.14
Feet.	10-ft. Lift.		15-ft. Lift.		25-ft. Lift.	
10	Sq. ft.	Acres.	Sq. ft.	Acres.	Sq. ft.	Acres.
12	37,161	.85	24,775	.57	14,768	.34
14	66,765	1.53	44,510	1.02	26,134	.60
16	85,982	1.97	57,321	1.31	34,757	.79

The table represents the number of square feet and acres the windmill will irrigate one inch deep per average day's work of ten hours. It is conceivable that a sixteen-foot mill will irrigate at least twenty acres of land, and by running double time, as some do, will store up water to supply deficiencies caused by lack of wind. At the rate of supply indicated, every acre will receive its inch of water on alternate five or ten days, which, during a growing season of ninety or one hundred days means ample to raise almost any sort of crop, provided small furrow or tight trough conveyances are used, and after cultivation practiced.

When it is considered that an inch of water on an acre of ground means 27,154 gallons, it will be easily comprehended that such a windmill working out of the growing or irrigating season will store abundant water in a storage reservoir. It means the storage of at least five million gallons that may be used for winter or fall irrigation and furnish an abundant supply for stock and household purposes.

As to the cost of such an irrigating outfit, exclusive of the cost of the well and reservoir, the following are the ruling prices complete, ready to put up and begin pumping:

Ten-foot mill, $62; twelve-foot, $97; fourteen-foot, $133; sixteen-foot, $195.

Of course, the purchaser must first find the water with which to irrigate, and plenty of it. He should avoid doing as did a friend of the author, who dug a well 108 feet deep, with about six feet of water at the bottom. After putting up a twenty-four foot mill, he began making preparations to flood forty acres of ground. In less than two hours his pump ran dry, and on investigating he found that the well was dry and it took eight hours for it to fill up again.

RESERVOIR.

The reservoir should be located on the highest point of land it is desired to irrigate, with the bottom of the reservoir above it if possible. Then plow deep around the line to avoid earth seams under the embankment.

The interior should be plowed and scraped toward the line of the embankment and harrowed until the earth becomes finely pulverized. This bottom should then be carefully and thoroughly puddled. If hard pan or clay can be found, then dig down to it and establish the bottom of the reservoir on it as a sure foundation for a water-tight receptacle.

The height of the embankment depends upon the amount of water capacity, but it should not be less than four by ten feet wide at ground level, and two feet wide at the tip. The inside slope should be gradual, to prevent washing by ripples or waves, and it may be sodded or seeded down to grass until a stiff sod is formed, which will prevent any washing away of the earth.

The outer embankment may be steep or nearly perpendicular, but as there will always be some seepage, it would be wise to make it slope gently and use it for raising garden truck, small fruits, or whatever else the farmer may fancy in the way of ornament or profit.

As to size, that must be governed according to the irrigator's needs. An acre of reservoir would not be too much to accommodate a good windmill, and this according to the measurements already given, may be made to contain half a million or a million gallons. If the stored water is to be used frequently, then the size of the reservoir may be lessened.

For stock purposes, a smaller reservoir may be constructed below or away from the larger one, and into this smaller one the water can easily be run as needed for a change or freshening; the excess of unused water may be run upon any plowed ground to soak into the soil, for after all is said, where there is moisture in the soil, the labor of irrigation is easy and the quantity of water required very much reduced. After once filling the reservoir it should never be entirely emptied, for if the bottom is permitted to dry it will surely crack and then, when refilled, the water will drain out.

TANKS.

It is well to have a tank of some kind to provide against sudden dearth of water from lack of wind, or stoppage of machinery for repairs. With a reservoir however, the necessity of a tank is not so apparent unless the water is to be used for household purposes. In many kitchen or truck gardens, it is recommended to sink a barrel or square tank at various places, say, at the head of the beds where gross feeding plants are raised. Beets, carrots, onions, etc., with radishes and lettuce, or salads of any kind, like plenty of water, and when they need it they must have it. It is not always profitable to run water in a furrow over a long stretch of soil to give a few vegetables the trifle of water they may happen to need. The waste is too great to be worth while. Hence tanks come to the rescue and the water may be raised from them by means of a hand pump.

In large fields, where drainage pipes or tile are laid, and a system adopted which will merge or unite the tile into one basin or large cross drainage tile, it has already been said that by sinking openings through the soil in the nature of wells down to the subterranean tile and stopping up the outlets, the water may be made to rise to the surface or near it and be utilized by means of pumps, or through ditches or flumes if the land below is down grade, or lower than the source of supply. Instead of a cross drainage system to catch the surplus water, tanks may be sunk and the drainage tile made to end in them.

For windmill purposes to store water for household uses, tanks may be purchased ready made in cypress, pine or iron at from about $8 for a 70-gallon tank to $100 for a 5,000-gallon one. These tanks are made all the way up to 100,000 gallons capacity.

HORSE POWER OUTFIT.

Pumps are arranged so as to be worked by horse power, using one or two horses. The one-horse power pump is fitted for a 3-inch suction pipe and a 2½-inch discharge pipe. This will deliver 53.9 gallons per minute. The two-horse power outfit is fitted with a 4-inch suction pipe and a 3-inch discharge pipe, the capacity of which is 102.9 gallons per minute. The cost of the one-horse power is about $210 complete, and the two-horse power, $240.

Some prefer the horse power outfit to the windmill, because they do not consider themselves at the mercy of the shifting and variable winds of heaven. On the prairies and near the sea coast, however, the windmill is preferred as the winds are nearly constant, at least they blow with sufficient force and long enough to supply all the water needed. Wind at fifteen miles an hour is strong enough to work a windmill up to its full capacity.

GASOLINE ENGINES.

The gasoline engine for pumping purposes is growing in favor, owing to the cheapness of the fuel and the capacity and simplicity of the engine. An engine that costs about $100 will furnish about 1¾ horse power, consume one gallon of gasoline in ten hours of steady work and supply 4,000 gallons of water. Other gasoline engines ranging up to a water delivery of 10,000 gallons and more an hour may be purchased at reasonable cost, and will do an enormous amount of work at a trifling expense. These engines are suitable in the barren regions where wood and coal can not be had for fuel without great expense.

OTHER PUMPING POWER.

Where conditions will admit of them, steam, hot air and even electricity are brought into requisition for pumping water to be used in irrigating land. Coal, wood and other fuel, however, must be at hand in unlimited quantities, for all such power is a voracious feeder—the more power the more fuel.

All the appliances and machinery for irrigation are being reduced to simplicity and the saving of water. Open canals and ditches with their loss of 50 per cent of water are becoming things of the past. Economy of use is now the rule, and the farmer who understands the needs of soil and plants makes a good profit out of his farm, whereas he would cultivate it at a loss without that knowledge. Raising crops for market for profit has become a matter of dollars and cents, and a penny saved is a penny earned in agriculture as well as in the mercantile business.

To save water is the great aim of irrigators, and where there were once open leaky ditches and canals there are now cemented water conveyances. On the large farm, as well as on the small one, it is beginning to be understood that gorging plants with water and saturating the soil is not the proper system for growing crops for profit. The lessons sought to be imparted in this book, if well learned and followed, can not fail to be of benefit to every farmer who reads it. The essential principles only are given; each farmer must apply them for himself, for he can not have an apostle at his elbow all the time to guide and direct him when he is on the point of making a mistake.

Chapter XX.

IRRIGATION OF PROFITABLE CROPS.

The crops a farmer should raise on his land with profit to himself depend upon numerous conditions, many of them variable. No matter what his desires may be, no matter what his neighbor may do or raise, or how much he may succeed, every farmer is a tub that must stand on its own bottom. He must say to himself: "What is my land fit for? What are my means of cultivation, my water supply? What does the market demand, and how can I reach that market without paying out all my profits in transportation?"

If all the conditions are unfavorable to the raising of crops with profit to himself, the author's advice to him is to raise nothing in the way of crops for market, but raise all the produce possible on your land and feed it to stock—cattle, sheep, hogs, poultry. There is always an unvarying demand for these products of the farm, and though the market may be glutted sometimes, yet on the whole, all the year 'round, the farmers always come out something ahead.

It appears to be the destiny of a farmer to always try experiments, put seed into his ground, and then toil and perspire to make it grow to maturity, and then get nothing for his pains. A farmer will put certain seeds into his ground, and, as this appears to be inevitable, the only thing that can be done is to help him realize on his expectations.

CEREALS.

Every farmer plants wheat. He is bound to do so or feel that he is not really a farmer.

This grain should always be sown on high ground and not in a deep, mellow soil, for it is not a deep-rooted plant. In the arid and semi-arid regions, where the rains do not fall until late in November or beginning of December, the wheat may be plowed under after sowing the surface, and this at any time during September and October. It is good dry farming to do so, and even if the grain is to be irrigated the effect is to have a good stand by the time water is put upon the land. The first rain that comes sprouts the seed and sends it up three or four inches, where it is ready for another rain or for an irrigation. It is the same with all other cereals.

This system would never do, however, in a moist soil. In such a case the soil should be carefully plowed shallow and harrowed and the seed drilled in, about a bushel to the acre. If the ground is surface dry it should be flooded, say two inches, then in twenty-four hours harrow and drill in the seed. Do not roll land where irrigation is practiced, because it is liable to cake, and this means evaporation. When the grains are up two or three inches it is good to run a light harrow over the field. It loosens the soil and does not harm the grain, even if it does pull up a few plants; there is always too much sown, anyway. Twenty to thirty days apart will be enough irrigation—the first one when the grain is five or six inches high, say two inches, and a month after that one inch. In hot climates it is beneficial to give a third irrigation when the grain is heading or when it is in the milk. The condition of the soil, as well as that of the plant, must be considered and the quantity of water gauged according to that. Digging down six inches will tell the condition as to moisture, and breaking off a stalk or two tell the condition of the plant. If "well" the stalk will be juicy and damp to the touch. If dry, yellowish, and breaks easily, give it water as soon as possible.

The Chinese and the Japanese plant their grain in ridges about twenty inches apart and use only about ten pounds per acre. But an acre will produce more, at least just as much, as when drilled or sown broadcast. One grain of wheat will "stool" out into sixty, and sometimes eighty, healthy stalks in this way. There are some small farmers who plant wheat along the borders of their vegetable and small fruit beds and give it careful cultivation. If planted farther apart, so as to admit of the passage of a cultivator between the rows and cultivated like corn, the result is most astonishing. The fact is that when a bushel of wheat can be grown in as small a space as a bushel of corn or potatoes there is no reason why wheat should not be grown in that manner, at least on small farms. One thing to be considered where wheat is concerned is that an excess of water spoils the food value of the grain. For feeding or forage purposes it does not make so much difference, as water in abundance increases the nutritive elements in the husk.

BARLEY.

Barley is the standard crop for forage, or "hay," in the arid and semi-arid regions. It will grow on almost any kind of soil, and being a deep-rooted plant it does not depend so much on irrigation as wheat. It will grow a good stalk and form a good head for hay with six inches of rainfall and produce good, marketable grain with ten inches and no irrigation.

The soil should be plowed deep and well pulverized, then drilled in either in the fall or spring, or sown broadcast. To raise it to perfection, and it repays the labor of doing so, it should be given water when about four inches high and another irrigation when the heads are in the milk. It is a very profitable crop to raise for brewing purposes, the demand for malting barley being constant and increasing. Moreover, the price is much better than that for wheat. It will grow two miles above the sea level and flourish in alkali soil that will kill a sugar beet.

OATS.

Oats, fall or spring planted, require plenty of water and attention, or they will refuse to grow. There is one exception, however, and that is the case of the "oat hills" in southern California, where a crop of fine oats springs up spontaneously every spring. The stalks grow as high as a man's head, with well rounded heads, juicy and succulent. Just before the fall rains the ground is cleared of the old stalks, a treetop or a harrow dragged over it roughly, and then left to itself; the grain comes up in about three days after the first rain of the season and does not require any irrigation at all. The origin of this singular exception to the rules relating to oats is in the old padres of the missions, who, when traveling about on their ponies for many hundreds of miles, always carried a bag of grain at their saddlebow, and when they came to a spot that looked fertile they scattered the seed with a blessing that it might grow. For over a hundred years this grain grew and there was no man to harvest it, so it ripened and returned back into the soil whence it came, and now, to this day, it keeps on sprouting and never ceasing, the soil below being dry and the seed sprouting when the moisture reaches it.

However, many farmers irrigate oats frequently under the supposition that they need more water than any other cereal, and the proof of it is that the crop is enormous when well irrigated.

RYE.

This is a hardy annual that will grow to full maturity and give a good harvest with very little care and irrigation. A medium irrigation when about half grown and another when heading is sufficient. Cultivation, however, should be deep and the soil well pulverized.

CORN.

Corn is a deep-rooted plant and hence the soil should be plowed deep and care taken that there is moisture in the subsoil. There is no need of surface moisture, wherefore deep furrow irrigation, with after-liberal cultivation and soil pulverization, will produce a fine crop.

A side hill where there is seepage water is most favorable for all the varieties of corn. In some instances small fields of corn on a side hill have produced marvelously by merely filling a ditch at the top of the slope and allowing it to seep down into the root zone. On flat land, with subsoil moisture, one watering when the plant is tasseling will be ample.

In the arid and semi-arid regions corn is plowed under dry, as is the case with wheat and other cereals. Five or six grains are dropped in every third furrow a good step of the plowman apart and left to itself with a good deep cultivation when about a foot high, the earth being thrown over against the stalks.

Corn does remarkably well in deep, rich soil, but will grow very well in any soil provided the roots can reach moisture. The manufacture of starch in the plant ecomony demands great drafts upon the chemical laboratory of the soil. The bottom of the stalk of a young shoot of corn is as sweet as sugar cane, which is proof that the plant is drawing its food far below the surface, and that it is preparing to manufacture the starch which is afterward found in the ripened grain.

Corn grows better in ridges than in hills, even when not irrigated. In all cases the earth must be pulled up around and close to the stalks, not only for the purpose of mulching against evaporation of the moisture, but to shield the process of converting sugar into starch, a process quickly stopped by exposure to the elements or to desiccating atmospheric air.

All of the foregoing cereals may be grown for forage, and if cut when in the milk they are productive of good flesh on cattle and will grow at the rate of from four to six tons to the acre. Where dry farming is practiced, and the season is unfavorable for the perfection of the grain, the plant is cut for fodder or hay and fed to the cattle, and in the case of corn it is fed green to milch cows.

RICE.

This is an amphibious plant; some call it aquatic. However that may be, the ground is prepared for it as for wheat, by thorough tilling and pulverizing. The rice is sown about eighty pounds to the acre and then harrowed and rolled. Left to itself, it sprouts and grows up to about five inches without showing any aquatic properties. But the farmer then puts about an inch of water, perhaps two inches—that is, covers the field under one or two inches of water—and as the plant grows he adds more water until the field is buried six to ten inches deep. The plant grows vigorously, and when the grain is in the milk the water is run off, and by the time the rice is ripe the ground is dry enough to harvest. It is harvested very much the same as wheat—put into bundles and piled up to be cured and ready for the separator or thresher.

In its wild state rice is essentially aquatic; the plant roots never find themselves in anything but mud. From time immemorial the Chinese have treated it as a semi-aquatic plant, and if any one has ever tried to raise it like wheat the author has not been able to learn. Perhaps it might be so grown and produce a new variety and be an addition to our valuable list of cereals.

COMMERCIAL PRODUCTS.

OISER WILLOW.

The oiser willow is used in the manufacture of baskets and its culture may be made very profitable if near the market of a large city or basket manufactory.

Some years ago Mr. G. Groezinger, a vineyardist near Yountville, Napa County, Cal., sent to Germany for some cuttings. He received about fifty and planted them along one of his lateral ditches, which always contained water, more or less of a good supply. The cuttings took root and grew beautifully, and the next year he pruned the plants down to stumps and planted the cuttings all along the ditch for several hundred feet. They grew bunchy, with thick clumps of long, slender branches drooping over the ditch and made a delightful shade. Calling the attention of a San Francisco basketmaker to them, the latter bought the supply on the ground and sent men out to prune the plants. They cut off the long branches and cast them into the ditch to soak in the water, and in a week or so came out again and stripped off the bark, leaving slender, white, pliable branches, which were speedily made into fine, marketable baskets of all sizes and shapes. After the fourth year of his planting the original cuttings Mr. Groezinger received more than $1,500 per year income from the cuttings, the purchaser doing all the work of harvesting them.

The plant will grow in any climate, provided it has abundant water during the growing season. Along a ditch is its habitat.

FLAX AND HEMP.

These two textile fabric plants, so to speak, may be raised to perfection by irrigation. They require, however, a moist soil, and for that sub-irrigation would be the proper system of irrigating them. They are deep-rooted plants and may be planted in drills or beds. Both plants are profitable for their fiber and for their seeds, the latter yielding up to twenty bushels per acre about a ton or two tons of fiber. The latter must be soaked in a ditch or other receptacle to separate the fiber from its hard envelope.

HOPS.

This plant should find a place in every garden and on every farm, if not for market purposes at least for household uses. It is very easily grown, being a deep-rooted perennial which needs a moist subsoil. The plant is propagated from cuttings, three eyes to each piece planted. At least four inches is the proper depth to plant the cuttings, and they will speedily come up and spread runners out in every direction. They should be pruned down to a few and then poled.

COTTON AND TOBACCO.

These two valuable products belong to field culture on an immense scale. Cotton may well be said to be "king" and tobacco its "heir apparent." There are no two plants in the world so necessary—that is, cotton for its economical uses and tobacco as an article of luxury. Cotton is a deep-rooted plant requiring a moist soil. Where irrigation is necessary the soil is irrigated preparatory to planting the seed and once again when the balls begin to form. The plant needs very little care, and in that respect it is the very opposite of tobacco.

Tobacco requires a soil very carefully prepared. The plants are raised from seed in frames and set out the same as cabbage and tomatoes, carefully puddled in and the rows irrigated by a small stream until the plants take root, which they will do in a few days. Frequent and thorough cultivation of the soil is necessary, but water must be applied sparingly, one irrigation during the middle period of growth being sufficient, provided the cultivation is thorough and the subsoil moist. When the soil is dry and warm, irrigation may be applied every ten days after the first month of growth. In the arid region top or leaf spraying is necessary, but tobacco is not recommended as a plant profitable in arid soil, it thriving best in a warm, moist climate.

STATISTICS OF PRODUCTION.

It may be of interest to know the amount of the foregoing profitable plants produced in the United States. The following is an approximate of quantities as nearly as can be ascertained from the means of information:

Wheat	753,460,218	bushels
Barley	178,795,890	bushels
Oats	736,808,724	bushels
Rye	30,344,830	bushels
Corn	2,522,519,891	bushels
Rice	283,665,627	pounds
Cotton	5,384,000,000	pounds
Tobacco	500,000,000	pounds
Hops	20,000,000	pounds (about)
Flaxseed	5,000,000	bushels (about)

The total value of which was in the neighborhood of two thousand million dollars ($2,000,000,000).

CHAPTER XXI.

IRRIGATION OF PROFITABLE PLANTS.

It has been impressed upon the mind of the reader in the preceding chapters that plants draw their food from moisture and not from water. True, moisture comes from water, but the meaning sought to be conveyed is that moisture is a food solution, a preparation for nourishing the plant—its "pap," so to speak. When water is applied to the soil it attacks the various soluble salts, both organic and inorganic, and causes a chemical change to take place, or, rather, a series of chemical changes, and in that way the elements in the soil are converted into food. There are fermentations, transformations and many radical changes effected, until the water converted into moisture can not be recognized as water at all or any more than vinegar, wine or potatoes can be called water, although they contain water as an element in their composition, as an ingredient.

This fact can not be overestimated, because on its understanding hinges the art of irrigation. There are air plants which have no rooting in the soil, yet they could not live without moisture. There are also plants which flourish in the desert, where the soil is entirely dry for a hundred feet below the surface, yet these could not live without moisture. The question is, Where do they get it? They certainly do not require water, for there is none within reach of their roots or leaves. They obtain it from the atmosphere, and this atmosphere is an element that must be reckoned with by every irrigator. We know that there is always a certain quantity of moisture in the atmosphere, which is better known by the name of "humidity," and this humidity can be easily measured.

When the atmosphere is charged with 80 to 100 per cent of moisture, or humidity, that moisture is precipitated upon the soil in the form of rain, snow, etc. From 50 per cent to 80, when the air is cool, we have dew, fog, etc., visible to the eye. When the air is warm, however, the moisture is not perceptible to the eye, but it is there nevertheless.

Now, with the atmosphere weighing or pressing upon the earth's surface about fifteen pounds to every square inch, there is not a nook, cranny or opening that it does not penetrate, and it carries with it the moisture it contains, and when it comes in contact with any absorbent, as the soil undoubtedly is, it leaves its moisture there. It is for this reason that it is insisted upon so strenuously that the farmer must keep his soil open to the air—the soil should be aerated as much as possible. This done carefully and constantly, the labor of irrigation is rendered easier, and its effects more perceptible; likewise less application of water will prove adequate to the raising of any plant.

The necessity for this aeration of the soil is the same in the cereals alluded to in the last chapter as in the root plants and tubers. In the case of cereals, however, taking a wheat field as an illustration, it is impossible to cultivate the soil because the plants cover the surface of the ground closely. What can and should be done is to till the soil as deep as possible before planting and harrow after the plants are up, say two or three inches. If any other sort of cultivation is attempted the wheat and other grain must be cultivated as in corn, by being planted in rows. The production per acre would be greater than when sown broadcast or drilled, but that method is not convenient, at least it is not in vogue in the United States, and probably never will be in large field culture, it being easier and less laborious to flood the soil with water to create the requisite amount of moisture.

But in the case of vegetables, roots and tubers there is no excuse for not aerating the soil, since these plants can not be planted so close together as to entirely cover the ground, except in the last stages of their leaf growth, when the crop is assured. Running ground vines even may be cultivated almost to the point of ripeness, and when, as in the case of watermelons, cucumbers and the like, or strawberries, the vines have covered the ground, a few rills of water permitted to find their own way beneath is better than a flooding, for the latter is apt to reach the stalks or stems and either rot them or bake the ground and choke off the air, thus killing the crop or injuring it materially. All this can be provided for at the last run of the cultivator, or stirring of the hoe, by leaving small furrows or depressions here and there for the water to run in as channels when cultivation is no longer possible without tearing up the plants.

VEGETABLES.

Potatoes and tubers generally favor a moist, cool soil, although in the arid regions under a very hot sun they grow to perfection and to an immense size. A 15-pound Irish potato or a 30-pound sweet is pleasant to look upon, but not so well adapted to culinary requirements as those of a smaller and more convenient size. With too much water or an abundant supply potatoes become watery, for they are gross feeders—gluttons, in fact—and they must be restrained.

It is not desirable to plant potatoes in hills where irrigation is practiced; better plant in rows on level ground and then run water in a furrow between the rows, which may be from three feet to four feet apart; the closer the rows the better, for then the vines will shade more surface and retain the moisture longer. In the rows plant the eyes from two to two and one-half feet apart. In the arid and semi-arid regions it is a good plan to plow under every third furrow, the plowman dropping several cuttings at every long step in the furrow. Of course, the soil must be well tilled preparatory to planting, and in a moist condition, then well harrowed and pulverized afterward. When the plants are up about an inch or two, run the cultivator through, or a small plow would be better, so that a small furrow can be left between the rows, the earth being thrown up against the plants. When the plants are up a foot and tubers begin to form, run water through the middle furrow for an hour or so and the next day run plow back and forth, throwing the earth over on the wet soil to form a ridge. The day after level the ground with a cultivator and let it alone for a week. After this, one more irrigation when the tubers are about the size of a hazelnut, or filbert, will be sufficient to mature the crop. The soil should always be kept open and the moisture near the surface, for the potato has a tendency to crowd out of the soil. In the arid regions a singular peculiarity of the early potato is to grow to maturity before the plant is ready to flower. This is owing to the rapid underground growth and is of no consequence except that the tubers are all the better for absorbing the nourishment that should go into the flowers. Sweet potatoes have this curious habit also. One case which has been called to the attention of the author is that of a 2-rod row of sweet potatoes. The vines refused to grow more than an inch or two above the ground; they did not become vines at all, but grew straight up as far as they grew at all. Thinking they needed water, they were irrigated liberally, and every few days for three months water was applied and the soil kept loose. Wearied with the efforts to make these vines grow, a wise neighbor was called in, and after studying the matter for a few minutes and listening to what had been done to encourage their growth he took a spade and dug down into the head of the row, unearthing a 30-pound sweet potato or yam. Continuing this exploration all along the row, at least 100 sweet potatoes were dug out varying from thirty pounds down to five pounds. The growth had all been under ground, the tubers taking all the nourishment, leaving none for the tops. Cooking disclosed the fact that they were very coarse and rank, unfit for human food but pleasant to the palates of a pair of hogs which devoured them with a relish and asked for more in their peculiar language.

For tubers generally, keep the water away from them and give them moisture. This may be done by permitting the furrow water to soak into the soil and then throwing it over toward the plants. Sub-irrigation is very favorable for the growth of tubers, and when the land is drained and the soil kept well open and finely pulverized there need be no fear of failure to raise a crop. Sandy loam is the best soil, although rich, well manured ground, consisting of mixed clay and sand or loam, is productive of good crops, but the richer the soil and the warmer, unless there is very quick, almost hothouse growth, is liable to cause rot or other diseases peculiar to tubers.

Sweet potatoes may be grown to perfection, that is they will grow to be sweet potatoes out of which the sugar will bubble when baked, if planted in almost pure sand. This, of course, in the humid regions, for an arid sandheap would cook the cuttings before they had a chance to sprout.

Turnips, beets, carrots, parsnips, salsify and other root crops will grow in any kind of soil if properly tilled and well irrigated, but if succulence is an object plant the seeds in rich, black loamy soil, plowed deep and well pulverized. They may be irrigated at any time the ground shows dryness by cutting a deep furrow within a foot or eighteen inches of the plant, taking care not to let the water reach the crown or rot will ensue. Flooding should not be practiced except in the case of field beets, and then only when the leaves shade the ground. Clean and thorough cultivation is necessary, and in the case of small roots moisture rather than water should be supplied by running water in a furrow at least twelve inches distant and then drawing the moist earth over toward the plant the next day, covering the furrow immediately upon completing the irrigation to prevent evaporation and baking of the soil.

THE KITCHEN GARDEN.

Here is where irrigation can be made to shine like a gem in a barren waste. Our markets are filled with tasteless vegetables, unfit for table use. Without flavor and stringy, the housewife buys them every day because they represent green things and look plump, as if filled with succulence. But they are like apples of Sodom, or like the book St. John ate—sweet in his mouth and bitter in his stomach.

The soil of a kitchen garden must be rich and extremely well tilled. It should be thoroughly broken up and pulverized after plowing under well-rotted manure. Fertilizers are unobjectionable, certainly, but they do not tend to open the soil as does ordinary barnyard manure. Besides, it is better to furnish the soil with the elements out of which the plant can manufacture its own food than furnish it with ready-prepared material. They know what they want better than man, and if it is not ready at hand they manufacture it. As is said in a preceding chapter, a plant and the elements in the soil constitute a perfect chemical laboratory, and any attempt to interfere with nature is apt to "boggle" the creative power of the plant. It does not want help; it must have material.

For the purposes of irrigation the land should be level and slightly elevated to permit the flow of water. Rather than flood the ground, as is a common practice, it would be better to run a number of close furrows and then turn the earth over as soon as the water stops running. This will moisten the ground and put it in better condition; moreover, it will give infiltration and capillary action a chance to operate and create moisture.

The salads and radishes require a good supply of water and this may be given them by small furrow irrigation and hoeing or cultivating over, or the rows may be sprinkled. If sprinkling is begun it must be continued, for the roots will come up near the surface for the moisture. These plants, however, are short-lived; a few weeks and they are ready to harvest.

Sub-irrigation is better adapted to celery than any other system. With rows of tiling ten or twelve feet apart, or less, any number of plants can be grown on an acre. By planting close, a few inches apart, and irrigated plentifully they are self-blanching, though to reap all the benefit of garden culture the old way of planting in furrows and drawing the earth up around the plant is the better method where flavor is desired. If the celery patch is small, a circular or cylindrical shade of cardboard or straw matting may be put around the plant. Lettuce is treated in this way to make it grow up long and blanched, which gives the well-known "salade Romaine."

Beans and peas are deep-rooters, the former growing deeper than the latter. Both love a sandy loam and may be planted in drills, the rows about twenty inches or three feet apart. If the soil is dry they should be irrigated between the rows when the first true leaves appear, and at least twice more before the flowers appear, at which period they should receive a plentiful supply of moisture. Once a week is not too often for irrigating these and all other leguminous plants.

Tomatoes may be well soaked when young and then left to themselves, giving them about three irrigations at regular intervals until the fruit sets. Too much water will cause them to run to vines, and, moreover, cause rot. Where there is any rainfall during the period of growth after the first irrigation, cultivate constantly and suspend water applications.

Melons and cucumbers require warmth, and hence if the water be cold the plants will be set back, particularly if young. Good soil moisture is all that is necessary with thorough cultivation, and when the vines cover the ground careful flooding will be beneficial. Keep the earth up around the plants and the water away from them, as they need plenty of air.

In the case of cabbages and cauliflowers the young plants should be puddled in and this followed by a good furrow irrigation close to the plants, followed by cultivation, throwing the earth against the stalks. After the plants show signs of heading, irrigate in furrows between the rows and the next day or so cultivate the moist ground over against the plant, or without touching it if possible.

It would require a volume to detail all the plants useful as food that may be grown in the kitchen garden. The main object of this book is to give the outlines of irrigation, and not how to plant, or specify varieties of plants. The rules to be observed are general, but in every case they may be adapted by using good judgment. Thus: When the sun is hot, if irrigation is necessary run the water in furrows, not so close to the plants as to wet the stalks or crown of the roots, then by cultivation the moist ground may be thrown close enough to the plant roots to enable them to reach it. If the day is cloudy and no indications of a hot sun, less care is required. Then it does not make any difference whether the plants are wet or not, but they must be hoed or the earth must be loosened around them to prevent hardening or baking, which is always detrimental in the case of every plant, whether hardy or tender.

To ascertain whether there is moisture enough in the soil, do not wait for the plant to tell you by drooping or twisting its leaves. Then it may be too late and the plant will have stopped growing, or the subsequent crop will be poor. Bore or dig down into the soil say one foot, and if the earth feels damp, or will slightly pack in the hand when squeezed, there need be no immediate application of water. But if comparatively dry, so that it will not soil a clean handkerchief, water must be applied, and the best way is to furrow the ground in small furrows and run the water in rills, cultivating as soon as possible; or if the plants are large, like sweet corn, cabbages, beets, parsnips, etc., cut a large furrow between the rows and run it full of water, permitting seepage, infiltration and capillary motion to carry it to the right place, the root zone. Whether it is doing its work properly can be ascertained by thrusting the hand down near the plant, the soil being supposed to be pulverized sufficiently to reach at least three or four inches down; if not, it must be made so.

Nothing has been said about weeds, because the supposition is that no farmer will permit a weed to grow on his land. Two plants can not very well grow in the same place, and in the case of the weed it will destroy the plant as quickly as vice will a man of good morals. As the story goes: A man planted pumpkin seeds with his corn, but the corn grew so fast that it pulled up the pumpkin vines. The reader is at liberty to doubt this story, but the idea of it is to avoid trying to make two plants grow in the same spot.

CHAPTER XXII.

ORCHARDS, VINEYARDS AND SMALL FRUITS.

If there is no water in the subsoil of an orchard, no ground water, or water table, as it is called, it will be advisable to create an artificial one. One great drawback in orchard cultivation in the arid and semi-arid regions is, that the moisture does not penetrate to a sufficient depth to enable the deep roots to derive any benefit therefrom. The consequence is that where the moisture occupies a shallow belt the small feeding roots are forced to come to the surface, or near enough to the surface to receive all the desiccating effects of a hot sun, and a dry atmosphere. As trees require their natural food as well as plants of the most succulent nature, it will be readily perceived that these surface roots will soon exhaust the nourishment they require and then the whole tree will feel the effects.

The finer and more highly flavored the fruit the more care must be taken to see that it has the proper quality and amount of food elements. It requires the destruction of a vast quantity of roses to obtain one single ounce of attar of roses, and to perfect the flavor of a single peach the distillation in the laboratory of the soil must be enormous. When it comes to one or several acres of luscious fruit, the quantity of elements necessary to perfect the fruit is simply incalculable.

From this idea will naturally be derived two suggestions: Let nothing grow in an orchard but the trees bearing fruit; second, see to it that the soil has moisture down to a good depth, five or six feet, before venturing to set out the selected trees.

It is sometimes customary to plant small fruits between the rows of fruit trees; some plant vegetables, strawberries, and even forage plants to occupy the ground and keep it busy while the fruit trees are grow-

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ing and coming into bearing. Better have only one tree in its twenty or thirty feet square of well tilled vacant soil, than ten trees surrounded by stranger plants to eat out their substance. There is a very good reason for not mixing up plants in this manner, which is, not all plants require the same amount of moisture, some requiring more, others less. Now if the orchard is made a hodge podge of plants with different appetites, and requiring a different diet, how will it be possible to administer to each one according to its necessities? Some will be overfed, other underfed, with the result that none of them will be perfect or produce what is expected or hoped from them. The only case where a little crowding will be justified is in the case of peach trees. These come into bearing very young, in some localities under the most favorable circumstances two or three years after setting out, at which time the tree will be about five years old. As peach trees bear heavily when fostered carefully, they are short lived, and therefore, many fruit farmers plant young peach trees in the rows about fifteen feet from the bearing trees when the latter are in their third or fourth year of bearing, and when the old trees shown signs of degeneracy they are cut down and the younger trees left to bear the burden of production alone. There is no harm in thus maintaining the full vigor of a peach orchard, for the trees belong to the same family and require the same food for their maintenance and practically the same quantity of irrigating water.

So far as filling the soil with water is concerned, where there is an absence of ground water it is better to irrigate for a full year or season before setting out the young orchard trees. If the soil is carefully tilled and pulverized, just as if the orchard were in good bearing, the next season will find an orchard ready for planting, and the process of growth will continue without any interruption and the applying of water be attended with less waste.

If there is ground water in plenty and within six or eight feet of the surface it is liable to come nearer by fresh applications of water and trench upon the root zone, thus destroying the trees. This will soon appear in evidence by the top limbs drying up or dying. It should be always borne in mind that generally there is as much of the plant under the ground as above it. Nothing but the tap root bores its way straight down; the rootlets and feeders spread out in every direction, something in the shape of a fan. Hence if some of these roots are injured the tops of the trees will also suffer. Metaphorically, the roots of every tree are its nerves, which can not be interfered with without injuring some member of the tree. Root-pruning is often practiced when taken in connection with limb-pruning, but where good, strong roots are desired top- or limb-pruning is beneficial. But the roots alone can not be tampered with except at the expense of the tree.

In the case, therefore, of too much ground water, or a liability to raising the water table, drainage tile should at once be put in at least five feet down, not in the middle of the rows, but comparatively near the trees, as far, perhaps, as they are buried underground. If arranged in this manner they will serve for drainage and also for sub-irrigation. The attention of the author has been called to cases where the subsoil was originally dry down for a hundred feet, and there was never a thought of the possibility of a water table ever forming. But it did, and by constant irrigations the water found an impervious strata and then began to collect and form a water table, which required drainage in the course of less than five years from the time of the establishment of the orchard.

Furrow irrigation is the most suitable, however, in most orchards, and it has always proved adequate to produce excellent crops. But the furrows must run deep and the after cultivation must be thorough or evaporation will injure the plants. Long furrows are to be avoided, and the water should never be "rushed" through them. Short furrows and a slow flow will tend to soak far enough down into the soil to reach the roots and far enough beyond that to enable the capillary motion to have a supply to carry up into the exhausted portions of the root zone. Three good irrigations during the season are ample and more than enough where there are ten inches of rainfall and a supply of underground water to draw upon. This can be acquired by fall and winter irrigation; that is, running the water into, not upon, the land after the leaves have fallen and following it up in the fall by deep plowing, cultivation and harrowing. Some dig a basin around their apple trees in the fall, and when freezing weather comes fill the basin with water and let it freeze. They say it prevents the tree from blossoming too early in the spring. Others mulch around their trees heavily with manure to keep out the frost. There is no way to reconcile these contradictory practices except by giving the soil moisture in the fall and winter and thorough cultivation. The earth will be a sufficient mulch and the moisture will freeze soon enough. But all the regulations in the world can not prevent the tree from following the course of nature. After the crop is gathered and the leaves departed, the tree still goes on preparing for the coming spring. It is busily engaged in ripening its wood and storing up food for the new buds, and ice around its trunk will not stop it, nor will a heavy mulch of manure prevent it from freezing unless the entire tree is enveloped in the mulch.

Constant cultivation and the stirring or mixing together of the food essentials are what the tree needs and demands, and when this is done and the compote of organic and inorganic elements mixed with water all that man can do is done. Care should be exercised in irrigating when the trees are in bud, for if the water reaches them while in flower the blossoms will fall off, and the same is the case when water is turned on when the fruit is ripening. In the case of apples, however, the fruit may be made to attain large proportions by copious applications of water, although in general the application of water at the time of ripening tends to loosen the stems and cause the fruit to drop off before fully ripe.

THE VINEYARD.

The plan adopted by the vineyardists of France to destroy the pest of the phylloxera demonstrated that the vine is no tender plant which requires nursing. The vineyards were flooded and the vines kept under water for a longer or shorter period until tests showed that the larvæ of the pest was extinct. The conversion of the vine into an aquatic plant did not harm its vitality, although a crop was lost through overmuch water.

There is a hint in this result worth remembering. Too much water, no crop. It should be considered as an axiom for every irrigator to carefully observe.

The affliction of every vineyard is an excess of water. Grapes love a warm soil, but too much irrigation, particularly on the surface, renders the soil cold through evaporation. Wherever there is evaporation cold is produced and the more rapid the evaporation the greater the cold and the stoppage of growth.

During the first two years of the growth of a grapevine the greatest care must be bestowed upon it, particularly the second year, for it is during the second year that the cane which will bear the fruit is formed. Cultivation and irrigation are the main causes of a good crop; irrigate every two weeks if the soil shows signs of dryness. Like all fruit moisture in the soil is absolutely necessary, and if this is supplied by irrigation it must be followed immediately by thorough cultivation to reduce evaporation to a minimum and prevent the soil from becoming cold.

If there is ground water there should be drainage, the same as in the orchard, the tiles of which may be used for sub-irrigation, and they should always be used for that double purpose when needed. In the latter case if the moisture in the soil is sufficient no irrigation is necessary until the fruit is forming. As in the case of orchard fruits, never irrigate when the vine is in flower. The vine roots penetrate to a great depth in the soil, and therefore deep plowing and cultivation is advisable. If drainage tile are laid for drainage and sub-irrigation they should be laid near the main roots, so as to carry off the excess of water from irrigation on the surface. Where surface irrigation is practiced it should be the furrow system between the rows and deep. The water will sink deep and reach the roots, whereas by mere surface applications the thread roots are liable to rot and cause damage. The usual practice is to irrigate when the grapes are about to ripen, when they will fill out and ripen more evenly. In the finer varieties of grapes, like the high-flavored ones, the Concord, Muscat of Alexandria, etc., water should be applied more sparingly than when wine is to be manufactured. Fall and winter irrigation is the same as in the orchard, but care must be taken not to soak the soil by applying too much water unless it can be drained off.

SMALL FRUITS.

By small fruits are meant blackberries, raspberries, currants, gooseberries, etc., and the ground vines, such as strawberries.

The bush fruits require a rich and highly-manured soil to attain perfection, although they will grow in any soil capable of growing corn.

They require plenty of water, for the soil must be maintained in a uniformly moist condition. When blossoming, irrigation should be suspended, but renewed every week or ten days when the fruit has set. It is usual to irrigate immediately after one crop has been gathered, the water hurrying another picking to maturity.

The tendency to mildew makes small-fruit growing somewhat of a risk, but by careful pruning to let in the light and the air this tendency will be checked and the berries ripen bright and clean.

Constant cultivation, fall and winter irrigation, as in the case of other fruits, are essential, and when drainage is adopted the perils of small-fruit growing will be reduced to a minimum.

Strawberry culture may be carried on several months during the summer in the humid regions and all the year 'round in the arid or semi-tropical regions of the country.

It is a self-perpetuating plant, propagating itself by means of runners, which take root at the slightest provocation. To foster this habit and obtain fresh plants for a continuing crop, the soil must be kept in a fine, pulverized condition, with plenty of moisture near the surface. The plants may be puddled in a small ridge, hollowed to receive a rill of water, and when the runners creep over the ridge into the paths a little water run in will aid them to take root. The direction of their growth may be easily controlled, and when they have taken root they should be cut loose from the parent stem. The matted bed system is the best for irrigation, for the leaves cover and shade the ground and prevent evaporation. When the fruit is ripening care should be taken when irrigating or running water on the beds, not to wet the fruit, a contingency which tends to rot them before they can become ripe.

FORAGE AND FODDER CROPS.

These crops require abundance of water and quick growth. There are many varieties of forage plants, but alfalfa and corn will always be the standards—corn for the silo and alfalfa for hay. The latter will produce from three to five full crops a year if well irrigated, and that irrigation is by flooding in large fields as well as small ones. Some alfalfa growers do not hesitate to turn in horses, cows, sheep and hogs in their order to pasture the alfalfa patch when the crop is removed. Then water is run on the field and permitted to stand a week before being run off. After that nothing more is done until the crop is ready to again cut.

Others will not permit pasturage on the alfalfa field, but after harvesting it flood the soil with water and again several times before harvesting again. The rule is different in the arid and semi-arid regions, more water and less care being given it, but it grows right along without being disturbed by inattention.

All forage plants, whether corn or the grasses, require flooding at various periods of their growth. The first time after planting, when up three inches, when half grown and about the ripening period. Then after the harvest the ground should be well soaked if it is desirable to use the land for pasturage, the after-harvest irrigation producing a good growth of succulent grazing. Fall and winter irrigation are unnecessary unless for the purpose of keeping the soil in a moist condition, which is always advisable in the arid and semi-arid regions.

APPENDIX.

This appendix contains land, water, and power measurements, and other information for reference by the reader.

LAND OR SQUARE MEASURE.

144 spuare inches equal....1 square foot.
9 square feet equal.......1 square yard.
30¼ square yards equal...1 square rod.
40 square rods equal......1 rood.
4 roods equal............1 acre.

SURVEYORS' MEASURE.

7.92 inches equal.........1 link.
25 links equal............1 rod.
4 rods equal.............1 chain.
10 square chains equal....1 acre.
640 acres equal..........1 square mile.

CUBIC MEASURE.

1,728 cubic inches equal..1 cubic foot.
27 cubic feet equal.......1 cubic yard.
128 cubic feet equal.......1 cord of wood.
40 cubic feet equal.......1 ton (shipping).
2,150.42 cubic inches equal.1 standard bushel.
268.8 cubic inches equal...1 standard gallon.

LIQUID OR WINE MEASURE.

4 gills equal.............1 pint.
2 pints equal.............1 quart.
4 quarts equal............1 gallon.
31½ gallons equal.......1 barrel.
2 barrels equal...........1 hogshead.

DRY MEASURE.

2 pints equal.............1 quart.
8 quarts equal............1 peck.
4 pecks equal............1 bushel.
36 bushels equal..........1 chaldron.

AVOIRDUPOIS WEIGHT.

6 drams equal............1 ounce.
16 ounces equal..........1 pound.
25 pounds equal..........1 quarter.
4 quarters equal..........1 hundred weight.
20 hundredweights equal...1 ton.

TROY WEIGHT.

(For Precious Metals and Jewels.)

1 pennyweight.	24 grains equal..........
1 ounce.	20 pennyweights equal....
1 pound.	12 ounces equal..........

APOTHECARIES' WEIGHT.

20 grains equal..........1 scruple.
3 scruples equal.........1 dram.
8 drams equal...........1 ounce.
12 ounces equal..........1 pound.

METRIC SYSTEM OF WEIGHTS AND MEASURES.

The nickel five-cent piece is the key to the metric system of linear measures and weights. The diameter of the nickel is two centimeters exactly, and its weight five grammes. Five of them placed in a row give the length of the decimeter, and two of them will weigh a dekagram. As the kiloliter is a cubic meter, the key to the measure of length is also the key to the measure of capacity.

The Metric System was legalized in the United States on July 28, 1866, when Congress enacted as follows:

"The tables in the schedule hereto annexed shall be recognized in the construction of contracts, and in all legal proceedings, as establishing, in terms of the weights and measures now in use in the United States, the equivalents of the weights and measures expressed therein in terms of the metric system, and the tables may lawfully be used for computing, determining, and expressing in customary weights and measures the weights and measures of the metric system."

The following are the tables annexed to the above:

MEASURES OF LENGTH.

Metric Denominations and Values.		Equivalents in Denominations in Use.	
Myriametre	10,000 metres.	6.2137	miles.
Kilometre	1,000 metres.	0.62137	mile, or 3,280 feet 10 inches.
Hectometre	100 metres.	328	feet 1 inch.
Dekametre	10 metres	393.7	inches.
Metre	1 metre.	39.37	inches.
Decimetre	1-10 of a metre.	3.937	inches.
Centimetre	1-100 of a metre.	0.3937	inch.
Millimetre	1-1000 of a metre.	0.0394	inch.

MEASURES OF SURFACE.

Metric Denominations and Values.		Equivalents in Denominations in Use.	
Hectare	10,000 square metres.	2.471	acres.
Are	100 square metres.	119.6	square yards.
Centare	1 square metre.	1,550	square inches

MEASURES OF CAPACITY.

Metric Denominations and Values.			Equivalents in Denominations in Use.	
Names.	Number of Litres.	Cubic Measure.	Dry Measure.	Liquid or Wine Measure.
Kilolitre or stere.	1-000	1 cubic metre	1.308 cubic yards	264.17 gallons.
Hectolitre	100	1-10 of a cubic metre.	2 bush. and 3.35 pecks	26.417 gallons.
Dekalitre	10	10 cubic decimetres	0.08 quarts	2.6417 gallons.
Litre	1	1 cubic decimetre	0.908 quart	1.0567 quarts.
Decilitre	1-10	1-10 of a cubic decimetre.	6.1022 cubic inches	0.845 gill.
Centilitre	1-100	10 cubic centimetres	0.6102 cubic inch	0.338 fluid ounce.
Millilitre	1-1000	1 cubic centimetre	0.061 cubic inch	0.27 fluid dram.

WEIGHTS.

Metric Denominations and Values.			Equivalents in Denominations in Use.
Names.	Number of Grams.	Weight of what Quantity of Water at Maximum Density.	Avoirdupois Weight.
Miller or tonneau	1,000,000	1 cubic metre	2204.6 pounds.
Quintal	100,000	1 hectolitre	220.46 pounds.
Myriagram	10,000	10 litres	22.046 pounds.
Kilogram or kilo	1,000	1 litre	2.2046 pounds.
Hectogram	100	1 decilitre	3.5274 ounces.
Dekagram	10	10 cubic centimetres	0.3527 ounce.
Gram	1	1 cubic centimetre	15.432 grains.
Decigram	1-10	1-10 of a cubic centimetre	1.5432 grains.
Centigram	1-100	10 cubic millimetres	0.1543 grain.
Milligram	1-1000	1 cubic millimetre	0.0154 grain.

PRACTICAL MEASUREMENTS.

TO ASCERTAIN THE WEIGHT OF CATTLE—Measure the girt close behind the shoulder, and the length from the fore part of the shoulder-blade along the back to the bone at the tail, which is in a vertical line with the buttock, both in feet. Multiply the square of the girt, expressed in feet, by ten times the length, and divide the product by three; the quotient is the weight, nearly, of the fore quarters, in pounds avoirdupois. It is to be observed, however, that in very fat cattle the fore quarters will be about one-twentieth more, while in those in a very lean state they will be one-twentieth less than the weight obtained by the rule.

RULES FOR MEASURING CORN IN CRIB, VEGETABLES, ETC., AND HAY IN MOW—This rule will apply to a crib of any size or kind. Two cubic feet of good, sound, dry corn in the ear will make a bushel of shelled corn. To get, then, the quantity of shelled corn in a crib of corn in the ear, measure the length, breadth and height of the crib, inside the rail; multiply the length by the breadth and the product by the height, then divide the product by two, and you have the number of bushels of shelled corn in the crib.

To find the number of bushels of apples, potatoes, etc., in a bin, multiply the length, breadth and thickness together, and this product by eight, and point off one figure in the product for decimals.

To find the amount of hay in a mow, allow 512 cubic feet for a ton, and it will come out very generally correct.

TO MEASURE BULK WOOD—To measure a pile of wood multiply the length by the width, and that product by the height, which will give the number of cubic feet. Divide that product by 128, and the quotient will be the number of cords. A standard cord of wood, it must be remembered, is four feet thick; that is, the wood must be four feet long. Farmers usually go by surface measure, calling a pile of stove wood eight feet long and four feet high a cord. Under such circumstances thirty-two feet would be the divisor.

HOW TO MEASURE A TREE—Very many persons, when looking for a stick of timber, are at a loss to estimate either the height of the tree or the length of timber it will cut. The following rule will enable any one to approximate nearly to the length from the ground to any position desired on the tree: Take a stake, say six feet in length, and place it against the tree you wish to measure. Then step back some rods, twenty or more if you can, from which to do the measuring. At this point a light pole and a measuring rule are required. The pole is raised between the eyes and the tree, and the rule is brought into position against the pole. Then by sighting and observing what length of the rule is required to cover the stake at the tree, and what the entire tree, dividing the latter length by the former and multiplying by the number of feet the stake is long, you reach the approximate height of the tree. For example, if the stake at the tree be six feet above ground and one inch on your rule corresponds exactly with this, and if then the entire height of the tree corresponds exactly with say nine inches on the rule, this would show the tree to possess a full height of fifty-four feet. In practice it will thus be found an easy matter to learn the approximate height of any tree, building, or other such object.

TO MEASURE CASKS OR BARRELS—Find mean diameter by adding to head diameter two-thirds (if staves are but slightly curved, three-fifths) of difference between head and bung diameters, and dividing by two. Multiply square of mean diameter in inches by .7854, and the product by the height of the cask in inches. The result will be the number of cubic inches. Divide by 231 for standard or wine gallons, and by 282 for beer gallons.

GRAIN MEASURE—To find the capacity of a bin or wagon-bed, multiply the cubic feet by .8 (tenths). For great accuracy, add 1/3 of a bushel for every 100 cubic feet. To find the cubic feet, multiply the length, width and depth together.

To Measure Corn or Similar Commodity on a Floor —Pile up the commodity in the form of a cone; find the diameter in feet; multiply the square of the diameter by .7854, and the product by one-third the height of the cone in feet; from this last product deduct one-fifth of itself, or multiply it by .803564, and the result will be the number of bushels.

CAPACITY OF CYLINDRICAL CISTERNS OR TANKS FOR EACH FOOT OF DEPTH (UNITED STATES GALLONS) FROM TWO TO FORTY FEET IN DIAMETER.

CAPACITY OF DRAIN-PIPE.

Size of Pipe.	Gallons Per Minute.							
	½ in. Fall per 100 feet.	3-in. Fall per 100 feet.	6-in. Fall per 100 feet.	9-in. Fall per 100 feet.	12-in. Fall per 100 feet.	18-in. Fall per 100 feet.	24-in. Fall. per 100 feet.	36-in. Fall per 100 feet.
3-inch.	21	30	42	52	60	74	85	104
4 "	36	52	76	92	108	132	148	184
6 "	84	120	169	206	240	294	338	414
9 "	232	330	470	570	660	810	930	1140
12 "	470	680	960	1160	1360	1670	1920	2350
15 "	830	1180	1680	2040	2370	2920	3340	4100
18 "	1300	1850	2630	3200	3740	4600	5270	6470
20 "	1760	2450	3450	4180	4860	5980	6850	8410

Diameter in feet	Gallons	Pounds	Diameter in feet	Gallons	Pounds
2.0	23.5	196	9.0	475.9	3.968
2.5	36.7	306	9.5	530.2	4.421
3.0	52.9	441	10.0	587.5	4.899
3.5	72.0	600	11.0	710.9	5.928
4.0	94.0	784	12.0	846.0	7.054
4.5	119.0	992	13.0	992.9	8.280
5.0	146.9	1,225	14.0	1.151.5	9.602
5.5	177.7	1.482	15.0	1,321.9	11.023
6.0	211.5	1,764	20.0	2,350.1	19.596
6.5	248.2	2,070	25.0	3,672.0	30.620
7.0	287.9	2.401	30.0	5.287.7	44.093
7.5	330.5	2,756	35.0	7.197.1	60.016
8.0	376.0	3.135	40.0	9.400.3	78.388
8.5	424.6	3.540	.....	....	.....

For square or rectangular tanks, multiply the length and breadth and depth together to get cubic feet, then multiply by 1,728 to get cubic inches, and this product, divided by 231, the number of cubic inches in a gallon, will give the number of gallons.

QUANTITY OF WATER DISCHARGED PER STROKE BY A SINGLE ACTING PUMP.

The first column of figures indicates the diameter of the pump cylinder in inches. The second column gives the area of the cylinder.

Diam. of Cyl. Ins.	Area Square Inches	LENGTH OF STROKE IN INCHES											
		2	3	4	5	6	7	8	9	10	12	14	15
		Capacity per Stroke in Gallons											
½	196	.0017	.0026	.0034	004	.005	.006	.007	.008	.009	.010	.012	.013
1	.785	.0070	.0100	.0140	017	.020	.024	.027	.031	.034	.041	.048	.051
1¼	1.227	.0100	.0160	.0210	.027	.032	.037	.042	.048	.053	.064	.074	.080
1⅜	1 485	.0130	.0190	.0250	032	.038	.044	.051	.058	.064	.077	.089	.096
1½	1.767	.0150	.0230	.0310	038	.046	.053	.061	.069	.077	.092	.107	.115
1¾	2 405	.0210	.0310	.0410	.052	.063	.073	.083	.094	.104	.125	.146	.156
2	3.142	.0270	.0410	.0540	.068	.082	.095	.109	.122	.136	.163	.190	.204
2¼	3.976	.0340	.0510	.0690	.086	.103	.120	.138	.155	.172	.206	.241	.258
2½	4.909	.0420	.0640	.0850	.106	.128	.149	.170	.191	.213	.255	.297	.319
2¾	5.940	.0510	.0770	.1030	.128	.154	.180	.206	.231	.257	.308	.360	.385
3	7.069	.0610	.0920	.1220	.153	.184	.214	.245	.275	.306	.367	.428	.459
3¼	8.296	.0720	.1080	.1430	.180	.215	.251	.287	.323	.359	.431	.503	.538
3¾	11.045	.0950	.1430	.1910	.239	.287	.334	.382	.430	.478	.573	.669	.717
4	12 566	.1090	.1630	.2170	.272	.326	.381	.435	.490	.544	.653	.761	.816
4¼	14 186	.1230	.1840	.2450	.307	.368	.430	.491	.552	.614	.737	.860	.921
4¾	17 721	.1530	.2300	.3070	.383	.460	.537	.614	.690	.767	.920	1.073	1.150
5	19.635	.1700	.2550	.3400	.425	.510	.595	.680	.765	.850	1.020	1.190	1.275
5¼	21.648	.1870	.2810	.3750	.468	.562	.656	.750	.843	.937	1 124	1.311	1.405
5¾	25 967	.2250	.3370	.4500	.562	.674	.787	.899	1.011	1 124	1.348	1.573	1.686
6	28 274	.2450	.3670	.4900	.612	.734	.857	.979	1.101	1 [illegible]24	1.469	1.713	1.836
6¼	30.680	.2660	.3980	.5310	.664	.797	.930	1.062	1.195	1 328	1 593	1.859	1.992
6¾	35 785	.3100	.4650	.6200	.774	.929	1 084	1.239	1 394	1.549	1.858	2 168	2.323
7	38 485	.3330	.5000	.6660	.833	1.000	1.166	1.333	1.499	1 666	1.999	2.332	2 499
7½	44.179	.3830	.5740	.7650	.956	1.148	1.339	1.530	1.721	1.913	2 295	2.678	2.869
7¾	47.173	.4080	.6120	.8170	1.021	1.225	1.429	1.633	1 837	2 042	2 450	2 858	3 063
8	50 266	.4350	.6530	.8700	1.088	1 306	1.523	1.741	1.958	2 176	2 611	3 046	3 264
8½	56.745	.4900	.7350	.9800	1.225	1.470	1.715	1.960	2.205	2.450	2 940	3 430	3 675
9	63 617	.5510	.8260	1.1010	1.377	1.652	1 928	2.203	2.478	2 754	3.305	3.855	4.131
9½	70.882	.6120	.9180	1.2240	1.530	1.830	2.142	2 448	2 754	3.060	3 672	4 284	4 590
10	78.540	.6800	1.0200	1.3600	1.700	2 040	2.380	2 720	3 060	3 400	4 080	4.760	5.100
11	95.033	.8230	1 2340	1 6450	2.057	2.464	2.879	3.291	3.726	4.114	4 937	5.760	6 171
12	113.098	.9790	1.4680	1.9580	2 448	2.938	3.422	3 917	4.406	4.896	5.875	6 854	7 344

For strokes, two, three or any number of times the lengths given above, the capacities may be found by simply multiplying the number of times, into the quantities per stroke given above. Doubling the diameter of pipe or cylinder increases its capacity four times.

QUANTITY OF WATER DICHARGED AND POWER REQUIRED

At different elevations based on a Pump efficiency of 50 per cent.

Lift in feet	½ H. P.	1 H. P.	3 H. P.	5 H. P.	7 H. P.	10 H. P.	15 H. P.	20 H. P.	30 H. P.	40 H. P.	50 H. P.
	GALLONS PER MINUTE										
10	100	200	600	1000	1400	2000	3000	4000	6000	8000	10000
20	50	100	300	500	700	1000	1500	2000	3000	4000	5000
30	33	66	200	333	466	666	1000	1333	2000	2666	3333
40	25	50	150	250	350	500	750	1000	1500	2000	2500
50	20	40	120	200	280	400	600	800	1200	1600	2000
60	16	33	100	166	233	333	500	666	1000	1332	1666
70	14	28	85	140	200	286	420	572	850	1144	1428
80	12	25	76	125	175	250	375	500	750	1000	1250
90	....	22	66	111	155	222	333	444	666	888	1111
100	....	20	60	100	140	200	300	400	600	800	1000
125	....	....	48	80	112	160	240	320	480	640	800
150	....	....	40	66	93	133	200	266	400	532	666
175	....	....	34	57	80	114	171	228	343	456	572
200	....	....	30	50	70	100	150	200	300	400	500
250	....	....	....	40	56	80	120	160	240	320	400
300	....	....	....	33	46	66	100	133	200	266	333
350	....	....	....	28	40	57	85	114	171	228	285

Doubling the lift or quantity of water handled also doubles power required; i., e, power required varies directly as either lift or quantity.

HEAD OF WATER IN FEET AND THE EQUIVALENT PRESSURE IN POUNDS

Feet Head	Lbs. Press.	Feet Head	Lbs. Press.	Feet Head	Lbs. Press.
5	2.17	70	30.3	200	86.6
10	4.33	80	34.6	250	108.2
15	6.50	90	39.0	300	129.9
20	8.66	100	43.3	350	151.5
25	10.83	110	47.6	400	173.2
30	12.99	120	52.0	500	216.5
35	15.16	130	56.3	600	259.8
40	17.32	140	60.6	700	303.1
45	19.49	150	65.0	800	346.4
50	21.65	160	69.2	900	389.7
60	26.09	180	78.0	1000	433.0

PRESSURE OF WATER IN POUNDS AND THE EQUIVALENT HEAD IN FEET

Lbs. Press.	Feet Head	Lbs. Press.	Feet Head	Lbs. Press.	Feet Head
5	11.5	70	161.6	180	415.6
10	23.0	80	184.7	190	438.9
15	34.6	90	207.8	200	461.7
20	46.2	100	230.9	225	519.5
25	57.7	110	253.9	250	577.2
30	69.3	120	277.0	275	643.0
35	80.8	130	300.1	300	692.7
40	92.3	140	323.2	325	750.4
45	103.9	150	346.3	350	808.1
50	115.4	160	369.4	400	922.6
60	138.5	170	392.3	500	1154.5

TABLE FOR OPEN WEIR MEASUREMENT

Giving Cubic Feet of water per minute, that will flow over an open Weir one inch wide and from ⅛ to 20⅞ inches deep.

INCHES.		⅛	¼	⅜	½	⅝	¾	⅞
0	.00	.01	.05	.09	.14	.19	.26	.32
1	.40	.47	.55	.64	.73	.82	.92	1.02
2	1.13	1.23	1.35	1.46	1.58	1.70	1.82	1.95
3	2.07	2.21	2.34	2.48	2.61	2.76	2.90	3.05
4	3.20	3.35	3.50	3.66	3.81	3.97	4.14	4.30
5	4.47	4.64	4.81	4.98	5.15	5.33	5.51	5.69
6	5.87	6.06	6.25	6.44	6.62	6.82	7.01	7.21
7	7.40	7.60	7.80	8.01	8.21	8.42	8.63	8.83
8	9.05	9.26	9.47	9.69	9.91	10.13	10.35	10.57
9	10.80	11.02	11.25	11.48	11.71	11.94	12.17	12.41
10	12.64	12.88	13.12	13.36	13.60	13.85	14.09	14.34
11	14.59	14.84	15.09	15.34	15.59	15.85	16.11	16.36
12	16.62	16.88	17.15	17.41	17.67	17.94	18.21	18.47
13	18.74	19.01	19.29	19.56	19.84	20.11	20.39	20.67
14	20.95	21.23	21.51	21.80	22.08	22.37	22.65	22.94
15	23.23	23.52	23.82	24.11	24.40	24.70	25.00	25.30
16	25.60	25.90	26.20	26.50	26.80	27.11	27.42	27.72
17	28.03	28.34	28.65	28.97	29.28	29.59	29.91	30.22
18	30.54	30.86	31.18	31.50	31.82	32.15	32.47	32.80
19	33.12	33.45	33.78	34.11	34.44	34.77	35.10	35.44
20	35.77	36.11	36.45	36.78	37.12	37.46	37.80	38.15

In making Weir measurements, place a board or plank in the stream at the point so that a pond will form above it. A rectangular notch is cut in it large enough so that all the water will flow over the notch. The length of the notch should be from two to four times its depth. The edges should be beveled to slope outward in the direction of the flow of the water. In the pond about six feet above the Weir a stake is driven so that its top is precisely level with the bottom of the notch, and at some convenient point for measuring. The depth of the water flowing over the Weir may then be ascertained by an ordinary rule, placed on top of the stake, measuring to the surface of the water, and the quantity figured from the table above

IRRIGATION QUANTITY TABLES

Amount of water required to cover one acre to given depths.			Second Feet reduced to Gallons and Acre Feet.				Gallons required to cover a given number of acres to a depth of one foot. (Acre foot.)	
Depth in inches and feet. (Acre inches and acre feet.)	Cubic feet (or second feet) contained in one acre to depths given in first column.	Gallons.	Second feet.	Gallons per minute.	Gallons per pumping day of 12 hours.	Acre feet per pumping day of 12 hours.	Acres (or number of acre feet.)	Gallons.
1 in.	3630	27154	¼	112.2	80790	.2479	1	325851
2 in.	7260	54309	½	224 4	161579	.4959	2	651703
3 in.	10890	81463	¾	336.6	242369	:7438	3	977554
4 in.	14520	108617	1	448.8	323158	.9917	4	1303406
5 in.	18150	135771	1¼	561.0	403948	1 2397	5	1629257
6 in.	21780	162926	1½	673.2	484738	1 4876	6	1955109
7 in.	25410	190080	1¾	785.5	565527	1 7355	7	2280960
8 in.	29040	217234	2	897.7	646317	1 9835	8	2606812
9 in.	32670	244389	2½	1122 1	807896	2.4793	9	2932663
10 in.	36300	271542	3	1346.5	969475	2 9752	10	3258515
11 in.	39930	298697	4	1795 3	1292634	3.9669	15	4887772
1 ft., 00 in.	43560	325851	5	2244.2	1615792	4 9586	20	6512029
1 ft., 2 in.	50820	380160	6	2693 0	1938951	5 9503	25	8146286
1 ft., 4 in.	58080	434469	7	3141.8	2262109	6.9421	30	9775544
1 ft., 6 in.	65340	488777	8	3590.6	2585268	7 9338	40	13034058
1 ft., 8 in.	72600	543086	9	4039.5	2908426	8.9255	60	19551087
1 ft., 10 in.	79860	597394	10	4488.3	3231585	9.9173	80	26068116
2 ft., 00 in.	87120	651703	20	8976.6	6463170	19.8345	160	62136232

One cubic foot of water per second (exact 7.48052 gallons), constant flow is known as the "Second Foot." The "Acre Foot" is the quantity of water required to cover one acre to a depth of one foot.

MISCELLANEOUS HYDRAULIC INFORMATION, ETC.

A common water pail holds nineteen pounds of water, or 2.272 United States gallons.

One horse-power will raise 16½ tons per minute a height of 12 inches, working 8 hours a day. This is about 9,900 foot-tons daily, or 12 times a man's work.

In Designing Hydraulic and Pumping Machinery, water is considered as incompressible.

"Head"—By "Head" is meant the actual elevation from the surface of suction water to highest point of discharge, plus the friction head, caused by flow of water through suction and discharge piping—often referred to simply as "lift" or "suction lift" and "discharge lift."

"Pressure"—To find the pressure due to the head, when water is at rest simply multiply the vertical height in feet, of the column of water, by .434. A quicker way to approximate is to divide the vertical height in feet by 2. The result is the pressure in pounds per square inch on retaining walls at bottom of water column, or plunger load.

A Double-Acting Pump discharges water on both forward and backward motions of piston, and has double the capacity of a Single-acting Pump.

A Triplex Pump is a three-cylinder Pump. The Cylinders are either Single or Double-acting. The discharge of a Triplex Pump is practically uniform and without pulsation.

To Find the Circumference of a Circle: Multiply the diameter by 3.1416.

Finding Capacities:—Of a Single-acting Pump: Multiply the square of the Cylinder diameter in inches by .7854, and by the length of stroke in inches. This product divided by 231 gives the capacity in gallons per stroke. Doubling the diameter of a Cylinder increases its capacity four times.

To find the number of gallons in a tank, multiply the inside bottom diameter in inches by the inside top diameter in inches, then this product by 34, point off four figures, and the result will be the average number of gallons to one inch in depth of tank.

For the circumference of a circle, multiply the diameter by 3.1416.

For the diameter of a circle, multiply the circumference by .31381.

For the area of a circle, multiply the square of the diameter by .7854.

For the size of an equal square, multiply the diameter by .8862.

For the surface of a ball, multiply the square of the diameter by 3.1416.

For the cubic inches in a ball, multiply the cube of the diameter by .5236.

SHORT FORMULAS FOR PUMP CAPACITY AND POWER

D—Diameter of Pump Cylinder in inches. S—Length of stroke in inches.
N—Number of strokes per minute. Q—Quantity of water in gallons, raised per minute.
H—Total height, in feet, water is elevated, figuring from surface of suction water to highest point of discharge.

THEN WE HAVE

$D^2 \times .7854$	—The Area of a Circle (or Cylinder) of given diameter.
$D^2 \times S \times .7854$	—Capacity of Pump in cubic inches, per stroke.
$\frac{D^2 \times S}{294}$	—Capacity of Pump per stroke in gallons.
$\frac{D^2 \times S}{2200.152}$	—Capacity of Pump per stroke in cubic feet.
$\frac{D^2 \times S}{35.266}$	—Capacity of Pump per stroke in pounds of water.
$D^2 \times S \times .7854 \times N$	—Capacity of Pump per minute in cubic inches.
$\frac{D^2 \times S \times N}{294}$	—Capacity of Pump per minute in gallons, (= Q).
$\frac{D^2 \times S \times N}{2200.152}$	—Capacity of Pump per minute in cubic feet.
$D^2 \times H \times .3409$	—Total pressure in pounds on the Pump Cylinder when at rest. When at work, add for pipe friction as determined from tables elsewhere.
$\frac{Q}{D^2 \times S \times .0034}$	—Number of strokes per minute necessary to raise a given quantity of water in gallons.

The above formulas will give results correct to the third decimal place.

HOW TO USE CEMENT.

The following general rules referring to the practical use of cement will be found convenient for reference:

Quality of Sand—The sand should be clean, sharp and coarse. When the sand is mixed with loam the mortar will set comparatively slow, and the work will be comparatively weak. Fine sand, and especially water-worn sand, delays the setting of the cement, and deteriorates strength. Damp sand should not be mixed with dry cement, but the cement and sand should be mixed thoroughly and uniformly together, when both are dry, and no water should be applied until immediately before the mortar is wanted for use.

Proportion of Sand—The larger the proportion of cement the stronger the work. One part of good cement to two parts sand is allowable for ordinary work; but for cisterns, cellars, and work requiring special care, half and half is the better proportion. For floors, the cement should be increased toward the surface.

Water in Concrete—Use no more water in cement than absolutely necessary. Cement requires but a very small quantity of water in crystalizing. Merely dampening the material gives the best results. Any water in excess necessarily evaporates and leaves the hardened cement comparatively weak and porous.

Concrete in Water—Whenever concrete is used under water, care must be taken that the water is still. So say all English and American authorities. In laying cellar floors, or constructing cisterns or similar work, care must also be taken to avoid *pressure of exterior water.* Cement will not crystalize when disturbed by the force of currents, or pressure of water, but will resist currents and pressure after hardening only. In still water, good cement will harden quicker than in air, and when kept in water will be stronger than when kept in air. Cements which harden especially quick in air are usually slow or worthless in water.

How to Put Down Concrete—When strong work is wanted, for cellar floors and all similar work, the concrete should be dampened and tamped down to place, with the back of a spade, or better, with the end of a plank or rammer; then finished off with a trowel, thus leveling and compacting the work. Only persons ignorant of the business will lay a floor or walk with soft cement mortar. All artificial stone is made in a similar way to that described, and, when set, is strong and hard as stone.

Delay in Use—Do not permit the mortar to exhaust its setting properties by delaying its use when ready. Inferior cements only will remain standing in the mortar-bed any length of time without serious injury.

Stone and Brick Work—In buildings constructed of stone or brick, the best protection from dampness and decay, and also from the danger of cyclones, is a mortar of cement and coarse sand. The extra cost is inconsiderable, and the increased value of the structure very great. Chimneys laid in this manner never blow down, and cellars whose foundations are thus laid are always free from atmospheric moisture. Cement may also be mixed with lime mortar for plastering and other purposes, to great advantage.

Effect of Frost and Cold—At a temperature less than 60 degrees Fahrenheit, all good cement sets slowly, though surely, but if allowed to freeze its value is seriously impaired. In cold weather or cold water do not fear to wait for your concrete to crystalize.

Damage from Moisture—Good cement is not injured by age, if carefully preserved from moisture. Lumps in bags or barrels of cement are caused by exposure to moisture. They prove the originally good quality of the cement.

WEATHER FORECASTS.

Almanac predictions can be nothing but conjecture, the earth's subjection to many unknowable and undeterminable forces rendering such calculations impossible. It is practicable, however, by the following rules, drawn from actual results during very many years and applied with due regard to the subjects of solar and lunar attraction with reference to this planet, to foresee the kind of weather *most likely* to follow the moon's change of phase.

PROGNOSTICATIONS.

If New Moon First Qr., Full Moon or Last Qr. happens	In Summer	In Winter.
Between midnight and 2 A.M.	Fair	Frost, unless wind is S. W.
" 2 " 4 "	Cold and showers.....	Snow and stormy.
" 4 " 6 "	Rain.................	Rain.
" 6 " 8 "	Wind and rain........	Stormy.
" 8 " 10 "	Changeable	Cold rain if wind W., snow if [E.
" 10 " 12 "	Frequent showers.....	Cold and high wind.
" 12 " 2 P.M.	Very rainy	Snow or rain.
" 2 " 4 "	Changeable	Fair and mild.
" 4 " 6 "	Fair.................	Fair.
" 6 " 8 "	Fair if wind N. W	Fair and frosty if wind N. or N. [E.
" 8 " 10 "	Rainy if S. or S. W...	Rain or snow if S. or S. W.
" 10 " midn't.	Fair.................	Fair and frosty.

OBSERVATIONS.—1. The nearer the moon's change, first quarter, full and last quarter *to midnight*, the fairer will be the weather during the next seven days.

2. The space for this calculation occupies from ten at night till two next morning.

3. The nearer to *midday* or *noon* the phase of the moon happens, the more foul or wet weather may be expected during the next seven days.

4. The space for this calculation occupies from ten in the forenoon to two in the afternoon. These observations refer principally to summer, though they affect spring and autumn in the same ratio.

5. The moon's change, first quarter, full and last quarter happening during six of the afternoon hours, *i. e.*, from four to ten, may be followed by fair weather, but this is mostly dependent on the *wind* as is noted in the table.

6. Though the weather, from a variety of irregular causes, is more uncertain in the latter part of autumn, the whole of winter and the beginning of spring, yet, in the main, the above observations will apply to these periods also.

7. To prognosticate correctly, especially in those cases where the *wind* is concerned, the observer should be within sight of a *vane* where the four cardinal points of the compass are correctly placed

POWER REQUIRED TO RAISE WATER: To find the Theoretical Horse Power to raise water, multiply the Gallons pumped per Minute by the Head in feet and divide the product by 4000 and the result will be the Theoretical Power required. Double the Theoretical Power should be allowed to do the work, although the better grades of Steam and Power Pumps use much less than this.

DUTY OF PUMPING ENGINES is a ratio of the work done by the Pump to the Steam or Fuel consumed, and is usually expressed in millions of foot-pounds per 1000 pounds of steam used.

THE PIPING OF PUMPS is a much more important matter than is commonly thought.

SUCTION PIPES should be short and straight as possible, of ample size and arranged to have no "pockets" where air can collect, and must be made up absolutely air-tight. Long Suctions or High Lifts should always have a Vacuum Chamber at the Pump.

DISCHARGE PIPES should be as large and as straight as possible, to avoid loss of power in overcoming the friction. The friction through one common Elbow is equal to that through 60 feet of straight pipe.

A MINER'S INCH of water is the volume flowing per minute through a square inch of opening under a fixed head—usually 6 inches, and varies from 10 to 12 gallons per minute. The only legal "Miner's Inch" we know of in the United States is the Idaho inch, which is the amount of water flowing through an opening one inch square under a four-inch pressure or head of water above the center of opening.

TO FIND THE SPEED OR SIZE OF PULLEYS:

To find the Diameter of the driving pulley: Multiply the diameter of the driven pulley by its speed and divide the product by the speed of the driving pulley.

To find the Speed of the driving pulley: Multiply the diameter of the driven pulley by its speed and divide the product by the diameter of the driving pulley.

To find the Diameter of the driven pulley: Multiply the diameter of the driving pulley by its speed and divide the product by the speed of the driven pulley.

To find the Speed of the driven pulley: Multiply the diameter of the driving pulley by its speed and divide the product by the diameter of the driven pulley.

SPEED OF GEARING is estimated in same way, substituting the *number of gear teeth* for "diameter".