compounds. Similarly soils with less than ∙1% of nitrogen are likely to be benefited by applications of nitrogenous manures. Too much stress, however, cannot be laid upon these figures, since the fertility of a soil is very greatly influenced by texture and physi­cal constitution, perhaps more so by these factors than by chemical composition.

At present it is not possible to determine with accuracy the amount of immediately available plant food-constituents in a soil: no doubt the various species of plants differ somewhat in their power of absorbing these even from the same soil. The method introduced by Dyer of dissolving out the mineral constituents of the soil with a 1 % solution of citric acid, which represents about the average acidity of the roots of most common plants, yields better results. In the case of arable soils, where the amount of phosphoric acid determined by this method falls below ∙01 %, phosphatic manuring is essential for good crops. The writer has found that many pasture soils containing less than ∙025 or ∙03 %, respond freely to applications of phosphates; probably in such cases even the weak acid is capable of dissolving out phosphates from the humus or other compounds which yield little or none to the roots of grasses and clovers. In soils where the potash available to citric acid is less than ∙005 %, .kainit and other potash fertilizers are needed.

*Water in the Soil.—*The importance of an adequate supply of water to growing crops cannot well be over-estimated. During the life of a plant there is a continuous stream of water passing through it which enters by the root-hairs in the soil and after passing along the stem is given off from the stomata of the leaves into the open air above ground. It has been estimated that an acre of cabbage will absorb from the land and transpire from its leaves more than ten tons of water per day when the weather is fine.

In addition to its usefulness in maintaining a turgid state of the young cells without which growth cannot proceed, water is itself a plant f∞d-material and as absorbed from the soil contains dissolved in it all the mineral food constituents needed by plants for healthy nutrition. .Without.a sufficient supply plants remain stunted and the crop yield is seriously reduced, as we see in dry seasons when the rainfall is much below the average. If one condition is more necessary than another for good crops it is a suitable supply of water, for no amount of manuring or other treatment of the soil will make up for a deficient rainfall. The amount needed for the most satisfactory nutrition varies with different plants. In the case of fair average farm crops it has been shown that for the production of one ton of dry matter contained in them from 300 to 500 tons of water has been absorbed and utilized by the plants. This may be more than the rainfall, in which case irrigation or special control of the water supply may be necessary.

The water-holding capacity of a soil depends upon the amount of free space betwτeen the particles of which it is composed into which water can enter. In most cases this amounts to from 30 to 50% of the volume of the soil.

When the pore-space of the soil is filled with water it becomes water-logged and.few plants can effect absorption by their roots under such conditions. The root-hairs die from want of air, and the whole plant soon suffers. Fields of wheat and other cereals rarely recover after a week’s submergence, but orchards and many trees when at rest in winter withstand a flooded or water-logged condition of the soil for two or three weeks without damage. The most satisfactory growth is maintained when the amount of water present is not more than 40 to 60% of what would saturate it. Under such conditions each particle of soil is surrounded by a thin film of water and in the pore-space air can freely circulate. It is from such films that the root-hairs absorb all that plants require for their growth. The movement of water into the root-hairs is brought about by the osmotic action of certain salts in their cell-sap. Crops are, however, unable to absorb all the water present in the soil, for when the films become very thin they are held more firmly or cling with more force to the soil particles and resist the osmotic action of the root-hairs. Plants have been found to wither, and die in sandy soils containing 1½% of water, and in clay soils in which there was still present 8 % of water.

When a long glass tube open at both ends is filled with soil and one end is dipped in a shallow basin of water, the water is found to move upwards through the soil column just as oil will rise in an ordinary lamp wick. By this capillary action water may be trans­ferred to the upper layers of the soil from a depth of several feet below the surface. In this manner plants whose roots descend but a little way in the ground are enabled to draw on deep supplies. Not only does water move upwards, but it is transferred by capil­larity in all directions through the soil. The amount and speed of movement of water by this means, and the distance to which it may be carried, depend largely upon the fineness of the particles composing the soil and the spaces left between each.. The ascent of water is most rapid through coarse sands, but the height to which it will rise is comparatively small. In clays whose particles are exceedingly minute the water travels very slowly but may ultimately reach a height of many, feet above the level of the “ water-table ” below. While this capillary movement of water is of great impor­tance in supplying the needs of plants it has its disadvantages, since water may be transferred to the surface of the soil, where it evapo­rates into the.air and is lost to the land or the crop growing upon it. The loss in this manner was found to be in one instance over a pound of water per day per square foot of surface, the “ water-table ” being about 4 or 5 ft. below.

One of the most effective means of conserving soil moisture is by “ mulching,” *i.e.* by covering the surface of the soil with some loosely compacted material such as straw, leaf-refuse or stable­manure. The space between the parts of such substances is too large to admit of capillary action; hence the water conveyed to the surface of the soil is prevented from passing upwards any further except by slow evaporation through the mulching layer. A loose layer of earth spread over the surface of the soil acts in the same way, and a similarly effective mulch may be prepared by hoeing the soil, or stirring it to a depth of one or two inches with harrows or other implements. The hoe and harrow are therefore excellent tools for use in dry weather.. Rolling the land is beneficial to young crops in dry weather, since it promotes capillary action by reducing the soil spaces. It should, however, be followed by a light hoeing or harrowing.

In the semi-arid regions of the United States, Argentina and other countries where the average annual rainfall lies between 10 to 20 in., irrigation is necessary to obtain full crops every year. Good crops, however, can often be grown in such areas without irrigation if attention is paid to the proper circulation of water in the soil and means for retaining it or preventing excessive loss by evaporation. Of course care must be exercised in the selection of plants—such as sorghum, maize, wheat, and alfalfa or lucerne— which are adapted to dry conditions and a warm climate.

So far as the water-supply is concerned—and this is what ulti­mately determines the yield of crops—the rain which falls upon the soil should be made to enter it and percolate rapidly through its interstices. A .deep porous bed in the upper layérs is essential, and this should consist of fine particles which lie close to each other without any tendency to stick together and “ puddle ” after heavy showers. Every effort, should be made to prepare a good mealy tilth by suitable ploughing, harrowing and consolidation.

In the operation of ploughing the furrow slice is separated from the soil below, and although in humid soils this layer may be left to settle by degrees, in semi-arid regions this loosened layer becomes dry if left alone even for a few hours and valuable water evaporates into the air. To prevent this various implements, such as disk harrows and specially constructed rollers, may be used to consolidate the upper stirred portion of the soil and place it in close capillary relationship with the lower unmoved layer. If the soil is allowed to become dry and pulverized, rain is likely to run off or “ puddle ” the surface without penetrating it more than a very short distance. Constant hoeing or harrowing to maintain a natural soil mulch layer of 2 or 3 in. deep greatly conserves the soil water below. In certain districts where the rainfall is low a crop can only be obtained once every alternate year, the intervening season being devoted to tillage with a view of getting the rain into the soil and retaining it there for the crop in the following year.

*Bacteria in the Soil.—*Recent science has made much progress in the investigation of the micro-organisms of the soil. Whereas the soil used to be looked upon solely as a dead, inert material con­taining certain chemical substances which serve as food constituents of the crops grown upon it, it is now known to be a place of habitation for myriads of minute living organisms upon whose activity much of its fertility depends. They are responsible for many important chemical processes which make the soil constituents more available and better adapted to the nutrition of crops. One cubic centimetre of soil taken within a foot or so from the surface contains from 1½ to 2 millions of bacteria of many different kinds, as well as large numbers of fungi. In the lower depths of the soil the numbers decrease, few being met with at a depth of 5 or 6 ft.

The efficiency of many substances, such as farm-yard manure, guanos, bone-meal and all. other organic materials, which are spread over or dug or ploughed into the land for the benefit of farm and garden crops, is bound up with the action of these minute living beings. Without their aid most manures would be useless for plant growth. Farm-yard manure, guanos and other fertilizers undergo decomposition in the soil and become broken down into compounds of simple chemical composition better suited for absorp­tion by the roots of crops, the changes involved being directly due to the activity of bacteria and fungi. Much of the work carried on by these organisms is not clearly understood; there are, however, certain processes which have been extensively investigated and to these it is necessary to refer.

It has been found by experiment that the nitrogen needed by practically all farm crops except leguminous ones is best supplied in the form of a nitrate ; the rapid effect of nitrate of soda when used as a top dressing to wheat or other plants is well known to farmers. It has long been known that when organic materials such as the dung and urine of animals, or even the bodies of animals and plants, are applied to the soil, the nitrogen within them becomes oxidized, and ultimately appears in the form of nitrate of lime, potash or some other base. The nitrogen in decaying roots, in the dead stems and leaves of plants, and in humus generally is sooner or later changed into a nitrate, the change being effected by bacteria. That