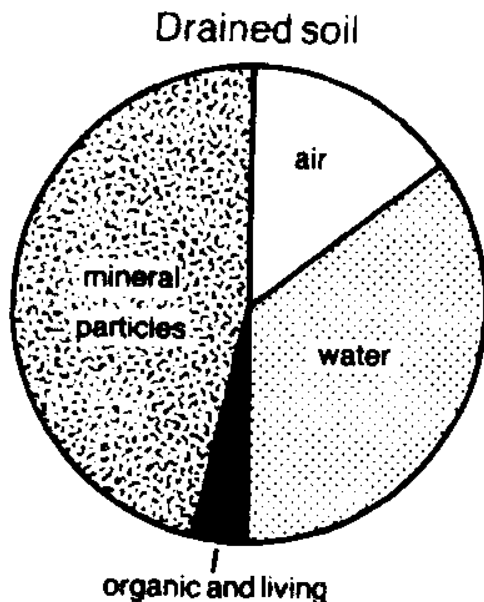


## SOIL AND ORGANIC GARDENING

Organic gardening consists of much more than just avoiding the use of synthetic fertilisers, pesticides and fungicides. Appropriate soil management lies at the heart of the method. By maintaining a healthy soil life, an adequately watered and well structured soil so that the natural processes of recycling plant nutrients can take place, plants are able to grow successfully, and in most cases cope with pests and diseases, with very little interference by the gardener.

### Soil Basics

For plants to grow well they require their roots to be continuously supplied with balanced proportions of water, air and plant nutrient elements. These needs are met when the five main components of soil viz, mineral particles, organic matter, water, air and living organisms, are present in appropriate proportions. For a typical well drained garden soil these proportions are shown below.



*Figure 1:* Proportions of the five main components of a well drained garden soil.

The activity of the gardener can have a significant affect on the proportions within the soil of all its components. For example, the water content of the soil depends on watering patterns, drainage, evaporation (mulching), organic matter content, soil structure etc. The amount of air in the soil also depends on soil structure and can be dramatically reduced through soil compaction and waterlogging. Plants suffer when the amount of water and air (oxygen) available to their roots is out of balance. A compacted soil also inhibits the development of the plant roots through restricting the plant's ability to push its roots through the soil and restricting the root's ability to access the oxygen necessary for their growth.

The amount of organic matter in the soil depends on gardening techniques such as the use of green manure crops, the manner of working the soil, composting and mulching etc and the

number of living organisms depends on the amount of food (organic matter in the soil), the pH, the techniques used for working the soil, damage caused by sprays and fertilisers used. These factors also influence the number of beneficial organisms and disease-causing organisms which can be supported by the soil and the balance between them. Soil life is also crucial to maintaining a constant supply of plant nutrients through their role in converting organic matter into forms available for plant use and in sustaining mutually beneficial symbiotic relationships between plant roots and certain bacteria and fungi. Soil acidity not only affects the balance between bacterial life and fungi, it also affects the availability of plant nutrients which can be accessed by the plant roots from soil water.

Clearly organic gardeners need to monitor the condition of the soil carefully to ensure that it is in optimum condition to maintain plant growth.

### **Soil Characteristics**

Soil properties can be categorised into three groups:

- Physical properties such as soil texture and soil structure;
- Chemical properties such as acidity, salinity, sodicity etc which are related to the chemical processes which affect the availability of nutrients to plants and soil life.
- Biological properties related to the health of the soil macro and micro-organisms.

These properties are not independent. They interact. For example, the biological activity of earthworms can change physical properties of the soil through aeration and the improvement of soil structure. Bacterial activity can change chemical properties through the release plant nutrients. Chemical activities can have a major impact of physical properties, for example the use of gypsum to improve the structure of clay soils, and high acidity inhibiting some forms of biological activity.

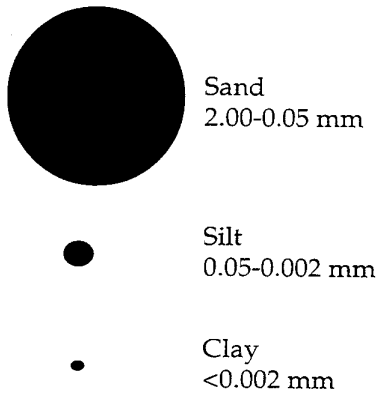
The role of the gardener is to understand the soil properties of the garden and to ensure that the soil is in such a condition that the plant's nutrient needs can be met throughout its life cycle. By appropriate soil management practices the organic gardener can achieve optimal physical, chemical and biological soil properties for the particular plants being grown.

### **Physical Properties**

From a gardening perspective, it is useful to have a good understanding of the texture and structure of our garden soil to ensure appropriate gardening methods are used to provide optimum conditions for our plants. For example, a very clayey soil will need to be treated differently to a sandy soil. Considerable care is needed to avoid compaction of a clayey soil but this is not such a problem with a sandy soil, on the other hand a sandy soil is more likely to be lacking in nutrients and it may be necessary to add much more organic matter to the sandy soil. The sandy soil will also be more susceptible to leaching and less able to store water requiring more care to avoid loss of nutrients and pollution of nearby streams through over-watering.

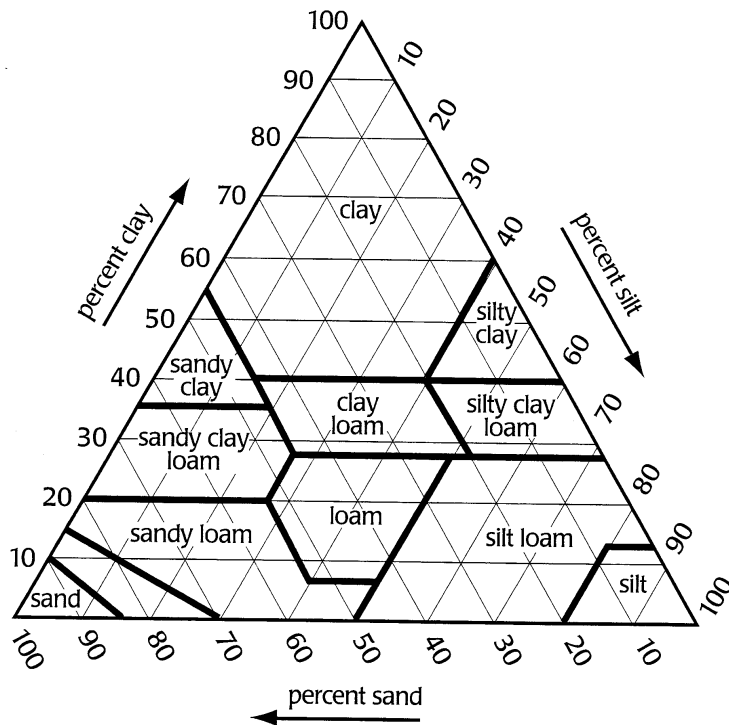
Soil texture can be regarded as the “feel” of the soil. By rubbing some soil through our fingers we can feel whether it is gritty, smooth and silky or somewhere in between. This “feel” of the soil depends on the relative amounts of sand, silt and clay which comprises the mineral

component of the soil. Sand is the coarsest material and clay the finest. The relative sizes (not actual sizes) of the mineral components of soil are illustrated below.



*Figure 2:* Relative sizes of particles of the mineral component of soil.

There is a universal system for categorising soils according to these relative amounts. It is summarised in the diagram below.



*Figure 3:* Soil texture triangle.

There are various methods available for determining which texture category a soil belongs to. The method below, taken from Handreck and Black, is a simple but standard method the home gardener can use. Other methods are also described in this book and references such as the NSW Agriculture’s *SOILPak for Vegetable Growers*.

### Assessing Soil Texture

- 1 Take a small sample of soil sufficient to fit comfortably in the palm of one hand. Discard obvious pieces of gravel.
- 2 Moisten the soil with water, a little at a time, and knead until there is no apparent change in the way it feels. Kneading will break aggregates so that they are no longer felt. This may take several minutes. The moisture content should be such that the soil just fails to stick to the fingers.
- 3 Inspect the sample to see if sand is visible; if not, it may still be felt and heard as the sample is worked.
- 4 Next squeeze the sample hard to see whether it will form a ball or cast, and if so, whether the cast is durable or falls apart readily.
- 5 Finally, squeeze it out between the thumb and forefinger with a sliding motion and note the length of self-supporting ribbon that can be formed and compare with the table below.

No coherence; cannot be moulded; single grains stick to fingers.	Sand
Forms a fragile cast that just bears handling; gives a short (6 mm) ribbon that breaks easily; discolours fingers.	Loamy sand
Forms a fragile cast; sticky when wet; many sand grains stick to fingers; discolours fingers with clay stain; forms minimal ribbon 5-15 mm long.	Clayey sand
Forms a cast that will just bear handling; individual sand grains can be seen and felt; gives a ribbon 15-25 mm long.	Sandy loam
As for sandy loams, except that individual sand grains are not visible, although they can be heard and felt; gives a ribbon 15-25 mm long.	Fine sandy loam
Forms a coherent cast that feels spongy but with no obvious sandiness or 'silkeness'; may feel greasy if much organic matter is present; forms a ribbon about 25 mm long.	Loam
Coherent but will crumble; very smooth and silky; will form a ribbon 25 mm long.	Silty loam
Forms a strongly coherent cast in which sand grains can be felt; forms a ribbon 25-40 mm long.	Sandy clay loam
Forms a coherent cast with a rather spongy feel; plastic when squeezed between thumb and forefinger; smooth to manipulate; will form a ribbon 40-50 mm long.	Clay loam
Forms a plastic cast, except that sand grains can be seen, felt or heard; forms a ribbon 50-75 mm long.	Sandy clay
Smooth plastic cast; slight resistance to shearing between thumb and forefinger; forms a ribbon 50-75 mm long.	Light clay
Smooth plastic cast, handles like plasticine and can be moulded into rods without fracture; some resistance to ribboning; forms a ribbon 75 mm or more long.	Medium clay
Smooth plastic cast that handles like stiff plasticine; can be moulded into rods without fracture; firm resistance to ribboning; forms a ribbon at least 75 mm long.	Heavy clay

To a large extent soil texture must be taken as a given by the gardener. It is very difficult, and expensive, to change the texture and probably not necessary. On the other hand soil structure can easily be enhanced (or destroyed) by the gardener through simple techniques and is usually more significant from the perspective of root penetration through the soil and water infiltration and retention.

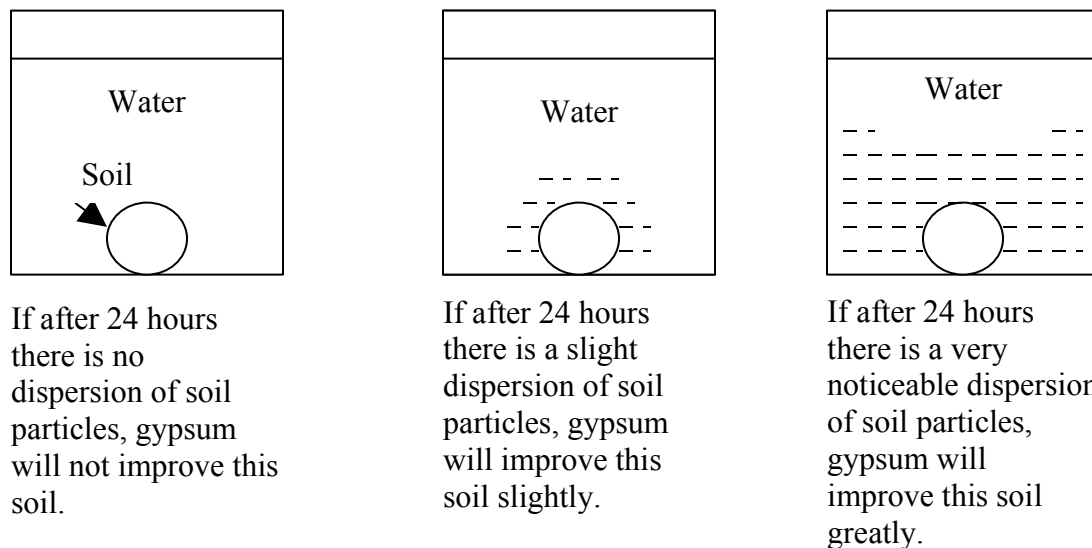
Soil structure is characterised by the way the soil particles (sand, silt and clay) stick together to form crumbs or aggregates of various sizes. These crumbs (called peds) come in all shapes and sizes and the spaces between them provide the pore spaces through which roots, water and air can penetrate the soil and, consequently, good soil structure is extremely important for plant development.

For a vegetable garden it is desirable to aim at a crumb size from about 0.2mm to 3mm across. Soils which have a weak crumb structure are easily destroyed by over-cultivating such as by using a chipping hoe too vigorously or a rotary hoe with high speed chopping motion. The soil becomes powdery and the crumb structure is destroyed. In such a condition the soil is very difficult to wet. However, when it does become wet if it experiences foot or other traffic it can be easily compacted, particularly if there is a reasonable clay content.

The strength of the crumb structure can be enhanced by the addition of organic matter and worm castings. It is not the organic matter itself which improves the soil structure but the slimes produced by soil microbes as they feed on the organic matter and the slimes which are produced in worms guts that hold the worm castings together. These slimes hold the soil particles together to form the crumbs. The hyphae of soil fungi (the sticky bands through which the fungi get their food) also play an important role in holding the soil crumbs together. The presence of clay, iron and aluminium and exchangeable calcium tend to enhance crumb formation but for the organic gardener probably the most effective method is to add organic matter to ensure a healthy and vigorous soil life and minimise the use of hoeing. The presence of exchangeable sodium tends to decrease the strength of the crumb structure so the use of bore water or dam water collected from the salt prone areas around the ACT should be approached with caution to avoid damaging the soil structure. Likewise, in an urban situation care is needed in the use of recycled water if high salt detergents have been used for washing.

At the other end of the scale some heavy clay soils form large solid clods or lumps which plant roots and air are unable to penetrate. The structure of these soils may, in some circumstances, be improved by the addition of gypsum. The Emerson dispersion test described below is used to determine whether or not gypsum will improve the structure of a heavy clay.

Place a small ball of soil into a beaker as shown. If after 24 hours a “halo” of soil forms in the water around the ball of soil as indicated in the diagrams below, the addition of gypsum will improve the structure of the soil.



*Figure 4:* Emerson's dispersion test to determine the likely efficacy of gypsum to improve the structure of clay soil.

The physical properties of soil can vary greatly from place to place and if the garden is large it is often advisable to dig several holes to get an overall picture of the soil profile, structure and texture of soil in the garden.

### **Chemical Properties**

The chemical properties of soil affect the chemical reactions within the soil which release plant nutrients in a form which plants can take up through their root systems.

All nutrients are usually present in the soil to some extent but the proportions of each can vary widely according to the nature of the parent rock from which the soil was formed and the history of the soil since its formation (eg whether it has been subject to severe leaching).

Nutrient requirements of plants can also vary widely, eg some have a high phosphorus requirement while others have a low requirement. This can result in a particular soil being ideal for one type of plant but may produce nutrient deficiencies or toxicities in another type of plant. Plant nutrient requirements also vary according to the stage of a plant's life cycle. Consequently, it is important that the gardener understands the nutrient needs of the plants being grown, how those needs change during the various stages of its life cycle and whether or not the soil can meet those needs. It is also useful to be aware of the chemical properties of the soil which affect nutrient availability and to be able to recognise the effects on plant growth of a lack or an over-abundance of various nutrients.

### **Plant Nutrient Needs**

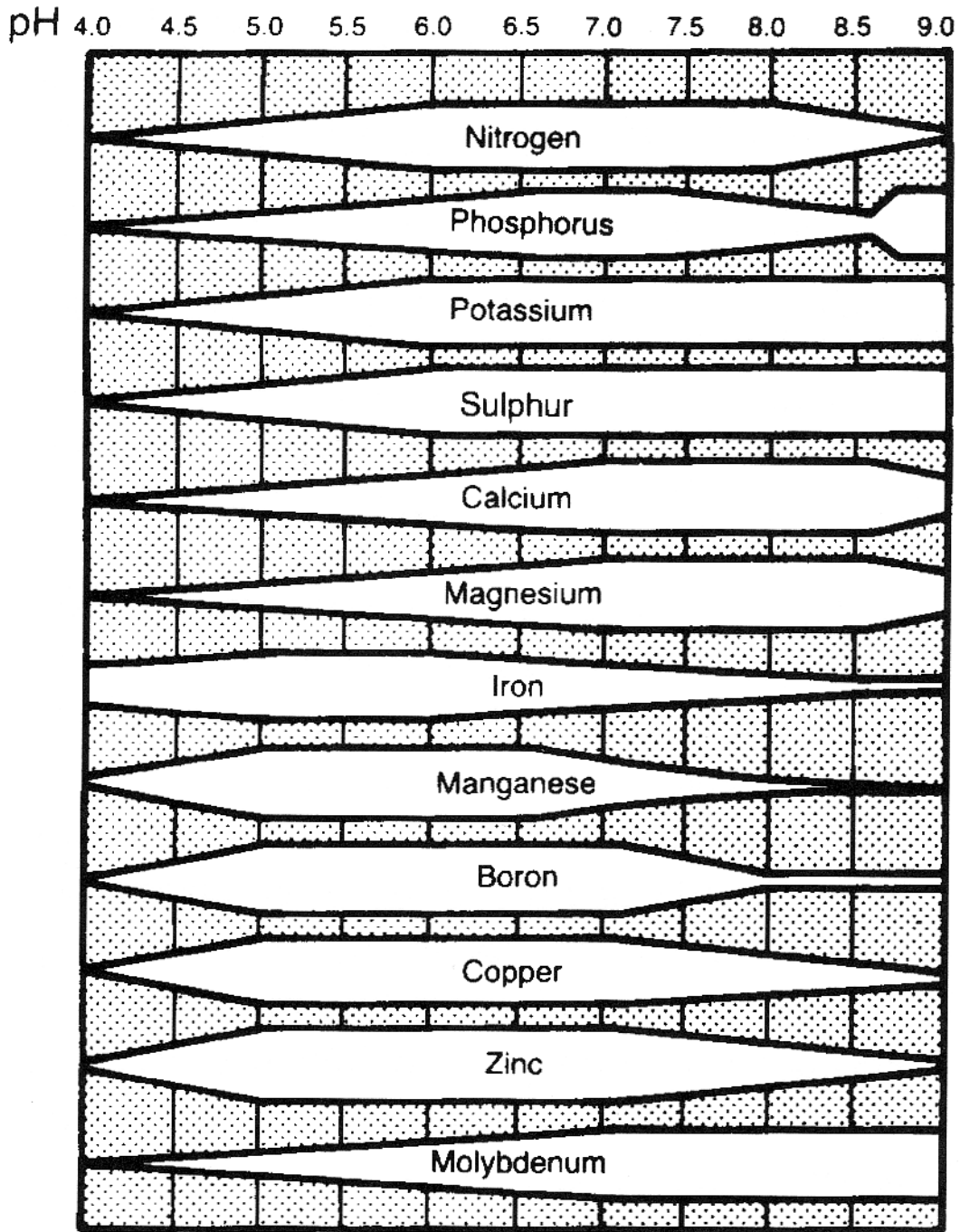
There are sixteen elements known to be essential for the successful growth of all plants. Of these, only carbon (from the carbon dioxide in the air) and oxygen are absorbed by plants directly from the atmosphere, hydrogen and some oxygen come from the soil water absorbed through plant roots. All the other nutrients are absorbed through the roots as ions dissolved in

the soil water. While some nutrients can be absorbed by the plant through the leaves (foliar fertilising), it is the soil which provides the vast majority of plant nutrient needs.

The amount of a particular essential nutrient element required by a plant varies according to the particular plant, the element and the particular stage of the plant's life cycle. Those nutrients which are required in the greatest quantities are referred to as the major or macro nutrients. They are carbon, oxygen, hydrogen, nitrogen, phosphorus, potassium, sulphur and calcium. Those nutrients needed in much smaller quantities are referred to as the minor, micro or trace elements. They are magnesium, iron, copper, zinc, manganese, molybdenum, boron and chlorine. Some plants also require traces of elements such as aluminium, sodium, silicon, cobalt, nickel and vanadium. While the above elements play an essential role in plants' biochemical processes, plants also take up many other elements, such as selenium, iodine, fluorine, bromine and arsenic which, though they do not seem to play a role in the biochemical processes of plants, are essential to animals. Consequently, plants may be perfectly healthy but may not provide all the nutrient needs of those who eat them if those nutrients required by animals are not present in the soil.

### Controlling Soil Acidity

One of the simplest chemical properties of soil to measure is its acidity or its pH. pH is a measure of the concentration of positively charged hydrogen ions (cations) in the soil. It has a scale of 0 to 14 where 7 is neutral, that is neither acidic or alkaline. Less than 7 is acidic and greater than 7 is alkaline. The pH scale is logarithmic which means a pH of 4 is ten times as acidic as a pH of 5 and one hundred times as acidic as a pH of 6. Acidity and alkalinity affect the chemical reactions which occur in the soil so that for some values of soil pH certain chemical nutrients which a plant requires may become chemically bound up in an insoluble compound and therefore unavailable to the plant, even though a soil test may indicate an abundance of the nutrient in the soil. The following diagram shows the change in the availability of various plant nutrients as pH changes even though the overall amount of the particular nutrient elements do not change.



*Figure 5:* The variation with pH of availability to plants of nutrient elements within mineral soils (not potting mix). The wider the bar, the greater the availability. From Handreck and Black p 91.

Most nutrients are readily available in a pH range between 6 and 7 and this suits most vegetables, although some ornamental plants such as daphne, azaleas, camellias prefer a pH range between 4.5 and 6 while some other plants such as artichokes and abelias prefer a pH range between 6.5 to 9. Few plants can survive if the pH is less than 4.5 or greater 9.5. At the extreme ranges of pH plant roots are damaged.

If nutrient deficiencies or toxicities are noted in plants the first step is to measure the pH rather than supplying fertiliser to correct the nutrient deficiency. The nutrient deficiency may be easily corrected by adding lime or dolomite to the soil if it is too acidic or sulphur if it is too alkaline to bring the pH into the 6 to 7 range. This will release the nutrients already present in the soil. If the nutrient deficiency or toxicity persists it may be possible to identify which nutrients are the problem by the symptoms exhibited by the plant and through better soil management those deficiencies or toxicities may be overcome.

#### Identification of Nutrient Deficiencies and Toxicities

Each nutrient has a range of specific roles in the biochemistry of a plant. Lack of particular elements disrupts these biochemical processes and produces visible symptoms in the plant. Some symptoms are specific to particular plants such as blossom end rot in tomatoes caused by calcium deficiency (usually due to irregular watering) but often general symptoms in the leaves can identify nutrient problems which can be dealt with by the gardener through soil management.

While the identification of nutrient deficiency can be quite complex, especially where there are interacting deficiencies and resulting stress on the plant has also led to disease or pest attack. However, the first step is to identify whether the older or newer leaves are the most affected. The nutrient elements nitrogen, phosphorus, magnesium, potassium, molybdenum are very mobile within a plant and consequently deficiencies appear on the oldest leaves first. Calcium, sulphur, iron, copper, zinc and boron are relatively immobile in a plant and deficiencies first show up on the youngest leaves and shoots. Manganese deficiencies can affect both old and new leaves. The COGS handout, *Nutrient Deficiencies in your Plants. How to Identify and Correct them – Organically*, summarises these symptoms. More detailed descriptions can be found in the CSIRO publication *Food for Plants*, in Weir and Cresswell and in Handreck and Black.

#### Capacity of soil to store nutrients

Some soils have a greater capacity to store plant nutrients than others but good soil management can increase that capacity. The very small soil particles viz, clay and humus, play an important role in the capacity of soil to store nutrients and facilitate access by plant roots to those nutrients.

Plant nutrients are present in the soil as ions. These are nutrient elements with a positive electrical charge (called cations) or a negative charge (called anions). The particles of clay and humus are also charged, usually negatively, consequently these soil particles are surrounded by a cloud of nutrient ions held in place by the electrical attraction of oppositely charged ions. This is a dynamic process and there is a constant exchange of ions with those dissolved in the soil water. The tiny root hairs through which plants absorb nutrients are also charged and give off hydrogen ions so there is also a continual exchange of ions between the roots and the soil water, or where they are in direct contact with clay and humus particles, with the cloud of ions surrounding those particles.

The capacity of soil particles to attract a cloud of nutrient ions varies greatly. A commonly used measure of this capacity is called the cation exchange capacity, known as the CEC and is measured in units of milliequivalents per 100g. The following table compares the CEC of various common soil particles and humus.

Clay	CEC	Meq/100g
Smectite (common in the black soils of northern NSW)	High	150
Vermiculite	High	150
Chlorite	Medium	50
Illite	Medium	50
Kaolinite (common clay particle in Canberra)	Very low	10
Humus	High to very high	150 - 500

Humus is the relatively stable part of soil organic matter remaining after the major portions of plant and animal remains have been decomposed. It consists of large organic molecules containing mainly carbon, hydrogen and oxygen but also considerable amounts of nitrogen and sulphur as well as lesser amounts of other elements. Clearly, because of the high CEC of humus, the organic gardening method of adding organic matter which is eventually broken down into humus will greatly increase the soil's ability to hold nutrients. This is illustrated by the following table taken from a study of clay and organic matter contents and cation exchange capacities of topsoils from the main soil groups of the Canberra area (J R Sleeman and P H Walker, CSIRO Division of Soils, Soils and Land Use Series, No. 58, 1979 – quoted in Handreck and Black). Note the increase in CEC with addition of organic matter in the italicised section of the table.

<b>% Clay</b>	8	9	10	10	<i>11</i>	<i>11</i>	<i>11</i>	14	16	18	20	23	25
<b>% Organic Matter</b>	1.9	1.6	1.8	2.9	<i>1.3</i>	<i>3.3</i>	<i>7.9</i>	3.1	4.2	4.2	3.6	7.3	5.8
<b>CEC (meq/100g)</b>	9.6	8.7	8.6	10.7	<i>8.1</i>	<i>9.1</i>	<i>16.3</i>	11.8	15.8	15.3	15.3	22.5	26.5

### Biological Properties

A healthy soil is teeming with living organisms besides plants, the vast majority of which are beneficial to plants. They are an essential component of healthy soil. One cubic metre of top soil contains about 2.5 kg of living organisms such as earthworms, millipedes, ants, nematodes, protozoa etc and other micro-organisms. This soil life is essential for releasing nutrients back into the soil in a form available to plants. A healthy soil life also helps to ensure that disease causing agents are kept within acceptable limits.

Organic gardening encourages the maintenance of this soil life by avoiding the addition of chemicals to the soil which will destroy parts of this life and avoiding the use of gardening methods which will interfere with the natural interactions which occur within this soil life. Even acceptable organic pesticides can have a devastating affect on soil life, for example, rotenone

(derris dust) (see *National Standard for Organic and Biodynamic Produce*) which is sometimes used by organic growers for controlling aphids and caterpillars is highly toxic to earthworms.

It is beyond the scope of this article to describe the great variety of this soil life and the role of each in maintaining a healthy soil and healthy plants. The soil environment such as its wetness, temperature, types and amount of organic matter it contains, types of minerals, oxygen supply, pH etc affects the types of organisms in the soil. For example, fungi prefer drier and more acid soil than bacteria consequently as soil becomes drier or more acid the microbial life of the soil has an increasing proportion of fungi. Many of these factors such as wetness, type and amount of organic matter, oxygen supply to the root zone, and pH are within the control of the gardener.

The two most common methods by which gardeners exploit the soil life is in the making of compost and in the encouragement of earthworms. A great deal of information of the nature, function and importance of the various aspects of soil life can be found in standard textbooks such as Handreck and Black.

### **Conclusion**

The foundation of successful organic gardening is the condition of the soil in which our plants grow. It is the soil which provides the majority of nutrients needed by plants and, consequently, much of the effort of the organic gardener is devoted to ensuring that the soil is in a condition which allows plants to access those nutrients efficiently and sustainably. The gardener will then be rewarded with a plentiful supply of nutritious and delicious food.

### **References:**

- Australian Produce Export Committee*; National Standard for Organic and Bio-dynamic Produce, 3<sup>rd</sup> ed, Australian Quarantine Inspection Service; 2002.
- COGS*; Nutrient Deficiencies in your Plants. How to Identify and Correct them – Organically.
- CSIRO*; Food for Plants; Discovering Soils No 6; CSIRO, 1978.
- Handreck, K and Black, N*; Growing Media for Ornamental Plants and Turf; 3<sup>rd</sup> ed, UNSW Press, 2002.
- McMullen, B*; SOILPak for Vegetable Growers; NSW Agriculture; 2000.
- Weir, R G and Cresswell, G C*; Plant Nutrient Disorders 3 – Vegetable Crops; Inkata Press; 1993.