WHAT’S WRONG WITH MY SOIL?
DISCOVERING soils; no. 4.


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Text by Kevin Handreck.

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WHAT’S WRONG WITH MY SOIL?

Discovering Soils No. 4
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- Soil - Australia's Greatest Resource
- Composting: Making Soil Improver from Rubbish
- What's Wrong With My Soil?
- Earthworms for Gardeners and Fishermen
- Food for Plants

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What's wrong with our soil?

Soil problems are serious; many plants, flowers, trees and shrubs don't emerge; bulbs in pots and pot plants never seem to grow; those that do seem to have a few of the symptoms that prompt people to ask: "What's wrong with my soil?" An instant answer has been supplied to that question; another may be asked: "OK, what can I do to fix it?"

This booklet outlines the most common of the problems we can have with our soil and briefly gives some of the remedial methods. More detailed information about some of these problems, it is felt, will be given in other booklets in the same series.

### Three types of problems

Problems we have with our soils can generally be put into one of three categories, depending on whether their cause is mainly chemical, physical or biological.

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### CONVERSION TABLE

<table>
<thead>
<tr>
<th>Unit</th>
<th>Conversion Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 kg</td>
<td>1 kilogram = 1000 grams = 1,000,000 milligrams = 2.205 pounds</td>
</tr>
<tr>
<td>1 mg</td>
<td>1 milligram = 0.001 gram = 0.000035 ounces (1 ounce = 28.350 mg)</td>
</tr>
<tr>
<td>1 g/m²</td>
<td>1 gram per square metre = 8.92 pounds per acre</td>
</tr>
<tr>
<td></td>
<td>= 0.0033 ounces per square foot</td>
</tr>
<tr>
<td></td>
<td>= 0.03 ounces per square yard</td>
</tr>
<tr>
<td></td>
<td>= 3 ounces per 100 square yards</td>
</tr>
<tr>
<td>1 t/ha</td>
<td>1 tonne per hectare = 100 grams per square metre</td>
</tr>
<tr>
<td></td>
<td>= 3 ounces per square yard</td>
</tr>
<tr>
<td>1 mm</td>
<td>1 millimetre = 0.04 inches (1 inch = 25.4 millimetres)</td>
</tr>
</tbody>
</table>
What's wrong with my soil?

Stunted plants, yellow plants, spotty plants, plants with curling leaves, seedlings that don't emerge, cracks in soils and buildings, water lying on soil surfaces. These are just a few of the symptoms that prompt people to ask: "What's wrong with my soil?" And once an answer has been supplied to that question, another may be asked: "O.K., what can I do to fix it?"

This booklet outlines the main causes of the problems we can have with our soils and briefly gives some of the remedies available. More detailed information about some of these problems is or will be given in other booklets in this series.

Three types of problems

Problems we have with our soils can generally be put into one of three categories, depending on whether their causes are mainly chemical, physical or biological.

Chemical problems are usually of the "too much" or "too little" sort. Our soil may have too much lime, be too acid, have too little of one or more plant nutrients, too much of some chemical, too much or too little water or too much salt.

The physical nature of our soil often causes us problems. Clodliness, surface crusts, difficulty in digging and, at the other end of the scale, an inability to retain water, are examples of problems of a physical nature we can have with our soils.
Root rots, blights, rusts, and a host of other diseases of plants can be lumped together under the term *biological problems*.

There is some overlap between these categories but they do provide a convenient way of understanding the complexities of soils.

**Chemical problems**

Poor nutrition is probably the most common cause of poor plant growth in home gardens, but deficiencies of plant nutrients can easily be overcome with plant foods — once we know which nutrients are in short supply in our soil.

**Nutrient deficiencies**

Eighteen chemical elements are known to be essential for plant growth. Plants starve if only one of these is in short supply, even though the others are plentiful.

Two of these elements, carbon (C) and oxygen (O), come from the air; one, hydrogen (H), comes from water; the rest come predominantly from the soil. "The rest" are usually divided into major and minor (or trace) elements according to whether plants need large or small amounts of them.

Plants differ widely in their needs for these elements but a rough idea of the amounts taken from soils by many plants can be gained from the table.

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount (mg)</th>
<th>Component</th>
<th>Amount (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>1,840,000</td>
<td>Magnesium (Mg)</td>
<td>580</td>
</tr>
<tr>
<td>(1.84 kg)</td>
<td></td>
<td>Iron (Fe)</td>
<td>28</td>
</tr>
<tr>
<td>Oxygen (O)</td>
<td>66,400</td>
<td>Manganese (Mn)</td>
<td>10</td>
</tr>
<tr>
<td>Carbon (C)</td>
<td>64,200</td>
<td>Zinc (Zn)</td>
<td>6</td>
</tr>
<tr>
<td>Hydrogen (H)</td>
<td>9,300</td>
<td>Boron (B)</td>
<td>6</td>
</tr>
<tr>
<td>Nitrogen (N)</td>
<td>7,200</td>
<td>Copper (Cu)</td>
<td>1.1</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>6,400</td>
<td>Molybdenum (Mo)</td>
<td>0.11</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>3,350</td>
<td>Cobalt (Co)</td>
<td>0.02</td>
</tr>
<tr>
<td>Sulphur (S)</td>
<td>1,700</td>
<td>Sodium (Na)*</td>
<td>700</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>1,000</td>
<td>Chlorine (Cl)*</td>
<td>470</td>
</tr>
</tbody>
</table>

*Very much smaller amounts of sodium and chlorine are actually needed, but plants usually take up much more salt (sodium chloride) than they need simply because it is in the soil.*
When a plant grows poorly because it cannot get enough of an essential element it is said to be deficient in that element. Deficiency can be caused by the soil having too little of the element or by the apparently ample supplies in the soil being unavailable to the plant.

For example, most Australian soils are deficient in phosphorus because they contain only small amounts. Unless we add fertilizer containing phosphorus — superphosphate, blood and bone, rock phosphate — plants are stunted, pale-coloured with a purplish tinge and produce few fruit or seeds.

On the other hand, many plants become deficient in iron on alkaline soils even though these soils may contain quite large amounts of iron. The plants cannot get at this iron because it is present in forms that are only very slightly soluble. We have to either make the soil more acid so as to release some of the iron or we must add a soluble iron compound such as iron sulphate or iron chelate to the soil, or spray the plant with one of these compounds.

A plant shows its lack of nutrient elements in ways that are characteristic for each element. For example, in tomatoes deficient in iron the youngest leaves are pale green, yellow or almost white, depending on the severity of the deficiency; nitrogen deficiency shows up as paleness in the oldest leaves and general stunting; phosphorus deficiency produces stunting and gives a purplish tinge to the leaves; potassium deficiency produces dark spots and scorching around leaf margins.

This might sound very simple: just learn the symptoms for each deficiency for each plant, diagnose, add the appropriate fertilizer, and all is well. But the real world is not like that.

Often a plant is deficient in two or more elements at once. Different combinations of deficiencies produce a confusing array of symptoms that are further confused by different climatic conditions. Often the deficiencies are "sub-clinical": growth is reduced, but otherwise there are no easily recognized symptoms. Sometimes diseases caused by viruses, fungi or insects produce similar symptoms to those of nutrient deficiencies. Sometimes the cause of stunting or "off-colours" is too much salt in the soil, low temperatures, poor soil structure (too compacted or too loose), herbicides used nearby, toxins produced by other plants, too much shade, not enough water, or too much water.

Because of these complications, it is often not possible to be absolutely sure that a particular set of symptoms is caused by a particular nutrient deficiency. However, with experience we can make shrewd guesses. Then, if adding the nutrient element suspected of being deficient gives
better growth, we have guessed correctly. If not, we try something else. Commercial growers often make use of soil and leaf analyses performed by Departments of Agriculture and commercial laboratories as an aid in diagnosis.

It is not possible here to describe all the combinations of symptoms for all the different species of plants. All we can do is give the broad guide in the table below. Using this guide, the next table, and other information given in this booklet it may then be possible to pinpoint the causes of poor plant growth. At the very least this information will help you describe the problem more accurately if you consult a garden adviser. More detailed information on plant nutrition is given in the companion booklet "Food for Plants".

### Nutrient deficiencies in plants – A quick guide

**Symptoms appear first in the OLDEST leaves**
- **Nitrogen**: general yellowing; stunting; premature maturity
- **Magnesium**: patchy yellowing; brilliant colours especially around edge
- **Potassium**: scorched margins; spots surrounded by pale zones
- **Phosphorus**: yellowing; erect habit; lack-lustre look; blue-green, purple colours
- **Molybdenum**: mottling over whole leaf but little pigmentation; cupping of leaves and distortion of stems
- **Cobalt**: legumes only, as for nitrogen
- **[Excess salt]**: marginal scorching, generally no spotting

**Symptoms appear first in either the OLDEST or YOUNGEST leaves**
- **Manganese**: interveinal yellowing; veins pale green, diffuse; water-soaked spots; worst in dull weather

**Symptoms appear first in the YOUNGEST leaves**
- **Calcium**: tiphooking; blackening and death
- **Sulphur**: yellowing; smallness; rolled down; some pigmentation
- **Iron**: interveinal yellowing; veins sharply green, youngest leaves almost white if severe
- **Copper**: dark blue-green; curling; twisting; death of tips
- **Zinc**: smallness; bunching; yellow-white mottling
- **Boron**: yellowing margins; crumpling; blackening; distortion
<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Soil Types and Conditions where deficiency is most likely</th>
<th>Crops most susceptible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>sands, leached soils, wet conditions, absence of legumes, non-use of nitrogenous fertilizers or compost</td>
<td>all non-legumes, especially leafy vegetables</td>
</tr>
<tr>
<td>Magnesium</td>
<td>acid soils, heavy application of potassium</td>
<td>cabbage, carrots, celery, cucumbers, melons, beans, tree fruits, onions, potatoes, tomatoes, turnips</td>
</tr>
<tr>
<td>Potassium</td>
<td>sandy soils in high rainfall areas, soils from which produce has been removed for long periods</td>
<td>most vegetables, especially leafy ones, many tree fruits</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>almost all Australian soils to which phosphatic fertilizer has not been added</td>
<td>all vegetables, many ornamentals except native plants</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>acid soils, leached soils</td>
<td>cauliflower, citrus, all legumes</td>
</tr>
<tr>
<td>Cobalt</td>
<td>coarse sandy soils in high rainfall. areas, soils with high manganese levels</td>
<td>legumes only</td>
</tr>
<tr>
<td>Manganese</td>
<td>sands, peaty soils, alkaline soils, including those given too much lime</td>
<td>leafy vegetables, beans, tree fruits</td>
</tr>
<tr>
<td>Calcium</td>
<td>acid soils, high applications of nitrogen and potassium</td>
<td>most vegetables, but uncommon because of the calcium supplied as a bonus in superphosphate or in lime and gypsum</td>
</tr>
<tr>
<td>Sulphur</td>
<td>sandy soils, especially in high rainfall areas, soils low in organic matter</td>
<td>citrus, legumes, most vegetables</td>
</tr>
<tr>
<td>Iron</td>
<td>alkaline soils, wet soils, soils that have received excessive applications of phosphorus</td>
<td>beans, peas, tree fruits, citrus, lawns</td>
</tr>
<tr>
<td>Copper</td>
<td>sandy soils, peaty soils, over-limed soils, high levels of iron and manganese</td>
<td>vegetables, tree fruits</td>
</tr>
<tr>
<td>Zinc</td>
<td>alkaline soils, leached soils, coarse sands, soils to which excessive amounts of phosphorus have been added</td>
<td>beans, citrus, onions, potatoes, tree fruits, sweet corn</td>
</tr>
<tr>
<td>Boron</td>
<td>acid, leached soils, coarse sandy soils, peats, over-limed soils, dry conditions</td>
<td>apples, beets, citrus, cauliflower, cabbage, celery, tomatoes, tree crops</td>
</tr>
</tbody>
</table>
Other chemical problems

Most other chemical problems are of the "too much" kind. Too much salt and a soil pH that is too high or too low are the most common causes. Other problems are caused by chemical elements, water, chemicals produced by other plants, chemicals produced by microorganisms in the soil and herbicides.

1. Soil Salinity (Salty Soils)

Salt is useful in soup or on fish-and-chips, but it is worse than useless in soils. Very large areas of Australia have saline topsoils, saline subsoils, or both. In fact, about 33 per cent of Australia's soils are to some degree affected by salt. The cost to agricultural and forestry production has not been accurately measured but must be enormous.

Much of this salt is of ancient origin. Some has come from the rocks of the area during weathering; some has reached the soil in rain and has remained; some was left by the evaporation of water from lakes left stranded by falling sea levels; some has been applied along with irrigation water and has been left behind after the water has evaporated.

Salt reduces a plant's ability to take up water from the soil. Its other main effect is to damage and destroy cells in the plant. This occurs first at the tips and outer edges of leaves, which darken and die as if they had been scorched. Oldest leaves are affected first.

Salinity problems are often worst on clay soils because the salt is difficult to leach from them.
SENSITIVITY OF PLANTS TO DAMAGE BY SALT IN SOILS AND WATER

Sensitive
Ornamentals
Violet, African violet, Primula, Gardenia, Begonia, Azalea, Camelia, Magnolia, Fuchsia, Dahlia.
Vegetables
Parsnips, Green beans, Celery, Radish, Cucumber, Squash, Peas, Onion, Carrot, Potatoes, Sweet Corn, Lettuce, French beans.
Fruit
Persimmon, Loquat, Cherry, Passionfruit, Strawberry, Avocado, Almond, Apricot, Peach, Plum, Lemon, Grapefruit, Orange, Grape, Walnut.
Crops and Pastures
Ladino clover, Red clover, Alsike clover, White Dutch clover, Subterranean clover.

Moderately sensitive
Ornamentals
Geranium, Gladiolus, Bauhinia, Zinnia, Rose, Aster, Poinsettia, Musa, Podocarpus.
Vegetables
Cauliflower, Bell pepper, Cabbage, Broccoli, Tomato, Broad beans, Field beans, Sweet potato, Artichoke.
Fruit
Mulberry, Apple, Pear, Raspberry, Quince.
Crops and Pastures
Cocksfoot, Perennial ryegrass.

Tolerant
Ornamentals
Stock, Chrysanthemum, Carnation, Hibiscus, Oleander, Bougainvillea, Vinca, Aust. Hop Bush (Dodonea attenuata), Coprosma (green and variegated), Japanese Pepper (Schinus terbinthifolius), Ficus spp. in general, Ficus hili, False acacia (Robinia pseudoacacia), Queensland Pyramid Tree (Lagunaria patersonii), N.Z. Christmas bush (Metrosideros tomentosa), False mahogany (Eucalyptus botryoides), Rottnest ti-tree (Melaleuca pubescens), Rottnest cyrus (Calitris robusta), Acacia longifolia, Buffalo grass, Kikuyu grass, Portulaca, Mesembryanthemum, Boobyalla (Myoporh acuminatum), Morrell (E. oleosa), Swamp yate (E. occidentalis), York gum (E. loxophloeba), Couch Grass, Bamboo, Kodinin blackbutt (E. kondininensis), Native pine (Actinostrobus pyramidalis).
Vegetables
Spinach, Asparagus, Kale, Garden beets, Gherkins.
Fruit
Olive, Fig, Pomegranate, Cantaloup.
Crops and Pastures
Oats, Wheat, Rye, Lucerne, Sudan grass, Paspalum dilatatum, Strawberry clover, Sweet clovers, Millet, Wimmera ryegrass, Rhodes grass, Couch grass, barley, Birdsfoot trefoil.

Very tolerant
Ornamentals
Canary Palm (Phoenix canariensis), Paspalum vaginatum (lawns), Salt sheoaks (Casuarina cristata), Salt sheoaks (Casuarina glauca), Salt river gum (Eucalyptus sargentii), Tamarisks (evergreen and deciduous), Saltbushes.
Fruit
Date palm.
Crops and Pastures
Salt water couch (Paspalum vaginatum), Puccinella ciliata.
Repeated watering of alkaline soils with brackish water (such as bore water and Adelaide tap water) can increase the pH to 9 and above, causing serious damage to some plants. Applications of sulphur at 25 to 50g per square metre will lower pH more rapidly and effectively than can gypsum. Apply in late autumn and if the pH is still high in mid-winter repeat the application.

If our soil is salty we can do three things:
- Grow salt-tolerant plants
- Wash the salt out with fresh water. This can be done if enough fresh water is available, if we can put drains in to carry the water away and if our soil is permeable enough to allow reasonably rapid movement of water. This is being done in many irrigation areas along the Murray River, where salty water leached through soils is pumped out into evaporation lakes.
- Add gypsum. Gypsum (calcium sulphate) opens up clay soils that have high levels of sodium (common salt is sodium chloride). Crusts are less likely to form on the soil surface, water can penetrate more easily and digging is easier. Gypsum does not reduce the more serious direct effects of salt on plants but it can help a lot. Add about 500 g per square metre (15 oz per square yard).

If our water is salty we should not get it on plant leaves any more than we can help, we should not water in the heat of the day, and we should water heavily once or twice a week rather than lightly each day.

Soil testing laboratories such as those of Departments of Agriculture have instruments for measuring salinity in soils and waters.

2. Soil pH (Acid and Alkaline Soils)

Acid soils are commonly termed sour, presumably after the sour taste of acids such as hydrochloric, and the acetic acid of vinegar. Alkaline soils are commonly termed sweet.

Soil acidity and alkalinity are measured in pH units, the term “pH” referring to the amount of positively charged hydrogen ions in the soil. The pH scale ranges from 1 to 14, with 1 being extremely acid and 14 extremely alkaline. A pH of 7 represents neutrality (neither acid nor alkaline). Soils range in pH from about 3 – peat bogs – to perhaps 10.5 – arid alkali soils. Most agricultural soils are in the range 4.5 to about 9.

Alkaline soils (pH’s over 7) are that way mainly because of the presence in them of calcium carbonate (lime), but by itself lime will not increase soil pH beyond about 8.3. However, pH’s above 8.3 are possible if moderate amounts of sodium are present in the soil along with the calcium carbonate. Adding gypsum to a soil with a pH of over 8.3 can reduce the pH to 8.3 if the sodium displaced from soil particles by the calcium of the gypsum (calcium sulphate) can be washed out of the soil. Gypsum has almost no effect on soil pH in soils with pH’s lower than 8.3.

Camellias come from the acid soils of the Himalayan foothills. If grown in an alkaline soil (pH higher than 7) they look pale and grow poorly. Lucerne evolved on alkaline soils in the Mediterranean area; it grows poorly, if at all, on
acid soils. These two plants differ in their ability to extract plant nutrients from a soil. That is the way they are. If our soil doesn’t meet their requirements, or the requirements of soil bacteria such as nitrogen fixers that the plants need, we either can’t grow them or we change the pH of our soil to suit them.

<table>
<thead>
<tr>
<th>Strongly acid</th>
<th>Medium acid</th>
<th>Slightly acid</th>
<th>Very slightly acid</th>
<th>Slightly alkaline</th>
<th>Medium alkaline</th>
<th>Strongly alkaline</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH 4.5</td>
<td>5.0</td>
<td>5.5</td>
<td>6.0</td>
<td>6.5</td>
<td>7.0</td>
<td>7.5</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>Phosphorus</td>
<td>Potassium</td>
<td>Calcium</td>
<td>Magnesium</td>
<td>Sulfur</td>
<td>Molybdenum</td>
</tr>
</tbody>
</table>
| Maximum availability is indicated by the widest part of the coloured bar

Changing soil pH has the effect of altering the availability of some plant nutrients: some nutrients are more easily dissolved from soil particles if the soil is acid, others are more easily dissolved if it is alkaline. The diagram summarizes the situation.

Soil pH can be measured electrically using a glass electrode and pH meter — really a special type of voltmeter — or with dyestuffs whose colour changes with pH. Kits based on dyestuffs are available commercially at about $12 (1977 price).

Soils that are considered to be too acid (say pH 4.5 or less) can be made less acid by adding lime (e.g. builders’ lime — calcium hydroxide), crushed limestone (calcium carbonate) or dolomite (calcium-magnesium carbonate). The amount needed depends on the initial pH of the soil, the desired pH, and soil type. Generally, clay soils need much more lime for the same effect to be produced than do sandy soils. As a rough guide a first addition of about 120 g/m² (1.2 t/ha, 3.6 oz per square yard) should be adequate for clay soils and about a quarter of this for sandy soils. If after a few months this seems to have all dissolved and the pH is still too low, more can be added.
To reduce the pH of a neutral or slightly alkaline soil to pH 6-6.5 add between 25 and 125g sulphur per square metre and dig in. The lower amount is for sandy soils, the higher for clay loams.

Wood ash is a rich source of plant nutrients and so is often spread on home garden soils. However, it has much the same alkalizing ability as lime. Care should be taken so that soil pH is not raised too high.

The pH of alkaline soils may be lowered with various acidifying agents, including ammonium sulphate, sulphur and sulphuric acid. Sulphur is the simplest material to use in home gardens. Large areas of soils containing more than about 1 per cent free lime cannot be acidified in this way, as it costs too much. The lime simply reacts with the added acid and leaves the soil with much the same pH as before. Cost may not be important for small areas in home gardens but here an alternative would be to buy some acid soil for growing a particular plant.

Measuring soil pH with a pH meter.

People living in areas with alkaline soils (e.g. the Adelaide plains) should ignore instructions on seed packets to add lime to their soils before planting. These instructions are written for acid soil areas. If in doubt, buy a pH test kit and check first.

Caution: It is better to add several small amounts of acidifying or alkalizing materials than to add one large dose that may turn out to be too much.

In changing soil pH it is generally best to aim at a pH of 6.5 (slightly acid). Most commonly grown vegetables and ornamental plants and their associated microorganisms thrive at this pH, although for many a pH in the range 5.5 to 7.5 is quite suitable. Many legumes tend to prefer the more alkaline end of the range. Higher or lower pH's are only needed if plants needing those conditions are to be grown. For example, some native plants need very acid soils for adequate growth; they develop iron deficiency if grown on even mildly alkaline soils. Others, mainly those from dry
inland areas, need more alkaline soils and can in fact be poisoned by the large amounts of iron, aluminium and manganese available to them in acid soils. The table gives the tolerances to soil acidity of some vegetables.

### Tolerance of vegetables to soil acidity

<table>
<thead>
<tr>
<th>Tolerance Level</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very tolerant (down to pH 5.0)</td>
<td>Potato, Rhubarb, Shallot, Watermelon</td>
</tr>
<tr>
<td>Moderately tolerant (down to pH 5.5)</td>
<td>Bean, Brussels sprout, Capsicum, Carrot, Cucumber, Eggplant, Garlic, Horse-radish, Parsley, Pea, Pumpkin, Radish, Tomato, Turnip</td>
</tr>
<tr>
<td>Slightly tolerant (down to pH 6.0)</td>
<td>Asparagus, Beet, Broccoli, Cabbage, Canteloup, Cauliflower, Celery, Leek, Lettuce, Onion, Parsnip, Silver Beet, Spinach</td>
</tr>
</tbody>
</table>

**Physiological Acidity and Alkalinity.** Many fertilizer materials change soil pH. Ammonium salts (e.g. sulphate and phosphate) and urea make soils more acid and so are referred to as physiologically acid fertilizers. This happens because plants take up the ammonium more rapidly than sulphate, phosphate or carbonate, leaving, in effect, sulphuric, phosphoric or carbonic acids in the soil. Repeated applications of these fertilizers to light-textured (sandy) soils that are already acid can reduce plant growth through manganese toxicity, molybdenum deficiency, or other causes. In time, it is necessary to add lime to increase soil pH again.

Calcium and sodium nitrates tend to make soils more alkaline. Sulphur, or one of the acidifying fertilizers may be used to correct this, if necessary.

Gypsum has almost no effect on soil pH. It certainly is not a liming agent as some people believe, by analogy with lime (calcium carbonate). If anything it might very slightly decrease soil pH.

Superphosphate does not in itself alter soil pH. The acidity of the leachate from a granule of superphosphate is balanced by the alkalinity of the remaining calcium hydrogen phosphate and so the overall effect is to leave soil pH unchanged. However, superphosphate can reduce soil pH indirectly under pastures and perhaps lawns. This happens because of a build-up of organic matter through the greatly increased pasture growth made possible by the superphosphate. Organic acids in this organic matter are responsible for the lowered pH. This does not happen in soils
that are cropped, as organic matter does not build up during cropping. The amount of lime needed to raise the pH of affected pasture soils will vary with soil type. It is not possible to make a firm recommendation; the figure given in the table is an educated guess. Superphosphate should not alter the pH of garden soils that are “cropped”.

<table>
<thead>
<tr>
<th>Fertilizers</th>
<th>Lime Kg needed to neutralize 1 kg fertilizer</th>
<th>Sulphur Kg needed to neutralize 1 kg fertilizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur</td>
<td>2.8</td>
<td>--</td>
</tr>
<tr>
<td>Ammonium sulphate</td>
<td>1.0</td>
<td>--</td>
</tr>
<tr>
<td>Urea</td>
<td>0.75</td>
<td>--</td>
</tr>
<tr>
<td>Ammonium nitrate</td>
<td>0.6</td>
<td>--</td>
</tr>
<tr>
<td>Ammonium phosphate</td>
<td>0.5</td>
<td>--</td>
</tr>
<tr>
<td>Superphosphate*</td>
<td>0.2+</td>
<td>--</td>
</tr>
<tr>
<td>Gypsum</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Sodium nitrate</td>
<td>--</td>
<td>0.2</td>
</tr>
</tbody>
</table>

* See text for a discussion of superphosphate
+ An educated guess — see text

Lawns are particularly prone to the damaging effects of physiologically acid fertilizers, as they often receive heavy and frequent applications. Regular checks should be made of soil pH under lawns.

The pH of alkaline soils is changed much less by physiologically acid fertilizers than are acid soils because the acid left by the fertilizer simply reacts with some of the lime in the soil. The more acid our soil to start with, the more careful we must be.

3. Chemical Elements

Toxicities caused by naturally occurring high levels of chemical elements (other than sodium and chlorine) are uncommon in Australia. More often the problems are due to the excessive use of fertilizers or to contamination of soils by industrial pollutants.

Examples of problems due to the excessive use of fertilizers include the production of magnesium deficiency by high applications of potassium in fertilizers, calcium deficiency by high levels of potassium, iron deficiency by too high levels of lime or dolomite, and toxicities produced
by the physiologically acid fertilizers.

Large amounts of soluble fertilizers applied to relatively dry soil can produce severe scorching of leaves and even death of plants. This happens because they dissolve in the soil solution (the water in the soil), so making it more concentrated. Water uptake is reduced or water can actually flow from the plant roots into the soil solution. The ability of different fertilizers to cause damage is given by the salt index; the bigger this is the more careful we should be.

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>Salt Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium chloride</td>
<td>116</td>
</tr>
<tr>
<td>Ammonium nitrate</td>
<td>105</td>
</tr>
<tr>
<td>Sodium nitrate</td>
<td>100</td>
</tr>
<tr>
<td>Urea</td>
<td>75</td>
</tr>
<tr>
<td>Ammonium sulphate</td>
<td>69</td>
</tr>
<tr>
<td>Potassium sulphate</td>
<td>46</td>
</tr>
<tr>
<td>Superphosphate</td>
<td>8</td>
</tr>
</tbody>
</table>

The moral? Go easy on soluble fertilizers. Use fertilizers containing only those elements needed. Add them in several small doses rather than one large one and water them in well. Use lots of compost and other organic materials — balanced, slow-release sources of plant nutrients.

4. Water

Water itself is never toxic, but if a soil is saturated with water for more than a few days the roots of plants growing in it cannot get enough oxygen. Prolonged waterlogging can kill plants. The cure is to dig drains or lay drainage pipes to get rid of the water.

At the other end of the scale, even temporary drought for a few hours can reduce the rate of growth of many garden plants for several days. This is because chemical processes slowed down in the plant during drought take several days to get back to normal. For sustained vigorous growth, keep your plants adequately supplied with water at all times.
Phosphorus (P) deficient grapevines (left and right) and an adequately fed vine.

Effect of calcium (Ca) deficiency on apples. This is the bitter-pit disorder.

Manganese (Mn) deficient cabbage.

Response to magnesium (Mg) of lucerne grown on a soil deficient in magnesium.

Harmful organism. Eggs released from a mature cyst of the cereal cyst nematode (or eelworm). Magnification x 20.

Adding sulphur (S) to this sandy Mallee soil has clearly overcome a deficiency in barrel medic.
Effect of increasing levels of salt (sodium chloride) on subterranean clover.

Severe leaf-fall in citrus caused by a high level of salt in the soil.

Manganese (Mn) toxicity in peas, caused by excessive application of ammonium sulphate.

Symptoms of chloride excess in grapevine leaves. Top left: a healthy leaf for comparison.

Beneficial microorganism. Spore of a VA mycorrhizal fungus infecting a medic root. Magnification x 35.

Boron (B) deficient red beet grown in nutrient solution, that is, grown hydroponically.
5. Chemical Warfare

Plants are good at using chemical warfare techniques to keep their competitors at bay. Ever noticed the sparseness of vegetation and the different range of plants under river red gums and Tasmanian blue gums compared with the range growing nearby? Both trees exude chemicals from their leaves which, when washed into the soil, stop the germination of some seeds, including their own, and inhibit the growth of some other plants. Many plants can also inhibit competitors with chemicals exuded from their roots.

Chemical warfare aids survival in the wild but can make gardening difficult. A few examples only can be given here.

Toxins leached from the leaves of such plants as stocks and chrysanthamums can inhibit the growth of succeeding crops of these plants grown in the same soil. The toxins are eventually decomposed, probably more rapidly in hot than in cold climates. Peaches replanted into old peach orchards are stunted and may die because of toxicity produced by the decomposition of chemicals exuded from the old peach roots. Cabbages, cauliflowers, turnips, swedes, broccoli and mustard (the brassicas) leave residues in soils that inhibit the growth of some other plants, especially their own kind, for many months. It is best, therefore, that we do not grow the same plant two years in a row in the same soil. We should rotate our crops.

Organic gardening books have lists of so-called “companion” plants and plants that “like” and “dislike” one another. These lists say, for example, that beans dislike onions, cabbages and broccoli dislike strawberries and tomatoes, whereas beans like potatoes, cucumbers and strawberries, and cabbages like beets and onions. Not enough research has been done to be sure whether these stated interactions are real and how big the effects are. Experience with other plants suggests that there may well be both beneficial and harmful interactions and that some of them may be caused by chemicals. Further experimentation may provide answers.

Weeds rob our plants of nutrients but some can also inhibit the growth of the plants we want through chemicals they produce. Thistles, wire weed, summer grass, fat hen, pig weed, chinese lantern, barnyard grass, evening primrose and many other plants can inhibit the germination of the seeds of other plants or reduce the growth of nearby plants. That’s another good reason for keeping our vegetable and flower gardens free of unwanted plants (= weeds).

Chemicals produced by soil microorganisms can also inhibit plant growth. The best known example is the reduction of seed germination and seedling growth often seen when rotting straw is close by. Toxins are produced
during the first few weeks of rotting but later they are broken down to other non-toxic chemicals. Farmers burn stubble to reduce this problem in cereal crops. One of the benefits of composting organic materials is that the toxic stage is past before the materials come in contact with plants.

6. Herbicides

Some herbicides act through leaves; some act through the soil and roots. Small amounts of some of the first sort (e.g. 2,4-D) drifting in from next door can kill our plants before we know what has happened. The second sort (e.g. diuron) can be washed downslope from a sprayed area and can kill our most prized specimen tree. Some of the symptoms can look very like those of nutrient deficiencies. Some herbicides (2,4-D for one) increase the susceptibility of plants to insect attack. The moral here, too, is to take care, very great care.

Physical problems

Gardening books and seed packets often state that our plants should be grown in deep, rich loam. Big joke, when our soil is either like concrete or thick porridge, when it’s so sandy water runs straight through or has such a hard crust on top that seedlings haven’t a hope of seeing the light of day. Our soils are often far from ideal: physical defects cause us a lot of problems.

But all is not lost. There are cures for difficult soils. First we need to find the cause of our problems and then we can work towards improving the textures of our soils.
Clay soils

Problems encountered with some clay soils include difficulty in digging, poor water penetration, poor root growth, waterlogging in wet weather, surface crust formation and cloddiness. These problems of clay soils are caused by lack of sand-sized particles, a high content of silt-sized particles, the types of clay minerals present, too much sodium or too little organic matter (humus), or a combination of two or more of these.

Adding sand to a clay soil can open up its structure, but very large amounts — of the order of 60 or more per cent of the volume of clay being treated — are needed to make loams from clays. Except for small areas of garden soils this is impractical.

Surface crusting can prevent the emergence of seedlings.

Gypsum improves the stability of aggregates in some soils, reduces the dispersion of some clays and so reduces the likelihood of surface crust formation. Left: Remoulded soil crumb with gypsum. Right: Similar crumb, but without gypsum added. Note the dispersion and slumping.

If too much sodium is our problem — and this can often be the cause of the formation of surface crusts and poor water penetration into clay soils — we can add gypsum (calcium sulphate). The calcium pushes sodium off the clay particles and allows them to aggregate together into small clumps around which water and air can circulate more easily. Adding gypsum at the rate of 500 g/m² (15 ounces per sq. yard) will improve many clay soils, especially those high in sodium. Make sure that the whole surface is covered.

Here’s how to test your soil: Drop a 6 mm (¼ inch) dry fragment of soil into a glass of rainwater or distilled water, and leave it stand for 24 hours. If the fragment is surrounded by a milky-brown halo, your soil will certainly respond to gypsum. The more obvious the milkiness, which is caused by clay dispersing, the greater should be the soil’s improvement after receiving gypsum.
If there is no milkiness, repeat the test with wet soil. Just sufficient water should be added to dry soil so that the soil can be rolled between the fingers into a 0.3 mm (1/8 inch) diameter thread. Break off a small piece and drop it into water. If a halo appears, adding gypsum will help prevent structural damage under wet conditions (see "other problems" on pages 19 and 20).

For home gardens, organic matter in the form of compost or animal manure is an excellent soil conditioner, an excellent improver of soil structure. The humus produced as it breaks down in the soil binds soil particles into aggregates or crumbs. The soil structure becomes more open; water, air and plant roots can move more easily through it and we find digging much easier. It is difficult to add too much organic matter to a soil. Rather, the problem is to find enough, as we need to keep on adding it to replace that broken down in the soil. Street leaves, lawn clippings, kitchen scraps, weeds, straw, sawdust, animal manures and seaweed can all be used, but care has to be taken to ensure a balanced mixture. Low nitrogen materials such as sawdust and leaves need to be mixed with high nitrogen materials such as lawn clippings, weeds and kitchen scraps. [See the companion booklet "Composting – Making Soil Improver from Rubbish]

**Sandy soils**

The trouble with sandy soils is that they don’t hold much water or plant nutrients. Drought and starvation are the hazards. We need to add materials that hold water and nutrients.

Mixing in some clay soil will help. Mixing in lots of organic matter will do a better job as it is a slow-release source of nutrients as well as a holder of water. Relatively insoluble fertilizers are preferable to soluble ones that can be easily leached down away from plant roots. The nutrient elements most often in short supply in sandy soils are nitrogen, potassium, phosphorus and sulphur.

Some sandy soils with less than 8 per cent clay become water repellent due to their sand grains being coated with secretions from fungi. Water literally sits in droplets on
top of them. The simplest cure in home gardens is to increase the clay content of the sand to above 8 per cent with a clay or clay loam soil. Bowling and golf greens are best treated by inserting numerous cores of loam to act as channels for water entry.

Water repellent sand. The darker soil is damp, the lighter is dry because water has not been able to penetrate into it.

Droplets of water simply sit on the surface of water repellent sandy soils.

Soil temperature

Seed germination, seedling emergence, root growth and general plant growth are all retarded by low soil temperatures. Plants of temperate origin are affected less than tropical plants. For temperate plants, root growth is almost non-existent below 7°C, reaches a maximum at around 25 to 28°C and then rapidly declines. Temperatures over 35°C are virtually lethal to roots and hence overall plant growth is much reduced. Tropical plants need soil temperatures of at least 12 to 16°C to show much growth, but their upper limit is much the same as that for temperate plants.

Effect of soil temperature on plant growth.
Some consequences of this are as follows:

- Mulches of straw, lawn clippings or other organic materials keep plant roots cool in summer and so aid plant survival on hot days.
- Mulches of black or grey plastic sheet can cook plant roots in summer.
- Mulches of straw or lawn clippings can retard winter and early spring growth in cool climates.
- Mulches of black or grey plastic sheet can increase winter and spring growth by warming roots.
- Applying cold water to plant roots temporarily checks their growth. Repeated applications delay maturity of crops.

Organic mulches can reduce the effects of drought. But keep them away from the trunks of trees, otherwise disease organisms may invade the bark.

Shade

Some plants need more intense light and/or more hours of it each day than do others. Thus, most “indoor” plants came originally from jungles where they were adapted to light of low intensity. Most vegetables and fruit trees need much more light than this. If they grow poorly and look spindly, it could be that they need more light, rather than that they need something extra from the soil.

Other problems

Sometimes plants growing in a very loose soil, perhaps one containing a lot of bulky, half-composted organic material, suffer from temporary starvation because their roots can’t make contact with enough soil. It is as if their roots were dangling in mid-air. Such soil as this should be partly compacted before or during planting.

Sometimes we have waterlogging problems on soils whose surface properties suggest that they should drain freely. This may be due to an impermeable clay layer somewhere below the surface. Boring holes through this layer may help, otherwise some sort of sub-surface drainage system is needed.

Crowding often reduces plant growth in gardens. Crowding reduces the volume of soil from which a plant can extract nutrients and the “air space” from which it can “extract” energy from the sun. It is best to follow the spacing instructions on seed packets.
Cultivating soils when they are very wet can cause problems later. Soil structure can be destroyed — leading to the formation of clods and surface crusts. The availability to plants of soil phosphorus can be severely reduced, too. Don’t cultivate until the soil has drained to a stage where aggregates do not glisten with water.

**Biological problems**

The Romans and Hebrews were well aware of plant disorders such as rusts and blights and attributed them to the anger of gods. For example, the Romans had a pair of rust-gods called Rubigus and Rubigo that were annually placated with sacrifices, to no avail. No doubt other peoples had similar practices.

We now know that many plant disorders are caused by bacteria, fungi, insects, small animals and viruses. Not all come from the soil, but enough of these organisms live in or spend a part of their lives in the soil to justify inclusion here.

**The living soil**

Soils teem with life: bacteria, fungi, insects and small animals in their millions vie with one another for a place. No one species wins. Rather, as the population of one grows the populations of predators also grow. A kind of fluid equilibrium is set up.

Any change in the soil environment, whether of natural origin (such as fire or changing seasons) or whether man-made (digging, planting a crop, removing trees, adding compost, fertilizers or chemicals) upsets the equilibrium. The populations of soil organisms respond until a new equilibrium is reached.

In a natural forest or grassland the equilibrium includes the plants. These feed on nutrients from the soil and those released from dead plant material by bacteria and fungi. Other bacteria and fungi attack the plants and may eventually kill them, so providing food for other bacteria, fungi, insects and soil animals. But some members of each species survive to produce further generations. In this natural environment each has his friends and each his foes.

The same patterns hold in our gardens, farms and planted forests, for how do bacteria know the difference between a tree that plants itself, as it were, and a similar one we plant? They don’t. Food is food. But here we change our view of things: we consider the bacteria harmful — foes if you like — and we try to get rid of them or control them. On the
The Nutrient Cycle

Nutrient elements taken up by plants from the soil eventually return to the soil in dead leaves and branches. Small animals and microorganisms use this litter as food and eventually release the nutrient elements from it for re-use by plants.

other hand, soil organisms that improve the growth of our plants — for example mycorrhizal fungi that help plants extract nutrients from soils — or that attack the bacteria that are attacking our tree, are considered by us to be beneficial — friends if you like.

Our foes are numerous and they can do a lot of damage:
• bacteria that cause such diseases as crown gall of peaches, bean blight, brown rot of potatoes and bacterial canker of tomatoes.
• fungi that cause such diseases as club root in cabbages; root rots, blights, wilts, rusts and smuts of many plant species.
• eelworms (nematodes) that attack plant roots.
• wire-worms, cut worms, snails, slugs, midges, locusts, root flies, red spiders, etc., that suck and chew their way through mountains of plant materials.
• insects that can transmit viruses from plant to plant.
Remedies

1. Chemicals

Chemicals such as methyl-bromide, chloropicrin, D.D., thiram and many others can be very effective controllers of soil-borne plant diseases. The trouble is that many of them kill friend and foe alike so that we can end up being worse off than before — if other foes, or the same ones, invade again.

Another problem is that many of these chemicals are toxic, either outright poisonous, or suspected of being poisons if used continually for long periods. Great care is needed to avoid injury to users and to consumers of food-stuffs grown on treated soils.

Another problem is that disease organisms develop resistance to chemicals so we either need to step up the dose rate, use other chemicals or use some other method of control.

Fumigating soil with methyl bromide — a dangerous occupation.

Sometimes we need to use chemicals, but we should do so with caution, sticking strictly to the instructions on the label. (See the CSIRO leaflet: Code of practice for safe use of pesticides).

SAFETY DIRECTIONS:

Avoid contact with the skin and eyes to prevent possible irritation. Wash concentrate from skin and eyes immediately. Avoid working in and breathing spray mist. Wash exposed parts of the body after use and before eating, drinking or smoking. If swallowed seek medical advice.

WARNING:

DO NOT contaminate feed, foodstuffs, water supplies or fish ponds. This product is poisonous to fish, therefore DO NOT contaminate dams, rivers or streams with the pesticide or used container.

DO NOT feed grass clippings from treated areas to poultry or animals.
2. Disease resistant plants

Plant breeders have put an enormous effort into selecting and breeding varieties of plants that resist disease organisms. Many of the vegetables we grow in our gardens have been selected because they are resistant to one or more diseases. Seed packets and catalogues tell the story. It is advisable to use these resistant varieties, but also to grow several varieties at once in the hope that if a new disease comes along or an old one suddenly develops new virulence, not all of our crop will succumb to the attack. In this we imitate the biological diversity of nature.

Poinsett or Green Gem. The long dark green fruit has strong resistance to both Downy and Powdery mildew. A really first class variety for both the commercial and home gardener.

$1.80 25 g; Packets 35c & 55c

3. Fertilize

A starved plant has low resistance to disease. Well-fed plants have their natural defense mechanisms working at full efficiency. Provide your plants with a full range of nutrients and they are much more likely to withstand the attacks of predators. Potassium seems to have a special ability in this direction.

4. Biological control

In biological control we alter soil conditions so that our foes are attacked more vigorously by their natural enemies.

There has always been biological control. The trouble is that our preoccupation with chemicals has caused us to ignore this fact for too long. Now we are learning anew, and, through research, finding improved methods of biological control. Here are some ways of encouraging these natural antagonisms.

Rotate crops. Growing the one species of plant, or closely related species such as cauliflowers and cabbages, year after year in the same soil enables large populations of disease organisms to build up. This build-up can be prevented by growing plants in rotation. For example, the soil that grew cabbages this season might be sown to sweet corn next season, then beans before going back to cabbages. Another example is a rotation of onions, lettuce and potatoes. Tomatoes, potatoes and capsicums are all susceptible to verticillium wilt so should not be grown after one another.

Crown galls on a young peach tree, caused by the bacterium Agrobacterium radiobacter. Research at the Waite Agricultural Research Institute, Adelaide, has led to the development of a simple and very effective method of biological control.
Strands of the fungus that causes the disease “take-all” growing on the surface of a wheat root. Magnification: x 240.

Part of the fungus is being attacked by bacteria — the small rod-shaped bodies. Magnification: x 560.

Spell the soil. An alternative or supplement to crop rotation is to spell or fallow the soil for a time to allow the numbers of disease organisms to decline either through lack of food or by being baked in the sun.

Use organic manures. Many reports have shown that the application of organic materials to soils can reduce the damage to plants caused by many disease organisms, including fungi and bacteria. The organic materials provide food for soil organisms. Add them to a soil and there is a population explosion, in the process of which disease organisms become food for the increased numbers of their natural enemies. Two reasons are given for this: (a) Many disease organisms only “winter-over” in the soil. Their active growth takes place in plants. Destruction of the “wintering-over” forms means that there are few to attack plants grown later. (b) Wintering-over organisms grow again in response to chemical signals from plants they like. Organic matter somehow stops or slows down the receipt of these signals by disease organisms.

However, organic materials are not infallible in controlling diseases. Sometimes they don’t work, and the reasons are not at all clear. Sometimes we actually add disease organisms along with the organic materials. Infected materials should be composted before use so that the disease organisms are killed. (See the companion booklet: Composting — Making Soil Improver from Rubbish). Although unreliable at times, organic materials can play a significant part in preventing plant diseases: in addition they benefit plants by providing nutrients and improving soil structure.

Green manure. Plowing or digging in legume cover crops is often a very effective means of biological control, perhaps even better than using compost for the control of some diseases. Chemicals released from the decomposing legumes can cause disease organisms to begin to grow and then die.
through lack of a host. It's trickery! Sometimes the legume greatly encourages the growth of one particular enemy of a disease organism. Green manures don't always control diseases but they do often enough to merit consideration by home gardeners if space permits.

Growing inhibitory plants. An alternative to soil fumigation for the control of eelworms is to grow one of several inhibitory plants. Marigolds (*Tagetes minuta* or *T. patula*) are effective with root-knot and other eelworms that are common attackers of vegetable crops.

What happens is that the eelworms attack the marigold's roots but are either poisoned by chemicals naturally occurring in the roots or are not able to lay eggs. There are very few eelworms left to attack the next crop. *Crotalaria spectabilis* grown before cucumbers has the same effect.

Some of the beneficial effects attributed to so-called "companion plants" by organic gardeners are due to inhibition of disease organisms. For example, asparagus reduces nematode attack on tomatoes through the release of a chemical. Potato plants are not attacked by the golden nematode (not present in Australia) if mustard is grown close by. A chemical given off by the mustard roots prevents hatching of the nematode's eggs.

*Inoculate with "friendly organisms"?* A number of "soil activators" or "enzyme" preparations are on the market. Manufacturers claim remarkable results in terms of increased yields and control of disease. Rigorously conducted experiments overseas have shown that apparently similar products were totally ineffective in improving plant growth. It could well be, however, that some of the products being marketed here have beneficial effects on plants but at present there are no reports of carefully conducted trials to substantiate manufacturer's claims.
These products could benefit plants either through the plant nutrients they contain or through the microorganisms in them. At the recommended rates of application such small amounts of nutrients are added to a soil that only in the poorest of soils is any increase in plant growth likely because of these nutrients. Increased plant growth in most soils would have to be attributed to the microorganisms in the "activators".

For these microorganisms to be beneficial they would have to multiply rapidly and extensively in the soil. Although many millions could be added in a recommended application it must be remembered that all soils contain many thousands of millions of microorganisms per cubic centimetre. If any of these are particularly antagonistic, the newcomers could easily be wiped out very quickly. This sort of effect could explain the frequently reported inability of scientists to duplicate in soils the beneficial effects obtained in purified growth media.

But if the added microorganisms become established they could benefit plants in at least three ways. Some of them could release hormones that stimulate plant growth. However, this stimulation could only be beneficial to the plant if there is an ample supply of nutrients available to it to support the extra growth made possible by the hormones. Otherwise, such stimulation could give a temporary boost followed by a sharp reduction in growth as nutrients run out.

"Activators" could also benefit plants by supplying nitrogen-fixing microorganisms. These microorganisms can be divided into two groups – the Rhizobium bacteria that live in the roots of leguminous plants, and the so-called free-living nitrogen fixers that live dispersed through the soil.

By now most Australian garden and agricultural soils probably have sufficient numbers of effective strains of Rhizobium bacteria for most of the legumes we want to grow. If there is doubt about this it would be better to buy a packet of locally produced inoculant containing the most effective strain for the particular legume rather than a
'shotgun' mixture that might not contain the best strain. These *Rhizobium* inoculants are readily available at larger garden supply stores or farmers' supply houses.

If free-living nitrogen fixers from an "activator" become established in a soil, they could increase plant growth. But this would only happen if there is sufficient phosphorus (and other nutrients) in the soil for the microorganisms to grow and multiply. Of course if effective free-living nitrogen fixers are already present in the soil in sufficient numbers, the "activator" will not improve plant growth by this means.

A third way in which "activators" could benefit plants is through predator microorganisms that attack those causing soil-borne diseases of plants. If an "activator" contains predators and if these become established in the soil in sufficient numbers, and if they reduce the population of a disease-producing microorganism and if this happens before the disease-producers attack the plants, plant growth could be improved through this biological control. These "ifs" are all very large and experience suggests that biological control by this means is a haphazard business and not easy to attain. "Activators" could in part work this way sometimes but the odds seem stacked against success.

A fourth way in which "activators" could benefit plants is through the ability of some of the microorganisms in them to dissolve plant nutrients (especially phosphorus) from minerals and organic matter in the soil. Some microorganisms can do this but many attempts over many years to repeat in field soils the successes in laboratories have never given consistent improvement in growth with these microorganisms. For example, the Russian preparation Phosphobacterin has had no effect on crop yields in the U.S.A. or in Europe. Products called Soilvita, Medina, Supernate and Farm Builder Biochem had no effect on crop growth while "Normal Soil" actually lowered yields.

By all means try these "activators", but do your own experimenting to see if they are really of any use in your situation. Apply them to only a part of your crop and if there is no difference in growth don't waste more of your money.

And remember, feeding your plants well with plenty of organic matter, manure and with appropriate fertilizers is probably going to be of greater benefit than any "activator".

5. **Grow more than you need**

Diseases cannot be completely eliminated. We can use all the preventive measures given above but unusual seasonal or other conditions can still cause disease to strike our plants. Better therefore to grow a bit more than we think we will need and we might end up with about the right amount.
Conclusion

Many things can go wrong with our soils, but for most problems there is a cure. Use this booklet as a guide for finding the cause of the problem and the sorts of cures that might be tried. But if in doubt seek advice elsewhere. Departments of Agriculture have people skilled in answering questions and solving practical problems. Other organizations, including CSIRO, Universities, nurserymen, amateur and professional associations and bookshops can all help. Finally, experiment yourself. You might come up with something really good.

Further reading

Biological Control of Plant Pathogens. K. F. Baker and R. J. Cook, 1974 (Freeman)
Soil Conditions and Plant Growth (10th Ed.) E. W. Russell, 1973 (Longmans)
Soil Organic Matter and its Role in Crop Production. F. E. Allison, 1973 (Elsevier)
The World of the Soil. E. J. Russell, 1959 (Collins/Readers Union)
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Conclusion

Many aid programs can be successful, but for them to be effective, they need a rigorous approach to addressing the needs of the people they are supposed to assist. This involves: identifying the needs of the beneficiary groups; developing appropriate interventions; conducting feasibility studies; implementing plans with attention to the social and economic context; and evaluating the impact of the programs to ensure that they are meeting their objectives.
Cover: The cauliflowers from this crop were small and of poor quality because of nitrogen deficiency aggravated by competition from weeds.