“Man, despite his artistic pretensions, his sophistication, and his many accomplishments – owes his existence to a six inch layer of topsoil and the fact that it rains.” Anon

“Ironically, however, the question [of soil condition] is mostly academic. The cure for heavy clay soil is to add organic matter to break up the clay and improve drainage. The cure for sandy, dry soil is to add organic matter to retain water. The cure for acid soil is to add organic matter, particularly bird manure, to bring the pH up and make more nutrients available. The cure for alkaline soil is to add organic matter to buffer it. The cure for hardpan is to add organic matter to feed earthworms.” Linda Woodrow, p.48 The Permaculture Home Garden, Viking 1996
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GREAT, BUT WHAT TO DO?

RESOURCES
Soil & its Aspects

Soil is a complex living system that best understood from at least three aspects: the physical or structural, the chemical, and the biological.

The Structural Aspect of Soil

Let’s start by asking what is soil, exactly? Soil is “the naturally occurring, unconsolidated or loose covering of broken rock particles and decaying organic matter on the surface of the Earth, capable of supporting life.” A good soil is about half air and water, 5% or more organic matter and 45% mineral particles – and is host to huge variety of living organisms. It formed by the interaction of geological and biological processes – the grinding of rocks into particles by erosion, glaciers and volcanic activity, and the efforts of plants, animals, fungi and soil microbes.

Sand, Silt & Clay

The soil categorisation triangle (above right) is used by structural engineers to assess soils before
building. You can use a ribbon test and/or a jar test to assess the percentages of your soil.

**Jar test:**
1. Collect about 1 cup of soil, not just from the surface, and remove the bulk of organic matter from the top.
2. Break up any clumps with a hammer.
3. Take 500ml glass jar with straight sides and put soil in.
4. Fill up the jar with water and shake it for five minutes.
5. Sit the jar down and wait 30 seconds and sand will have settled. Mark this level on the jar.
6. Wait a further three minutes and mark again for silt level.
7. After 24 hours or when water is clear, you can see the total height and depth of clay layer.

See attachment on using the ribbon test.

Besides sand, silt and clay, as gardeners we are also interested in organic matter, air, water and the structure of the soil.

Clay soils tend to be waterlogging and difficult for roots to penetrate or extract nutrients. Sand based soils do not hold nutrients or water effectively. We'll talk later about how to address these issues.

**Soil layers**

Plants and microbes work to concentrate and balance nutrients and build humus in the upper layers of the soil (topsoil). Organic matter comes from above and from the roots and microbes within, and minerals come from the source rock from below. Abundant or excessive nutrients are left to accumulate below via leaching. It is important not to mix the layers when working the soil!
Australian soils

Australia does not have active volcanoes, glaciation, or much geological uplift. As such our soils are considered the oldest in the world. Many of our soils are duplex with just a thin layer of topsoil. However there are several rich basaltic patches all along the east coast, and the western plains of Victoria.
Melbourne soils

The grey is Silurian era (around 430 million year old) sediments consisting mainly of siltstones. The pink and orange are much more recent volcanic rocks (from lava flows), consisting of basalt, which formed in the last 65 million years up to only a few thousand years ago. The yellow areas are Tertiary (between 2 and 65 million years ago) era sands. The greens are recently formed alluvial soils. Outside the reach of this map there are some granites such as in the Dandenongs.

Some notes on each:

- **Silurian siltstones.** Dominate the Eastern hills. They produce pale heavy silty clays with poor mineral balances and thin topsoils (duplex). They look pale yellow or grey with chips of rock in them. Generally deficient in calcium, manganese and boron. This area of Melbourne is generally wetter and was originally forested. Better suited for fruit trees than veggies in general but in both cases liming and lots of organic matter is recommended. Basalt rock dust is a good amendment or other broad spectrum fertilisers.

- **Western plains basalt.** The basalt produces heavy clays known for cracking and drying
out in summer and waterlogging in winter. They range in colour from black to brown to rust red. They are rich in most nutrients but usually have poor structure and are very calcium deficient. These areas are generally dryer and traditionally grasslands or grassy woodlands, they are suited to grazing primarily, but with organic matter and lime can make excellent garden soils.

- **Sandbelt.** Some of the sand belt in Melbourne’s south east was former swamp and has good drainage, organic content and a layer of clay beneath. Some is essentially like beach sand with little water or nutrient holding capacity! They are some of Melbourne’s best and worst soils. There still is much market gardening on some of the good stuff. If you’re on the latter you need lots of organic matter, mulch and partial shade can help.

- **Alluvial soils.** Often on flat areas near creeks and streams. They tend to be rich in organic matter, minerals and with good loamy structure. Alluvial soils fed from the volcanic areas are best, such as the former Werribee River delta where most of Victoria’s vegies are grown.

## The Chemical Aspect of Soil

### Mineral balances

Ultimately, the minerals in our bodies come from the soil. High mineral levels and a good soil mineral balance is important for healthy plants, and healthy animals, and healthy humans. There are two approaches:

- **Law of minimum;** the most deficient nutrient will set the level of productivities

- The ratio or balance of certain minerals may be as important as absolute levels. The capacity of soils to contain certain minerals is measured as 'Cation Exchange Capacity'. (A cation is a positively-charged mineral).

<table>
<thead>
<tr>
<th>Calcium</th>
<th>Magnesium</th>
<th>Potassium</th>
<th>Sodium</th>
</tr>
</thead>
<tbody>
<tr>
<td>68%</td>
<td>12%</td>
<td>2-5%</td>
<td>&lt; 1%</td>
</tr>
</tbody>
</table>

*Table 1.* William Albrecht argued that soils with certain proportions of exchangeable cations will show excellent structure and optimal nutrient availability, maximising productivity and making management easier. It can’t hurt to aim for these levels, however addressing the minimum available nutrient is probably a more important step, since scientific research has shown that plants can thrive in a wider range of ratios. *(The above ratios are modern recommendations from Holmgren’s Permaculture Principles and Pathways)*
You can have your soil tested for these at a lab such as APAL, see Resources. You can diagnose some deficiencies from signs on the leaves such as different colours and forms of mottling. See table below.

Mineral balances can affect soil structure. The level of sodium and the ratio of calcium to magnesium can be particularly important on many clay soils. High ratios of sodium creates 'sodic' clays, which are generally sticky masses with little structure. Too much Magnesium can have similar effects. A Ca:Mg ratio of around 6:1 means that your clay can form good crumb structure (peds). Gypsum and/or lime can help in both displacing sodium and lifting the Ca:Mg ratio, if your soil test or local knowledge suggests that would be a good thing. Dolomite, which is high in magnesium, can make the structure of some clay soils worse.

**Soil pH**

pH is a measure of soil acidity and should be around 6.5. At different pH levels different minerals become more or less available as the following diagram shows. As a rule of thumb, lime will lift pH whilst sulphur lowers it.

![Soil pH diagram](image-url)
# Nutrient deficiency symptoms in plants

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td>General yellowing; stunting; leaf drop;</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>Loss of sheen/darkening; red/purple/bluish tones (may affect leaf underside more) with some yellowing of lower leaves; stunting; erect habit;</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>Scorched margins; spots surrounded by pale zones; small fruit</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>Intervenial yellowing; brilliant colours or bronzing, in extreme cases, burning around edge in V shape, often with green triangle tongue from petiole along midrib.</td>
</tr>
<tr>
<td>Molybdenum (Mo)</td>
<td>Mottling over whole leaf; little pigmentation; cupping of leaves; distorted stems (Uncommon)</td>
</tr>
<tr>
<td>Cobalt (Co)</td>
<td>Legumes only, as for nitrogen (Uncommon)</td>
</tr>
<tr>
<td>Excess salt</td>
<td>Marginal scorching, generally no spotting</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>Intervenial yellowing. Similar to Iron but less detailed yellowing, broader band of green along veins, no leaf shrinkage</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>Tiphooking; blackening &amp; death; newly emerged leaves develop abnormally</td>
</tr>
<tr>
<td>Sulphur (S)</td>
<td>Yellowing; small size; rolled down</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>Intervenial yellowing; veins green; youngest leaves almost white if severe</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>Dark blue-green, curling; twisting; death of tips</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>Smallness; bunching; yellow-white mottling</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>Yellowing margins; crumpling; blackening; distortion</td>
</tr>
</tbody>
</table>

*Table 2 - Nutrient deficiency symptoms of plants. Adapted from the work of Kevin Handreck (What’s Wrong With My Soil, 1977, CSIRO) and Carol Curtis.*
A Note on Soil Toxins

Unfortunately urban soils often contain toxins. Potential toxins include heavy metals such as Lead and Cadmium, residual pesticides (such as DDT and Dieldrin), petrochemical residues such as polyaromatic hydrocarbons (PAHs) and others. In general it’s worth being aware but not alarmed.

Lead is probably the most common soil contaminant. It is particularly a concern for children as it can affect mental development if ingested. It occurs naturally in soils, but as it was used as a petrol additive, in paints and elsewhere, it can be in toxic excess in the city. Assume you have excessive levels in the soil wherever your land was settled pre-1970 (when lead paint was phased out), or if you are on a major road. One piece of good news is that lead rarely makes it into fruit in any appreciable quantities (including tomatoes, eggplants, pumpkins etc.), however some leafy plants such as lettuce will take some up from the soil. If soil is suspect, root vegetables should be peeled. Most exposure comes from breathing in or eating dust, so wash your produce. The main strategies for limiting plant uptake is lots of organic matter, and liming the soil if it is acidic, so that it becomes neutral. Similar strategies apply to cadmium and other heavy metals.

We use www.amalanalytical.com.au for soil toxin testing. The non-profit www.lead.org.au have good deals for testing just for lead. VEG has a soil doctor service for interpreting the results and dealing with the issues, based on extensive reading of the scientific literature.

www.veryediblegardens.com/soil-testing
The Biological Aspect of Soil

An example food web in the soil.

The Soil Food Web

The soil is brimming with microbes, fungi, nematodes, mites, springtails and worms. A complex ecosystem in microcosm. In nature, plants absolutely depend on this for nutrients and sometimes water access, for breaking down organic matter, for disease protection and for building soil structure:

- Bacteria make micro-aggregates
- Fungi make macro-aggregates

A single teaspoon of good soil contains anywhere up to 1 billion organisms of 10,000 species. The combined weight of these organisms is as much mass as two cows per acre. Complex microbial ecosystems existed in the soil long before plants and animals evolved. By numbers or biomass they still rule the earth.

To care for soil we need to appreciate that it is very much alive. Like us, it needs:

- **Food** – eg. in the form of compost and mulch
Know thy Soil Notes

- **Water** – when soil dries out, much of your life and organic matter is lost

- **Air** – soil should be damp, not sodden. The ‘good guy’ soil life requires air. Anaerobic (no oxygen) bacteria produce stinky and toxic acids and attack plant roots.

- **Shelter** – mulch holds in moisture, and protects the surface of the soil from UV light and temperature extremes

- **No poisons** – pesticides, herbicides and artificial fertilisers all tend to be antagonistic to soil life

### Humus

Humus is the most important form of organic matter in the soil. It is produced from plant and animal residues decomposed by bacteria and fungi. Humus is a chocolaty brown colour and consists of large and very complex organic molecules. It gives fertile soils their open, sponge-like texture. Humus can hold the equivalent of 80-90% of its weight in moisture, and helps open the soil allowing air and plant roots to penetrate the soil. Humus helps the soil hold and circulate nutrients, and is a perfect home for essential soil microbes. Humus has a fairly neutral pH so helps to moderates soil pH imbalances. Humus can immobilise toxic heavy metals so they are no longer available to plants.

### Great, but What to Do?

Luckily, there are some simple strategies that apply in almost any situation:

- **Compost!** It introduces humus, recycles nutrients, and is chock full of good soil life. It must be aerobic (well oxygenated) and with a good carbon to nitrogen balance of ingredients for good soil life. (See compost link below for more info.)

- **Mulch!** It mimics the natural process of a forest or plains, protecting the soil and feeding it. Use straw mulch for veggies, woody mulches for trees and perennials.

- **Plants!** Plant roots build soil and feed soil life with their exudates and dead roots. Plant foliage protects soil from the elements and mulches the soil. Aim to have 100% plant coverage of soil as much as possible. Some plants are better soil builders than others, but anything is always better than nothing. Pulsed grazing of grasses is one of the great soil building strategies. Many acacias are great soil builders.

- **Water!** Keep it moist to maintain fertility.

Every situation is different, but by way of a summary, we often recommend:

1. Check your pH and adjust if necessary (lime lifts pH whilst sulphur lowers it)
2. Add organic matter (compost, manures, mulch)
3. Ensure there is adequate drainage for the plants you want to grow
4. Ensure the soil is not too compacted (a broadfork can help here). You want to get air, organic matter, seeds, microbes, minerals, nutrients, and water down deeper into the soil profile.
5. Mulch with something similar to plant you want to grow (e.g., wood chips for trees, straw for vegies)
6. If you are having problems consider a soil chemistry test

Resources


Compost notes on the Very Edible Gardens website:

[www.veryediblegardens.com/iveg/composting](http://www.veryediblegardens.com/iveg/composting)

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