Commercial Vegetable Production

Lesson 2

This is just a cover sheet, turn to the next page to continue.

Cultural Practices for Vegetables

Lesson Aim

Explain general cultural practices used for vegetable production.

Growers need to understand the soil in which they are growing their crops as well as the nutritional requirements of specific plants. Soil is not just dirt, it is the storehouse of all the nutritional requirements of plants as well as home to millions of micro-organisms that help to break down these nutrients into an available form. Sometimes due to specific soil conditions these nutrients may need to be 'unlocked' before plants can use them an informed farmer will have the knowledge to do this.

Vegetables have the advantage of giving a relatively quick return. Most vegetables only take from 6 weeks to 6 months between planting and harvesting. However, vegetables can be a gamble. Prices can change overnight. You might hope to sell your crop at a reasonable price, but you cannot count on it. You sometimes make a lot out of a crop but other times you lose! When growing vegetables it is essential to be sure to know and keep in tune with the market place. Before any large scale planting you are advised to contact and speak to your local Department of Agriculture adviser, or another reputable expert. Better returns are often obtained if your crop is grown to mature early or late in the season.

CROP ROTATION

The likelihood of nutrition or disease problems can be reduced by practicing crop rotation. This involves continually changing the type of vegetable grown in a particular spot. Look at the list of 'groups' of vegetables outlined below. Do not grow a vegetable in a particular area if another vegetable out of the same group was grown in that spot recently. Keep alternating the type of vegetable in a particular spot!

Brassicas (Brassicaceae = Cruciferae): Broccoli, Brussels sprouts, Cabbage, Cauliflower, Sea Kale, Kohl Rabi, Turnip, Swede, Radish, Horseradish, etc.

Cucurbitaceae: Cucumber, Marrow, Pumpkin, Squash, Cantaloupe (i.e. Rock Melon), Zucchini.

Liliaceae: Onion, Leeks, Garlic, Asparagus, Chives.

Legumes: Peas and Beans.

Poaceae: Corn.

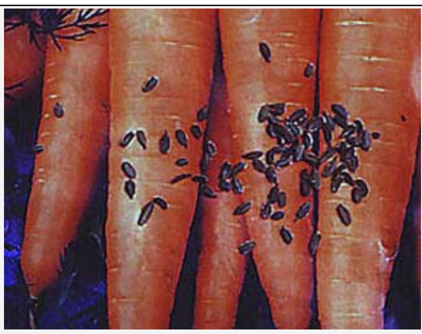
Apiaceae (Umbelliferae): Celery, Carrot, Parsnip, Fennel.

Asteraceae (Compositae): Chicory, Lettuce, Endive, Globe Artichoke.

Chenopodiaceae: Silver Beet, Red Beet (i.e. Beetroot), and Spinach.

Solanaceae: Tomato, Capsicum, Potato, Egg Plant.

VARIETIES and SEED



To get the most out of a crop you must have reliable seed and the correct variety for the time of the year. With many types of vegetables, if you plant the wrong variety at the wrong time the plant may produce seed instead of producing the crop you want. With some vegetables, old seed will not germinate very well at all. Some seed companies supply more reliable seed than others. Check your seed supplier before ever growing any reasonably large quantity of a crop. Talk to other people who have used that brand of seed. Do not consider a company reliable just because it is a well-known name!

SOILS

Put simply, the thin layer of soil at the earth's surface is essential for maintaining life. If soil is lost or degraded, then the potential of an area to support life, both plant and animal, is greatly reduced. In sustainable agriculture terms, maintaining or even hopefully improving the soils you farm is vital.

It is important to understand that soil is not the property of the land owner, the lease holder or the renter of the site. It is the property of everyone, now and in the future. It may take many thousands of years for a soil to form, but only a few years for it to be degraded or lost due to poor management practices. For this reason, it is critical that the techniques we use to manage our soils will maintain them in a manner that ensures that they are at least as productive for future generations as they are now, and hopefully are even improved.

Most soils can be used to grow some type of vegetable. Not all soils suit all types of vegetables though. One of the main factors you should consider in any soil for vegetable growing is 'drainage'. If the soil is sandy and well drained you may be able to cultivate and plant straight into it but in most soils it is advisable to work the soil into mounds, a metre or so wide with trenches between, to take excess water away. Vegetables will, after a couple of crops, drain the soil of nutrients. In order to maintain good crops it is important that you continually replenish the nutrients that are being lost. Vegetable crops require feeding if the soil is not to deteriorate.

Plant Foods

There are basically two types of plant foods:

a) Inorganic (Artificial) Fertilisers - these are chemicals which are made by man. They tend to be more soluble and therefore are absorbed into the plant (but also lost from the soil) quicker.

b) Organic (Natural) Fertilisers - these originate from animal or plant material. They are slower to become 'available' for use by the plant but continue feeding the plant over a long period of time (e.g. blood and bone, bone meal, seaweed fertiliser etc.).

COVER CROPS

A cover crop is simply a plant which is grown for the purpose of improving the condition of the soil it is grown in. It is most commonly ploughed in, but can also be cut and left to lay on the soil. The latter method is very slow, but can be effective. In theory, a cover crop should increase the organic content and fertility of the soil but research has shown that this is not always the case. The real contribution of a cover crop is affected by:

- The amount of growth achieved.
- The plant varieties grown (e.g. legumes add more nitrogen to the soil than they take out).
- Whether any part of the cover crop is harvested and removed from the paddock (perhaps as hay).
- Whether there is a strong leaching effect (e.g. in sandy soils or on steep slopes).
- Temperature and moisture conditions (excessive heat and moisture can result in rapid decay of organic material and in fact little, if any, increase in soil organic content. Excessive dryness can result in very little decomposition).
- Carbon/Nitrogen ratios of residues (high ratios such as 100:1 are slow to decompose, but lower ratios may be much better).
- Soil life (the presence of certain micro-organisms, worms, etc. can have a significant bearing upon decomposition, release of nutrients, and even mixing of residues into the soil mass).

Farmers use cover crops for varying combinations of the following reasons:

- To improve soil fertility, soil structure or tilth

- Control erosion
- Reduce the need for fertiliser and other soil amendments
- To increase nitrogen levels (i.e. legumes as a green manure)
- Improve nutrient availability
- Minimise leaching
- Weed, pest, or disease control
- Preparing land for production of other crops (e.g. vegetables or grain)
- As a livestock feed supplement.

The cover crops used must be matched with the desired outcome.

Guidelines/Principles

The following tips will help in determining selection of a cover crop:

- Type of Crop - Perennial crops are generally preferred over annuals. With annuals, large populations of nematodes often move into the soil after maturing, causing problems for the root system of any subsequent plantings.
- Effect on soil pH - Alkaline tolerant plants such as sorghum and barley, can be grown to reclaim alkaline (lime) soils. Growing a single crop of these plants may cause sufficient acidification to allow less lime tolerant legumes to be grown, further acidifying and allowing it to be used for livestock or a cash crop.
- Timing - The crop should be incorporated (tilled) before maturity (i.e. before flowers and seeds form).
- Water Use - While cover crops, like any other crops, do use water their root growth can lead to better penetration of water into the soil. Additionally, residual organic material left by the plants will lead to increased water conservation.

Legume Cover Crops

Legumes commonly have 15-30% more protein than grasses, giving them better food value for livestock. Another advantage of legumes as a cover crop is the production of rhizobium. Rhizobium is a bacterium which legumes can be inoculated with, resulting in production of hydronium ions in the soil. These ions in turn lower the soil pH, making the soil increasingly acidic.

The decomposition of organic residue also has an acidifying effect on soil. Increased organic matter does however buffer (i.e. slow down) this acidification. Nevertheless, excessive and continual use of cover crops, especially legumes, without liming or use of a similar treatment can result in soil becoming too acidic and losing productive capacity.

Inoculation of Legumes

You can use pre-inoculated or pelleted seed, or you can inoculate seed yourself.

Inoculating seed

- Add the inoculant to another medium (e.g. peat mixed with water and gum arabic). Use 1 part sticking substance (e.g. gum arabic) to 10 parts water. Other sticking materials that can be used include corn syrup, sugar, powdered milk, or various commercial stickers.
- It is critical to use only fresh inoculant in the appropriate concentration.
- Use the appropriate rhizobium for the legume being grown. Keep in mind that rhizobia perform better on some legumes (e.g. alfalfa) when seed is coated with calcium carbonate, whilst others perform better when left uncoated (e.g. red clover).
- Check the expiry date. Commercially produced, pelleted seed should be sown as soon as possible, at least within 4 weeks of production, as it does not store well.
- Always store inoculant in a cool, dark place.
- In dry conditions, inoculant rate may need to be doubled.

- If legumes exhibit yellowing of foliage, this may indicate nitrogen deficiency resulting from failure of the inoculant.
- Applying some nitrogenous fertiliser when planting a cover crop may actually enhance the nitrogen fixation of the legumes (e.g. around 30 kg per hectare of starter nitrogen). Excess nitrogen fertilisation can result in ineffective nitrogen fixation.
- Generally soil pH needs to be over 5.5 for rhizobium to survive.

Shade Tolerant Cover Crops

These include Cowpea, Burr medic, and Hyacinth Bean.

Salt Tolerant Cover Crops

Strawberry Clover, White Clover, Burr Medic, Field Pea, and Barley 'Salina' are all ideal for use in areas of high salination or heavy salt spray.

TYPES OF COVER CROPS

Alfalfa - see Lucerne

Barley

Growing Conditions

- Suited to cool, dry climates, including higher altitudes
- Moderate frost resistance
- Moderate drought tolerance.

Soils and Nutrition

- Will tolerate alkalinity but not highly acidic conditions
- High tolerance of salinity, best of the cereal crops
- Moderate biomass production as cover crop
- Grown to increase organic content of soil
- Strong, well-established root system aids erosion control.

Uses

- Hay, grain and silage
- Good cover crop and green manure properties prior to cash crop sowing
- Light grazing potential
- Used in conjunction with other cover crops to reduce weed infestations
- Improves water infiltration rates.

Problems

- Host for Thompson seedless grape nematodes
- Not as suited to companion planting as some cereal species because of competitiveness.

Buckwheat

Growing Conditions

- Warm season crop, plant late spring in temperate areas
- Plant seed at 30-45kg per hectare.

Soils and Nutrition

- Tolerates poor soils.

Uses

- To smother weeds when densely planted (fast growing)
- As a green manure cultivated in 7-10 days after flowering (around 5-6 weeks from planting)
- Deep rooting and can increase nutrient availability and improve soil structure.

Problems

- Frost sensitive
- Can harbour root nematodes.

Canola: *Brassica napus*: (also known as Rape or Rape seed)

Growing Conditions

- Plant seed 2.5mm deep
- Sown in spring or autumn in temperate areas.

Soils and Nutrition

- Has the ability to accumulate nitrogen that otherwise may be leached from the soil (better than most other non-legume cover crops).

Uses

- Grown to suppress weeds, increase organic content, encourage soil life
- Decomposes fast when tilled under
- Attracts various types of hoverflies which are predators of aphids
- Grown as a cover crop, forage plant, for bird seed, or to produce foods (e.g. canola oil, used in cooking, for margarine).

Problems

- Avoid growing in areas where brassica crops have been grown or brassica weeds (e.g. wild radish) are growing as this can lead to build up of pests such as aphids.

Field Pea

Growing Conditions

- Requires a reasonable tilth and even seed bed
- Sow in autumn, grow over winter at 2.5 to 7 mm deep
- Germinates quickly
- Germinates at temperatures as low as 5°C, although germination is better around 24°C
- Does not tolerate excessive heat, dry or wet conditions
- Intolerant of salinity
- Does not self-seed very well, requires replanting
- Has been grown successfully in semi-shade between nut trees
- Does not regenerate well after mowing.

Soils and Nutrition

- Prefers reasonably fertile, drained soils.
- Grows in pH from 4.2 to 8.3
- Has greater ability to acidify soil than some other legumes (e.g. lupins).

Uses

- A cover crop rotated with vegetables or field crops - excellent for raising nitrogen
- Used for forage, hay, silage, grain or green manure
- Useful for weed competition in areas with strong winter weed growth (roots exude a chemical that inhibits seedling growth of some grasses and lettuce)
- Suppresses weeds better when inter-planted in high density with barley.

Problems

- Susceptible to various pests and diseases (fusarium, sclerotinia, powdery mildew, aphids) so avoid preceding or following with other plants susceptible to such problems
- Excessive use can cause acidification
- Not tolerant of extreme conditions
- Susceptible to various nematodes.

Lucerne: Medicago sativa: (also known as Alfalfa)

Growing Conditions

- For better establishment, lucerne should be grown with a companion grass such as perennial ryegrass
- For maximum production, lucerne should be cut for hay as any grazing will reduce yields significantly
- Loss of leaf should be kept to a minimum by careful handling
- In dry-land areas, lucerne is used only for grazing. Yields are kept high by use of rotational grazing practices with at least two spells of rest, each of 4-6 weeks duration, throughout the growing season
- Will grow at medium to high temperatures if there is sufficient water and humidity is not high.

Soils and Nutrition

- Adaptable, preferring moist but well drained soils
- Deep rooted so will tolerate dry periods
- Prefers neutral to alkaline soils
- Responds well to superphosphate applications.

Uses

- Highly palatable, productive fodder crop
- One of the best legumes for raising nitrogen levels in soils
- Useful for out competing some problem weeds.

Problems

- Heavy user of calcium and repeated cropping of an area can result in increasing acidity. Regular liming required for repeat cropping
- Danger of bloat when grazed by ruminants. Lucerne for grazing is best mixed with other pasture species
- Some varieties are prone to pest problems such as aphids, red legged earth mite, and lucerne flea and to diseases such as verticillium wilt

- Lucerne is difficult to make into silage unless it is grown with a companion grass crop as the high levels of alkaline materials contained in the plant tend to the neutralise the acid levels required for good fermentation, and make the silage unpalatable.

Lupins

(Including *Lupinus albus*, *L. luteus* and *L. angustifolius*)

Growing Conditions

- Generally suited to cooler climates and are often grown as a winter annual.

Soils and Nutrition

- Suitable for a wide range of soil types, with some species tolerating saline conditions
- Moderate nitrogen fixing qualities
- Positive soil improvement capabilities such as aeration and opening of compacted soils due to deep taproots
- Increases availability of Phosphorus, Manganese and Nitrogen to surrounding plants making it ideal for inter-cropping with cereals such as wheat or oats
- Beneficial insect attracting qualities
- Gradual lowering of pH in alkaline soils.

Uses

- Alkaloid free lupins used for silage
- Alkaloid present lupins used as cover crops in paddocks out of stock rotation.

Problems

- Possibility of poisoning in livestock due to quinolizidine alkaloids
- Evidence of harbouring of pest insects in low alkaloid strains of lupins
- Some intolerance to even low level herbicides in some species of lupin.

Oats: Avena sativa

Growing Conditions

- Cool season grass growing to 1.2m tall in temperate climates
- Seedlings may tolerates to minus 8°C
- Susceptible to hot dry conditions
- Tolerates wetter conditions than barley - needs more moisture than many other small grains
- Typically seeded at 90 kg per hectare
- Sow 2.5 to 5cm deep.

Soils and Nutrition

- Grows well over wide pH range - tolerates to pH 4.5
- Grows on wider range of soils than most other cover crops, fertile or infertile, sandy or not sandy
- For maximum yields, NPK fertiliser application may be needed at planting (requires nitrogen fertiliser in particular if temperatures are low)
- Less salt tolerant than barley.

Uses

- Hay, pasture, green manure, cover crop
- Very palatable to livestock (more than cereal rye)
- In North America, grown in rotation with corn

- Grown for silage and hay prior to seed maturing
- Oat straw is excellent for animal bedding
- In some places sown in late summer/early autumn as a cover crop, following a cash crop
- High C-N ratio so decomposes slowly.

Problems

- Easily over-grazed because of high palatability to livestock
- In most countries, oats are highly susceptible to a wide range of disease and pests but various resistant varieties are now available.

Ryegrass

Lolium multiflorum is Annual or Italian Ryegrass: *Lolium perenne* is Perennial Ryegrass (there are also hybrids and other species).

Ryegrasses are the most important pasture grasses throughout the world. They are tuft forming and many varieties with varying characteristics are available.

Growing Conditions

- Generally prefer mild and moist conditions
- Frost resistant
- Italian rye is a cool season crop.

Soils and Nutrition

- Grow best on fertile soils
- Selected varieties adapt to varying soil conditions.

Uses

- Italian Ryegrass is used for temporary pasture
- Perennial ryegrass is suited to permanent pasture in areas with dependable rainfall.

Problems

- Droughts can be a problem due to their moisture requirements.

Sorghum

There are hundreds of cultivars but they vary in characteristics and uses. They may belong to any of a number of species, the most common being *S. bicolor*. Some authorities divide them into four main groups:

1. Grain Sorghum - non saccharine plants, grown mainly as grain for livestock. Similar nutrition to corn but higher in protein and lower in fat. Most have a relatively dry stalk.
2. Sweet Sorghum - stalks contain more sugar, used for forage, silage, or making molasses.
3. Broom Corn - Stalks are very dry and woody, grown for making straw brooms.
4. Grass Sorghum - grown for pasture, silage, hay, or as a cover crop. Until plants are at least 50 cm tall, prussic acid in the foliage can cause food poisoning to grazing livestock.

Growing Conditions

- Warm season annual grass, up to 2 m tall
- Sow after threat of frost in spring - frost tender
- Sow 2.5mm deep in moist soil or 5cm deep in dry soil
- Rows spaced at 25-50 cm, seeds 5-10cm apart
- Germinates ideally at soil temperature of 18°C
- Tolerates high pH, may be used with barley to reclaim alkaline soils

- Needs minimum annual rainfall of 400 mm, preferably higher.

Soils and Nutrition

- Best in reasonably fertile and friable soil, but will adapt to many other soils
- Uses high levels of nutrients so for optimum results, farmers may apply up to 160 kg of nitrogen fertiliser per hectare on poor soil (half or less on fertile soils). Phosphorus and potassium are often not needed.

Uses

- Uses vary according to type (see above), though any forage types are good as a cover crop, to increase organic content, promote microbes, and control weeds
- Performs well as a cover crop mixed with cow pea, buckwheat, or sun hemp
- A crop can be cut and baled 3-4 times (at 60 day intervals) over a season
- Very high C-N ratio - so slow to decompose.

Problems

- Failed crops are usually because of cold soils, hard soils (soil crusting or poorly prepared seed bed), poor seed quality, or incorrect planting depth or spacing
- Young plants may be toxic to livestock
- Can harbour nematodes that may lead to reduction in productivity of vegetable crops following sorghum
- As a cover crop, it can lead to a decrease in nitrogen availability
- Can harbour pests of some other plants (including pecans, and more particularly cereal and grain crops). Note: Many new varieties have disease and insect resistance bred into them.

Subterranean Clover

Growing Conditions

- Self-seeding, easily established, annual
- Prefers cool or mild winter (dies in heat)
- Early maturing varieties planted autumn to mature in winter
- Water requirement varies according to variety but generally 400 mm or greater
- If grown with white clover, white clover dominates in wet soil and subterranean clover dominates in dry soil
- Mowing and grazing help control weeds in subterranean clover.

Soils and Nutrition

- Does not do well on alkaline soils
- Tolerates pH 5 to 8, prefers 6 to 7.

Uses

- The most useful annual clover
- As green manure, component in high quality pasture, weed suppression and nitrogen fixation, useful
- in orchards. (Note: there is some evidence that subterranean clover may cause a reduction in grape productivity, though the mechanism is unexplained. This does not appear to be a problem with white clover though)
- Many authorities claim that benefits are maximised when grown mixed with warm season grasses. Shading by grasses can however weaken sub clover.
- Some claim overall clover may be more productive when subterranean clover is mixed with another clover species such as crimson clover.

Problems

- Nematodes can develop and may affect succeeding vegetable crops, but the true significance is unknown.

Trifolium (Clovers)

Growing Conditions

- Usually a temperate climate species
- Clover requires constant close grazing in order to control weed and other competitive pasture species.

Soils and Nutrition

- An excellent nitrogen fixing species
- pH range 5 to 10.5
- Requires suitable amounts of phosphorus
- Some species of *Trifolium* are saline tolerant.

Uses

- High stock production properties, especially in dairy stock
- Encourage microbial soil activity
- Increase water infiltration and holding capacity
- Controls soil erosion through heavy root system
- Can be used as hay and silage.

Problems

- Cattle that are exposed to lush new clover growth should be drenched to avoid bloat
- Several nematodes species can cause damage to trifolium pastures
- Periodic local damage can result from numerous insect pests.

White Clover (*Trifolium repens*)

This is a persistent, perennial legume and many different cultivars are available. Small leaved forms generally tolerate a wider range of conditions than large leaved forms. Some types can grow to 25 mm tall.

Growing Conditions

- Small leaved forms generally tolerate a wider range of conditions than large leaved forms
- Grows best under cool, moist conditions
- Varieties bred to tolerate different conditions (e.g. poor drainage, drought, heavy soil, acidity, salinity, alkalinity, etc)
- Less heat tolerant than strawberry clover
- More shade tolerant than strawberry clover
- Seed sown at 0.4 to 5 kg per hectare
- Responds well under grazing or mowing
- Often sown with barley or oats in autumn (these plants establish faster than clover and help nurse the clover until it becomes established).

Soils and Nutrition

- Generally best on well drained, fertile loam or clay soil
- Most cultivars do not tolerate high salinity
- Grows under pH 4.5 to 8.2 but ideal pH is 6 to 6.5.

Uses

- One of the most nutritious forage legumes, often used as irrigated pasture plant
- In the USA grown under some fruit orchards and vineyards (sometimes mixed with strawberry clover, bird's foot trefoil and red creeping fescue)
- Probably better suited to vineyards, in particular, than subterranean clover which may inhibit grape production
- Creeping habit is excellent for soil stabilisation
- Because it dries slowly if harvested, white clover is better used for silage rather than hay.

Problems

- Nematodes can damage white clover in some parts of the world.

OTHER COVER CROP PLANTS

Other plants which are often used as cover crops in different parts of the world include:

Annual Fescue, Barrel Medic, Burr Medic, Cereal Rye, Common Vetch, Cowpea, Crimson Clover, Kentucky bluegrass, Millet, Mustards, and Strawberry Clover.

Ways of Using a Cover Crop

1. The Main Crop in the Primary Growing Season

Grown in a paddock during a fallow year.

2. A Companion Crop

Grown for its ability to repel insects, enhance flavour, or give other desirable benefits to the main crop.

3. A 'Catch Crop'

Grown between rows of a main crop as a groundcover, where it controls erosion and keeps the ground cooler. It can also be planted after harvest to catch nutrients and reduce leaching.

4. A Feeder Crop

Grown amongst other crop plants to increase or maintain nutrient levels e.g. clover grown amongst other plants helps maintain nitrogen levels in the soil for the other plants. Garlic and other related plants may raise sulphur availability to adjacent plants, increasing resistance to diseases.

5. An Off-Season Crop

Grown during a part of the year when the main crop cannot be grown.

Reference: Dr Mary Peet: 'Sustainable Practices for Vegetable Production in the South': North Carolina State University.

GROWING MEDIA

The growing medium is the material (or space) which a plant’s roots grow in. This has traditionally been soil but with the application of modern technology, we are provided with other options for growing media.

There are three main options:

1. Sustained Organic Soils

In nature, the best soils contain at least 5-10% organic matter. Some soils may have low organic matter content. Maintaining the organic matter levels of these soils is vital.

2. Technologically Supported Soils

By adding fertilisers, soil ameliorants (e.g. lime), and heavily irrigating, technology enables us to grow almost anything in almost any soil but this is an inefficient use of resources and can result in serious degradation of soils as well create further problems such as excess nutrients entering our waterways resulting in algal blooms.

3. Hydroponics

Despite being an 'artificial' way of growing plants, hydroponics can be sustainable if it is well managed and it is and relatively environmentally friendly. It allows you to take full control over the root zone:

- Excess nutrients are not 'lost' and washed into surrounding areas
- Chemical residues can be collected, treated, and disposed of properly
- Water loss can be minimised and water use maximised.

Of the three options above, the least sustainable is the most commonly practiced (i.e. technologically supported soils). This is probably because it is the easiest approach in the short term to overcome existing problems. However, what usually occurs is that this method develops its own problems.

Cultivation Techniques

Cultivation involves ripping, digging, scratching or mixing the soil. This may be done for any of a range of reasons, including:

- To mix in compost, fertiliser, or a cover crop
- To kill weeds
- To break an impermeable layer on the surface to allow water or nutrients to penetrate
- To improve drainage
- To allow for better plant root penetration
- To break up an impermeable sub-surface layer.

Cultivation can, however, also cause problems. Over-cultivation or regular turning can damage soil structure. Cultivation damages some of the small aggregates, allowing the organic matter which binds these aggregates to be consumed by micro-organisms. Cultivation is one of the main culprits in causing erosion and soil structure decline. It can also change drainage patterns of the soil and can cause the fertile top layer to be diminished by mixing it up with lower soil layers.

Minimal cultivation is normally preferred in sustainable agriculture, but cultivation is a necessary part of any farming operation. Some ways to minimise damage include:

- Tilling only where necessary. For example, leaving strips of land unturned staggered with tilled soil.
- Tilling only when necessary.
- Not tilling when soil is overly wet. A simple test is to take a hand-full of soil and squeeze it in your hand. Moisture levels should be no more than you would get with if you had squeezed a sponge dry.
- It is preferable to use discs or ploughs rather than rotary hoes or tillers which mix the soil more.

Conservation Tillage

This aims to reduce tillage operations or cultivations to only one or two passes per crop. It has been made possible by the use of herbicides to kill crop residues or pasture prior to planting, and the development of direct drilling seeding machinery capable of seeding through stubble. For some farmers the extensive use of these herbicides does not fit in with their view of what sustainable farming should be, however, for many farmers the disadvantages of using such herbicides are more than offset by the benefits of maintaining or improving soil characteristics and in particular its structure. Conservation tillage has been shown to give sustained, improved yields when compared with cultivated paddocks. There are also considerable benefits in reduced labour costs, less wear and tear on equipment, and decreased fuel costs as a result of the reduced number of passes required.

Stubble retention (from the previous crop) is a major component of conservation tillage. The stubble provides a protective layer on the soil, reducing evaporation losses, and reducing the impact of rain drops. This prevents the formation of surface crusts, and improves aeration and water infiltration. There is also a reduction in diseases of legume crops that are spread by raindrop splash. Soil micro-organisms have also been shown to increase in numbers, further helping to improve soil structure and fertility.

The biggest barrier to the use of conservation tilling has been the cost of buying or modifying tillage and seeding machinery. Conventional seeding machinery has had difficulty coping with the retained stubble. As this method of cultivation has increased in popularity, there has been extensive development of new machinery that can cope with such demands. The gains, however, are seen to more than outweigh the cost outlays, and this method of farming is sure to increase.

(Reference: 'There's No Money in Dust: A Guide for Farmers Modifying Their Seeders for Conservation Tillage' by Nicholas Bate)

Using Compost

Any organic material, if left long enough, will eventually rot down due to the action of micro-organisms. Composting is simply a way to harness (control) this process, speed up the rate of decomposition, and minimise nutrient loss due to the process. Compost incorporated to the soil on the farm, whether broadcasted over the land or actually ploughed in, will improve the physical and chemical features of the soil. This improvement, like most other sustainable practices will not occur immediately. Time is required.

A farmer may have access to bulk supplies of organic materials. In this situation, it is recommended they accumulate fresh material and stock pile it until a suitable time period has lapsed (about 2-4 months) before it is used on the farm. If material is well aged to begin with, then immediate use may be possible.

The raw material for any compost is organic matter. This may be in the form of unharvested plant material, windbreak prunings, grass slashing of the edges, dead animals and birds, manure, household or farm organic garbage, haw, straw, paper even sawdust. The smaller and finer the particles are cut up, the quicker the composting process will be.

Diseased plant material should not be used in the compost as it may contaminate new areas when the compost is spread around at the later date. If the farmer has access to dead animal products such as bone, skins, offal or similar, it is important to consider health regulations.

Animal manures are an excellent source of matter for compost. The most commonly used are sheep, cattle, poultry, horse and pig, although others can be quite valuable if you can obtain them in large enough quantities. Animal manures need to be composted for a minimum of six weeks to prevent problems such as burning of leaves and roots from the presence of high levels of ammonium ions in the fresh manure. The ammonium ions are rapidly lost during composting.

Composting of manures is also valuable in reducing potential weed problems that may arise due to the presence of large quantities of seed eaten by grazing animals. The seed passes through the animal and is deposited in the animal droppings where the nutrients present in the manure and the warmth generated as it decomposes create an ideal environment for the seeds germination. Incorporating manure in a compost heap results in much higher temperatures that will kill a large percentage of the weed and grass seeds prior to, or just after germination.

The basic condition of compost the farmer needs to be aware of are:

- Moisture - this should be between 40 and 60%. Take a handful of the composting material from at least 15 or 20cm deep into the heap/mound and squeeze it. It should be about as moist as a moderately squeezed wet sponge. If it is too dry, add water to the heap. If it is to wet, you may need to cover the heap with plastic or turn it over regularly to allow for more evaporation to occur.
- Oxygen - this is incorporated by aerating and turning the heap over occasionally.
- Temperature - this should be between 40 and 60 degrees Celsius.
- pH - the pH will change during the stages of maturity. Generally you need not do anything to alter pH.

- C/N Ratio - a Carbon/Nitrogen (see next page for explanation) ratio should be aimed for around 25-30:1.

If the compost process is permitted to fall outside these guidelines, then the compost will take longer to produce and may lose some nutritional value.

What is the C/N ratio?

For effective composting to occur, the microorganisms that break down the plant materials require food in the form of Nitrogen, Phosphorous and Potassium. Phosphorous and Potassium are generally quite plentiful in composting materials, but there is often a lack of Nitrogen. The most important requirement is the ratio of the percentage of carbon (C) in the materials, to the percentage of Nitrogen (N). This is called the Carbon/Nitrogen ratio. Raw garbage, for example, has 25 times as much Carbon as it has Nitrogen, so its C/N ratio is simply expressed as the number 25. A C/N ratio of around 30 is required for compost activity to take place at an optimum rate. To get a suitable C/N ratio it is necessary to mix materials with a high C/N ratio, such as sawdust, with materials that have a low C/N ratio, such as manures.

CROP SCHEDULING

Throughout the life of any crop, you will need to do a range of things. It is often helpful to break down the growing period into weeks designating the tasks which are to be undertaken each week. Obviously, the actual time taken to carry out any task will vary a little according to changes in the weather and different varieties of plant, etc.

Example of a Simple Flow Chart for Growing Lettuce

Week	Task
1	Sow seed in 75% sand and 25% peat and place in a greenhouse
2	Check for germination Keep well-watered
3	Check for damping off, thin out if necessary Spray fungicide if necessary
4	Plant seedlings Spray with insecticide for caterpillars, etc Feed with high nitrogen fertiliser
5	Check for insect and fungal problems Remove affected leaves from plants, or spray
6	Treat with fungicide
7, 8	Check for disease, insect damage and nutrient deficiencies
9	Harvest

Obviously some crops involve more work such as pruning, changing nutrient solutions, shading, temperature control, staking, etc. Any such tasks should be included in a flow chart.

Analysis of the crop's life in this way will help you plan your production.

PLANTING VEGETABLES

There are three main ways of planting vegetables. These are by:

1. Direct sowing by seed.

2. By transplanting young seedlings.

3. Growing from offsets, crowns, tubers etc.

SEEDS

Sources of Seeds

It is very important where you get your seed from. The quality and purity of seed supplied is not always reliable. Seeds may lose their viability if kept in storage for too long. Seed you buy may not have come from vigorous parents and hence the vigour of the seed may not be high.

There are four major sources of seed:

1. Seed Collected Yourself

This seed is likely to be cross-pollinated and you may not be sure how true to type it will grow, or its viability or vigour.

The major advantages of this source are:

You have control over collection, storage, and treatment of the seed.

You can save on the cost of purchasing seed.

2. Commercial Seed Suppliers

This seed has usually been tried and tested. It should have good viability, the vegetables should be vigorous, virus-free, and some will be treated with fungicides. The vegetables germinated will have known characteristics.

3. Organic Vegetable Growing Supplies

This seed is usually of a non-hybrid variety. This seed cannot be guaranteed virus-free. However, the vegetables grown from this type of seed often have superior taste to the commercially produced seed. Whilst taste is often better, production quantities are often less than with the new hybrids. Old varieties that can no longer be obtained in shops or by commercial seed suppliers can be bought from this source.

4. Garden Clubs

This is a source whereby home gardeners exchange seed. Such clubs are important as a source of the more scarce varieties of vegetables.

HYBRID SEED

An f1 Hybrid plant is produced from seed which is obtained from cross pollination between two different species or two different varieties of the same species. Hybrids often have significant advantages over other varieties. They might have greater disease resistance or produce a better crop.

The major disadvantage of hybrids is that they often do not produce viable seed, so you cannot collect your own seed and regrow the next season's crop. With many hybrids, you must return to the company that breeds the seed and purchase new seed each year.

STORING SEED

Seeds are alive and like any living thing they can be harmed by adverse conditions. The seeds of some species do not store for very long at all and propagation should be done with fresh seed only. Most seeds however, will store for at least 6 months without loss of viability provided that the environmental conditions of their storage are right.

a) Many short lived seeds lose viability if they become dry.

b) Medium to long lived seeds, on the other hand, need to be dry to survive long periods of storage. Many commercially supplied seeds come in sealed foil packets that help maintain desirable moisture levels in and around the seeds.

c) Fluctuations in moisture levels during storage will reduce longevity and for this reason, seeds keep better in dry climates than in areas of high humidity.

d) Most seeds will store for longer periods at lower temperatures.

e) For seeds not adversely affected by low moisture, each 1% decrease in seed moisture between 5% and 14%, doubles the life of the seed. Each decrease of 5° Celsius between 0 and 45° C will double the seed storage life. The life of many vegetable seeds can be extended by storing them in the non-freezer section of your fridge. It is important however, to be careful that seeds which prefer dry conditions do not become overly moist and begin to rot.

SOWING SEED OUTDOORS

Seed can be sown directly into position in the vegetable bed or sown in specially prepared seed beds and containers from where germinated seedlings are later transplanted into the vegetable bed. Most commercially supplied seeds come with instructions for sowing. In general though, the following rules should be remembered when sowing seeds:

1. Use good quality seed.
2. Sow at the right time of year. Environmental factors, particularly temperature and moisture levels, play an important role in the successful germination of seeds.
3. Do not sow too deeply. In nature, seeds are generally dispersed from plants onto the ground surface.
4. Do not sow too thickly. Germinating seedlings will compete for space and nutrients. Pest and disease problems are also generally increased.
5. Have the soil in your vegetable bed well prepared, or use a good quality seed raising mix when using a container.
6. Maintain adequate moisture for seeds to germinate but do not overwater.

Straight rows can be marked in a vegetable bed (or container if it is large enough) using a length of taut string or a straight-edged piece of wood. Then, using a pointed or sharp edged object make a slight furrow or trench along the row to the depth recommended for that particular vegetable seed. Sow the seeds thinly along the row. Avoid sowing directly from the seed pack, particularly with fine seed, as it is very hard to get an even distribution of such seed.

Large seeds can often be easily placed evenly along the furrow, however fine seeds may need to be mixed with some fine sand to get a more even spread. For very large seeds such as melons, cucumbers and beans it is usually easier to drill a hole with a sharp stick or dibber to the required depth and then place the seeds directly into position. Once sowing is completed, lightly cover the seeds by replacing the soil that has been removed whilst making the furrow or hole. This soil should then be lightly firmed down.

Generally, for most conditions it is recommended that seeds be given a thorough watering taking care to disturb the soil surface as little as possible. Fine mist sprays or watering cans with fine nozzles would be suitable for most vegetable seeds.

As seeds germinate and emerge from the soil, they can be thinned out to the required distance apart. Any gaps can often be filled by seedlings thinned out from elsewhere in the bed, etc.

SOWING SEED INDOORS

Vegetable seeds are often planted into a pot or seedling tray and germinated indoors. This allows you to 'get your plants started' before the weather is good enough outside.

For most vegetables, here is how to do it:

1. Use a pot or seedling tray with lots of holes in the bottom (drainage is most important).
2. Wash your pot or tray in Dettol, antiseptic solution, or a household bleach to kill any diseases and then rinse off in hot water and allow to dry.
3. Use a 'clean' propagating mix. An ideal mix has no soil (thus little chance of disease) and drains very well.
4. A standard propagating mix is 75% coarse sand and 25% peat moss or vermiculite.
5. Fill the container to within 1cm of the rim and soak (by immersion) in water.
6. Sow the seed on the surface of the media. Be careful with small seeds not to sow them too thickly. Remember each seed might grow into a plant.
7. If seedlings are too close together they are more susceptible to disease.
8. Cover the seed with a sufficient layer of propagating mix. Usually a layer 2 to 3 times the diameter of the seed is sufficient.
9. Place in a greenhouse, cold frame, or near a window which gets good light inside your house.
10. Keep watered and do not allow seeds to become dry.
11. Once most seedlings have 4 leaves they can be removed from the pot by gently washing the propagating mix from the roots.
12. Do this by immersing the whole pot in water as you remove the seedlings.
13. Seedlings can then be either planted individually into pots, or if conditions are good, planted into the vegetable garden.
14. If grown on a little longer in pots, do not let them get too big before planting out.

TRANSPLANTING SEEDLINGS

This involves the movement of seedlings grown elsewhere to their permanent cropping position. Seedlings are obtained from a variety of sources including those that you may raise in special seedling beds, those grown from seed into containers, and those left over from thinning out of other sections of the vegetable patch (suitable for some vegetables but not all).

Large quantities of vegetable seedlings are grown commercially in punnets (usually small plastic rectangular containers) to supply commercial and domestic vegetable growers.

Both the seedlings to be moved and the site to which they are being moved should be well watered the day before transplanting is to occur. For container growing plants (punnets), watering may be needed up to an hour or two before transplanting commences in order to maintain sufficient moisture in the root zone.

The watering helps reduce the shock to the plant of the transplanting procedure, in particular by helping to keep soil or seedling mix bound together around the roots of the seedling. If the soil etc. is dry, it tends to crumble away from the root ball readily during transplanting. This exposes the roots to the atmosphere where they are more likely to dry out causing damage to the plant which does not occur if some soil remains around the plant roots.

Seedlings should be gently lifted out of the bed or container in which they are being grown, taking care to maintain as much soil around the roots as possible. A hole is then made in the vegetable bed with a sharp stick or dibber and the seedling planted into the hole, making sure that the seedling is at the same depth as it was in the seed bed or container.

Soil is firmed around the plant to hold it in position and the plant is then well watered.

BUYING SEEDLINGS

When selecting seedlings for purchase you should always consider the following points:

1. Choose only plants with a healthy appearance. Seedlings should have no obvious discolouring, stunted growth, signs of damage, etc.
2. Reject any seedlings with obvious signs of pest or disease damage.
3. Do not choose seedlings that appear crowded in their container, or which have extensive root growth protruding from the seedling container. These seedlings will often not transplant as readily as smaller ones that are not pot-bound.
4. Be wary of very small seedlings that appear very soft. These may have recently come out of a protected seedling raising area such as a greenhouse and have had insufficient time to 'harden up' before being offered for sale.

TRANSPLANTING CROWNS, OFFSETS, TUBERS, ETC

Some vegetables, particularly perennial types, are often available as crowns, offsets of established plants, tubers, and so on. Examples include: asparagus, globe artichoke, rhubarb, and potatoes.

SOME USEFUL SUGGESTIONS ON PLANTING

- Grow your perennials together in one section of the vegetable patch or in a separate bed where they will not be disturbed by the necessary preparations for the planting and cultivation of shorter lived crops.
- Plant tall crops, where possible, on the southern side of the vegetable patch where they will not shade out other crops.
- Plant crops in long rows rather than in clumps or short rows. This makes cultivation easier, particularly if you are going to use rotary hoes, etc.
- Crops that mature around the same time should be planted together so that an entire section of a bed becomes available for preparation for the next crop rather than patches here and there.

SOWING AND TRANSPLANTING GUIDE

Crop	Spacing (cm)	Depth (average in cm)	Weeks to Maturity	Remarks
Broccoli	50 X 70	1.5	1016	Seed or seedlings. Thin later
Brussels Sprouts	"	"	1825	"
Beetroot	"	2.0	912	Seed
Silver Beet	"	2.0	812	Seed
Cabbage	"	1.5	816	Seed or seedlings
Capsicum	45 X 70	1.0	1216	Seed or seedlings
Carrot	5 X 60	1.5	1020	Seed
Cauliflower	40 X 70	1.5	1226	Seed or seedlings
Celery	40 X 70	1.5	1016	Seed or seedlings. Thin later

Chicory	18 X 75	2.0	1016	Seed or seedlings
Cucumber	25 x 140	2.0	9 14	Seed
Egg plant	60 X 80	1.0	14 18	Seed or seedlings
Kohl Rabi	20 X 80	1.0	1012	Seed. Thin later
Leek	10 X 40	2.0	2024	Seed
Lettuce	30 X 90	1.0	912	Seed or seedlings
Onions	10 X 40	2.0	2440	Seed or seedlings
Parsnips	10 x 80	1.5	1825	Seed
Potatoes	25 X 90	812	1220	Sprouting tubers
Pumpkins	50 X 1.5	3.0	1422	Sow September to November
Radish	2 X 30	1.5	45	Seed
Spinach	10 x 40	2.0	710	Seed or seedlings
Turnip	10 X 40	1.0	1416	Seed
Tomatoes	40 X 100	1.5	1216	Seed or seedlings

UNDERSTANDING SOILS

Soil is important to the plant in providing the following:

Nutrition: the plant derives its food from nutrients in the soil.

Support: the soil holds the plant firm and stops it falling over.

Water and AIR: the roots absorb both water and air. The soil must contain both. A soil with too much air leaves the plant starved for water. A soil with too much water leaves the plant starved for air.

Different soils have different characteristics with respect to the above factors. For example, a sandy soil provides less support than a clay soil. A clay soil provides less air, but a greater capacity to hold water than sand. An organic soil has a great ability to hold water, but does not always provide good support, etc.

NAMING THE SOIL

Soils are usually named according to texture. Work through the following steps to classify the soil:

1. Place a small quantity of soil in the palm of your hand and add just enough water to make it plastic. Does it:

A. Stain your fingers — Yes or No?

B. Bind together — Yes or No?

C. Feel gritty — Yes or No?

D. Feel silky or sticky — Yes or No?

E. Make water cloudy — Yes or No?

2. The following soil types will give typical answers:

SOIL	A	B	C	D	E

Sand	NO	NO	YES	NO	NO
Sandy Loam	NO	YES	YES	NO	NO
Loam (Or Silt)	NO	YES	NO	NO	NO
Clay Loam	YES	YES	NO	NO	YES
Clay	YES	YES	NO	YES	YES

3. You should also be able to distinguish by the amount of grittiness whether it is a coarse, medium, or fine sand. You will also find varying grades of other soil types by how well they bind together, etc. For example, a clay will bind so tightly that it can be rolled into a ball and formed into shapes (just like potters clay).

4. Organic soils are ones which have a large proportion of organic matter (more than 25%). These are usually black or brown in colour and feel silky. It is possible to get organic types of all of the above soils. Also, these soil types may be distinguished from others by placing a small amount in a glass of water. If more than a quarter of it floats on top, then it is an organic soil.

THE SOIL

The success or otherwise with which plants may be able to grow in soil will depend upon a combination of environmental factors. Different plants will be adapted to different situations, but most will produce close to optimal growth within a fairly broad range. Certain general statements may be made regarding these factors, applicable to almost any horticultural situation.

SOIL STRUCTURE

Soil structure has a great effect on the nutrient status and other aspects of the soil. With a desirable structure nutrients are held in the soil closely enough for plants to absorb them, but will leach away (or wash through the soil) fast enough to prevent salts building up to toxic levels.

There are basically four component particles in soil:

1. **Gravel**: particles larger than 2mm
2. **Sand**: particles between 0.02 to 2mm in diameter
3. **Silt**: particles between 0.002 and 0.02mm in diameter
4. **Colloids**: particles less than 0.002mm in diameter (i.e. these are either clay or organic).

Colloid particles are small enough to disperse in water. That is, improving soil structure has the effect of flocculating (i.e. clumping the particles together). Leached clay soils which are high in sodium tend to have poor structure. Too high a proportion of dispersing clay can cause the following:

- Poor drainage.
- Small pore spaces i.e. spaces between the soil particles. This can lead to deficiency of air available to roots and soil compaction becomes more likely.
- Cultivation and weeding becomes more difficult.
- Fertilisers move slowly - they can be held more tightly by the clay particles than sand.
- Poor root penetration.
- Increased tendency for soil erosion.

Colloids function in soil by holding and supplying nutrients to plant roots. Due to their very small size, they represent an enormous surface area on which nutrients may be held. The creation of conditions which allow the various soil particles to form structured 'peds', will not only improve the balance between drainage and water retention, but will give plant roots access to the greatest possible quantity of nutrients on the colloids.

Specifically, organic colloids decompose to form a film or 'skin' which binds soil particles into the structural aggregates known as peds. Thus, micropore space is confined to the interior of the ped (so water holding capacity is maintained), while macropore space is increased (improving drainage). Plant roots may associate with these peds and their roothairs penetrate the micropores. Nutrients may then become available to the plant from three sources:

1. Soil water (within and between peds).
2. Adsorbed onto the surface of the clay colloids within peds.
3. From the decay of organic material (of the 'skin' which covers and binds peds and organic colloids within them).

The formation of peds depends on the soil having the proper chemical balance and certain physical forces bringing the soil particles together into aggregates. These aggregates are then stabilised by natural cementing agents, e.g. organic matter.

Soils without structure have no noticeable peds. It may be an unconsolidated mass (e.g. single grains of sand) or a cohesive mass as could occur in some loams or clayey soils. These latter soils are called 'massive'. In strongly structured soils, most of the soil mass is visible as peds and these peds can be handled without their breaking.

Sand, added to a clay soil may improve drainage and have some effect on structure. Usually, large quantities of sand are required to cause any noticeable effect though.

- Too high a proportion of sand however, can lead to the following:
- Drainage is too quick and the soil becomes susceptible to drying.
- Soil does not hold together well and erosion can be a problem.
- Nutrients leach out and plants cannot fully utilise them.

The presence of organic colloids in the soil will both supply nutrients and serve to bind other soil particles into peds. Raising the level of organic matter in the soil will have a number of effects:

- Binds soil particles together, but keeps soil open and prevents compaction.
- Restricts erosion to some degree.
- Holds moisture in the soil.
- As it decomposes it provides nutrients for the plants.
- Slows down the rate of soil temperature changes.
- Aids root penetration.
- Retains nutrients in an available form.

The nature of a soil will depend on the relative proportions of sand, silt, clay and organic matter. Soils which are very sandy are usually better for propagating seed or cuttings, but need to be kept well watered.

Sandy soils are suitable for some types of plants while heavier soils are better for other types of plants.

The principle behind improving soil structure is based on correcting imbalances in the relative proportions of the four basic components in soil.

WATER AND AIR

The plant roots need water and air (or oxygen) just as much as nutrients.

Water

All nutrients entering a plant (except carbon and oxygen) do so when dissolved in water. Water itself is also needed by the plant for metabolism, where it is important in the processes of respiration and photosynthesis.

Air

Soil air is richer in carbon dioxide and poorer in oxygen than atmospheric air. The amount of soil air depends on the size of pore spaces between soil particles. Soil air is necessary! Only a few plants can survive with very little air about the roots. Thus, water logging will damage plants by depriving the roots of oxygen, not because there is too much water.

SOIL TEMPERATURE

The rate of absorption of water and nutrients is affected by the temperature of the soil. Too much heat or cold will slow the whole metabolism down. Soil temperature is not always the same as atmospheric temperature. Mulching a plant, or adding organic matter to the soil will even out (or lessen) the fluctuations in soil temperature. As with most organisms, plant roots will grow within a particular range of tolerance which will vary from one species to another.

SOIL LIFE

Earthworms

Earthworms are very important in the soil. A plentiful supply of earthworms in your soil is a good indication of a healthy soil. As earthworms work, they pass soil through their bodies mixing layers of soil and leaving loosely packed material in their tracks. Along with microorganisms, they also help to break down organic matter turning it into humus which is an important soil conditioner.

Earthworms thrive on organic matter. Organic matter sometimes lacks the nitrogen earthworms need. If worm numbers are low, it may be useful to add manure or some other high nitrogen fertiliser to encourage their growth and population. Nitrogen fixing plants such as legumes also attract and support earthworms. Commercially grown earthworms can be added to soils and compost heaps, as long as they have a high organic matter content. The most commonly available varieties are:

Lumbricus rubellus Red Worm

Helodrilus foetidus Tiger Worm

MYCORRHIZA

Various fungi are often found to be associated with particular types of plants. These fungi are found to have a special relationship with tree roots forming a structure called a Mycorrhiza. Most healthy trees will tend to show this condition. The fungus appears to get nutrition from the tree, whilst not harming the tree itself. The presence of the fungi can assist in the trees growth by increasing the tree's root absorptive area. Eventually infected roots are shed by the tree and the fungus utilises them as food.

Many mycorrhiza live in a symbiotic relationship with a plant, many of which are legumes such as peas, beans, lupins, and wind shelter trees like she-oaks (Casuarina).

NITROGEN FIXING

Some plants, such as the legumes, have the ability to fix atmospheric nitrogen into the soil. What this means is that the plant is able to convert nitrogen in the air, into a compound that can be used in the soil by plants. This is carried out by microorganisms, such as *Rhizobium* bacteria, that live in swellings on the roots of legume plants. These plants can be a valuable source of nitrogen to a soil.

IMPROVING SOILS

Before deciding how, or even whether it is necessary, to improve a soil you need to know whether a soil is good, poor, or somewhere in between. Three important qualities to consider are drainage, nutrition, and structure.

Drainage

This can be tested easily by observing the way in which water moves through soil which is placed in a pot and watered. However, when soil is disturbed by digging, its characteristics may change. Another way to get a more reliable result is to use an empty tin can. With both the top and bottom removed it forms a parallel sided tube which can be pushed into the soil to remove a relatively undisturbed sample. Leave a little room at the top to hold water and add some to see how it drains. Then saturate the soil and add some more water to the top. You will often note slower drainage in saturated soil.

Soil Nutrition

This is (to some extent) indicated by the vigour of plants growing in a soil.

Soil Structure

This usually changes from the surface of the soil as you move deeper down into the earth. One reason for this is that surface soil usually contains more organic matter than deeper soil. Surface layers frequently drain better the drainage rate decreases as you get deeper. This natural change means that water moves quickly away from the surface of soil but slows down its rate of flow as you get deeper. Bad cultivation procedures can damage this characteristic of a gradation in structure through the soil profile, by destroying the structure at the surface. Such a situation can be very bad!

By contrast, good cultivation procedures will improve soil structure and increase the depth in the profile to which structured soil extends.

Soil structure can be improved using two approaches. Firstly, where the soil has not been badly leached the addition of organic material, use of crop rotations (with legume cover crops to fix nitrogen), and proper (not excessive) cultivation will improve soil structure. This will normally give the best long term results. However, where soils have been leached and have become very acidic, or very alkaline, the use of soil ameliorants such as lime and gypsum may be required. These act not only to adjust soil pH, but to replace sodium ions in the soil with others (principally calcium and magnesium). These help 'flocculate' the clay into larger particles and so produce some initial structure that will allow the soil to drain better and be worked as above.

There are several ways to improve soils, and these include:

- Adding sand to clay soils to improve drainage.
- Adding clay or organic material to sandy soil to improve its ability to hold water.
- Adding organic matter to sand: whilst improving water holding capacity it will not affect drainage to the same degree as the addition of clay will.
- Adding sand or organic matter will help break up a clay soil, making cultivation easier - although the two will act in different ways.
- Adding organic matter will usually improve the nutritional status of any soil.
- Use of soil ameliorants lime, gypsum, sulphates.
- Crop rotations and correct cultivation.

SAMPLING SOILS

The treatment we apply to improve a soil is based upon what we assess the soil's needs to be. Such an assessment should always be based upon a 'representative' sample. If we only test one small part of a property which has sandy soil and ignore the rest which is a heavier (more clay) soil, then we may end up doing the wrong thing to the soil. Similarly, if we only take a sample from the top centimetre or half inch of the soil, we may be only sampling the fertile topsoil. The soil below may be totally different.

Therefore, ALWAYS take samples from a variety of different points across the surface and take samples to an appropriate depth. If you collect a variety of samples and mix them, you will be more likely to have a result that reflects how the soil might be after cultivation.

SOILS AND PLANT GROWTH

Plant growth is directly affected by the type of soil the plants are grown in. The majority of plants depend on soil to provide nutrition, physical support (i.e. a place for roots to anchor), water and air. The exceptions to this are those plants that are known as epiphytes. These grow in such places as tree trunks, on rocks, or on fallen logs. The quality and quantity of plant growth will also affect how well other organisms (e.g. grazing animals, humans) will survive.

As stated previously soil is made up of particles. These particles are further divided into:

- Mineral particles of various sizes including clays, silts and sands.
- Organic material in varying states of decomposition.
- Living organisms mostly microscopic, but also including insects, earthworms, nematodes, etc.
- Water, which contains varying amounts and types of nutrients (and other chemicals) in solution.
- Air.

These things affect the soil's ability to grow plants. It is possible to grow some plants in soils without living organisms, organic matter, or mineral particles but plant roots must have air, water, and nutrients. Generally, however, you will require some amount of each of the above components to get the best growth from your plant.

The best types of soil for most agricultural production can be described as having the following attributes:

- Well drained
- Deep rooting zone capacity
- Easily penetrated by air, water and roots
- Good water-holding capacity
- Maintains a balanced nutrient supply
- Resists erosion.

Where these attributes do not exist or are in need of aid, then man (the farmer, landowner, etc) needs to carry out management practices that will improve these characteristics, and ensure their sustainability.

IMPROVING SOILS

Nearly any soil can be ‘improved’ in some way to make it more suitable for agricultural or horticultural production. This is more readily done for small areas where the inputs required (e.g. soil additives, time, labour and machinery) are small, but can require considerable expenditure for large areas. Long-term increases in production will generally make such efforts very worthwhile. The following are common ways of improving soils using sustainable methods:

Adding Organic Matter

Most soils will benefit from the addition of organic matter, except those rare soils that are already high in organic matter such as peaty soils. Soils with good levels of organic matter are generally easily worked (we say they have a good ‘tilth’ if they are easily worked). If you squeeze a handful of soil into a ball in your hand and it remains in a hard lump, then it has a poor tilth and hard clods will result when it is ploughed. If it crumbles, then it is well granulated - organic matter promotes granulation. Cultivated soils with good tilth are less subject to wind and water erosion.

Organic matter will improve the soil by:

- Helping to improve soil structure. This will also improve water penetration and drainage, as well as improving aeration. Adding organic matter is particularly valuable for poorly structured clay soils.
- Adding valuable nutrients to the soil.
- Helping to retain moisture in well drained soils e.g. sandy soil. Every percentage point of soil organic matter is considered capable of holding the equivalent of 25 mm of rainfall.
- Acting as a buffer against sudden temperature or chemical changes which may affect plant growth.
- Encouraging the activity of beneficial soil organisms i.e. earthworms.

It may be difficult to increase the percentage of organic matter in a soil, but it is important to try to maintain that percentage. The average mineral soil contains around 2 to 5% organic matter. Organic content will drop if you remove plants from a soil and don't return organic material to the soil. Organic matter can be added in the following ways:

- The roots of crop plants should be cultivated back into the soil when the plant has finished growing.
- Compost can be added regularly (see section on compost in this chapter).
- Organic mulches should be regularly applied to the surface of the soil (see section on mulches in this chapter).
- Feed plants with manure (preferably well-rotted), and other organic fertilisers.
- Crops can be rotated to support organic soil content e.g. use 70% of a farm for cash crops while you grow a cover crop on the other 30%. The cover crop is then ploughed in, replenishing the lost organic content from the previous season (see the section on cover crops in Managing Plants 1).

Problems with Organic Materials

Soils containing high levels of materials such as: peat, bark, and sawdust can be very hard to re-wet if they are allowed to dry out. Organic materials can coat soil particles (particularly in sandy soils) and make the whole soil difficult to re-wet. In very bad cases you can get water droplets just sitting on the soil surface and not infiltrating into the soil at all. To cope with this problem you can do several things. If the soil is mechanically mixed it will assist wetting, then you can help keep it wet with mulching and frequent watering.

Phyto-toxicity is where `poisonous' parts of organic matter cause harm or even death to living plants. Phyto-toxins can come from residue of decomposing micro-organisms, fresh plant residues dug into the soil, and even from the plants themselves. The older the plant is when it is incorporated into the soil, the more likely it is to be toxic, so avoid planting in that area for a while. Young green crops generally have only a low level of toxicity when incorporated into soil.

These problems can be avoided to a degree if the residues are not dug in, but left on the surface as a mulch, or composted. Common phyto-toxicity problems can also occur with mulches of fresh shredded or chipped pine bark or eucalyptus. These materials should be composted for 6-8 weeks before being used.

Decomposing fresh organic material releases carbon dioxide which can damage roots. Fresh organic materials (particularly animal wastes) may also release levels of ammonia gas that can cause burning to plant roots and foliage. Such wastes should be composted for a few weeks prior to being used, or used only in small amounts at a time. It is important not to put anything too fresh on plants, and wherever possible, to compost organic materials prior to use.

In warm, wet climates, the organic content of the soil can be low (under 0.5%), because organic material breaks down faster in these areas. This is particularly a problem in sandy soils. In these areas, add 4% compost (or organic material) or higher to crop areas (e.g. vegetable beds) when you prepare it, and top up annually with the same amount.

Adding Non Organic Materials to Soil

Light sandy soils can often be improved by the addition of materials with fine particles such as clay and silt. This will help improve moisture and nutrient retention. The addition of coarse materials such as sand to heavy clay soils can help improve drainage and water penetration. Generally, fairly high amounts need to be added to be effective. Any added material should be thoroughly mixed in.

Be careful to avoid adding material that may be contaminated in some way (e.g. with lots of weed seeds, pollutants, pests or diseases, or salts). This type of soil mixing is generally impractical for broad-acre farming, but can be useful for improving soils on a smaller scale (e.g. intensive cropping systems).

Add Lime

This is the main way to raise the soil pH if it is too acid. Soils can be naturally acid, or may become too acidic when fertilisers such as sulphate of ammonia have been extensively used, where excessive manures or mulches are applied, or if plants that deplete the soil of calcium (e.g. legumes) have been grown. Lime might also be used if you are growing lime-loving plants such as cabbage, cauliflower and broccoli.

The main liming materials are:

Crushed limestone (calcium carbonate) the most commonly used and least expensive form of lime.

Dolomite a mixture of calcium and magnesium carbonates is commonly used, especially in the nursery industry where soilless growing mixes are often used.

Quicklime calcium oxide and builders lime, also known as 'Limil'. More concentrated and expensive than limestone or dolomite, and can be easily over-used raising the pH to a much higher level than desired. If a quick result is needed for small areas, then builders lime is quite useful.

The amount of lime to be applied will depend on a number of factors:

- How acidic the soil is.
- The buffering capacity of the soil - or how resistant it is to a change of pH.
- How acidic the subsoil is.
- The quality or purity of the liming material to be used (i.e. how much calcium carbonate it contains).
- How often the lime is to be applied.
- What you want to grow (each plant having its own preferred pH range).

Approximate amounts of calcium carbonate needed to raise the pH by one point of the top 10 cm of soils of different texture in grams per square metre (g/m2) of soil surface. (Reference: Pearson, R.W. and Adams, F. (Eds.): 'Soil Acidity and Liming', Agronomy Series No 12 American Soc Agronomy, (1967).

Soil Texture	**pH 4.5 - > 5.5**	**pH 5.5 - > 6.5**
Sand, Loamy Sand	85	110
Sandy Loam	130	195
Loam	195	240
Silty Loam	280	320
Clay Loam	320	410
Organic Loam	680	790

The percentage of calcium carbonate in the liming material used will generally be stated on the packaging or for large lots provided by the supplier.

Adding Acidic Materials to Lower soil pH

Sometimes it is necessary to lower the soil pH to provide the ideal growing conditions for particular plants. To try and alter soils with a higher pH than 7.5 can become quite expensive, and it is often best to simply grow plants that suit the alkaline conditions, or to slightly reduce the pH, rather than to try for major reductions in pH. This can be achieved on a large scale by the use of acidifying fertilisers, such as sulphate of ammonia and superphosphate, or by the regular additions of organic matter, in particular manures. These will generally take several years to be effective.

On a much smaller scale try the following:

- The addition of sulphur. Sulphur is oxidised into sulphuric acid by soil micro-organisms. This acid reacts with calcium carbonate in the soil to form gypsum, which has a pH close to neutral. The conversion of the alkaline calcium carbonate to gypsum therefore reduces soil pH. For soils that are neutral to slightly alkaline use between 25 grams for sands, to 100 grams for clays, of sulphur per m^2 to lower the pH in the top 10 cm of soil to around pH 6.0-6.5. This is equivalent to 250 Kg of sulphur per hectare for sands, and 1000 kg of sulphur for clays per hectare. To achieve greater reductions would necessitate quite extensive applications of sulphur, which would be very expensive. For quickest results mix the sulphur into the soil rather than spreading it on the soil surface.
- Adding material such as peat or coconut fibre, which has considerable acidifying abilities. One cubic metre of peat has an equivalent acidifying effect to about 320-640 grams of sulphur. To lower the pH one point in the top 10 cm of soil, one cubic metre of peat incorporated into the soil will be effective over an area of about 3.25 m^2 for clay soils, ranging up to about 13 m^2 for sandy soils.
- Ferrous sulphate can be used at a rate of around 50-150 gm per m^2. Diluted solutions of iron sulphate or phosphoric acid can also be used.

Adding Gypsum

Gypsum is commonly applied to hard packed or poorly structured clay soils. It has the ability to cause clay particles to aggregate together in small crumbs (or peds), thereby improving structure. It is also used to reclaim sodic soils. Gypsum contains approximately 23-25% calcium and 15% sulphur. It will not affect soil pH to any great extent. Rates of up to 2 tonnes per hectare are used to treat hard-setting cereal growing soils, and up to 10 tonne per hectare to reclaim saline-sodic clay soils.

Note: The previous three treatments require moist soil conditions over several months to have a noticeable effect. It is important not to expect immediate results.

CATION EXCHANGE CAPACITY

Cations are atoms which have lost electrons. As such, they are particles which have a positive charge. Many important plant nutrients occur in a soil or nutrient solution as cations (i.e. potassium, calcium and magnesium). These particles will be attracted to particles which have a negative charge, hence staying in the soil, or other medium, and being available to the plant roots for a longer period of time.

Organic matter such as peat moss, and fine particles such as clay, have a lot more negative charges on their surface, hence a greater ability to hold cations (higher cation exchange capacity) than larger sand or gravel particles. Soil or media with a very low cation exchange capacity will require more frequent application of nutrients than ones with a higher cation exchange capacity. When a nutrient is applied to a soil (or growing medium) with a low cation exchange capacity, but high water holding capacity, the medium might remain moist but many nutrients will be lost with drainage of excess irrigation water so becoming leached more rapidly. A higher cation exchange capacity will reduce this tendency.

SOIL PH

In rough terms, this can be described as a measure of the relative proportions of positive hydrogen ions in the soil. Pure water has H+ ions balanced by an equal number of OH and so the pH = 7 which is said to be neutral. A scale of 0 to 14 (called the pH scale) is used to record this measurement of pH.

0 Acid 7 Alkaline 14

^-------------------------------------^---------------------------------^

Most plants prefer a pH of 6 to 6.5 (i.e. slightly acidic), although there are many exceptions and often it is the effect of pH on the soil (rather than on the plant directly) which causes harm.

Generally, plants may grow outside of their ideal pH range but they will not grow as well. If the pH is below 4.5 or above 8 it is very bad for the vast majority of plants.

Soil pH can be adjusted by the use of chemicals known as soil ameliorants. These include lime (to raise pH) and sulphate (to lower pH). However, the soil will tend to buffer the effect of these chemicals and so calculation of the amounts required is often difficult. The general rule is to apply small amounts until the required result is obtained better too little than too much!

When lime is added to break up hard clay soils, it will also raise the pH of the soil (i.e. make it more alkaline). Addition of organic matter (e.g. manure or compost) which contains weak acids, will cause the pH to drop. If fresh manure is used it can cause a drastic drop in pH. Sulphate of ammonia will also cause pH to drop. Some examples of the effect of ameliorants include:

a) 1kg (2.2lb) of lime dug into sandy soil to a depth of 15cm (6inches) inches over 30metres (100sq.ft) will raise pH from 4.5 to 5.5

- In loam 2.75kg (6lb) is needed to do the same.
- In clay 4.5kg (10lb) is needed to do the same.

b) 800g (27oz) of powdered sulphur cultivated over 30m (100 sq. ft.) to a depth of 20cm (8 inches) in sandy soil will lower pH from 7.5 to 7.

- In loam 2.4kg (80oz) is needed to do the same.

NUTRIENT AVAILABILITY AND PH

The ease with which nutrients are able to enter a plant is greatly affected by pH. Extremely acidic or alkaline soils can often stop the nutrients present being absorbed and used by the plant. The plant will suffer a nutrient deficiency, not because the required nutrient is not in the soil, but because the plant cannot get it (i.e. it is not available).

The ideal pH for nutrient availability is different for each nutrient. A pH that makes iron very available will make calcium much less available. The only answer is to compromise go for a pH in the middle, where no element is so available as to become toxic and the amounts of others can be increased to compensate for any loss in availability.

Optimum pH for nutrients:

Nitrogen	6 to 8	Calcium	7 to 8.5
Phosphorus	6 to 7.5	Potassium	6 to 10
Magnesium	7 to 8.5	Sulphur	6 to 10
Iron	4 to 6	Manganese	5 to 6.5

Boron	5 to 7	Copper/Zinc	5 to 7

CONDUCTIVITY

Conductivity is a measure of the rate at which a small electric current flows through a solution (it is also known by the terms 'EC' or 'CF'). When there is a greater concentration of nutrients, the current will flow faster and when there is a lower concentration, the current flows slower. By measuring conductivity, you can determine just how concentrated a nutrient solution may be. A conductivity meter is used to make such measurements.

Conductivity can be measured in one of the following units:

- EC this is short for 'electro conductivity'. EC is expressed as either milliohms per centimetre (i.e. mMho/cm) or as millisiemen per centimetre (i.e. mS/cm). Note: 1 mMho/cm = 1 mS/cm.
- CF this is short for 'conductivity factor'. CF is expressed on a scale of 1 to 100, where 0 stands for pure water containing no nutrient and 100 represents maximum strength of nutrient salts in solution.
- EC is generally measured at 25 degrees Celsius, and most literature and recommendations are based upon the nutrient solution being at that temperature. If the temperature of a solution is raised, the EC will increase, even though there are no extra nutrients added. If the temperature drops, the EC will decrease. It is possible to calculate the change in EC when temperature changes, by multiplying the EC by a conversion factor for the temperature it is changed to (refer to table below).

Temperature conversion factors for determining EC at temperatures varied from the standard of 25 degrees Celsius.

Temperature °C	Conversion Factor
15	1.247
20	1.112
22	1.064
25	1.0
27	0.96
30	0.907

Conductivity and Plants

- Different plants have preferred conductivity levels at which they will grow their best. These levels can vary from early to later in a crop's life.
- You should predetermine the desired conductivity for the plant being grown, and any changes in that desired level from one stage of a plant to the next.
- As a soil loses nutrients, the EC will drop. When a drop is detected, nutrients should be added to soil to bring it back to the desired level.

Salinity Build Up

When a plant uses a nutrient from a chemical 'salt' molecule supplied in a nutrient solution, it is in fact only using one part of that molecule. The remaining part of the molecule generally stays in the soil or nutrient solution (in the case of hydroponics). Some may be used by the plant, but more commonly, it builds up and can reach a level where it causes damage to the plant. This is referred to as 'salt build up' or a 'salinity' problem.

Salinity problems are most common in soils, or other media, which have a high cation exchange capacity or when using a closed hydroponic system with the same nutrient solution for an extended period.

Salinity problems will sometimes be visible. If you see a white caking around the edges of drainage outlets or on the surface of media, this indicates the problem is reaching a dangerous level.

Salinity can sometimes be cured or prevented by simply leaching the salt out of the root growing area, by washing it out with clean water. This water, of course, must be drained out of that area. In many soils, then, improved drainage will be more effective than increased irrigation.

ORGANIC MATTER

Soils with a good organic matter content are generally easily worked (we say they have a good tilth if they are easily worked). If you squeeze a handful of soil into a ball in your hand and it remains in a hard lump, then it has a poor tilth hard clods will result when it is ploughed. If it crumbles, then it is well granulated organic matter promotes granulation. Cultivated soils with good tilth are less subject to wind and water erosion.

It is difficult to increase the percentage of organic matter in a soil, but it is important to try to maintain that percentage. The average mineral soil contains around 2 to 4% organic matter. Organic content will drop if you remove plant material that grows in a soil and do not return organic material to the soil. This can be done the following ways:

- The roots of plants grown, once finished, should be cultivated back into soil.
- Compost should be added regularly.
- Organic mulches should be used on the soil.
- Plants should be fed with manure (preferably well rotted).

NUTRITION

If inadequate nutrients are present in the soil, plant growth will be stunted. This effect is subtle and not usually noticed until it becomes severe. It can be that nutrient requirements drop to as low as 30% below the optimum level before deficiency symptoms (such as discolouration) appear in the leaves. By this time, the overall growth rate and general health of the plant has been affected significantly.

Every plant variety has its own unique set of nutrient requirements. Some plants need more iron and less phosphorus, others need more phosphorus and less potassium there are tens of thousands of different 'ideal' nutrient conditions one for each different plant.

We can get a guide to the individual requirements of a particular plant variety by chemically analysing the nutrients found to make up the leaf tissue of a very healthy specimen of that particular variety.

Analysis of sick plants can also be carried out and compared with the analysis of healthy plants to make comparisons this can tell us what nutrients are missing in the sick plants.

REFERENCE: Plant Analysis: An Interpretation Manual by Reuter.

MYCORRHIZA

Some beneficial fungi grow in a symbiotic relationship with the root cells of higher green plants. This is termed a mycorrhizal association. Roots of many cultivated plants including corn, soybeans, cotton, tobacco, peas, red clover, apples, citrus, pines, eucalypts and others have mycorrhizal relationships with higher fungi. The mycorrhizae appear to be highly beneficial for optimal growth of many plants. Establishing proper mycorrhizal fungi with cultivated plants offers a great potential for improved plant growth.

Some mycorrhiza form a kind of sheath around the roots sometimes giving a hairy or cottony appearance. The plant roots transmit substances to the fungi and the fungi aid in securing and transmitting nutrients and water for the plant roots. Because they provide a protective cover, mycorrhizae increase the plant's tolerance to drought, high temperatures, infection from disease causing fungi, and even to extreme soil acidity.

Because mycorrhizae are able to improve the efficiency of nutrient absorption, their use in horticulture is likely to become more widespread as the cost of fertiliser increases. Relatively cheap mycorrhizal inoculations are likely to become more available.

Mycorrhizae are killed by steam sterilisation or fumigation. Thus, when nursery soils are sterilised, or artificial mixes are used, it is usually beneficial to inoculate them with the appropriate mycorrhiza.

Mycorrhizae grow and develop best in a well aerated soil, in a sunny position. High applications of nutrients tend to inhibit their development. The greatest growth responses to mycorrhiza are likely to occur in highly weathered soils which are low in basic cations and are low in phosphorus.

Types of Mycorrhiza

Ectomycorrhizae - these form on the outside of the roots without actually penetrating the root cells. They are common on pines and eucalypts. Infected roots become shorter and thicker and are often more branched. The fruiting bodies of these fungi form easily recognised mushrooms and toadstools.

Endomycorrhizae - these penetrate the roots and form small nodules inside the plant cells. They are found on a great variety of plant species.

Ectendomycorrhizae - these are somewhere between the other two and are found on ericaceous plants (e.g. Erica, Rhododenndron, Arbutus, etc).

Mycorrhizae work by effectively increasing the amount of soil or growing medium from which nutrients may be extracted. In return for the additional supply of nutrients, the plant supplies carbohydrates to the fungus.

Inoculating seed with ectomycorrhizal fungi is a process that is widely carried out. The seed must initially be washed free of undesirable fungi. A suspension of spores is then made by shaking fruiting bodies of the required fungus in distilled water and mixing this with the seeds. The seeds can be sown immediately or dried and stored for a short while before sowing. Producing inoculum of endomycorrhizal fungi is more difficult and involves growing large amounts of infected root tissue to be incorporated into the soil.

COMPOSTING

Any organic material, if left long enough will eventually rot down due to the action of micro-organisms. Composting is simply a way to harness (control) this process, speeding up the rate of decomposition and minimising nutrient loss due to the process.

Conditions in a Compost Heap

Moisture - should be between 40 and 60%. If it is outside this range, the rate of decomposition will be slower. Note: 5055% moisture is when the material is about as wet as a squeezed sponge. Keep it damp but not saturated.

Oxygen - decomposing microorganisms require oxygen to survive. By turning your compost heap you mix oxygen into the material (i.e. aeration is improved). Compost bins which are filled to the brim and sealed to the outside with a plastic lid can be very slow since there is little air (therefore oxygen) available in this compost.

Temperature - decomposition occurs when the temperature is between 40 and 60 degrees Celsius. If the temperature drops below 40° C the rate of decomposition decreases, if it goes over 60° C, many of the micro organisms causing decomposition will die. Temperature conditions will always vary from one part of a compost heap to another. Usually the centre of the heap is the warmest and usually decomposition is, for this reason, faster in the centre of the heap. Therefore, it is advisable to mix the contents of a heap from time to time. A heap of 1 to 3 cubic metres volume maintains reasonable temperature conditions. A smaller heap will be too cold in the centre at times a larger heap will get so hot in the centre that micro-organisms die.

pH - the acidity of a compost heap will decrease in the early stages of decomposition, but will return to normal as time progresses. Lime is sometimes added to offset this initial drop of pH. However, tests conducted by the University of California as far back as 1953 showed that the addition of lime can lead to serious losses of nitrogen from compost.

What to Use in Compost

The best type of compost will result from using the best type of organic material. The organic matter used should have the ratio of carbon to nitrogen averaging between 25 and 30. Below are some examples of Carbon/Nitrogen ratios:

Lawn clippings	20	Weeds	19	Chicken Manure	7
Leaves	60	Fruit waste	35	Cow Manure	10
Sawdust	450	Straw	100	Food Waste	15

Despite this consideration for what is ideal, you can use absolutely anything organic on your compost heap if you wish just realise that if the carbon/nitrogen ratios are not right, it may take a very long time for decomposition to occur. You are advised if using a lot of material with a high ratio, that you should add a nitrogen fertiliser such as sulphate of ammonia or blood and bone. This will help reduce the ratio.

What Can Go Wrong?

The main reasons for compost failing are as follows:

- The compost is too WET. If there is a presence of foul odours, this is probably the case. Extra turning or the addition of dry materials can overcome this problem.
- The heap is too DRY. If the centre of the heap is dusty, this is far too dry.
- Lack of NUTRIENTS. Sometimes superphosphate is needed to help a heap work.
- Carbon/Nitrogen ratio incorrect. Lack of nitrogen because of too much high ratio material is common. (To correct add sulphate of ammonia).
- POTASH. Often the nutrient most lacking in compost is Potash. Small amounts of Sulphate of Potash will correct this.

THE FINISHED PRODUCT

Compost is ready to use when:

- It is crumbly and generally an even texture. (Material such as straw, or flower stems might still be intact).
- It drains well, but still has good moisture holding capacity.
- It is dark in colour.
- It smells earthy, not rotten or mouldy.
- The high temperatures which occurred in the centre of the heap during decomposition have dropped.
- There are few, if any, disease organisms or weeds left alive in it.

Guidelines for using compost:

- Compost can be used either as a mulch spread on the surface of the ground, or dug in (mixed with soil) to improve the structure of soil.
- In temperate areas, the best time to add compost is in autumn. Let it lie on the surface over winter and then dig it in spring.
- Do not leave compost too long (particularly in warm weather) before using it, as nutrients can be lost over time.
- Do not plant in pure compost alone. Compost is good for most plants, but does not have everything a plant needs. Soil is necessary too.

Sheet Composting

This is a useful method for farmers. The area may have to be lightly cultivated in order to sow a green manure crop such as soybeans, clover, or cowpeas. After the green manure has germinated and before the nitrogen rich plants reach maturity, compost materials are spread over the area. Low nitrogen materials such as sawdust, corncobs, and wood chips can be spread without any fear of causing nitrogen shortages later on. After spreading, the whole mass is worked into the soil, preferably with a rotary hoe. The aim should be to incorporate the organic material evenly into the top 10cm of soil. It is also a good idea to add limestone, phosphate rock, granite dust, or other natural mineral fertilisers along with the other sheet compost ingredients since the decay of the organic matter will assist the release of the nutrients locked up in those relatively insoluble fertilisers.

C/N Ratios of Some Composting Materials:

Material	**C/N Ratio**
Cow Manure	15
Eucalypt Bark	250
Sawdust (old)	200
Eucalypt Sawdust (fresh)	500
Grass Clippings	20-25
Leaves (Mature)	60
Lucerne Hay	13
Paper	170
Peanut Shells	12
Pine bark (fresh)	500
Composted pine bark (average)	200
Poultry Manure	7
Poultry Litter	1011
Rice Hulls	140
Mixed Weeds	19
Straw (Wheat)	128
Straw (general)	100
Straw (Oat)	48
Corn stalks, leaves & cobs	50 to 100
Oak leaves	50
Bracken leaves	48
Green rye grass	36
Ash leaves	30
Clover (old plants)	20 to 30
Vegetable peelings	20 to 30

Fruit wastes	35
Well rotted manure (average)	20
Seaweed (average)	20 to 25
Pea or bean plants	15
Clover (young seedlings)	12
Cabbage heads	12
Tomato leaves & stems	12
Mature compost	10
Comfrey Leaves	10
Chicken litter (average with sawdust)	10
Chicken manure (no sawdust)	7
Blood Meal	4

PLANT NUTRITION: THE NUTRIENT ELEMENTS

Research in the past has shown that at least 50 different elements may be used by plants. This does not mean all of these are necessary to all plants though. The elements usually considered necessary to the life of all plants include: Carbon(C), Oxygen (O), Hydrogen (H). These elements are required by all living things as the basis of all organic molecules.

A number of other elements are required by plants and these are generally divided into two groups:

the MAJOR elements or MACRONUTRIENTS, and

the MINOR elements or MICRONUTRIENTS.

There are six macronutrients plants need and these are: Nitrogen (N), Phosphorus (P), Potassium (K), Magnesium (Mg), Calcium (Ca), and Sulphur (S).

The micronutrients include all those elements taken up by plants in only small amounts. The number and importance of elements in this group will vary according to the type of plant and the use to which it may be put (i.e. some are only required for human nutrition). It would also be possible to include a third group of elements. These are nontoxic elements taken up, but not required by plants. This group could be very large, including even Gold (Au), but is of no importance to our discussions here. The micronutrients (also called 'trace elements') include: Iron (Fe), Zinc (Zn), Manganese (Mn), Copper (Cu), Boron (B), Chlorine (Cl), and Molybdenum (Mo).

Some elements are more important for human nutrition than for the plant. Some examples include Cobalt (Co), Chromium (Cr) and Iodine (I). Other elements are only needed by certain types of plants, or their requirements are uncertain. These include Sodium (Na), Aluminium (Al), Silicon (Si), and Selenium (Se).

For all these elements, there are generally only two routes of entry into the plant – by air and by water. Carbon and oxygen are all obtained mostly from the air. Also, as they are required by all parts of the plant, the roots will rely heavily on the 'soil air' for their supply of Oxygen. Thus, the so called condition of water logging is really more a form of suffocation. The soil is so saturated with water that the roots can no longer obtain the oxygen they need. All other elements enter the plant dissolved in water. This is generally taken up by the roots from the soil or other growth medium. However, the plant also has a certain capacity for nutrient uptake from solutions sprayed onto the leaves.

MAJOR ELEMENTS

Nitrogen, phosphorus, potassium, calcium, magnesium and sulphur are needed by plants in much larger quantities than any other elements (except carbon, oxygen and hydrogen). Most soils have ample supplies of calcium and magnesium; hence fertilisers which are used in horticulture are usually almost completely made up of nitrogen, phosphorus and potassium foods. (The one exception is hydroponics where it becomes necessary to add large amounts of magnesium and calcium).

Every nutrient has its purpose, and a deficiency or oversupply of even a minor nutrient can have a major effect on the plant. Deficiencies can be difficult to detect, but as time passes symptoms will appear. Signs are stunted growth, unhealthy leaves that may be mottled, stunted and dying off, distorted stems and undeveloped root systems. If a nutrient is easily dissolved, the older leaves will be affected first, otherwise the growing tips, i.e. the new leaves will be affected.

An oversupply of nutrients may initially cause extra growth but may then become toxic, and plant growth will be reduced. Deficiencies are not always a result of the nutrient not being present. It may be the nutrient is being held in some form which prevents the plant taking it up. For example, it could be attached to an insoluble material (known as 'immobilisation' or being 'locked up'), or be affected by pH.

In simple terms, in order to ensure healthy plant growth do not let plants suffer from nutrient deficiency or toxicity. For the organic farmers and gardeners, supply of minor trace elements to suffering plants may seem a bit daunting.

Provided you use a wide range of organic fertilisers as sources of organic matter, it is unlikely that plants will suffer from any deficiencies. In fact, soils high in organic matter hold more nutrients than inorganic soils.

Nutrients can also be readily lost from the soil through erosion, through leaching (the loss of soluble nutrients down through the soil profile in soil water), through conversion of nutrients to gaseous forms (e.g. ammonia gas) which escape to the atmosphere, and through the removal of plant material (e.g. crops). Compensation for the loss of nutrients by such means should be a major priority. Chemical fertilisers will compensate for these losses in the short term however the sustainable farmer should be looking more towards cover crops, mineral powders, and composts which release nutrients slowly. This requires careful planning as benefits will only accumulate gradually.

Choosing the Right Fertiliser

This helps minimise wastage, reduce costs, and reduce negative effects on the environment whilst maximising plant growth.

- Timing is important so as not to waste fertiliser. In winter, some plants may be dormant so the fertiliser will not be taken up. Heavy feeding at the wrong time of year can also cause fruit trees to produce plenty of leaves at the expense of fruit.
- Commercial fertilisers are available for certain types of plants (e.g. azalea food, rose food) or as general preparations to suit most plants. However, some are produced from non-renewable resources.
- Quick-release or soluble fertilisers are very mobile which makes them easier for the plants to get at but, unfortunately, most of the nutrients can be leached into streams or ground water eventually ending up in rivers, bays, dams, and estuaries, where they can cause such problems as algal blooms.
- Using slow-release fertiliser can be a more efficient way of feeding plants, but again these may not be made from renewable materials.

- Homemade fertilisers can be prepared using compost, animal manures, and mulch material. Some plants themselves are excellent sources of nutrients, including legumes (e.g. Lucerne). Often weeds are able to absorb minor nutrients from the soil, so they can also be used if care is taken to ensure that the weeds have not set seed, or will not re-establish. A handy way to make your own liquid fertiliser is to quarter fill a large container with weeds, and/or manures and legumes, top up with water to cover the material and then leave it all to stew for a couple of weeks, stirring occasionally. The resulting dark liquid should be diluted with water (1:100) and applied to the soil or used as a foliar (leaf) application. The brew may be regularly topped up with water and other ingredients. Be careful to keep it covered, or agitate it regularly, to prevent mosquitoes breeding in the container.

The golden rules in using any liquid manure are 'diluted' and 'frequent'. There comes a point whereby strong organic manure can be as disastrous as chemical manures used injudiciously. Urine is excellent liquid manure if diluted to about 1:20, but if used at full strength it will kill almost any plant.

Nitrogen

This element is essential for good foliage and stem growth. When there is a flush of rapid growth, nitrogen requirements become particularly high. Adequate nitrogen is essential for good fruiting and other plant processes as it is required in the synthesis of proteins and enzymes in every living cell, though it is more closely related to the green growth.

Nitrogen is obtained via the roots from the soil solution (and to a degree from the atmosphere by legumes). Nitrogen fertilisers are applied to plants in order to stimulate green, vegetative growth. Obvious situations to apply nitrogen would be on leafy vegetables, on young plants to stimulate faster growth, on lawns, and on plants grown for their foliage. Symptoms of deficiency include stunted growth and general chlorosis, whilst toxicity is generally first noticed by a lush green overgrowth with increased susceptibility to frosts, etc and eventual collapse.

Nitrogen fertilisers include:

- Sulphate of ammonia
- Blood and bone
- Sodium nitrate
- Calcium nitrate
- Potassium nitrate
- Urea

Phosphorus

Adequate phosphorus is essential to maximise root development, for growth and energy transfer. Deficiencies lead to poor fruiting and spindly growth. Other symptoms may include purplish tinting of leaves and poor seed set. Lack of phosphorous is common in some soils, e.g. in Australia, making it essential to fertilise well with phosphorous to achieve good growth with many types of crops. It should be remembered, however, that of any amount of phosphorus applied to the soil, only about 20% may be immediately available to the plant, the rest being released slowly over a period of time. Some Australian native plants have adapted to low phosphorous soils to the extent that they can easily be harmed by fertilising with phosphorous (e.g. *Grevillea spp.).*

Good sources of phosphorous include:

- Superphosphate
- Monocalcium phosphate
- Shrimp waste
- Raw sugar waste
- Bone meal and other organic foods (including blood and bone).

Potassium

Potassium is required by the plant in quite large amounts and is necessary to maintain cell turgor and the plant's water relations, controlling the opening of stomata, etc. Soils in dry areas usually have good reserves of potassium. It is very soluble and very mobile in the plant. It is known that good levels of potassium are needed, in particular, for flowering and fruiting. It is also very active in meristematic tissue where it appears to behave in a similar way to calcium. Deficiency symptoms include marginal chlorosis of older leaves, low yields, weak stems and meristematic necrosis.

Good sources of potassium are:

- Potassium sulphate (sulphate of potash)
- Potassium chloride (muriate of potash)
- Wood ash and organic fertilisers (seaweed, straw, and most manures etc).

Magnesium

Magnesium is essential to chlorophyll formation and energy transfer processes. Developing fruit have a high requirement. Deficiencies are usually noted by interveinal chlorosis and stunting.

Fertilisers include:

- Dolomitic limestone (dolomite)
- Epsom salts.

Calcium

The main role of calcium is in the formation of peptic compounds of the middle lamella. It is not transportable in the phloem, where it is rapidly precipitated as calcium oxalate. Thus, symptoms of deficiency occur in active meristematic tissue as apical and marginal chlorosis of young shoots and leaves, as well as in developing fruits. Calcium fertilisers include:

- Slaked lime
- Agricultural limestone
- Dolomite
- Gypsum.

Sulphur

This element is not often deficient, as many forms of fertiliser are provided as sulphates. Also, toxicity is rare due to high tolerances in many plants. This, along with their solubility, is the reason for the use of sulphates in fertilisers. Sulphur is, however, very necessary for plant growth and a plant may require almost as much sulphur as it does magnesium. One of its main functions in the cell is the formation of disulphide bonds in protein molecules. These bonds are largely responsible for the tertiary structure of many proteins and so deficiency will inactivate them. When deficiency occurs, it is usually noticed as chlorosis of the leaf veins (as opposed to the interveinal chlorosis of other nutrient deficiencies).

MINOR ELEMENTS

Many of these are just as essential as the major elements but are not required in as large a quantity. Deficiency of a minor element can have just as devastating results as deficiency of a major one.

Iron essential for the functioning of a number of accessory photosynthetic pigments (cytochromes, etc). Lack of the small amount of required iron will cause plant growth to cease and produce interveinal chlorosis in many plants. Iron deficiencies are more common than any other minor nutrient problem. Plants which commonly suffer iron deficiencies include: Banksias, Proteas, Grevilleas, Citrus, Azaleas, Daphnes, etc. Iron can be fed to a plant by applying iron chelate, iron sulphate, or even some old rusty nails.

Zinc contributes to the manufacture of carbohydrates and proteins by functioning as an activator of a number of enzyme reactions. It is a common deficiency in some countries, notably Australia. Fertiliser: zinc sulphate.

Manganese – is necessary, but the quantity varies greatly between species. Its functions are similar to those of zinc. Evergreens generally use more than deciduous plants. Fertiliser: manganese sulphate.

Copper very small quantities are needed, although it is known to be essential. Little is known of its function but excess copper is known to be toxic and, in some plants, causes an iron deficiency. Fertiliser: copper sulphate.

Molybdenum essential in nitrate reduction, a component of some enzymes, important in nitrogen fixation which occurs in the roots of legumes. Deficiency occurs more often on acid soils. Fertiliser: ammonium molybdate.

Boron may assist utilisation of calcium, may play a part in formation of cell walls, involved in cell division and essential to carbohydrate and nitrogen metabolism. Fertilisers: borax or boric acid.

Chlorine this element is essential, but tolerances vary widely and the precise function of this element within the plant is still uncertain. There are no records of a plant needing to be fed chlorine although toxicities are known, especially in tobacco and potatoes.

Cobalt there is no direct proof that this is absolutely necessary in plants although it does seem to be important to nitrogen fixation in legumes. It is important to human nutrition in the formation of certain compounds such as Vitamin B12. The amount of cobalt in plants can vary greatly.

Silicon occurs in greater quantities in monocotyledons (e.g. Grasses, Iris, Lilies, Orchids etc). Silicon does improve the growth of some plants. Some say it is necessary in minute amounts but this is by no means an established fact.

Aluminium essential in some species only (e.g. Peas, Corn, Sunflower and some Grasses). Over 10ppm is toxic. It can also help reduce the effects of phosphorus toxicity to some degree.

Selenium is used in varying amounts by some species only.

Sodium although not usually considered essential, sodium can replace potassium as a nutrient to a limited extent.

TOTAL SALTS

Most nutrients in the soil exist in the form of a salt (e.g. common table salt is sodium chloride). 'Total salts' refers to the combined effect of all different types of salts in the soil. Individually salts might not have any effect, but combined they may be toxic to a plant. Excessive salt is often indicated by a whitish caking on the surface of the soil.

Symptoms:

Drying of the leaf margin beginning at the tip is followed by death of the tip and then marginal leaf burn. In severe cases, leaves shrivel and whole branches suddenly wilt. Chemical laboratory analysis is needed to confirm the problem.

The only solution is to wash the salts out of the soil. In places with inadequate drainage this is next to impossible. The soil may be permanently damaged unless some form of drainage system can be installed.

DIAGNOSIS OF NUTRITIONAL PROBLEMS

The following key may be used to identify nutrient deficiencies from visual symptoms. Note, however, that deficiency may exist with no symptoms other than stunted growth or reduced yield. Also, combined deficiencies are very common and may not be identifiable from this key. In such cases, laboratory analysis of plant tissue may be necessary to identify the problem. This key will not be useful for diagnosis of toxicities (for these refer to notes on individual elements).

A: Older or lower leaves mostly affected.

B: Effects generalised over the whole plant, with the older leaves showing the worst symptoms.

C: Plant light green, lower leaves predominantly yellow, drying to light brown. Leaves small and thin, with strong autumn colours and drop early. Compound leaves have fewer leaflets. Flowers bloom heavily but late. Fruit set is light, small, highly coloured and early to mature. Stalks are slender, short, and possibly reddish or reddish brown - NITROGEN.

CC: Plants dark green, often developing red or purple tints particularly in the veins, petioles and the lower surfaces (especially when young). Foliage is sparse, smaller than normal and distorted. Leaves drop early. Flowers are few. Fruit is sparse and small. Shoots are normal in length unless the deficiency is severe, but smaller in diameter - PHOSPHORUS.

CCC: Leaves display marginal and interveinal chlorosis and scorching that moves inward between the main veins to the entire leaf. Leaves may wrinkle and roll upwards. Flower buds are few. Fruit is small and poorly coloured. Shoot tips die back in late season - POTASSIUM.

BB: Effects mostly localised to older leaves.

D: Mottled or chlorotic leaves which may redden, sometimes with dead spots. Tips and margins curled upwards - MAGNESIUM.

DD: Spots generalised and rapidly enlarging, generally involving areas between the veins. Leaves thick and stems with shortened internodes - ZINC.

AA: Symptoms localised to young leaves and buds.

E: Distortion of young leaves followed by death of buds.

F: Young leaves become hooked and die back at tip and margins, finally dying back to the bud - CALCIUM.

FF: Young leaves light green and growth becoming twisted, finally dying back to the bud - BORON.

EE: Terminal bud commonly remains alive.

G: Young leaves permanently wilted, sometimes the stem below the tip will bed over - COPPER.

GG: Young leaves not wilted.

H: Young leaves chlorotic, with dead spots common. The veins remain green and symptoms may sometimes spread to older leaves - IRON.

HH: Young leaves AND veins yellow - SULPHUR.

HHH: Dead spots scattered over leaf, smallest veins remain green, giving a chequered effect – MANGANESE

FERTILISERS

There are a tremendous variety of fertilisers available, and each one is different. Using the wrong fertiliser or the right fertiliser at the wrong rate, can create problems in your garden rather than overcome them.

The variables:

- Relative proportions of each nutrient.

- Actual concentration of the nutrient (this is different in different types of fertilisers).
- Solubility.
- Period of time over which the nutrient will be used.
- What else is with the nutrient? E.g. nitrogen applied as potassium nitrate will also supply potassium.
- Method of fertiliser application - to roots or foliage? Broadcast on the soil surface or buried in holes? In liquid or dry powder form? Watered in or not?
- Type of soil - will the fertiliser remain in the soil or be leached out?
- Type of plant and time of year - will the plant use the fertiliser quickly? Is it growing rapidly?

Nitrogen

Nitrogen can be obtained naturally by growing leguminous plants alongside other plants or as a cover crop to be ploughed in before planting. Legumes e.g. peas, clover, wattles, etc have colonies of bacteria in small nodules on their roots. These bacteria do not damage the plant. In fact, they extract nitrogen from the atmosphere and make it available for use by the plant.

Nitrogen fertilisers include:

- Sulphate of ammonia (21% nitrogen)
- Potassium nitrate (34% nitrogen)
- Urea: cheap but can burn (46% nitrogen)
- Blood and bone, fowl manure, etc.

Phosphorus

Rock phosphate: insoluble

Superphosphate: this is a soluble phosphate plus gypsum and is excellent in dry, sandy situations.

Potassium

Potassium Sulphate: expensive (41.5% potassium)

Potassium Chloride (muriate of potash): cheaper (50% potassium).

How Much to Apply

It is always better to apply too little than too much. You can always add more, but you cannot take it out of the soil and put it back in the bag!

Always read the instructions on fertiliser bags. If applying to young plants or less hardy plants (e.g. some indoor plants) you are better to put on less fertiliser.

NATURAL FERTILISERS

Nutrients can be added to soil by digging in kitchen scraps, animal manures, cover crops, natural minerals such as rock dusts, and synthetic chemical fertilisers. Nutrients are also obtained from irrigation water, rainfall, from the atmosphere (i.e. micro-organisms converting atmospheric nitrogen) and from the natural weathering of rock and soil itself.

The source is unimportant to the plant; nitrogen from animal manures is exactly the same as nitrogen from sulphate of ammonia, and phosphorus from rock dusts is exactly the same as phosphorus from superphosphate.

The choice of which source of nutrients to use should depend on the effect that it will have on the soil.

Artificial fertilisers are easier to apply and manage than animal manures and organic fertilisers, but can create major soil problems, in particular soil acidification. These fertilisers release nutrients quickly so nutrients are easily washed through the soil where they can pollute rivers and creeks. Organic fertilisers generally don't cause these problems, and have the added advantage of improving soil structure, and promoting beneficial soil life.

Table: Average Relative Nutrient Content, Rate and Availability

Fertiliser	% Nitrogen	% Phosphorus	% Potassium	Nutrient Availability	pH
Sewage	3.0	2.0	0.3	Slow	Acid
Cocoa shell	2.5	1.5	1.5	Slow	Neutral
Peat	2.0	0.3	0.7	Very slow	Acid
Fish meal	10.0	4.0	0.0	Slow	Acid
Blood meal	12.0	1.5	0.8	Slow	Acid
Hoof & horn	12.0	2.0	0.0	Slow	Neutral
Bone meal	3.5	22.0	0.0	Slow	Alkaline
Powdered rock phosphate	0.0	33.0	0.0	Very slow	Alkaline
Seaweed	1.0	0.0	5.0	Slow	Acid
Wood ash	0.0	2.0	4.0	Slow	Very alkaline
Urea	45.0	0.0	0.0	Fast	Very acid
Cow manure	0.25	0.15	0.25	Medium	Acid
Horse manure	0.3	0.15	0.5	Medium	Acid
Sheep manure	0.6	0.35	0.75	Medium	Acid
Poultry manure	2.0-6.0	1.0-4.0	0.5-3.0	Fast	Acid
Pig manure	0.3	0.3	0.3	Medium	Acid
Green bracken	1.5	0.2	1.5	Slow	Acid
Apple cores	0.5	0.02	0.1	Medium	Acid
Coffee grounds	2.0	0.4	0.7	Medium	Neutral
Citrus peel	0.2	0.1	0.2	Slow	Very acid
Peanut shells	0.8	0.15	0.5	Slow	Neutral
Tea leaves	4.2	0.6	0.4	Medium	Neutral

Reference: ‘Fertility Gardening’ by Hills (1981) David and Charles Hydro Story by Sherman and Brenizer: Nolo Press

A LOOK AT ORGANIC FERTILISERS

It is important that all of the materials used in either composting or as fertilisers be free of chemical contamination. This includes antibiotics, growth stimulants and other products that may have been fed to livestock.

Animal Manures

All animal manures are useful as fertilisers. When mixed into compost as part of the composting process, the final material provides excellent all-purpose fertiliser.

Manures can be used directly on plants; however they vary greatly in their nutrient content. It is impossible to give accurate figures on the micro-nutrients in animal manures, because they can vary so much, depending on what the animal eats. Some idea of the nitrogen content is important in any manure you use. High levels of nitrogen can burn the plant roots. Well-rotted cow, sheep, horse and goat manures are generally safe (nitrogen is not too strong).

Pulverised and partly composted cow manure can be used generously on a bed in preparation to plant seedlings on the same day, provided it is thoroughly mixed in the top 68cm of soil. (The same treatment with an equal amount of poultry or pigeon manure would result in disaster, with most, if not all of the seedlings dying within a few days.)

Poultry Manure

Poultry manure may be available either as pure manure without litter, or as dry deep litter material (mixed together with wood shavings). When using pure poultry manure, make sure that the chicken farmers have not sprayed the manure heaps with insecticides, a common practice in some farms. Deep litter poultry manure is always a safer bet because it is far less likely to have been sprayed (NB: Chickens scratching the litter eat insects and spraying is unnecessary).

Blood and Bone Meal

Dried blood used in a number of commercial organic manures has probably the highest nitrogen content of any organic manure about 11.5%. It is, however, expensive. Blood meal has approximately 1% phosphorus. Bone meal contains around 4% nitrogen but over 20% phosphorus.

Rock Dusts

Rock dusts are simply ground up or crushed rocks. Natural weathering in farms or gardens gradually leaches out many of the original nutrient reserves in the soil. Many of these nutrients originally came from silt or weathered rock, so it is argued by some organic gardeners that applying rock dust may replenish the nutrients in the soil. Some experts are still sceptical about the benefits of rock dusts. Some rock dusts used in agriculture and horticulture are:

- Gypsum to supply calcium and sulphur
- Dolomite to supply calcium and magnesium
- Limestone to supply calcium
- Scoria to supply iron
- Basalt to supply calcium, magnesium, phosphorus, potassium and a range of minor nutrients

Seaweed

- Many types of seaweed do not contain cellulose like other plants. This causes it to rot down faster than other plants.
- It is ideal to use in a compost heap.
- Wash harmful surface salt off the plants before use.
- A rich source of boron, iodine, calcium, magnesium, sodium and other trace elements.
- The readily available nutrients can lead to nutrient toxicities (causing leaf burn) if overused.
- It is safe to mulch plants with a generous layer of seaweed about once every four years, making it suitable for long-term crops such as fruit and vine plants.
- Different types of seaweed have different nutrient values. The kelps are the best source of potash. These are the large flat, brown straplike seaweeds.

Seaweed Extracts

There is a range of liquid fertilisers on the market but they do vary in quality. Although seaweed doesn't have high levels of nitrogen, phosphorus or potassium, it does contain a broad spectrum of micronutrients, and many people attest to strong plant growth, vigour and general good health when they use seaweed extracts (such as Maxicrop and Seasol).

The fact that this cannot be attributed only to the direct absorption of those nutrients supports the probability of other benefits (i.e. that plant nutrition is enhanced by increased bacterial, enzyme and other biological factors in the soil, that in turn provide far better nutritional status).

It is difficult to overdose plants with liquid seaweed. Some people even dip cuttings in it to encourage root formation.

COMPONENTS OF POTTING MIXES

Soils

- The best medium for growing plants in containers.
- Soils are well buffered so pH changes are slow to happen.
- Soils do not have the complicated chemical toxicity problems which can occur in soilless mixes. For this reason, some soil is often advantageous even in what is predominantly a soilless mix.
- Reliability of supply of soil with 'known' characteristics is difficult.

Sands

- Supply of sands with 'known' characteristics is more reliable than many other components.
- Sands can be added to mixes to improve drainage and aeration.
- Sand makes pots heavier to move.
- Sand is generally close to inert - it has no effect on the chemical balance of the overall mix.

Peat

- Peat moss is lightweight, porous, well aerated, and drains well.
- It mixes well with other components but often requires moistening before use (if it dries out it can be difficult to wet).
- Its pH can be low (i.e. 4 or 4.5) and mixes incorporating peat may need lime added to offset this effect.
- Occasionally, some types of peat can be found with a salt toxicity.
- Its main disadvantage is cost.

Pine Bark

- Available shredded into different grades (i.e. different sized pieces).
- Fresh pine bark is toxic to plants: it requires proper composting for several months before use.
- Bark which has not been composted ties up nitrogen available to the plant since the action of micro-organisms in the decomposition of the bark uses any nitrogen which is there. Thus, the plant shows symptoms of nitrogen deficiency.
- Bark which has a resinous smell or is reddish in colour should not be used.
- It is frequently used in proportions of 50 to 70% of the potting mixture.

Sawdust

Like pine bark, sawdust causes problems with toxins and nitrogen availability.

Composting is necessary - hardwood sawdust should be composted for 6 weeks or more with the addition of the following fertilisers to every cubic metre of sawdust being composted:

- 2.6kg urea
- 2.0kg superphosphate (less if growing phosphorus sensitive plants)
- 0.5kg potassium sulphate
- 18kg dolomite (for a final pH of 6.5)
- 9kg dolomite (for a final pH of 6.0)
- 5kg dolomite (for a final pH of 5.5)
- Trace elements might also be added in small quantities.

Lignite

- Also called ligna peat, or brown coal, this substance is not coal but is taken from coal mines.
- It has a great water holding capacity which can be problematic by keeping the mix too wet if it is used in large quantities.
- Lignite's main advantage is its cheap cost.

Other components which have been used include: perlite, scoria, rice hulls, peanut shells, polystyrene balls, blue metal, and vermiculite.

SET READING

Refer to, and read any reference material you have access to that relates to the aim of this lesson.

This may include any of the following:

- Books in your own possession, or which you find in a library
- Periodicals you have access to (i.e. magazines, journals or newspapers)
- Websites

Spend no more than 2 hours doing this.

SET TASK

Activity 1

Visit at least three properties where commercial vegetable growing is carried out. Find out all that you can about their operations, including:

- Types of vegetables grown, and when they are grown
- Why those particular varieties are grown
- Soil management techniques (prior to crop establishment, and during crop production)
- Crop establishment techniques (how crop is planted\sown, spacing, etc.)
- Any cultural techniques carried out on the crop (e.g. trellising, pruning, feeding, weeding)

(If this task proves too difficult because of accessibility problems you may visit one home vegetable garden, plus the websites of 5 different commercial growers as an alternative task).

Activity 2

You are required to cultivate a vegetable bed over a period of three months or more, growing at least eight different vegetable varieties suited to your local conditions, and keeping a log book of all work carried out, from preparation of soil to harvesting (including records of quantities of materials used and quantities of vegetables harvested). Your log book will be submitted as part of the assignment for lesson 5.

What is a Log Book?

A log book is like a diary.

It is simply a book in which you can write down everything you do with respect to a particular task, over the duration of that task.

A vegetable growing log book can be as simple as a list of dates starting from when you begin preparing the soil for the vegetable plot to the final date when you harvest the vegetable. Beside each date, you can write down what you did on that date e.g. water, weed, fertilise, mulch, spray insects, remove diseased leaves, etc.