circumstances, or may need to be replenished or increased by additions to the soil of manures or fertilizers (see Manure).

*Chief Constituents of the Soil.—*An examination of the soil shows it to be composed of a vast number of small particles of sand, clay, chalk and humus, in which are generally imbedded larger or smaller stones. It will be useful to consider the nature of the four chief constituents just mentioned and their bearing upon the texture, water-holding capacity and other characters which were referred to in the previous section.

Sand consists of grains of quartz or flint, the individual particles of which are large enough to be seen with the unaided eye or readily felt as gritty grains when rubbed between the finger and thumb. When a little soil is shaken up with water in a tumbler the sand particles rapidly fall to the bottom and form a layer which resembles ordinary sand of the seashore or river banks. Chemically pure sand is silicon dioxide (SiO2) or quartz, a clear transparent glass-like mineral, but as ordinarily met with, it is more or less impure and generally coloured reddish or yellowish by oxide of iron. A soil consisting of sand entirely would be very loose, would have little capacity to retain water, would be liable to become very hot in the daytime and cool at night and would be quite unsuitable for growth of plants.

The term clay is often used by chemists to denote hydrated silicate of alumina (Al2O3∙2SiO2∙2H2O), of which kaolin or china clay is a fairly pure form. This substance is present in practically all soils but in comparatively small amounts. Even in the soils which farmers speak of as stiff clays it is rarely present to the extent of more than 1 or 2%. The word “clay” used in the agricultural sense denotes a sticky intractable material which is found to consist of exceedingly fine particles (generally less than .005 mm. in dia­meter) of sand and other minerals derived from the decomposition of rocks, with a small amount of silicate of alumina. The peculiar character which clay possesses is probably due not to its chemical composition but to its physical state. When wet it becomes sticky and almost impossible to move or work with farm implements; neither air nor water can penetrate freely. In a dry state it becomes hard and bakes to a brick. It holds water well and is consequently cold, needing the application of much heat to raise its temperature. It is obvious, therefore, that soil composed entirely of clay is as useless as pure sand so far as the growth of crops upon it is concerned.

Chalk consists, when quite pure, of calcium carbonate (CaCO3), a white solid substance useful in small amounts as a plant food­material, though in excess detrimental to. growth. Alone, even when broken up into small pieces, it is unsuitable for the growth of plants.

Humus, the remaining constituent of soil, is the term used for the decaying vegetable and animal matter in the soil. A good illustra­tion of it is peat. Its water-holding capacity is great, but it is often acid, and when dry it is light and incapable of supporting the roots of plants properly. Few of the commonly cultivated crops can live in a soil consisting mainly of humus.

From the above account it will be understood that not one of the four chief soil constituents is in itself of value for the growth of crops, yet when they are mixed, as they usually are in the soils met with in nature, one corrects the deficiencies of the other. A perfect soil would be such a blend of sand, clay, chalk and humus as would contain sufficient clay and humus to prevent drought, enough sand to render it pervious to fresh air and. prevent water­logging, chalk enough to correct the tendency to acidity of the humus present, and would have within it various substances which would serve as food-materials to the crops.

Generally speaking, soils containing from 30 to 50% of clay and 50 to 60% of sand with an adequate amount of vegetable residues prove the most useful for ordinary farm and garden crops; such blends are known as "loams,” those in which clay predominates being termed clay loams, and those in which the sand predominates sandy loams. "Stiff clays” contain over 50% of clay; “light sands ” have less than 10%. In the mechanical analysis of the soil, after separation of the stones and. fine gravel by means of sieves, the remainder of the finer earth is subjected to various processes of sifting and deposition from water with a view of determining the relative proportions of sand, silt and clay present in it. Most of the material termed “ sand ” in such analyses consists of particles ranging in diameter from ∙5 to ·05 mm., and the “ silt ” from ∙05 to ∙005 mm., the “clay” being composed of particles less than ·005 mm. in diameter. The proportional amount of these materials in a sandy soil on the Bagshot beds and a stiff Oxford clay is given below :—

|  |  |  |
| --- | --- | --- |
|  | Soil on  Bagshot Beds. | Soil on  Oxford Clay. |
| Coarse sand 1—2 mm. . | 32 % | 11 % |
| Fine sand ·2—·04 mm. | 40,, | II1»» |
| Silt ∙04-∙ 01 mm. | 12 „ | 19 »» |
| Fine silt ·oi—004 mm. | 8 „ | 19 .» |
| Clay below \*004 mm. | 8 „ | 40 »» |

The pore-space within the soil, *i.e.* the space between the parti­cles composing the soil, varies with the size of these particles and with the way they are arranged or packed. It is important, since upon it largely depends the movement of air and water in the land. It is generally from 30 to 50% of the total volume occupied by the soil.

Where the soil grains are quite free from each other the smaller grains tend to fill up the spaces between the larger ones; hence it might be concluded that in clays the amount of pore-space would be less than in coarser sands. This is the case in “puddled ” clays, but in ordinary clay soils the excessively minute particles of which they largely consist tend to form groups of comparatively large composite grains and it is in such natural soils that the pore-space is largest.

*Chemical Composition of the Soil.—*It has been found by experiment that plants need for their nutritive process and their growth, certain chemical elements, namely, carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, potassium, magnesium, calcium and iron. With the exception of the carbon and a small proportion of the oxygen and nitrogen, which may be partially derived from the air, these elements are taken from the soil by crops. The following table shows the amounts of the chief constituents removed by certain crops in lb per acre :—

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Crop. | Nitro­gen. | Phos­phoric Acid. | Potash. | Lime. | Mag­nesia. |
|  | ft | ft | ft | ft | ft |
| Wheat .... | 50 | 21 | 29 | 9 | 7 |
| Meadow hay | 49 | 12 | 51 | 32 | 14 |
| Turnips | no | 33 | 149 | 74 | 9 |
| Mangels . | 149 | 53 | 300 | 43 | 42 |

Plants also remove from the soil silicon, sodium, chlorine, and other elements which are, nevertheless, found to be unessential for the growth and may therefore be neglected here.

Leguminous crops take some of the nitrogen which they require from the air, but most plants obtain it from the nitrates present in the soil. The sulphur exists in the soil chiefly in the form of sulphates of magnesium, calcium and other metals; the phosphorus mainly as phosphates of calcium, magnesium and iron; the potash, soda and other bases as silicates and nitrates; calcium and magne­sium carbonates are also common constituents of many soils.

In the ordinary chemical analyses of the soil determinations are made of the nitrogen and various carbonates present as well as of the amount of phosphoric acid, potash, soda, magnesia and other components soluble in strong hydrochloric acid.

Below are given examples of the analyses of a poor sandy soil and an ordinary loam :—

|  |  |  |
| --- | --- | --- |
|  | Poor sandy Soil on Bagshot Beds. | Loam or Lias. |
| Nitrogen | •19 % | •17 % |
| Phosphoric acid | ∙ι8' | •32 „ |
| Potash | •19 >. | ‘57 »» |
| Carbonate of Lime | •23 „ | I∙22 „ |

Since the dry weight of the first foot of soil over an acre is about 4,000,000 lb the poor sandy soil contains within it :—

Nitrogen 7,600 lb

Phosphoric acid 7,200 ,,

Potash 7,600 „

Lime 9,200 ,,

From the figures given previously of the amount of nitrogen, potash and phosphoric acid removed by a wheat or mangel crop it would appear that this soil has enough of these ingredients in it to yield many such crops; yet experience has shown that these crops cannot be grown on such a poor sandy soil unless manures contain­ing phosphates, potash and nitrogen arc added.

Many attempts have been made to correlate the results of the analyses of a soil with its known cropping power, but there is yet much to be learnt in regard to these matters. A great proportion of the food constituents which can be extracted by strong hydro­chloric acid are not in a condition to be taken up by the roots of plants; they are present, but in a “ dormant ’’ state, although by tillage and weathering processes they may in time become “avail­able ” to plants. Analyses of this character would appear to indicate the permanent productive capacity of the soil rather than its immediate power of growing a crop.

Soils containing less than ∙25 *% of* potash are likely to need special application of potash fertilizers to give good results, while those containing as much as ∙4 or \*5% do not usually respond to those manures. Where the amount of phosphoric acid (P2O5) is less than ∙05% phosphatic manures are generally found to be beneficial; with more than ·1 % present these fertilizers are not usually called for except perhaps in soils containing a high percentage of iron