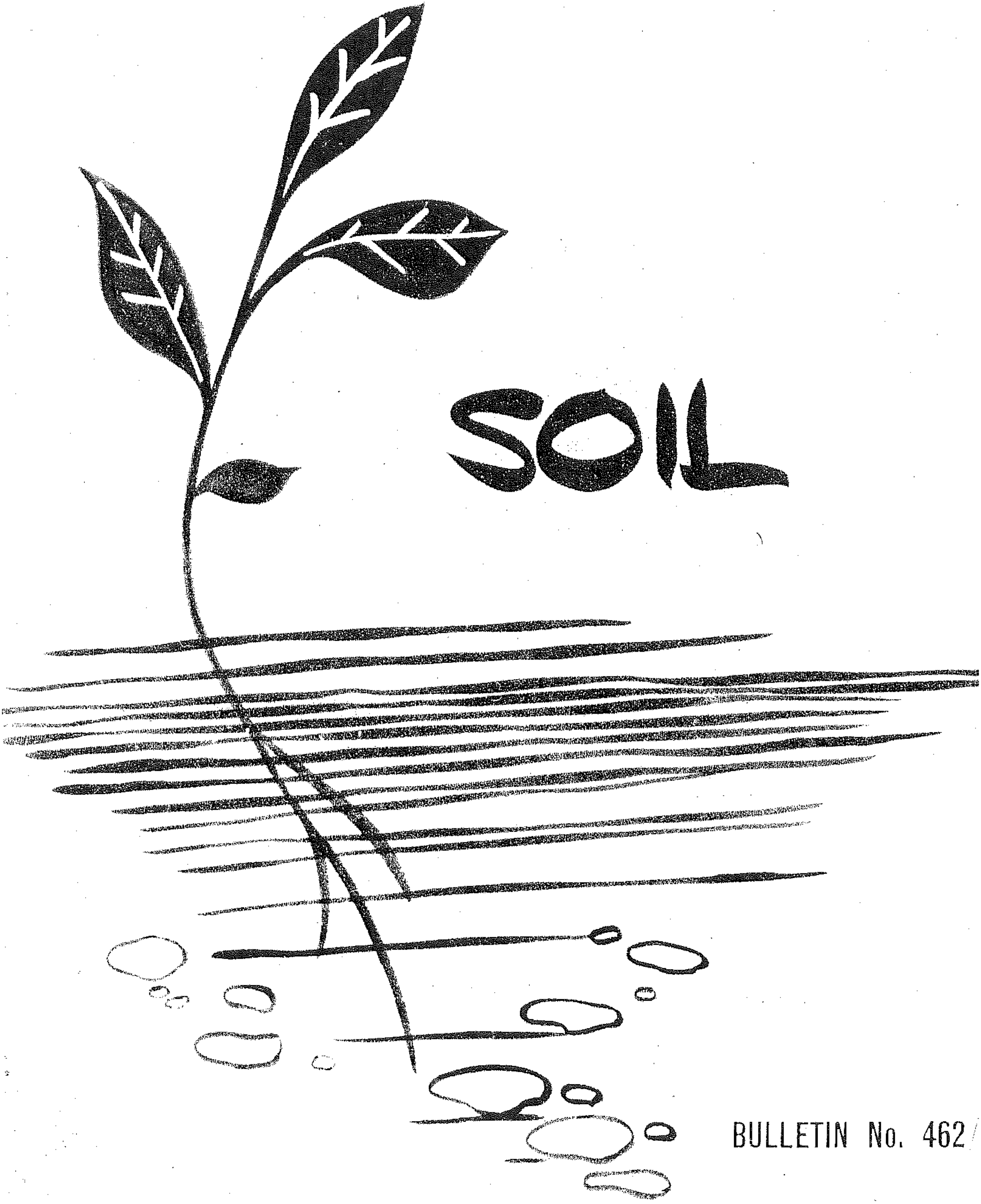
SOIL



BULLETIN No. 462

DEPARTMENT OF AGRICULTURE, SOUTH AUSTRALIA

SOIL

A reprint of a series of articles on soil properties

in the

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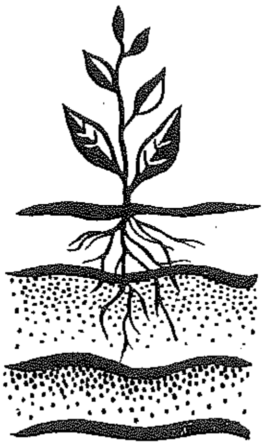
SOILS cannot be judged simply by looking at the top few inches, without any regard for what lies beneath. To get a true picture we have to examine the various layers which make up . . .



THE SOIL PROFILE

By **J. P. BLENCOWE**, D.D.A.,

Soil Conservation Adviser

WHEN we examine a soil face in a pit or cutting we see that the soil is made up of several layers. These layers may differ in colour, texture, structure or depth.

The soils shown in Figs. 1 and 2 both have grey, sandy topsoils. Looking at the surface only, they would seem to be equally productive.

The profiles tell a different story. The soil in Fig. 1 has a clay subsoil at nine inches and is much more productive than that in Fig. 2, where there is rock at nine inches. Thus subsurface layers can vitally affect the productivity of soils, and a soil cannot be judged by its surface layer alone.

Fig. 1. This profile shows a clay subsoil at a depth of 9in.

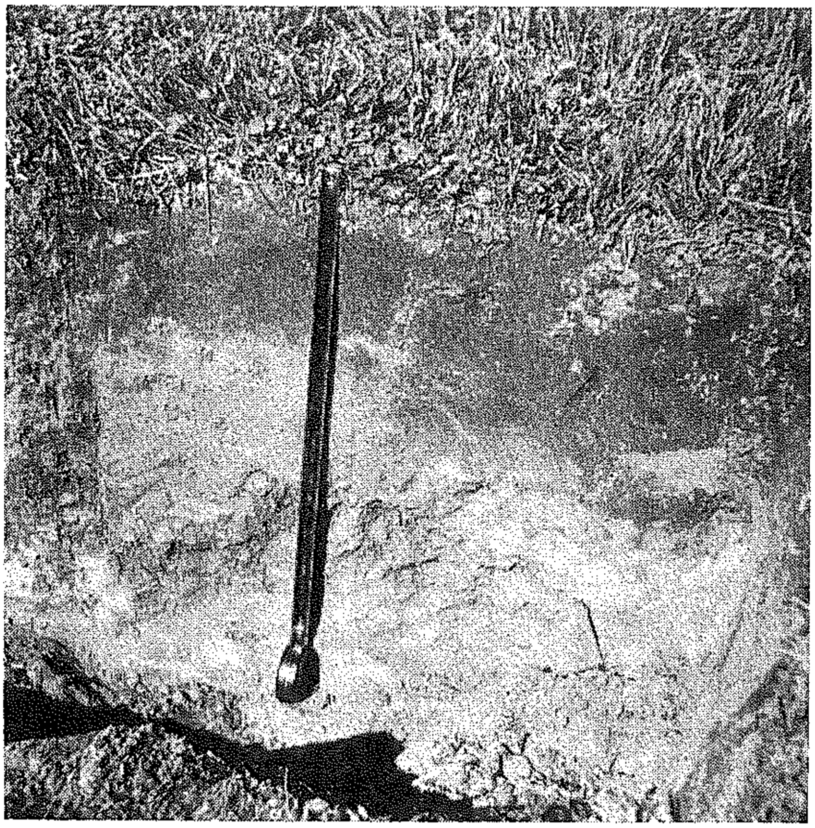


Fig. 2. The profile here shows the same 9in. of top soil as in Fig. 1, but beneath it is rock instead of clay.

The various layers arise from the way in which the soil developed from parent rock. Many factors affect this development—among them age of the soil, climate, slope, type of rock and the vegetation growing in the soil. As a result, soils usually develop into three main layers—(1) topsoil, (2) subsoil, (3) parent material. The soil scientist labels these layers the A, B and C horizons; together they form the soil profile.

"A" HORIZON.

The A horizon is the most important part of a soil, as it is the cultivated layer and contains most of the available plant nutrients. The upper part of the A horizon (A^1) usually contains organic matter in the form of decayed or partly decayed plant leaves, stems and roots. This usually gives it a darker colour than the lower half of the topsoil layer (A^2), which often has little or no organic matter.

"B" HORIZON.

This is the zone which receives the materials leached from the A horizon. Because

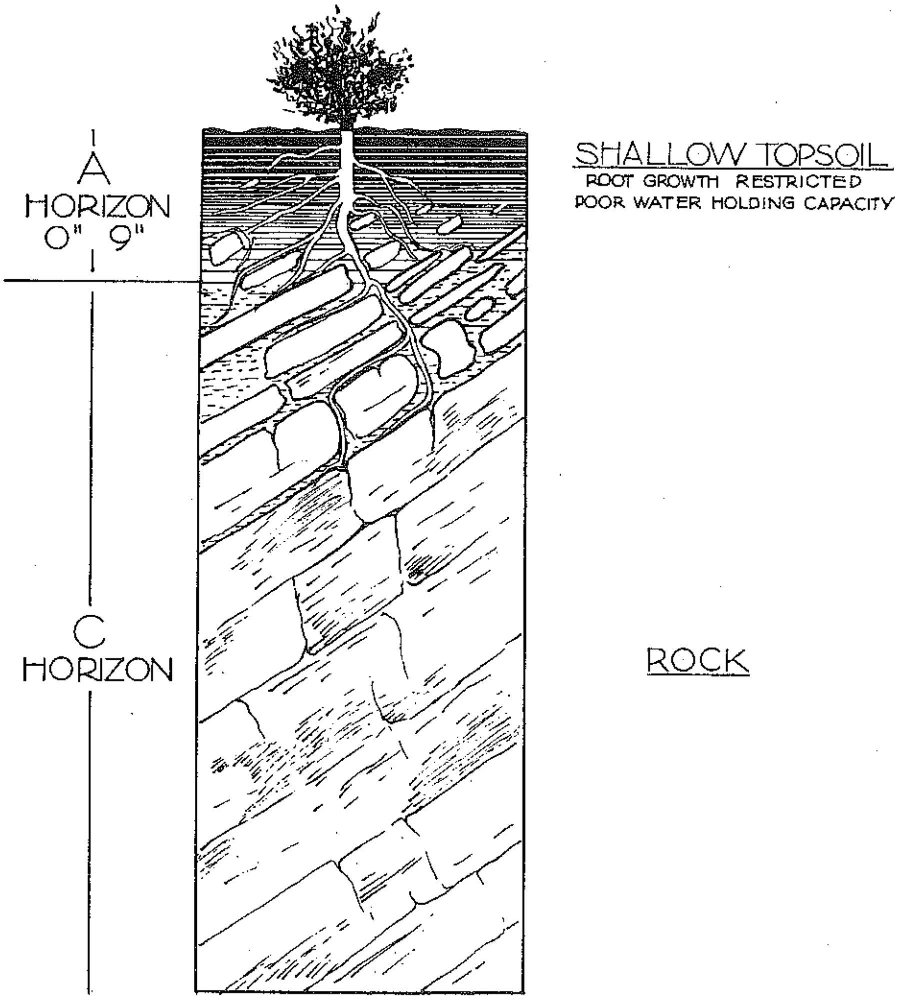


Fig. 3. A soil without a "B" horizon. The shallow topsoil cannot store much water, and the rock directly beneath it restricts root growth.

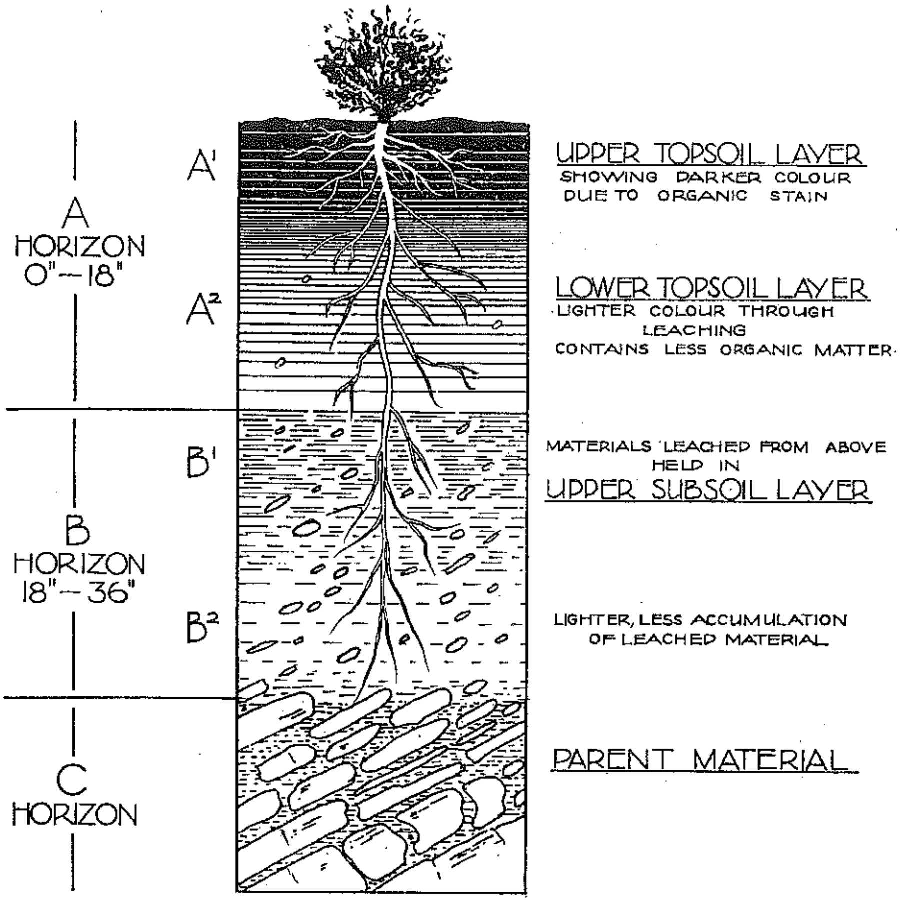


Fig. 4. A soil with all three horizons. In this case the "C" horizon is relatively unimportant because the topsoil and subsoil layers are deep and of good structure.

of this, it can differ from the A horizon in colour, texture and structure.

The amount of material brought down by leaching will depend on the porosity of the soil and the rainfall. Materials are leached down in the order of solubility. Soluble salts and gypsum may be leached down right out of the profile. Calcium carbonate (lime), being less soluble, generally settles in the B^2 layer, with the clay remaining in the B^1 horizon. Iron and aluminium oxides are still less soluble and remain in the upper part of the profile, contributing to the soil colour. These oxides are only removed in very heavy rainfall areas.

The depth and water holding capacity of the B horizon greatly affect the value of the soil for plant growth. A friable subsoil allows water and air to penetrate and plant roots to make full growth. Where the subsoil is heavy clay, on the other hand, plant growth may be restricted.

The chemical composition of the B horizon is less important, although some elements lacking in the A horizon may be supplied to deep-rooting plants such as lucerne.

"C" HORIZON.

The C horizon is usually parent material underlying the actual soil. The nature and depth of this parent material has to be taken into account in assessing the value of a soil for plant growth.

If the soil is shallow and the C horizon is unweathered rock, plant roots cannot penetrate, and growth is restricted. In weathered rock, such as shale, plant roots can generally find their way down through the cracks and crevices.

In valleys and flats the C horizon often consists of transported or alluvial material brought down from higher ground.

Not all horizons are present in every soil. The profile in Fig. 3 for example, has only A and C horizons. Due to age and limited rainfall the B horizon has not developed. This soil cannot store enough plant nutrients or moisture, and consequently plant growth will be poor.

The soil in Fig. 4 has all three horizons, but the C horizon is relatively unimportant because of the depth and good structure of the A and B layers. A soil such as this will have a good reserve of minerals, will be capable of storing large amounts of moisture and will allow unrestricted plant growth.

SOIL TEXTURE and STRUCTURE

Let's be clear about what these terms mean

TEXTURE and structure are probably the two most misinterpreted terms in soil science. One is often used where the other is meant.

"Texture" refers to the fineness or coarseness of soil particles and is determined by the proportion of sand, silt and clay particles which make up the soil. Terms like sand, sandy loam, loam, clay loam and clay, refer to the texture of a soil.

"Structure," on the other hand, means the way soil particles are aggregated or grouped together. When we talk of a soil being in good condition or "good heart" we are referring to the favourable structure of the surface soil.

So we see that the quantity of each fraction —sand, silt and clay—decides the texture; and the way they are assembled decides the structure.

Both terms are used in describing soils and both can be measured in the laboratory. The following short articles discuss these terms and their place in soils work.

Soil Texture

By
S. D. MOORE, R.D.A.,
Soil Conservation
Field Officer,
Kapunda.

LIGHT and heavy soils differ in texture. "Texture" refers to the fineness or coarseness of soil particles and is determined by the proportion of sand, silt and clay particles which make up the soil.

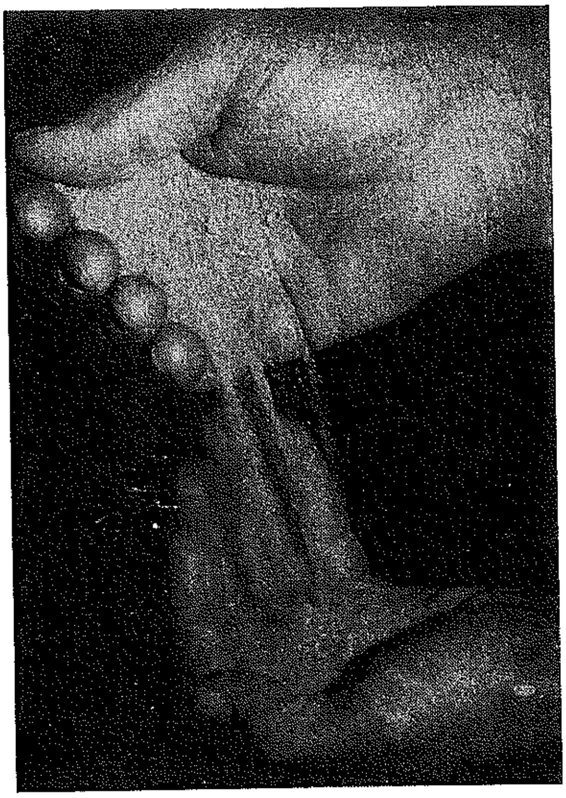
Texture is one of the most important terms used in describing soils and one of the properties measured in soil analysis. It is expressed as:—

	Particle Size.
Coarse sand	2— .2 mm.
Fine sand	.2— .02 mm.
Silt	.02—.002 mm.
Clay	Less than .002 mm.

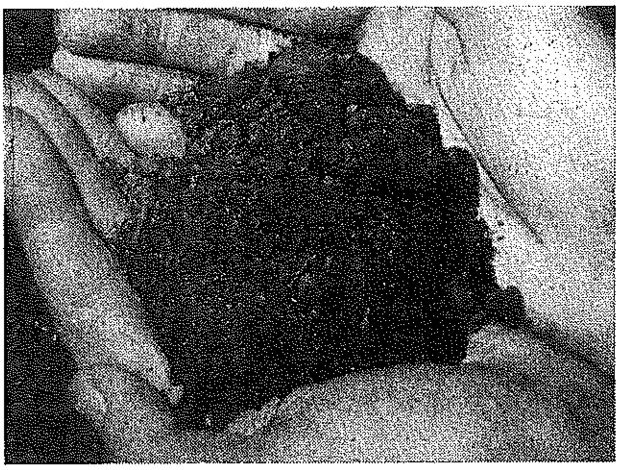
The percentage of these different fractions, decides whether a soil is a—

SAND, LOAM, or CLAY

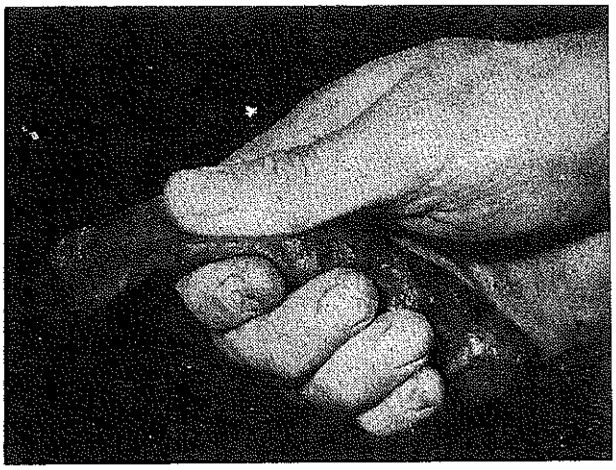
or one of the finer divisions, e.g., sandy loam, sandy clay loam, or clay loam.



Sand is single-grained and lacks cohesion.



A well structured loam.



Clay is plastic and will ribbon out between the fingers.

IN the field, texture can be felt by wetting the soil and working it between the thumb and forefinger.

Sand—is coarse to the touch, has no cohesion and falls apart when moulded.

Loam—has a smooth feel and can be moulded by hand, but will not ribbon.

Clay—is sticky and plastic, and will ribbon out between the fingers.

Texture is a stable feature of the soil and cannot be changed by normal farming methods.

It is useful in assessing—

Moisture holding capacity.
Ease of working.
Fertility.

MOISTURE HOLDING CAPACITY.

Heavy soils can store more water for plant growth than light soils. A heavy clay may hold 2½in. of available moisture in each foot of soil, whereas a coarse sand may hold only ½in.

The same rain will wet sandy soils to a greater depth than heavier soils, so that although 25 points of rain may wet a sand to 6in. it may only wet a clay to 2in.

Sandy soils therefore respond readily to light rains but have low water holding capacity.

The ideal soil for storing and giving up water is probably a sandy loam overlying a retentive clay loam subsoil.

EASE OF WORKING.

Sands and friable loams are easy to work, and the term "light" refers to ease of working. Conversely, the finer textured clay loams and clays are "heavy" to work.

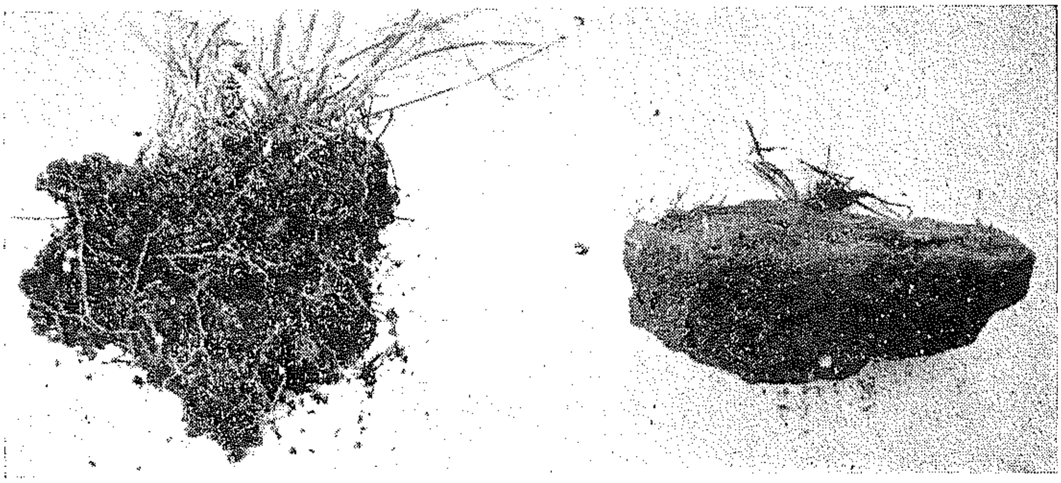
FERTILITY.

Light sandy soils are readily leached by rain and are likely to be deficient in plant nutrients, especially nitrogen.

The clay fraction of soils contains most of the mineral-matter, and so the heavier loams and clay-loams are our most fertile soils.

SOIL STRUCTURE

By **GAVIN J. YOUNG,** R.D.A.,
Soil Conservation Adviser, Cleve



A contrast in structure. Soil at left is from under the fence and shows outstandingly better structure than that at right, which comes from the cultivated part of the paddock.

DRAINAGE, root penetration, and ease of working are among the many properties we look for in a soil.

The ability of any particular soil to supply these depends to a large extent upon its structure. If a soil has a good structure then drainage is good, plant roots can penetrate easily in search of food, implements can also penetrate easily, and less power is needed for cultivation.

What is this property called soil structure which apparently controls so many of the better qualities of a soil?

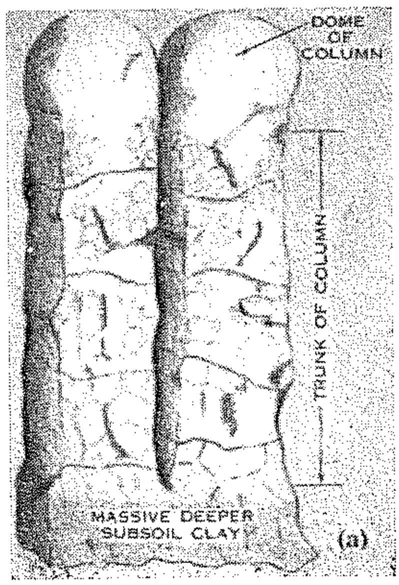
BRIEFLY, it is the way the minute separate particles of sand, silt, clay and organic matter are put together to form soil crumbs or aggregates.

The main types of structure can be conveniently divided into surface and sub-soil structure. These are listed below.

TYPES OF STRUCTURE.

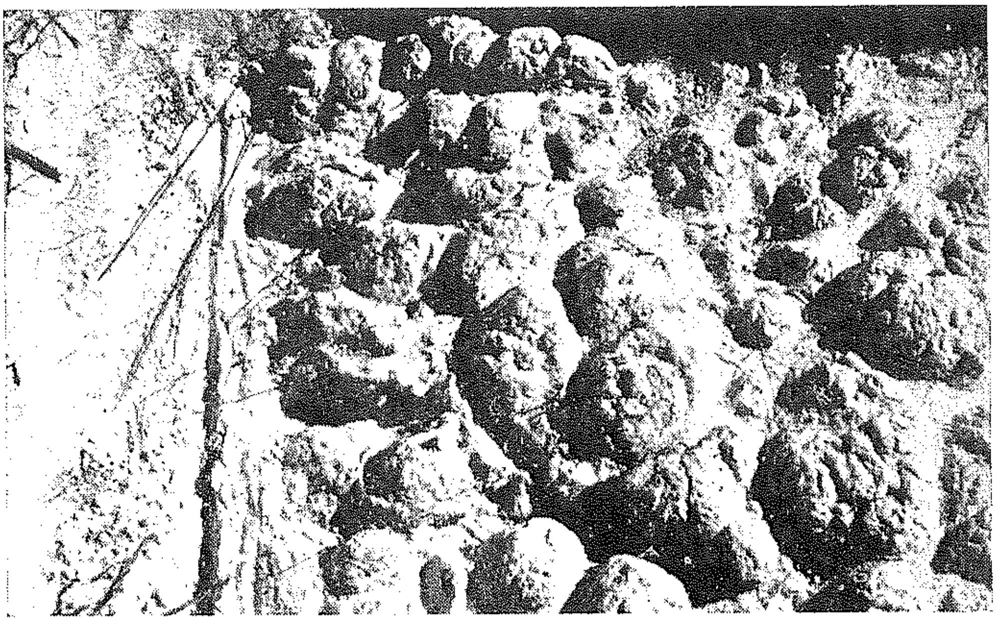
Surface Soil.

1. *Structureless* is used to describe sands where one grain tends to separate from the other on drying, or for the compact amorphous surface of heavier soils brought about by overworking. Alternatively these types of structure may be termed "single-grained" or "massive."



This diagrammatic sketch of columnar structure shows the deep vertical cracks which divide the subsoil clay into pillars, each one separated from its neighbours on all sides. Rounded cappings over the pillars show that this is what is termed a "domed" columnar structure.

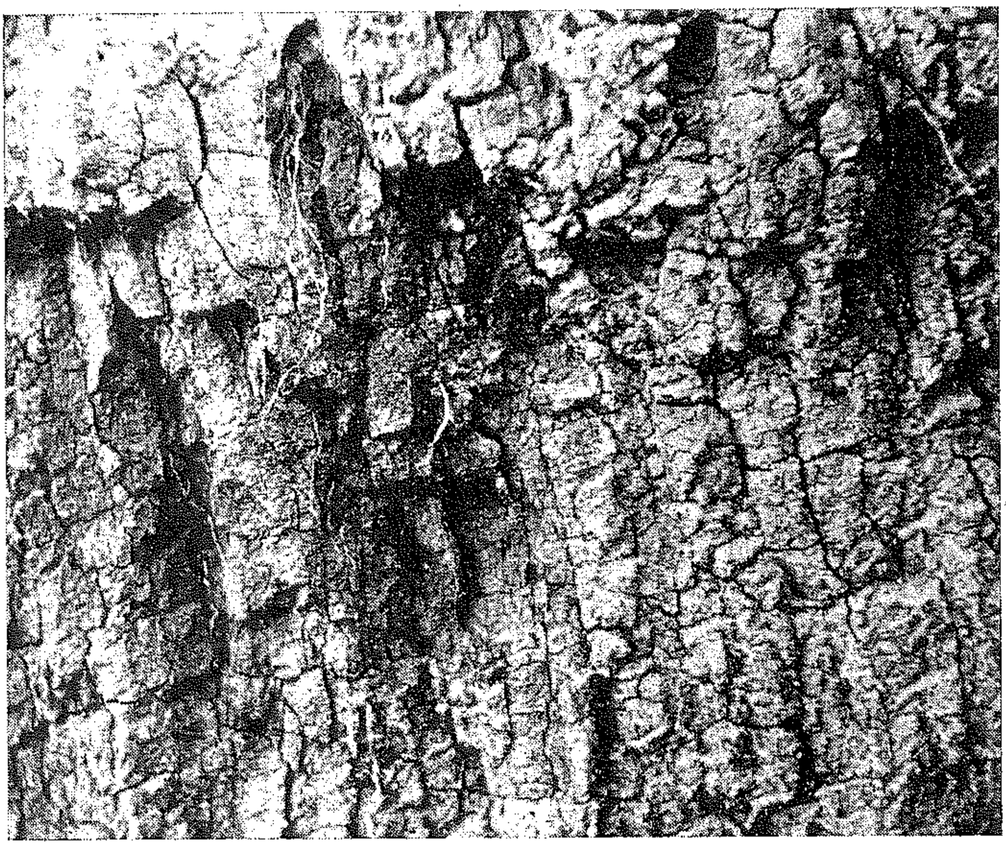
[*C.S.I.R.O. Div. of Soils.*]



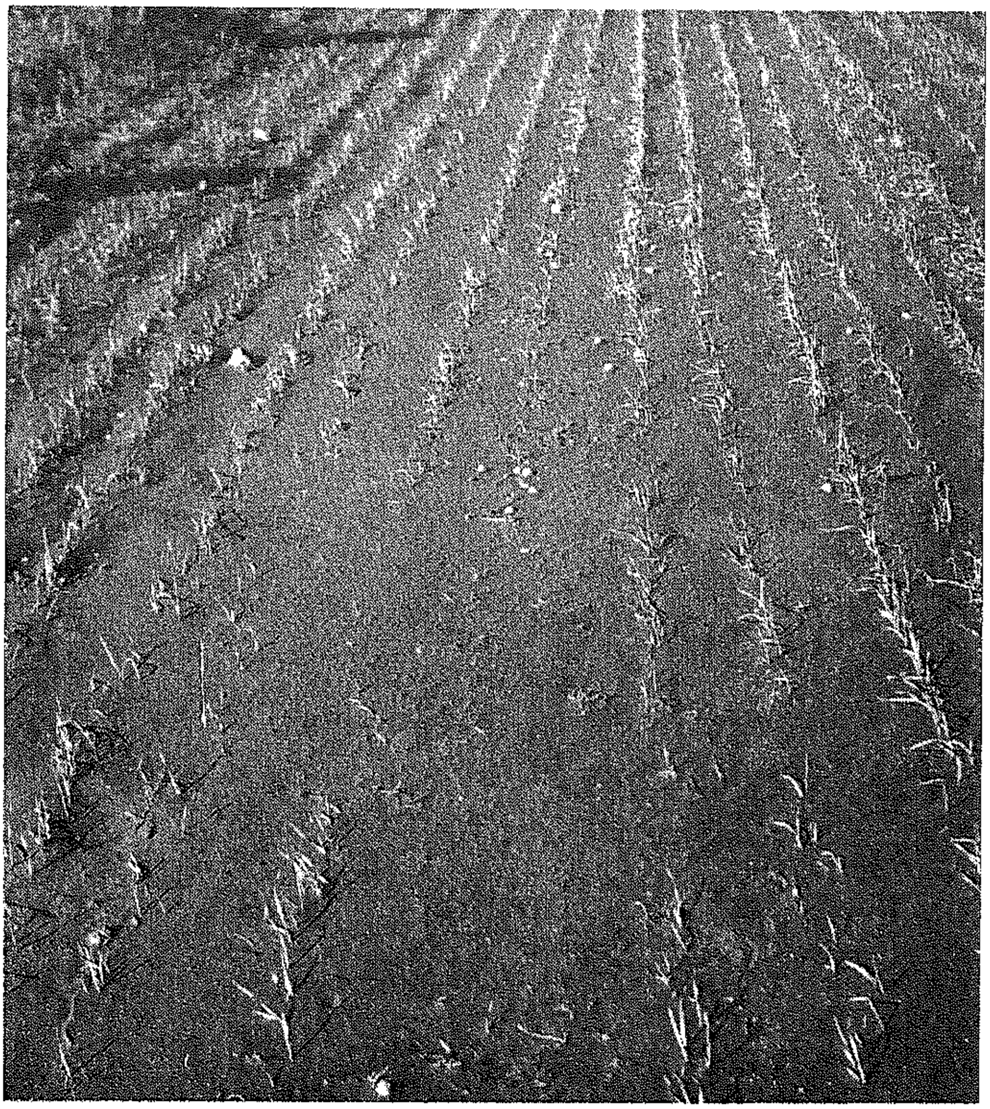
"Domed" columnar structure of a clay subsoil. Surface soil has been removed to show the rounded cappings of the pillar-like subsoil formation.

2. *Granular and crumb.* The soil when dry breaks up into granules of varying sizes without sharp edges and flat faces. These soils are usually referred to as "self-mulching." Crumb structure is similar to granular but is more open. It is usually associated with cultivated soils.

3. *Platy.* The soil tends to form a series of fine, flat flakes. The condition is rare and not normally seen in cultivated soils.



A subsoil showing prismatic structure. Soil is divided into elongated blocks with straight sides and edges.



One of the signs of broken down soil structure—a patch where germinating wheat plants failed to break through the hard surface crust.

Subsoil.

1. *Columnar*—the subsoil when dry contracts into a series of pillars, each one separated from its neighbour on all sides. When the columns have hard, rounded tops they are said to be "domed."

2. *Prismatic*—when the subsoil cracks into elongated blocks with straight sides and edges.

3. *Blocky.* Is similar to prismatic but the blocks have equal length and breadth.

STRUCTURE AND FARMING.

Both surface and subsoil structure are important in farming.

Subsoil structure in many instances is nearly as important as surface structure, but as it is beyond the depth of normal cultivation it is not easily altered. The practice of deep ripping has only a temporary effect, and the main hope of improving poorly structured subsoils lies in the use of deep rooted perennials like lucerne, phalaris and evening primrose.

WITH THE SURFACE IT IS A DIFFERENT STORY.

Poorly structured surface soils are largely man-made, and the signs are easy to read:—

- The paddock which crusted on top following the heavy rain just after seeding.
- The crop which couldn't break through in many places so that the paddock had to be harrowed and in parts re-sown.
- The "slick" spots which shed water rapidly and set hard when they dry.
- The paddock showing rilling and muddy run-off.

These are the signs of structure decline. The causes are now well known—too much cultivation, working when the soils are too wet and too dry, working at speed, burning the stubbles.

"Structureless" surface soils, like the one shown here, develop a hard crust after rain falls on them.

The answers are:—

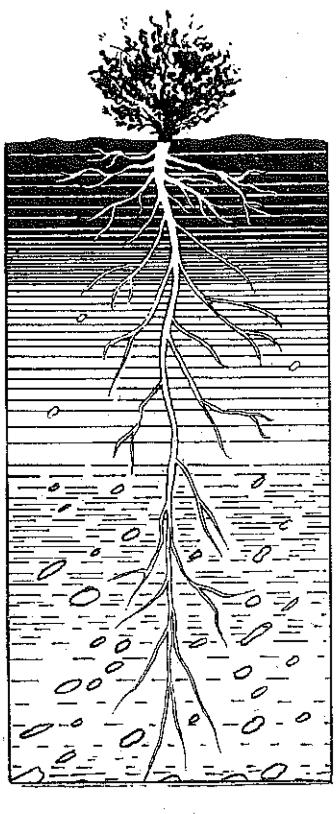
- Widen the rotation and sow the paddock down to pasture.
- Topdress the pasture, and see that it is a good one.
- Leave the matches at home, and work all crop and pasture residues into the soil.
- Reduce the number of workings.

Maintaining the surface soil in "good heart" is one sure sign of a successful farmer.

SOIL COLOUR

THE colour of a soil is perhaps its most obvious characteristic. Along with texture and structure it forms the basis for soil classification.

By
R. C. SHEARER, B.Ag.Sc.,
Soil Conservation Officer



This diagram of a soil profile shows the range of colours in a normal soil.

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HOW DO SOILS OBTAIN THEIR COLOUR?

THERE are two main sources of colour in the soil:—

1. Mineral matter.
2. Organic matter.

Mineral Matter.—Soils are formed by the breakdown of rocks. Sometimes these rocks give their own colour to the soil. This has occurred in the red soils of the Gawler Ranges.

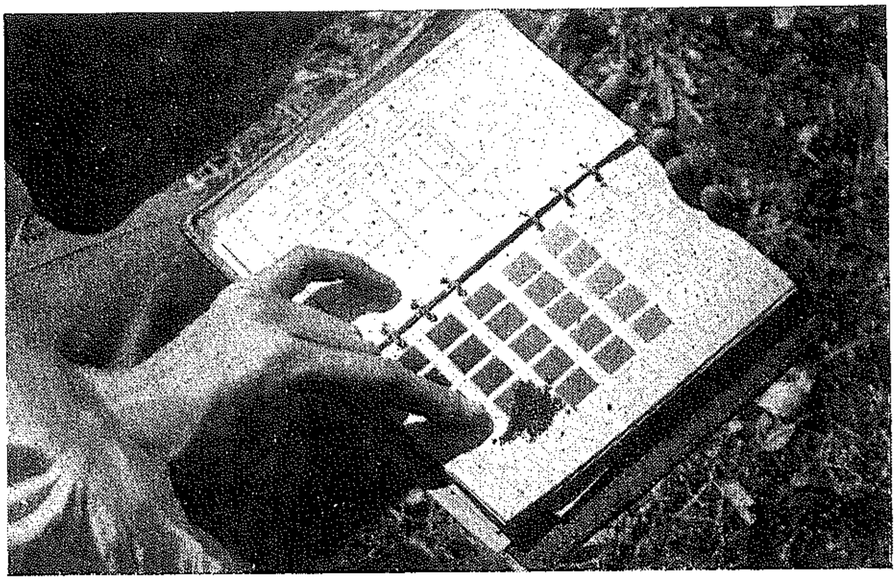
Normally the colour of a soil results from compounds formed during the breakdown of the parent material. Thus red, yellow, grey, and bluish-grey colours result from compounds of iron. Under average conditions of air and moisture, iron forms a yellow oxide. Where soils are better drained or drier, water is removed from the yellow oxide, and colour changes to red. In waterlogged soils where air is lacking we get reduced forms of iron giving a grey or bluish-grey colour.

A white or pale colour in soils may be due to:—

(1) Large amounts of lime, gypsum and other minerals; or

(2) It may result from intense leaching. The pale, bleached sub-surface of podsols and similar soils is due to intense leaching of salts from this layer so that only the white quartz sand remains.

Organic Matter.—This imparts a brown colour to the soil. Humus, a stage in the breakdown of organic matter, is black. Thus soil colour can vary from brown to black



Checking a soil colour with the Munsell Colour Chart. The sample is compared with a range of standard colours.

depending upon how much organic matter and humus it contains. The well drained soils of the warmer, moister areas are brown, due to larger amounts of organic matter; but the poorly drained soils, with larger amounts of humus, are black.

The intensity of the colour can also vary with the distribution of the organic matter and humus. The higher the sodium content of a soil the darker the organic colour becomes. This is because sodium causes the organic matter and humus to disperse more readily and spread over the soil particles.

Texture also affects the organic colour. The lighter the texture the more easily the soil particles are coated, and the darker the colour.

Usually colours seen in the field result from the mixing of colours formed by mineral and organic matter. Thus a red-brown colour may be formed from a mixture of red iron oxide and brown organic matter.

However, climate also affects colour. In the warm, moist areas where weathering is more intense, the soils are more highly coloured than the soils of cool, dry climates.

The colour of soils is therefore a reflection of their mineral content, their organic content, and of the effect of climate.

HOW IS COLOUR MEASURED?

In the field, colour is determined by experience. As two people may give different names to the same colour, standard colour charts have been developed to avoid confusion. One of these is Munsell's colour chart—a small book containing coloured chips against which the soil colour is compared. The colour is given in terms of three variables known as "hue" (or the main colour), "value," and "chroma." The last two are a measure of the shade and purity of the colour.

For example, a soil we call reddish-brown might be expressed as 5 YR 4/3 on the Munsell scale, 5 YR referring to the hue, 4 to the value, and 3 to the chroma.

As soils are darker when wet, the colour given usually refers to the moist soil. Descriptions for technical use may include both dry and moist colours if these vary much.

WHAT DOES SOIL COLOUR TELL US?

We all know how essential are organic matter and humus for good fertility. Thus, except for the poorly drained soils, we can expect the brown and black soils to be fertile. However, the organic coloration cannot be satisfactorily used as a measure of the *amount* of organic matter or humus in the soil.

Red coloration in our soils tells us that the soil is adequately aerated and drained and that little leaching of salts has occurred.

The reddest soils are found in the deserts. Where the red soils occur in the better rainfall areas they are usually fertile; and the darker the red the more fertile they are likely to be, as this indicates higher amounts of organic matter.

However, not all red soils are fertile. Some, like those derived from lateritic ironstone and others which set very hard on the surface, may be infertile.

Where the colour is due to iron compounds the sequence red-yellow-grey indicates increasing wetness or waterlogging. Grey mottling in a yellow-brown soil indicates that periods of waterlogging and drying out occur. This means that drainage is poor and plant growth may be affected in wet winters. The nearer the mottled layer is to the surface the poorer will be the plant growth.

We must remember, though, that grey can also result from the effects of humus on white soils or lime on black soils.

White or pale colours indicate that intense leaching has occurred or that the soil contains large amounts of calcium carbonate or other minerals. These soils are generally unproductive and need special treatment.

In the surface soils a gradual loss of soil colour, say from red-brown to light brown or dark grey-brown to brownish-grey, shows that organic matter is being removed and not returned. It is a sign that the soil is being overworked.

Like other soil properties, colour must always be observed throughout the whole profile. A soil may be reddish-brown on the surface and appear to be fertile. However, this colour may only occur to a depth of a few inches and then change to a mottled yellow-grey. Growth on such a soil would be poor.

Colour, with texture and structure, may sometimes be used to determine the most productive soils on a farm.

SOIL pH.

| ←———— INCREASING ACIDITY ————— 14

NEUTRAL POINT = 7

By R. HAGERSTROM, Soil Conservation Field Officer, Cleve.

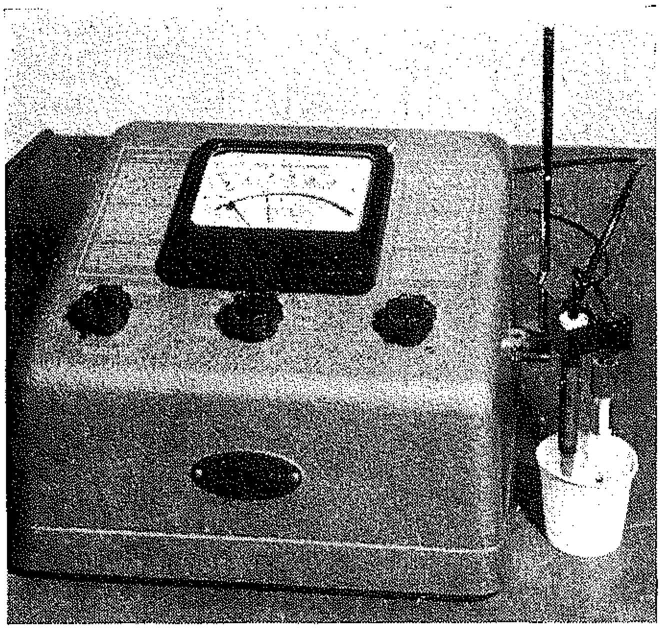
ACIDITY is a word in everyday use. We are all familiar with strong acids like sulphuric or hydrochloric acid.

Just as we can measure temperature in degrees Fahrenheit or Centigrade and pressure in lbs. per square inch, so, too, can we measure acidity, but in this case the results are expressed in terms of pH.

The pH scale has a range from 0-14, the strongest acids having the lowest pH values and the strongest alkalies, like caustic soda, having the highest pH. The neutral point, the pH value of distilled water, is 7.

Each *decrease* of one unit on the scale means a tenfold *increase* in acidity. Thus a pH of 5 is ten times more acid than pH 6 and pH 4 is 100 times more acid than pH 6.

pH is one of the commonest and most useful measurements in biological science. It is also a very valuable measurement in soil science.



Laboratory instrument for measuring soil pH. Beaker at right contains a suspension of soil in water. Electric current passes through it *via* the glass electrode.

Most soils lie within the middle range of the pH scale. Usually they are only slightly acid or slightly alkaline, with values ranging from pH 6 to pH 7.5. In fact, nearly all our South Australian soils come within the range pH 5.0 to pH 8.5

Rainfall and soil type are closely connected with soil pH. Water leaches mineral salts down through the soil, particularly the sandy soils, and concentrates them in the subsoil.

For this reason the sandy soils of higher rainfall country are usually acid.

Because of leaching, the pH of an individual soil usually increases with depth, and surface soils are usually more acid than their subsoils.

The pH changes in a typical red brown earth of the Mid North are:—

Depth.	*pH.*
0in.-3in.	6.3
3in.-9in.	6.6
9in.-22in.	7.8
22in.-39in.	8.7

MEASUREMENT OF pH.

The pH of a soil can be measured in the laboratory and in the field.

In the laboratory the pH of a soil-water suspension is measured electrically by the glass electrode method.

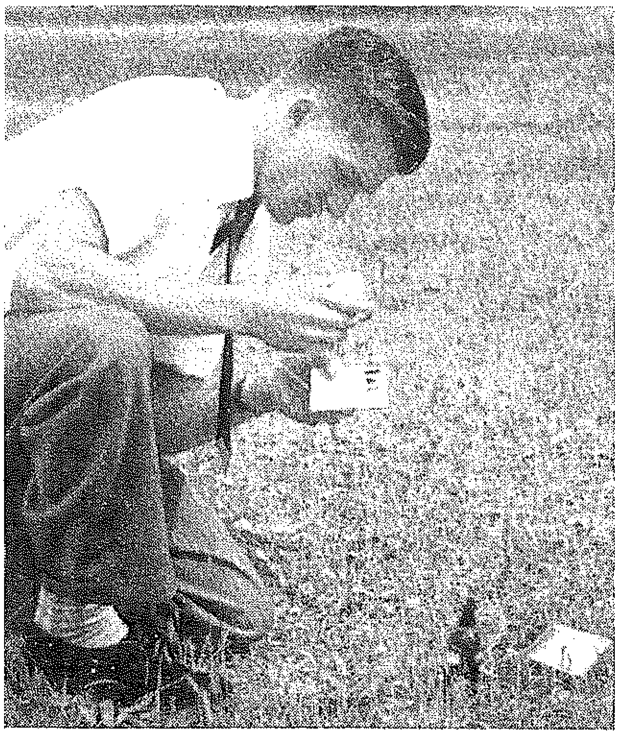
The field test for pH compares the colour of a prepared sample of soil, plus colour indicator, with a standard colour chart. It is not as accurate as the laboratory method but provides useful information for field use.

pH AND PLANT GROWTH.

Different plant species have fairly well defined upper and lower pH limits outside which they make poor growth or fail to grow.

Oats, for example, is much more tolerant of acid conditions than barley and will grow quite well down to a pH of 4.7.

Most plants grow best on slightly acid soils, and the pH range from 6.0-7.0 suits most crops.



Above: Applying the reagent to soil samples on the palette. Soil colour changes according to reaction.

USING A FIELD KIT TO TEST SOIL pH.

Below: Comparing the treated samples with the colour chart. Colours indicate extent of acidity or alkalinity.

pH AND PLANT NUTRIENTS.

Soil reaction, or pH, has an effect on the availability of plant nutrients. For example, phosphate fixation, which makes phosphorus unavailable to plants, is most marked in soils that are strongly acid or strongly alkaline.

The trace elements copper, zinc and manganese are more readily available under acid conditions, whereas molybdenum is more available where soils are alkaline. Manganese deficiency, for example, is common in the calcareous soils of southern Yorke Peninsula, lower Eyre Peninsula and near Mount Gambier; and on the acid ironstone soils of Kangaroo Island and the Southern Hills molybdenum deficiency occurs.

pH AND FERTILIZERS.

The prolonged use of fertilizers tends to alter the soil pH. Repeated dressings of superphosphate may bring about a slight increase in acidity: and sulphate of ammonia has a pronounced acidifying effect if used continually.

CHANGING SOIL pH.

The pH of a soil can be modified by applying lime or sulphur, but this is costly.

In practice, sulphuring, or adding alum to increase acidity is only used in suburban gardens for special purposes like growing blue-flowered hydrangeas.

On the other hand liming to decrease acidity is a recognised agricultural practice in many countries, and it may have a bigger part to play in the higher rainfall areas of this State.

At present, apart from the small amounts applied in establishing lucerne and subterranean clover on the acid sands of the South East, lime is seldom used in South Australia.

Some caution is needed in liming acid soils which are low in trace elements, as liming raises the pH and makes most trace elements, except molybdenum, less available. Liming the ironstone soils of Kangaroo Island for example, has decreased acidity and caused symptoms of lime-induced zinc and manganese deficiency in clover.

pH is probably the most common soil measurement made. Because of the close connection between soil reaction, or pH, and many other soil properties, it enables a good deal to be inferred about a particular soil from field examination.

ORGANIC MATTER

Key to Good Soil

IT is common to speak of farming practices "building up" or "depleting" the soil. What do we really mean by this? What are we building or depleting? The answer in nearly every case is soil organic matter.

The five questions answered here by M. I. H. BROOKER, B.Ag.Sc., Soil Conservation Officer, tell us just how great a part organic matter plays in keeping soil fertile and workable.

WHAT ARE ORGANIC MATTER AND HUMUS?

ORGANIC matter consists of plant and animal remains in all stages of decomposition. Certain portions which resist decay in the soil and remain undecomposed are called humus.

The amount of organic matter in the soil differs from place to place depending on climate, soil type and land use.

All soils contain some organic matter. The amount ranges from less than 1 per cent in deep sands to over 50 per cent in peat. The following table shows the organic matter content of some South Australian soils:—

Soil.	Locality.	Organic Matter. %
Peat	Eight-Mile Creek	60
Alluvial soil	River Murray Swamp	13
Ground-water rendzina	Lower South-East	7
Black earth	Claremont	6.5
Red-brown earth	Northern Cereal Areas	2.2
Mallee soil	Murray Mallee	1.3
Deep sands	Upper South-East	0.8
Desert loam	Northern Pastoral Areas	0.3

Because most plant and animal remains are returned to the soil surface, the biggest concentration of organic matter is found in the top few inches of the soil. This causes a darkening in the surface and can be readily seen in the top foot of a sandy profile. However, in some soils, *e.g.*, the black earths, the organic matter extends further down the profile.

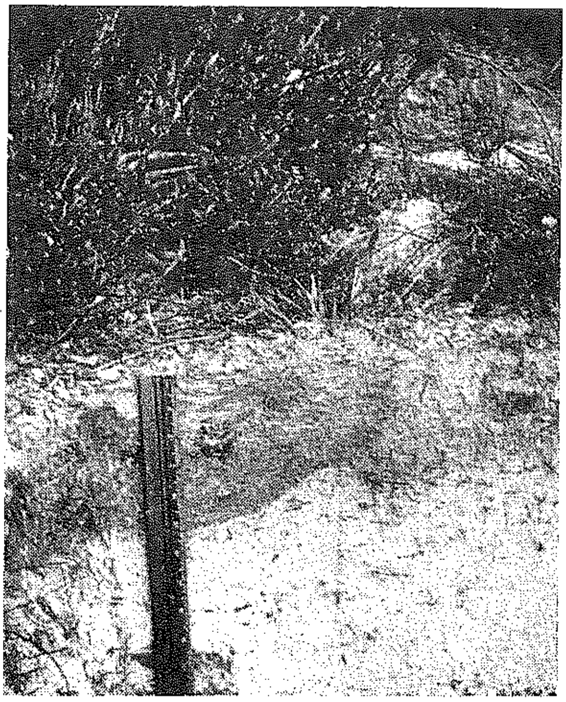
WHY IS ORGANIC MATTER IMPORTANT?

The most important effect of organic matter in soils is to maintain physical conditions favourable for plant growth by improving their structure and increasing their water-holding capacity.

We all know that a heavy clay with a low level of organic matter is hard to work and slow to absorb water. Rain and irrigation water tend to run off and are not absorbed. Clay soils with adequate organic matter, on the other hand, are porous, friable and generally well structured. As a result, the soil can absorb water rapidly and hold it for the use of plants. Such a soil is well aerated, allowing good germination and growth of plants. Crumb structure also prevents the formation of surface crusts which increase the risk of erosion on sloping country.

A disadvantage of light, sandy soils is that water penetrates too fast. Their water holding capacity is low, and nutrients are leached into the subsoil away from the plant roots. Increasing the organic matter content of sandy soils improves their water-holding capacity. Nutrients also become attached to the organic matter, thus keeping them in the root zone of the plant.

Furthermore, organic matter or humus is a reservoir of plant nutrients, particularly nitrogen. However, plants cannot use the nitrogen in humus—it must first be broken down by the soil micro-organisms. Their waste products (which include soluble nitrates) are then available to the plant.



CONTRAST IN SOIL ORGANIC MATTER.

These photos. of the upper horizons of two soils show the contrast between the organic matter in a deep sand and a black earth. The deep sand (*left*) shows only a staining of the top few inches by organic matter, whereas the black earth (*right*) is rich in organic matter right down to the subsoil.

HOW IS ORGANIC MATTER LOST FROM THE SOIL?

In a virgin soil, the organic matter is in a state of balance, where the amount broken down each year is about equal to that replaced by rotting plants.

When such land is used for farming, the balance is upset. The amount of organic matter lost may be much greater than the amount returned to the soil. With good farming, however, the organic matter level is kept as high as possible while still making good use of the soil.

Organic matter is lost principally by frequent cultivation and by keeping the soil bare for long periods. Fallowing, when carried out with frequent cultivations, results in a rapid decline of organic matter. Cultivation aerates the soil, and this greatly hastens the breakdown of humus. The breakdown also results in the production of soluble nitrogen, which is used by the following crop. However, this nitrogen is obtained entirely from the soil's store of organic matter. If this is not replenished, the level of organic matter declines and future crops may not have enough available nitrogen. The result is a gradual decline in yields.

HOW CAN ORGANIC MATTER BE RETURNED TO THE SOIL?

Organic matter is returned to the soil by the decay of plant tops and roots and by animal dung and urine. The most effective way, then, of restoring the organic level is by the use of pastures or fodders grown for grazing. With phalaris, for example, about 48 per cent of the plant is available as feed and the remainder, made up of roots and butts, is eventually returned to the soil as organic matter. Where clovers or lucerne can be grown the increase may be as high as 500 lb.-1,000 lb. of organic matter per acre each year.

This method is being used most effectively in some of the very infertile soils of our higher rainfall country—for example, the deep sands of the upper South-East.

In cereal areas, temporary pastures have a similar role. Ploughing in the crop stubble is not enough on its own. The cereal straw has some value in building soil organic matter, but these residues cannot be used immediately by the plants.

It is well known that some crops grow poorly after a great bulk of straw has been ploughed in. What is known as the "carbon/nitrogen ratio" is involved here. Straw contains about 45 per cent carbon and 0.6 per cent nitrogen, *i.e.,* a ratio of 75:1. Humus, on the other hand, has a ratio nearer 12:1. When straw with its wide carbon/nitrogen ratio is ploughed in, the micro-organisms which break down the residues into humus use all the nitrogen in the straw for their own needs, and they also draw on the nitrogen in the soil. Consequently, a crop grown immediately after straw has been ploughed in shows the typical symptoms of nitrogen deficiency—it is yellow, stunted and low yielding.

In orchards and vineyards, the use of pastures is only possible with some form of supplementary irrigation. Cover crops such as peas, tick beans and barley can be grown, provided nitrogen fertilizer is added, and provided also that the crops are ploughed in while still green. Clovers, on the other hand, when used for cover crops, do not require nitrogen fertilizer. Unlike straw, which is low in nitrogen, the clovers have a carbon/nitrogen ratio much closer to that of soil humus. As a result acute nitrogen deficiency does not occur.

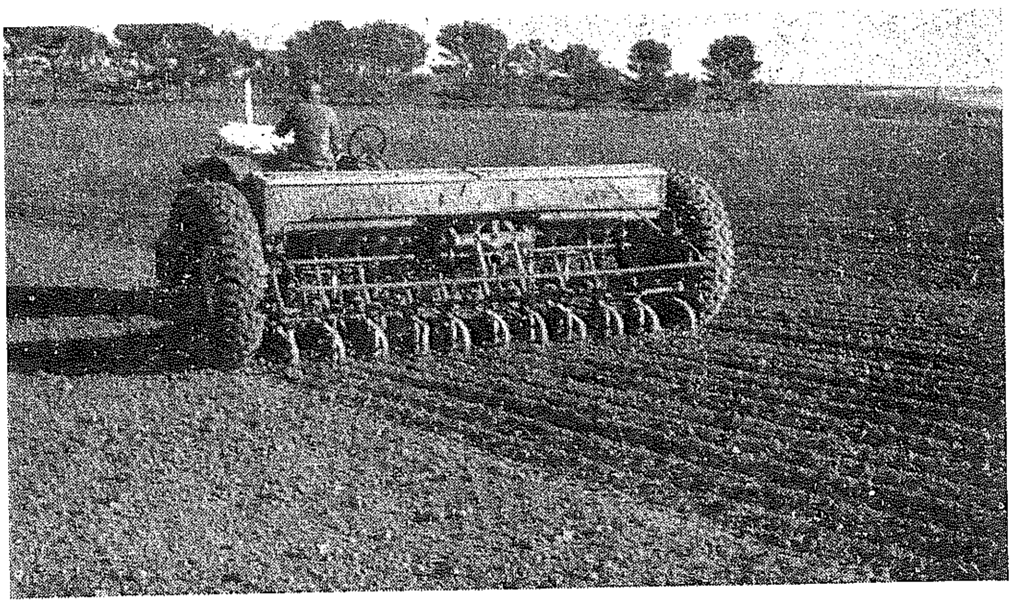
A common practice in European countries is to return farmyard manures to the soil. Under our conditions, this is only possible on a minor scale and then only in the intensive dairying districts. However, the fact that pastures are grazed means that dung and urine are still returned to the soil, though harrowing is sometimes necessary to spread the manure more evenly.

Organic manures such as blood and bone and meatmeal are valuable sources of plant nutrients, mainly nitrogen. They also add to the organic matter of the soil, but this is a secondary effect. Their high cost restricts their use to home gardens and intensive vegetable growing.

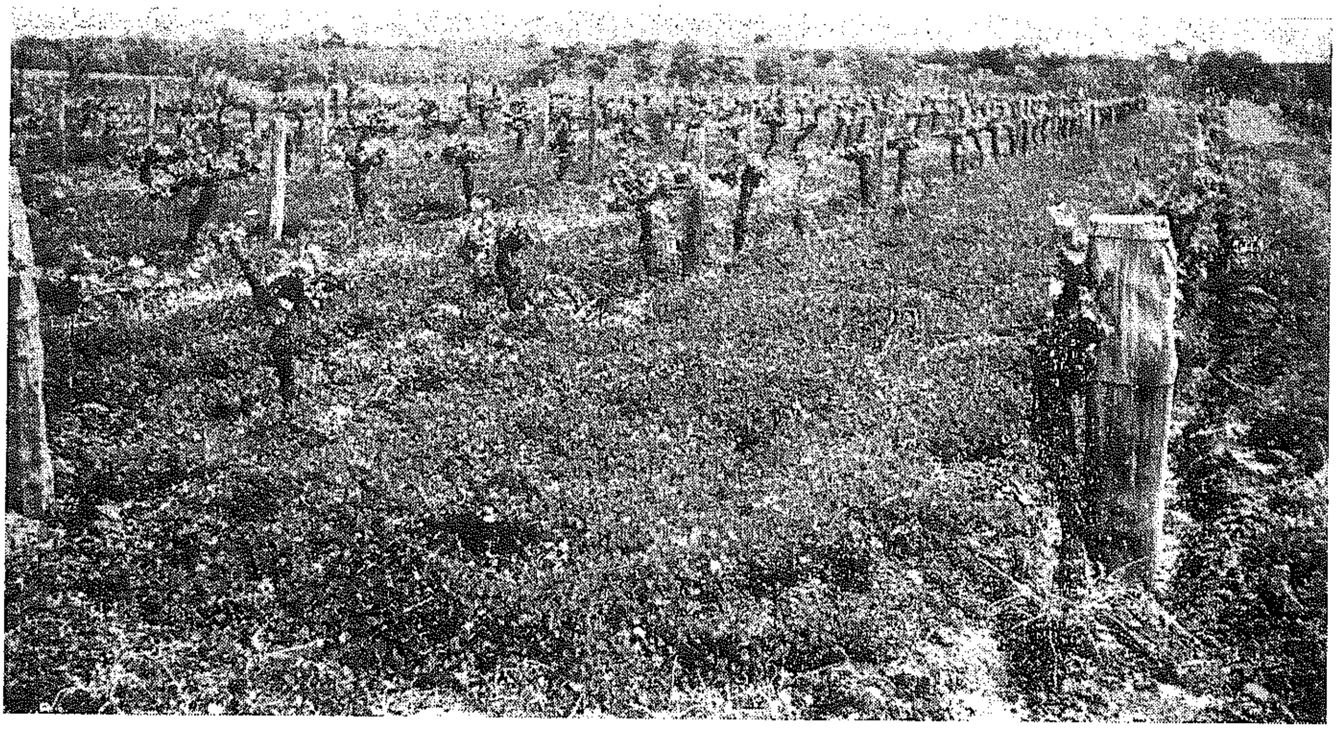
WHAT IS THE BEST WAY OF MAINTAINING SOIL ORGANIC MATTER?

Methods of maintaining soil organic matter vary from district to district, depending on land use. Where the land is chiefly used for grazing, as in much of the country with more than a 20-inch rainfall, pasture management becomes important. Suitable pasture mixtures and adequate top dressing are essential if the organic matter is to be increased. High grazing rates, which result in bare soils and excessively short pastures for much of the year, must be avoided.

In cereal areas, the maintenance of organic matter depends on crop rotations which include temporary pastures with a legume such as barrel or subterranean clover. Experience over the last 20 years has shown how wider rotations, plus the use of clovers or lucerne, can stop the decline in soil structure and restore the organic matter to our wheat belt soils.



Fallow workings help to increase crop yields, but the repeated cultivation greatly hastens the breakdown of organic matter and humus. Temporary pastures are needed to restore the balance.



In orchards and vineyards cover crops are the best means of returning organic matter to the soil. Photo. shows a clover cover crop in a River Murray irrigated vineyard.

In vineyards and orchards, green manure crops are the best way of preserving soil organic matter. In non-irrigated areas such as the Barossa Valley there may not be enough moisture to meet the demands of both the cover crop and the trees or vines. Then it is necessary to turn in the cover crop by the end of the winter, before the tree or vine makes its initial spring growth.

This problem does not arise in the irrigated areas. Here, the practice of maintaining a permanent sod or pasture has been tried with considerable success under some conditions, although it cannot be used everywhere.

Regardless of how the land is used, soil organic matter is one of the key indicators of soil fertility. Any kind of farming which brings about a continuous decline in organic matter can only result in lower yields and the appearance of soil problems; whereas, if organic matter is increased or maintained, the fertility of the soil is assured.

SOIL PERMEABILITY AIDS PLANT GROWTH

By **W. M. CONLEY,** *Soil Conservation Officer,*

THE term "permeability" refers to the ease with which water can enter and move through a soil. The permeability of the surface soil, or in other words, the infiltration rate, decides the rate at which soils can absorb water; but permeability of the soil as a whole also includes its capacity to drain water.

If a soil is permeable to water it will also admit air and plant roots. Thus, good soil permeability is important to plant growth.

WHAT ARE ITS EFFECTS ON FARMING?

AS well as influencing plant growth, soil permeability has other effects on our agriculture, notably in respect to run-off, to irrigation and to salt problems.

Run-Off.

Soils with a low infiltration rate benefit less from heavy rains. This is because they cannot absorb the water quickly enough. The water accumulates on the surface, and in sloping country it runs off. The result is erosion of the topsoil; and, furthermore, some of the rainwater runs down gullies or creeks and is wasted.

In many of the hard setting red brown earths of the upper and mid-north, lack of rain is the main factor restricting crop and pasture growth. In these areas any improvement in surface permeability means less rainwater wasted as run-off.

Irrigation.

Irrigated soils need good permeability not only at the surface but—even more important—in the sub-surface layers, as this ensures quick removal of excess water.

An impermeable layer beneath the surface makes some soils almost useless for irrigation. An example of this is the so-called "solidised solonetz" soil—usually a sand or sandy loam overlying a heavy, poorly structured clay. Such dense clay layers make satisfactory irrigation impossible.

When water reaches the impermeable layer it can only drain away very slowly. The water therefore accumulates in the soil above. In extreme cases, where water cannot escape either downwards or sideways, a "perched" water table is formed. The soil pores of the water-logged zone become filled with water to the exclusion of air. Under these conditions plants soon become unhealthy and eventually die. Lucerne is particularly susceptible to water-logging.

Another outcome of poor permeability is the development of certain salt patches, the root of the problem being a poorly drained or impermeable subsoil. On sloping land, water seeps downhill on top of the clay layer, carrying salts which are present in the soil as it goes.

The salt laden water eventually drains into low lying areas, and when these have an impermeable layer, water builds up near the surface. Then, during the hot weather, the water evaporates, leaving the salt behind. The concentration of salt gradually increases over the years. Eventually it becomes so high that plants cannot grow—and a barren salt patch is formed.

WHAT MAKES A SOIL PERMEABLE?

What makes a soil permeable or impermeable? Usually it is a combination of texture and structure.

Texture.

The term "texture" refers to the fineness or coarseness of the soil particles. A sandy soil absorbs water rapidly and has good permeability. This is because sandy soils are made up of large particles, which leave plenty of large pore spaces for easy percolation of water.

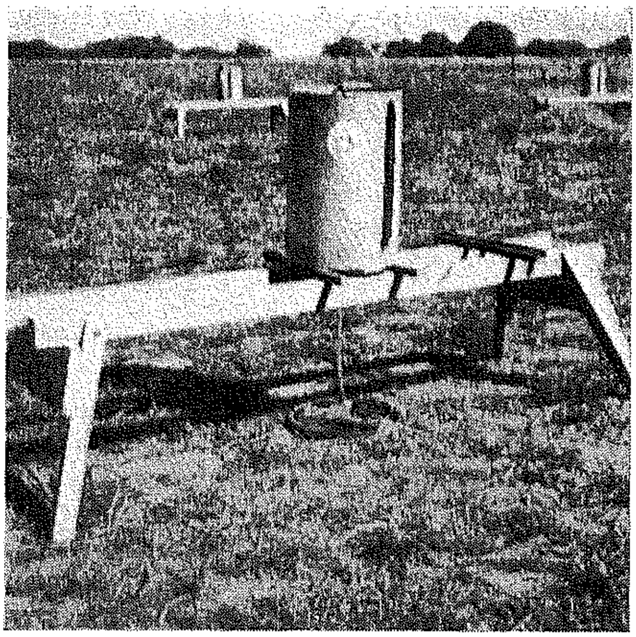
On the other hand, a heavy soil has small particles which often pack together tightly. These soils have many pores, but seldom are they big enough to allow easy movement of water.

Structure.

Good structure is a factor which can offset the tendency of heavy soils to have poor permeability.

In a well structured soil many of its particles are bound together into small crumbs or aggregates which make the soil porous. The binding effect is caused by certain types of clay and by organic matter.

Other soils, such as the black earths, develop deep cracks on drying out. These soils can absorb very large quantities of water until the soil becomes thoroughly wet and the cracks seal. When this happens the permeability of the soil becomes very low and they are then sticky and difficult to work.



The Infiltrometer, a device for measuring infiltration rates and hence soil permeability.

As the soil absorbs water from the ring set into the ground, the level of water in the reservoir tank drops. The level in this tank is measured at half-hourly intervals. In this way the apparatus measures the rate at which the soil absorbs water.

[*Aust. Jnl. Agric. Science.*]

WHAT CAN THE FARMER DO ABOUT PERMEABILITY?

Thus far we have discussed the effects of permeability and the things that affect it. The next question is "What can the farmer do towards improving or maintaining the permeability of his soil?"

As far as the subsoil is concerned he can do little. Subsoiling or deep tilage is seldom a practical proposition. But he can do something about the top soil, particularly the top few inches where cultivation and root growth have their greatest effects. Tillage, rotations and plant cover all come into this.

Cultivation.

Repeated cultivation breaks down soil structure by destroying organic matter and breaking up the soil crumbs. We all know that soils which are cultivated too often become very prone to crusting or surface sealing after a rain. When raindrops strike the poorly structured surface they break up granules and pack soil particles closer together. Water then carries these smaller particles into the soil. Here they are trapped and eventually block the pores.

When these soils dry out, they have a thin crust or surface seal. This not only reduces the permeability of the soil surface but may have a bad effect on germination of cereals or pasture plants.

Moderate tillage, then, is one way of maintaining the infiltration rate.

Rotations.

Suitable rotations are the best way to offset the destructive effects of cultivation. Some soils can be cropped every other year quite safely. Others are naturally poorly structured and need a longer term under pasture. The pasture phase of the rotation builds up soil structure by adding organic matter, mainly in the form of plant roots.

The ideal rotation for any one area, then, depends on many factors—soil type, slope, rainfall and whether soil structure is being maintained or not.

Surface Cover.

A good cover of plants protects the soil from the pounding action of raindrops. Leaves and stems intercept the rain so that it reaches the soil surface only as a gentle trickle of clear water. This prevents the soil pores from being blocked with mud and preserves the permeability of the surface.

CLAY . . . *by* J. S. POTTER, *B.Ag.Sc.*

Soil Conservation Officer, Jamestown

SOILS contain sand, silt and clay. The amount of any one of these materials varies from one soil to another and thereby affects the soil's characteristics.

Of the three, clay has the greatest effect. It is a substance with a number of peculiar properties, which enable it to exert an important influence on—

- **The amount of water which can be stored in the soil.**
- **The amount of water available to plants.**
- **The storage of many of the plants' foods.**
- **Soil structure and erodibility.**
- **Ease of cultivation.**

PROPERTIES OF CLAY.

Clay is a specific soil particle of definite size, shape and composition.

Size.

Clay particles are extremely small. The largest of them are less than 1/12,000 of an inch in diameter.

They are so small that when shaken in water and allowed to stand most of the particles do not settle out but remain suspended. This is why dam water stays muddy after it has been stirred up.

Fortunately it is possible to get the particles out of suspension. Certain chemicals when added to the water cause the particles to flock together so that their combined weight causes them to sink to the bottom. For instance, by adding alum to muddy dams we can make the particles settle out and leave the water clear. This process is called flocculation.

Many of our soils contain plenty of these flocculating chemicals, especially calcium compounds, so the clay occurs in a flocculated state. Not only is it held together itself but it also helps to bind sand and silt particles together as well. So, even though clay particles are very small, they are often found naturally bound together into crumbs.

It should be the aim of all cultivation practices to retain these crumbs so that the soil structure is preserved. Excessive cultivation tends to break up the crumbs into individual particles, so producing poor structure.

Common salt also tends to disperse the clay particles, and therefore poor structure is a common fault of sodium clays. These clays can be improved if the sodium on the clay particles is replaced by calcium. This is what happens when gypsum is used as a soil amendment to improve the structure of irrigated soils.

Shape.

Clay particles are not round. They are flat crystals made up of many thin sheets which are tied firmly together by either hydrogen atoms or water molecules.

Composition.

A clay particle is a very complex mineral. Each sheet of the crystal has a framework of tightly packed oxygen atoms into which fit atoms of silicon, aluminium or iron.

The number and the arrangement of these atoms varies from one type of clay mineral to the next. This shows up in the colour and structure of the clay in the field.

For example, high silicon clays are usually grey, sticky and compact, whereas clays high in aluminium and iron are usually red, porous, and friable.

The type of clay mineral also decides the clay's ability to absorb and hold water and to hold plant nutrients. These aspects will be discussed later.

THE EFFECTS OF CLAY IN THE SOIL.

Texture.

The amount of clay in soils varies considerably and has a big influence on soil texture.

There is some clay in all soils, *e.g.*—

A sand may contain 0-9 per cent clay.

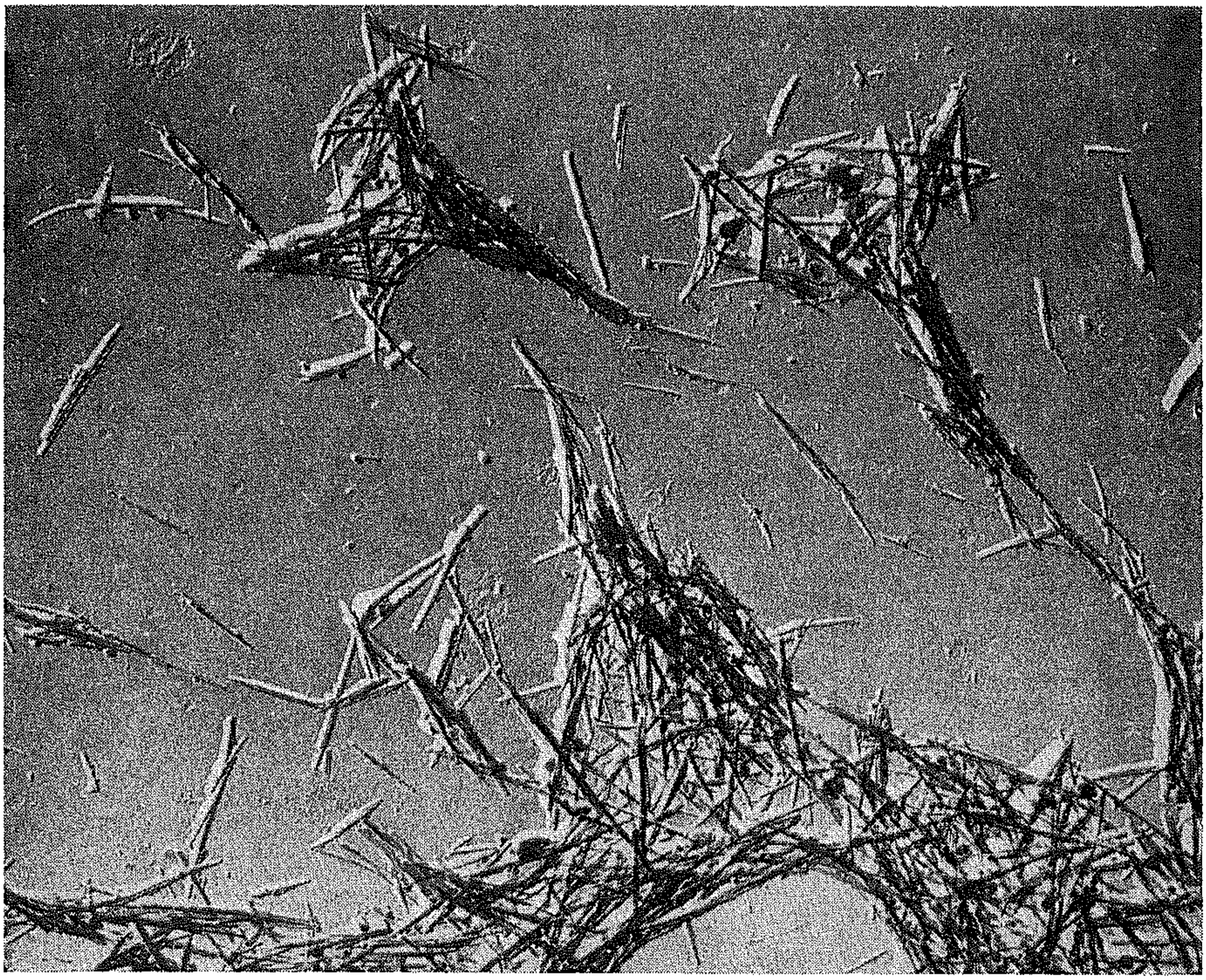
A sandy loam may contain 8-21 per cent clay.

A loam may contain 10-26 per cent clay.

A clay-loam may contain 21-40 per cent clay.

A clay soil contains more than 31 per cent clay.

The amount of clay also varies with depth. The subsoil usually has more, because the fine clay particles have been washed down by rain over the years.



CLAY CRYSTALS UNDER THE MICROSCOPE.

The photograph shows the thin, rod-like shape of the individual particles of a clay from central Australia. It was taken with an electron microscope having a magnification of approximately x 10,000, and the clay was suspended in liquid (in other words, muddy water). As can be seen, the clay particles are definitely crystalline. Other types of clay show different crystal shapes and are often more disc-like than these.

[*Photo.: Physics Department, University of Adelaide.*]

Water Storage.

Although the sheets of the clay crystal are tied firmly together, water is still able to get in between them. This means that soils with a high clay content have a lot more space to store water than those which are mostly sand, because sand crystals are solid and cannot take up water.

However, all this stored water is not readily available to plants. Clay tends to hold back quite a lot of water from the plants' roots. Furthermore, once the soil is dry it takes a considerable amount of rain before the clay's requirements are met and there is any available for plants. On the other hand, sandy soils give up their moisture easily, and plants growing in them can make use of even a very light rain.

Fertility.

Clay particles have a big bearing on a soil's capacity for storing plant nutrients. This comes about because they have a strong negative charge. Many of the plants' foods in the soil solution have a positive charge. These cations, as they are called, are attracted and held by the clay particle. This attraction is strong enough to prevent water washing the nutrients beyond the plant's reach. The main cations held are calcium, magnesium, potassium, sodium and hydrogen.

Nutrients can only be removed from the clay's surface if there are other cations to replace them. Plant roots get food from the clay in this manner; they replace the cation they need with another which they have in excess. This is known as cation exchange.

The clay mineral, then, plays an important part in supplying the plant with some of its essential foods. The more clay there is in the soil the more of these foods can be stored for future plant use.

The type of clay also has an important bearing on how much food can be stored. Suffice it to say here that the clay minerals associated with the black earths and red brown earths of the Lower North can store more plant foods (have a higher cation exchange capacity) than, say, the clay minerals of the ironstone soils of Kangaroo Island and the pod-solic hills soils.

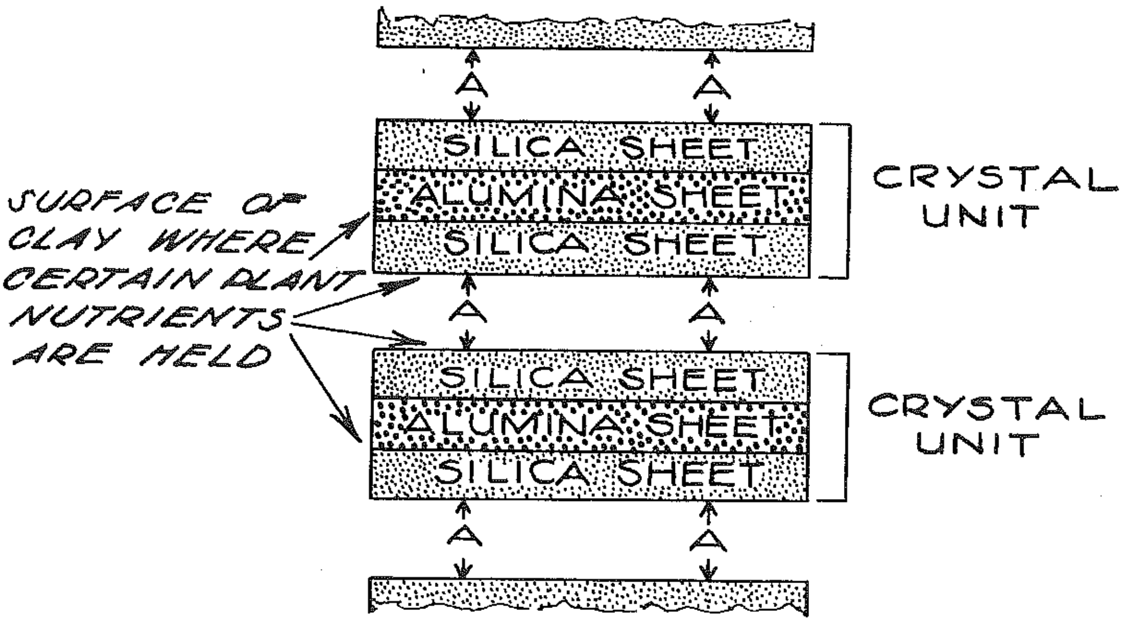


Fig. 1.—Diagram of a vertical section of a clay mineral which occurs commonly in soils. It shows two crystal units which are loosely held together. The distance between the units (shown as A) is variable. As water is added to the soil it is absorbed between the units, pushing them apart. The distances at A are increased and the clay as a whole swells. As water is removed by evaporation or used by plants, so the units come together again and the clay shrinks. The large surface area, both external and internal, enables great amounts of plant nutrients (cations) to be held. Soils containing this clay mineral are, as a result, usually fertile.

Ease of Working.

Soils high in clay are usually stiff and heavy to work. This is because they become mouldable, or plastic, when a certain amount of water enters between the sheets of the crystal. Plasticity varies from one clay to the next. Grey clays are highly plastic and most difficult to work, but red clays are usually more friable and easier to work.

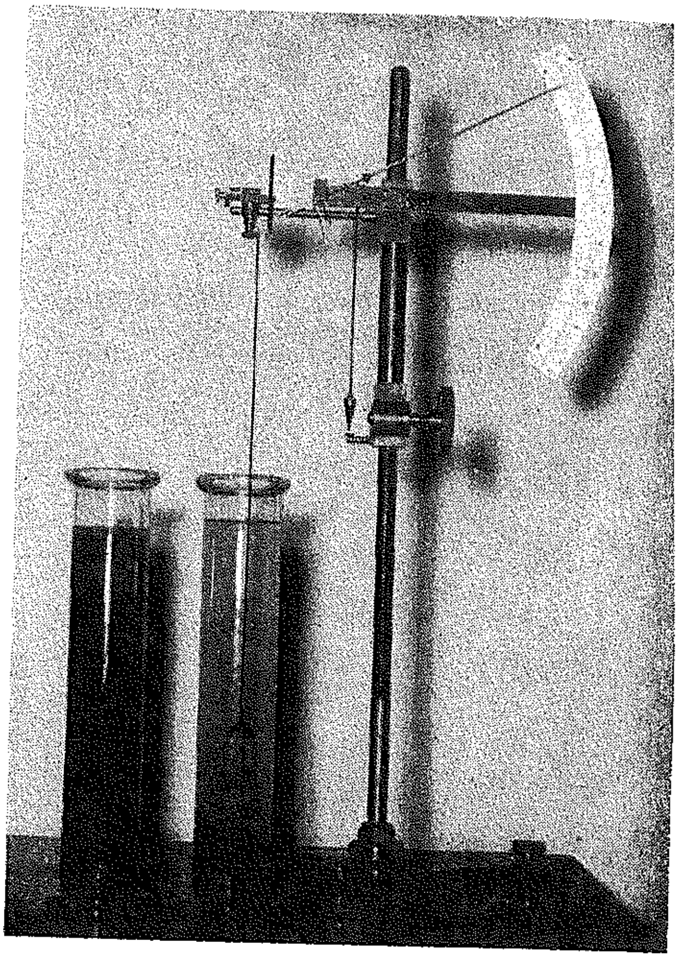
Swelling and Shrinkage.

Clay swells when wet because water enters between the sheets of the crystal. Conversely, when it dries out it shrinks. In some soils we see the effect of shrinkage as large cracks in the ground.

This property is most marked in our "Bay of Biscay" soils, which have these properties of shrinking and swelling to such a marked degree that they are unsuitable for building unless special foundations are used.

CONCLUSION.

A farmer must accept the fact that he cannot change the amount of clay in his soil or alter its composition. He can however, modify its effects somewhat by using amendments such as gypsum or by carrying out practices which increase or decrease organic matter content of the soil. But in most cases all he can do is recognize how clay affects the properties of his soil and learn to farm his land accordingly.



The plummet balance—an instrument for measuring the percentage of clay in soils. The soil is dispersed in water (as in the glass cylinders shown here). After the larger soil particles of sand and silt have settled out, the plummet is inserted, and the percentage of clay can then be read on the scale. Cylinder at left contains a soil with a large amount of clay. Cylinder at right contains soil with little clay. The principle involved is the increase in density of the suspension as the amount of clay increases.

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