Lesson 2

ESTABLISHING A KITCHEN GARDEN

Aim
Discuss the potential for increasing self sufficiency by growing your own food in a kitchen garden.

Growing vegetables for consumption can be a valuable tool in increasing your self sufficiency, whether it is at a personal scale or at the scale of a family or a small community. A kitchen garden is one way that the individual or small community can provide themselves with a steady supply of fresh vegetables throughout the year. Not only does this food source reduce dependency on society at large, but it can also increase personal health, because fresher vegetables frequently have a greater nutritional value.

But in order to be successful, a kitchen garden must be well planned. This planning must take into account what can be grown in the area (this is influenced by the soil, climate, and other local factors), as well as what vegetable products are required. It can be difficult to produce consistent volumes and variety of produce, and management of the vegetable garden needs to aim to provide this consistency and variety.

Even in today's complex and technology driven society the hunter-gatherer instinct is strongly present within most of us. Growing edible plants and creating beautiful garden spaces is a way that we can keep in touch with nature and the simpler joys of life.

Why Grow Herbs and Vegetables?
Watching plants grow from seed to harvest and knowing that the armful of vegies and herbs you have just gathered for the evening meal will be on the table within an hour or two of harvest, can be an exciting and satisfying experience.

Other Reasons to Grow Vegies
- money savings
- satisfaction of being self sufficient
- knowing what you are using (you can never be sure that purchased products are pure and uncontaminated)
- reliable supply of preferred varieties
- fresher food
- just for fun

Can You Be Self Sufficient on an Average Home Site?
It is possible to provide for many of your needs but you may need to modify your expectations. If you want every luxury that modern society can offer, then you are going to need more than what your garden can give you, but if you are prepared to be only part self sufficient or to live with less, then go for it.

Uses of Vegetables and Herbs in the Garden
The most obvious reason to grow vegies or herbs is to harvest and use them; but that isn't the only reason. Many vegetables and herbs can be just as attractive or functional as the ornamental and amenity plants we grow. Use herbs and vegies for better visual impact. It is all a matter of plant selection and arrangement. You can also use them to manage the soil by controlling erosion, dealing with excess water or dry soil, or to improve soil fertility.

Ways of growing vegetables and edible plants
- row crops
- permaculture garden with companion planting
- containers
- no dig or organic
- home garden IPM
- biodynamic
- hydroponic

What Can You Produce in Your Garden?
What you produce from your garden will depend on the amount of space that you have. Obviously the larger the property the more potential you will have to produce a large variety of crops. Large properties can support a range of fruit trees, vines, vegetables, herbs, grains and even hay and straw as well as animals and chickens. The smaller the property the more thought you will need to give to what you do and don't grow.

Some produce you could consider:
- Fruit and nuts
- Vegetables and herbs
- Eggs
- Honey
- Meat (poultry, rabbits, pigs)
- Fuel (wood, methane gas, electricity)
- Building materials
- Fibre and craft materials

What Can You Make Using Produce From Your Garden?
Turning the fruits of your labour into preserves and other usable items can be as much fun as the actually growing. For those who are looking to be self sufficient this is an extension of growing your own food, and a necessity to help you through winter and early spring, when fresh produce can start to dwindle.

The following is a short list of what you could consider making:
- Preserves or chutney
- Dried foods
- Oil or soap
- Cloth
- Fertiliser, compost or mulch
- Seed (for next year's planting)
- Fruit juices or wine
- Wine

IT'S ALL A MATTER OF TIMING

The problem with most edible produce is that it grows and matures at certain times of the year. You may have a glut of produce in the summer and autumn only to find that you have little in winter and are virtually starving in early spring! This may not be a problem if you have decided to only grow vegies at certain times of the year and have no intention of aiming towards self sufficiency. However, if you would like to be self sufficient and grow most of the produce you need to sustain you and your family throughout the year, then you will need to carefully plan your garden to ensure that these needs are meet.

Whatever you decide you should be aware that different types of plants will yield different results. You need to carefully select what you will grow and where you will grow it, particularly if you have limited space or limited time in which to care for crops:

- Some plants, once established, require relatively little attention (eg. nut trees or raspberries), while others need constant attention (eg. lettuce or tomatoes).
- Some plants produce a lot in a small space (eg. berry fruit) while others take large spaces to produce even small quantities of produce (eg. wheat).
- Some plants take a long time to produce a crop, others bear quickly.
- Some plants require a lot of capital outlay initially (cost of the plant, cost of fertiliser)
- Some fruit trees bear their fruit biennially (particularly if allowed to produce heavy crops, thinning of crops is essential to prevent biennial cropping) whereas others bear fruit annually**.**

Another simple approach is to be in rhythm with nature i.e. eat what is in season but don't forget that you can extend cropping naturally by choosing and planting early, mid and late season varieties. Unless it is an area of particular interest to you; trying to grow crops outside of their natural growing seasons i.e. expecting to eat strawberries in winter in a cooler climate, is a waste of time and energy for the home gardener.

MAKE YOUR GARDEN MORE PRODUCTIVE

Don't waste space. Keep lawns, paving and ornamental flowerbeds to a minimum. If you like colourful flowers, there's no reason they can't be planted amongst vegetables. If you choose the right species, they can act as 'companion' plants to aid the growth of the vegies and herbs. Many vegetables and herbs can be grown not only to produce food, but also as attractive garden features.

The foliage of many vegetables and herbs is highly ornamental, and many also have flowers that are both visually attractive and pleasingly fragrant. Include multi-functional plants as much as possible, such as those that produce food and also have a number of other uses. For example, a tree could provide fruit and shade for people and foraging poultry, pollen for bees, windbreaks, firewood, timber, and leaves for use as mulch or to compost.

Build up the soil and improve its fertility. This is the key to a healthy, thriving garden. Compost all the kitchen scraps and garden clippings and animal manures then dig the compost into the soil. Also add seaweed and any other organic material that will break down in the soil. Earthworms will thrive on the organic matter, further improving the soil structure and fertility. Set up a worm farm and harvest their castings to use as a soil conditioner.

If you have chickens give them all the vegetable scraps and fresh grass clippings and excess vegetables from the garden. Use a deep litter system (i.e. straw, old hay or sawdust) and simply toss all your composting material (other then onions, leeks and garlic) onto the litter. The chickens will soon turn it all into lovely compost that you can later add to your garden. Use organic mulches on the soil surface to stop weeds competing with the productive plants, and to reduce the need for watering. Compost produced by chickens is ideal for this as it will also be weed free.

Collect your own rainwater. You could install an underground well that is filled from the under-ground water table. Chinese style pumps are an easy way to access this water supply. An alternative is to collect water from guttering by sending it straight into barrels or tanks. Not only will these methods cut down on your water bill, but you can be sure that the water you collect does not have any unhealthy additives. Install a grey water filtration system and use this water for the ornamental garden saving the fresh storm water for the fruit, vegetables and herbs.

Make Every Inch Count

On a small property, you will need to use all your available space efficiently. Make an inventory of your garden and think about how each feature or structure could be used or modified to produce something. Here are some examples:

- Walls and fences for supporting climbing plants and espaliers, also to shelter plants and to improve fruit ripening.
- Verandas and balconies can be used for growing potted plants that need extra protection, use as a potting area, for tool storage or for drying herbs and other produce.
- A garden shed can have a shade house, greenhouse or chicken run added.
- Pergolas can be used to support climbers.
- A swimming pool can be converted to an aquaculture garden that supports fish, ducks and productive water plants.
- Incorporate terraces supported by retaining walls on sloping sites.
- Rotate vegetable and crop plantings to get the most out of each bed of soil.
- Make the most of window boxes, pot stands and shelving in greenhouses.

Minimising Water Use in the Herb, Vegetable and Fruit Gardens

Gardeners often tend to over water. Most plants will adapt to less water by sending their roots down further and wider in search of soil moisture, through this they develop a larger root mass that has the ability to forage a larger area. Even vegetables will grow well without the need for daily watering as long as the soil is well prepared, moist at planting time and mulched immediately the area is planted, or the seedlings are up. Bare soil is the enemy of the garden. Soil moisture soon evaporates even during mild conditions.

Once vegetables are harvested, more compost should be added and a new crop planted. During winter or other fallow times, plant a cover crop that can be dug in as green manure later (see chapter three for more information about green manure/cover crops). This is another way to conserve water by protecting the soil from moisture evaporation, as well as increasing soil fertility by adding extra valuable organic matter. Alternatively mulch the area thickly with compost and straw and let the earthworms do the job for you.

Where Do We Have Dry Garden Areas?

- in dry climates (low rainfall)
- in very sandy soils that don't hold water well
- under the eaves of a house or against a wall (in a rain shadow)
- in pots that dry out easily (especially terracotta)
- under the canopy of a large tree
- on a steep slope, where water is lost quickly
- in hot paved areas
- coastal sites

If you've got a problem with a dry garden or a dry spot in the garden, there are solutions:

- improve the soil's water holding capacity (add organic matter, water crystals)
- decrease water loss (with mulch and shade)
- grow more dry tolerant plants

Use a drip irrigation system. Sprinklers are a wasteful use of water as they tend to water the surrounding areas i.e. pathways grassed areas as well as the vegetable garden. Micro sprayers are prevalent to water loss due to drift from wind even a slight breeze can effect the efficiency.

Integrated Pest Management (IPM) for the Home Garden

The approach that IPM takes is to look carefully for pests throughout the season and make decisions on what to do based on the results of the monitoring process

Through the implementation of an IPM system pests are more likely to be found when they are still only in low numbers due to the fact that the plants are being checked regularly for signs of infestation or disease. The problem will be dealt with early before the outbreak becomes too big.

There will always be some pests present in a crop or on plants. This does not necessarily mean that a control method needs to be implemented that quickly kills the pest, in IPM the best control method will also take into account control measures already in place i.e. biological control and not jeopardise their effectiveness. It must be ascertained just how many pests can be tolerated without damage to the plants or crop and this is dependant on the location, variety and other crops growing nearby.

Using an IPM you need to be able to identify the many different insects including pests and those that are not pests as well as diseases found on your crops or plants, you should know when action is needed by ascertaining whether an infestation is at a level so as to be of concern, and to ascertain the number of beneficial insects present. You also need to know how many pests can be tolerated before you need to take action; resistance to insecticides is an outcome as a result of chemical overuse in the past. Monitoring crops on a weekly basis will enable you to determine what the pests and beneficial insects are doing and whether the beneficial insects are controlling the pests, intervention should only occur when biological and cultural controls are not sufficient.

THE NO DIG METHOD OF GROWING

If your soil is poor quality then it may be better to grow vegetables in a no-dig garden. The 'no-dig' method involves building a slow working compost heap straight onto the surface of the soil as a "raised garden bed", and planting direct into the pile. In the home garden, no-dig gardens can be a very effective, easy growing method, once established the garden requires minimal maintenance. Esther Deans in Australia has promoted this style of gardening through her best-selling gardening book. The no-dig method has also been popularised by the permaculture movement.

A typical no dig garden could be made as follows:

1. Weeds are removed first by mowing, physically removing, burning or some other method.

2. Very thick layers of newspaper is laid on the surface to inhibit further weed growth (up to 50 sheets thick is not uncommon).

3. A layer of straw or lucerne hay (weed seed free) is placed on top of the newspaper (at least 10 cm thick). Other materials such as weed-free compost, grass clippings, or sawdust might also be used.

4. The straw or hay is covered with rotted manure to a thickness where the straw or hay can barely be seen.

5. A further 8-12 cm of lucerne hay is placed on top.

6. The surface is sprinkled with blood and bone fertilizer, or chicken manure pellets. Small quantities of these materials may also be mixed with the hay, sawdust or other materials.

7. Plants are planted direct into the top layer with a few handfuls of good quality compost around the roots of each when planted.

8. Once the plants are harvested, the materials will have decomposed, just add more layers on top and plant a new crop. Eventually you will have an amazingly fertile garden full of worms.

PERMACULTURE GARDENING
A permaculture garden is the ultimate productive garden. A well designed permaculture garden will overflow with plants that you can use for food, fuel, crafts, or any of a multitude of other purposes.

What is a Permaculture Garden?
Permaculture is a concept that combines the words “permanent” and “agriculture”. It was developed in Australia by Bill Mollison and others with the aim of creating sustainable production systems. It is based on ecological principles and incorporates other natural gardening and farming systems such as organic gardening, no-dig gardens, companion planting and biological pest control.

The result is a landscape that once established properly, should require little work to stay in balance and at the same time will allow you to be continually harvesting from it. The concept can be adapted to whatever space you have available, including a suburban block, hobby farm or even a balcony if that is the only space you have.

Permaculture concentrates on function and gives low priority to conventional ideas of aesthetics. As such, a Permaculture system does not need to look 'nice', but it does need to serve its intended purpose.

The Main Principles of Permaculture Designs include:
- All elements (i.e. plants, soil, water, building, animals, etc) in the landscape are interconnected.
- Every design should include as many elements as possible and they should serve many functions.
- Use renewable biological resources that can be produced within the design, where possible.
- Use minimal energy, and design the system to optimise the energy generated by plants and animals.
- Incorporate as many plant and animal species as possible into the design to ensure biological stability.

The Structure of a Permaculture Garden
The typical permaculture garden is divided into zones to maximise production and minimise work and energy inputs. The zones should be thought of as ideas, rather than as fixed boundaries. It is the first two zones that are most relevant to suburban gardens.

Zone 1 is the area around the house. This is the most intensively developed area. The main feature of this zone is an organic vegetable and herb garden.
Zone 2 is the orchard. It provides fruit, fuel and mulch. It also acts as a windbreak and provides shelter and food for free-range poultry and bees.
*Zone 3 i*s a broad-scale cropping and foraging area. It provides timber, nuts, larger scale fruit orchards and crops such as corn and rice. It is also used for raising larger animals such as cattle and sheep.
Zone 4 is a forest with long-term timber plantings.
Zone 5 contains the natural forests which are preserved for their biodiversity.

Permaculture on a Suburban Block

When you design a permaculture garden, first look at the microclimates in your garden these might be the shaded area on the southern side of the house or a warm sheltered spot that gets all-day sun. You can take advantage of these microclimates to grow a more diverse range of plants and to extend the growing season.

The Main Features

- Sustainable herb and vegetable garden beds, incorporating perennial, self-seeding, self-layering, nitrogen-fixing and self-mulching plants.
- The inclusion of productive domestic animals such as poultry and goats.
- Fruit and nut trees for shade, food, mulch and animal forage.
- Stacking of plants (in layers of groundcovers, shrubs and trees, similar to a natural forest). This allows intensive use of space and maximises productivity.
- Abundant and diverse plantings reduce the incidence of pests and diseases and stabilise the environment.
- Heavily mulched beds minimise work and improve plant growth. No-dig methods are used to create the beds.
- Water gardens modify the microclimate and provide habitat for fish, insects, etc. The size depends on available space.
- Edge design is an important design concept utilising microclimates and maximising growing areas. Garden beds may have wavy edges or be shaped in a keyhole or spiral design.
- Organic gardening, using composting, water recycling and natural pest controls.

Structures

Permanent structures in a small-scale permaculture garden include:

- paths that link buildings and garden beds
- greenhouse/shadehouse
- garden shed/potting area
- worm farm
- composting and recycling area
- water gardens
- animal housing (bee hives, chook pens)
- water tank
- pergolas and trellises for shade, shelter and to support climbing plants
- movable chicken coup (moves from bed to bed in a rotating system, by the end of each season all the beds in the system will have been fertilised by the chickens)

Pest Management

Using seeds and cuttings from healthy, locally grown plants will reduce the incidence of pests and disease. Permaculture also reduces the likelihood of devastating insect and disease attacks by encouraging biological diversity. The reduced use of chemical controls allows beneficial insects to prosper and encourages other natural controls such as birds

BIODYNAMICS

Biodynamic farming and gardening is a natural practice that developed from a series of lectures given by Rudolf Steiner in 1924. It has many aspects in common with other forms of natural growing, but it also has a number of characteristics which are unique. It views the farm or garden as a "whole" organism and attempts to develop a sustainable system, where all of the components of the living system have a respected and proper place. There is a limited amount of scientific evidence available relating to biodynamics, some of which suggests biodynamic methods do in fact work! It will, however, take a great deal more research for mainstream farmers to become convinced widely of the effectiveness of these techniques; or in fact for the relative effectiveness of different biodynamic techniques to be properly identified.

Principles of Biodynamics:

- Biodynamics involves a different way of looking at growing plants and animals.
- Plant and animal production interrelate.
- Manure from animals feeds plants. Plant growth feeds the animals.
- Biodynamics considers the underlying cause of problems and attempts to deal with those causes rather than dealing with superficial ways of treating problems. Instead of seeing poor growth in leaves and adding nutrients; biodynamics considers what is causing the poor growth eg soil degradation or wrong plant varieties. It then deals with the bigger question.
- Produce is a better quality when it is "in touch" with all aspects of a natural ecosystem. Produce which is produced artificially (eg. battery hens or hydroponic lettuces) will lack this contact with "all parts of nature", and as such the harvest may lack flavour, nutrients, etc., and not be healthy food.
- Economic viability and marketing considerations affect what is grown.
- Available human skills, manpower and other resources affect what is chosen to be grown.
- Conservation and environmental awareness are very important.
- Soil quality is maintained by paying attention to soil life and fertility.
- Lime, rock dusts and other slow acting soil conditioners may be used occasionally.
- Maintaining a botanical diversity leads to reduced problems.
- Rotating crops is important.
- Farm manures should be carefully handled and stored.
- Biodynamics believes there is an interaction between crop nutrients, water, energy (light, temperature), and special biodynamic preparations which result in biodynamically produced food having particularly unique characteristics.
- Plant selection is given particular importance. Generally biodynamic growers emphasise the use of non-hybrid open pollinated seed which has been chosen because it is well adapted to the site and method of growing being used.
- Moon planting is often considered important. Many biodynamic growers believe better results can be achieved with both animals and plants if consideration is given to lunar and other cosmic cycles.

Developing a Biodynamic Farm or Garden

The first step is always to look at the property as a single organism, and to appreciate that whatever changes are made to the property can have implications to many (probably all) of the component parts of that property. There is an obvious (though sometimes subtle) relationship between every plant and animal and its surroundings, both the nearby and the more distant surroundings.

Biodynamic Preparations/ Sprays
These are a unique and important aspect of biodynamics. There are all sorts of biodynamic preparations. There is a wide experience (throughout many countries) which suggests the use of these preparations is beneficial, resulting in both morphological and physiological changes in plants (eg. better ripening rates, better dry matter, carbohydrate and protein rates).

Some of these special preparations are outlined below:

- In the book "Organic Farming" by Lambkin (Farming Press, UK); two different sprays (500 and 501) are mentioned as being commonly used. These are made from a precise formulation of quartz and cow manure and are sprayed on soil or crops at very diluted rates. Biodynamic growers also use preparations made from plants to stimulate compost and manure heaps.
- Biodynamic growers use a variety of different preparations to add to compost heaps or spray on paddocks or garden plots to encourage faster decomposition. Preparations have included: Yarrow flowers, Valerian flowers, Oak bark, Calendula flowers, Comfrey leaves and preparations from *Casuarina* and *Allocasuarina* species.

Other Gardening Methodologies
Natural Gardening
This is the principle of developing a natural ecosystem in the garden that will become relatively self-sustaining through a natural succession of seeding, growing and dying. The use of chemicals and artificial pest and weed control is discouraged.

Organic Gardening
Organic growing is gardening without the aid of artificial chemicals. Organic gardening emphasises use of natural products to control insect pests, diseases and weeds, and to enrich the soil. Thus practices such as mulching, composting, companion planting, green manuring and biological control, are widely used by organic growers.

THE IMPORTANCE OF SOIL

Soil is composed of five main components:

- Mineral particles
- Humus and organic matter
- Water containing dissolved nutrients
- Air
- Living organisms

Soils vary from region to region, from locality to locality within a region, and can even vary considerably within a single garden. The relative amounts of each of the component parts will vary in different soils, and this will have a direct affect on plant growth in the area. The majority of plant roots are located in the top 10 - 20 centimetres of soil, but all plants have much longer roots that penetrate deeply. Carrots, onions and other vegetables often have fine roots well over one metre long.

Some plants have very specific soil requirements, and successful growth will depend on the grower providing the correct conditions if possible. However, most plants will grow successfully in a fairly broad range of soil types. Understanding their soil will help growers develop strategies for good management.

The success, or otherwise, with which plants may be able to grow in a particular soil often depends upon a combination of environmental factors. Certain general statements may be made regarding these factors, applicable to almost any horticultural situation.

Soil Physical Characteristics

Soil Profile

Soil consists of several layers, generally referred to as topsoil, subsoil, bedrock etc. these layers are collectively referred to as the **soil profile**. Soil characteristics such as structure, texture, colour, and nutrient content can vary from layer to layer. To check the profile: dig a pit at least one metre deep and wide/long enough to see all four sides clearly. Clean up one side so that the changes in the soil layers can be seen. Topsoil is the darkest layer, and can be anything from a thin crust, to 60cm or more in depth. Subsoil is much paler in colour, and again the layer can vary hugely in thickness. Underlying everything is the bedrock.

Soil Texture

The mineral component of the soil determines its texture. There are basically four component particles in soil:

GRAVEL, particles larger than 2mm
SAND, particle between 0.02 to 2mm in diameter
SILT, between 0.02 and 0.002mm in diameter
COLLOIDS, less than 0.002mm in diameter (usually clay or organic particles)

Soil texture is classified according to an established scale of mineral ratios. The texture classification is based on the proportions of these four groups. For example, a sandy clay loam has a higher proportion of sand than a clay loam. Soil texture plays a significant role in soil water retention and drainage.

Identifying Your Soil Type

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

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

1. Stain your fingers Yes or No?
2. Bind together easily Yes or No?
3. Feel gritty Yes or No?
4. Feel silky or sticky Yes or No?
5. Make water cloudy Yes or No?

2. The following soil types will give typical answers:

	1.	2.	3.	4.	5.
a. SAND	NO	NO	YES	NO	NO
b. SANDY LOAM	NO	YES	YES	NO	NO
c. LOAM (or SILT)	NO	YES	NO	NO	NO
d. CLAY LOAM	YES	YES	NO	NO	YES
e. CLAY	YES	YES	NO	YES	YES

3. You should also be able to distinguish by the amount of grittiness, whether it is coarse sand, medium sand, fine sand or very fine sand. You will also find varying grades of other soil types by how well they bind together. For example, 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 much of it floats on top, then it is an organic soil.

Sandy soil will always be hungry and dry, as nutrients and water flow easily through the larger air spaces. Erosion can also be a problem in dry windy weather. On the plus side, sandy soils warm up early in spring, and are easy to work.

Clay soil will always have problems with poor drainage and compaction. It is slow to warm up and hard to cultivate. In long dry spells, the soil cracks and becomes like rock. However, as the air spaces are so small, nutrients are retained, so clay soils are usually high in available nutrients.

Silty soils tend to ‘slump’ in wet weather, and become porridge-like and hard to cultivate in wet conditions. In dry weather they become dust-like, and erosion is common.

Soil Structure

While soil texture is fixed, depending entirely on the proportion of the different mineral components, structure can be altered according to the management of the soil. Structure plays an important role in water movement, heat transfer, aeration, and porosity of soil.

In an organic growing system, good soil structure is one of the key elements in growing healthy vigorous crops.

Soil structure has a great effect on both 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 (wash through the soil) fast enough to prevent excess amounts building up to toxic levels.

Colloids (minute particles)
These function in the 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.

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 root-hairs penetrate the micropores. Nutrients may then become available to the plant from three sources: soil water (within and between peds), adsorbed onto the surface of the clay colloids within peds, and 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 stabilized by natural cementing agents eg. organic matter.

The greatest improvement in soil structure can be achieved by raising the level of organic matter. This will have a huge number of beneficial effects which include:

- Binding soil particles together into aggregates, while keeping soil open
- restricting erosion to some degree
- holding moisture in the soil
- during decomposition, providing nutrients for the plants
- slowing down the rate of soil temperature changes
- aiding root penetration
- retaining nutrients in an available form

Soil Chemical Characteristics
Soils vary enormously in their chemistry, and the soil supports many chemical reactions and interactions. Factors such as nutrient balance, acidity or alkalinity (pH) and salinity can be quantified using field or laboratory tests. Other factors such as cation exchange capacity (a soil's ability to retain nutrients in a form available to plants), organic matter levels and biological activity can also be quantified. Soil pH and nutrient levels are commonly used chemical characteristics to evaluate the suitability of soil for crop growth.
Soil pH
pH is a measurement of the hydrogen ion concentration in a particular medium, such as soil. More simply it refers to the acidity or alkalinity of that medium.

Very high and low pH values can also affect plants as follows:

1. As the pH of a soil changes so does the availability of nutrients. The majority of nutrients are best available at a pH range of 6 to 7.5. Somewhere in this range is generally considered to be the ideal for growing the majority of plants, although there are plants that prefer higher or lower pH conditions. In some circumstances, particularly at very low or high pH conditions, some nutrients may become 'locked up' and unavailable to plants. Although the nutrients are present, the plants can't use them. At **very** low pH conditions, toxic levels of some nutrients, such as manganese and aluminium, may be released.

2. As the pH of some soil is raised, more negative charges are produced on some colloid (particle) surfaces, making them capable of holding more cations. This allows some soils to hold larger quantities of nutrients.
Soils and growing media that contain clays, or some of those derived from volcanic materials are most affected.

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. Thus they will remain in the soil, or the growing medium, and become 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 growing 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, becoming leached more rapidly. A higher cation exchange capacity will reduce this tendency.

3. Like plants, micro-organisms have a preferred pH range in which they thrive. Altering the pH may severely affect the populations of both beneficial and detrimental micro-organisms. For example, the bacteria that convert ammonium to nitrogen prefer a pH above 6. Most mycorrhizal fungi prefer a pH range between 4 and 8.

Adjusting pH
On a new growing site, soil pH should always be tested. If a soil's pH is either too high or too low, it can be changed to a certain extent. Slow-release lime will raise pH, and sulphur chips will reduce it. Organic growers should check with their certification authority to verify what they may use, and in what quantity. But this will always be a temporary amendment. It is far better to grow the plants that suit your soil, rather than have a constant, time and money consuming, fight with nature.

pH and Nutrient Availability
The ease with which plants can take up nutrients is greatly affected by pH. Extremely acid or alkaline soils can often prevent plants using available nutrients. Nutrient deficiency can be caused by incorrect pH. The ideal pH is often slightly different for each nutrient.

Iron and calcium differ more than most. The only answer is to compromise, aiming for a pH in the middle.

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

Water and Air

The plant roots need water and air just as much as nutrients.

BUFFERING CAPACITY

The soils ability to withstand rapid pH fluctuations is known as 'Buffering Capacity'. The greater ability a soil has to withstand fluctuations the greater the amount of acid which must be incorporated with a material to alter the pH. Sandy soils that have little clay or organic matter have low buffering capacity. Soils that have lots of mineral clay and organic matter have a high buffering capacity. Soils with low buffering capacity need less lime to raise the pH then soils with a high buffering capacity.

Water

Nutrients (except carbon and oxygen) must be dissolved in water for plants to absorb them. 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 essential! It is richer in carbon dioxide, and poorer in oxygen, than atmospheric air. Only a few plants (specifically water plants) can survive with very little air about the roots. The amount of soil air depends on the size of pore spaces between soil particles. 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 the fluctuations in soil temperature. As with most organisms, plant roots will grow within a particular range that varies between species.

Humus

Humus is organic matter that has decomposed into a stable, 'colloidal' form. A colloid is a solid that is held in suspension (like jelly). Because of its colloidal form, humus can retain nutrients and prevent them from leaching out of the soil.

IMPROVING SOILS

There are several ways to improve soils, including:

- 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, while improving water holding capacity, 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 the soil.
- Use of soil ameliorants - lime, gypsum, sulphates etc.
- Crop rotations and correct cultivation.

Structural problems can include compaction, hard-pans, surface crusting, lack of coherence etc. All of these factors can lead to reduced root penetration, water repellence or poor drainage, lack of soil air, and other problems such as erosion. Soil structure can be improved by cultural means and by addition of particular inputs.

The following methods can be effective:

- Organic matter will help bind non-coherent soils and likewise will help to make massive soils more friable. Organic matter can be imported in forms such as mulch, manure and compost. More or less any form of organic matter can be useful although some are more readily utilised than others, some may contain chemical residues, and some may have more desirable features such as appearance. Organic matter can also be produced within the garden (for example grass clippings, prunings, green manure crops).
- Composts are a particularly beneficial form of organic matter. Compost contains humus, which is a form of organic matter in which nutrients, water, carbon etc are all held in a stable, plant-available form.
- Correct cultivation. Cultivation can be used to break up hard pans surface crusts and massive soil structures, aerate soil, and improve drainage. Correct methods are essential though. Care should be taken not to turn the soil (i.e. don't mix up the soil profile) as this can hinder biological activity and the natural shape of the soil. In the garden, a garden fork is a useful tool for cultivation. It can be used to aerate lawns and garden beds, break large soil clods etc, and also to move grass clippings and other mulch.
- Cultivation to improve soil structure works best in association with cultivation of deep rooted plants. Letting lawns grow a little longer can increase the depth of root penetration into the soil for example, or deep rooted legumes such as Lucerne can be sown as green manures in the garden.
- Inputs like gypsum, lime, dolomite, and vermiculite can all improve the soil structure in various ways such as adjusting pH, replacing sodium in the soil with other minerals such as calcium or magnesium, or assisting soil particles to cohere to one another.

Improving Fertility
Fertility can be improved through cultural methods such as growing legume green manures to increase the nitrogen content of soil, and by the addition of nutrients in various forms.

- 'Natural' fertility inputs include raw or pelletised manures, rock phosphates and minerals, dolomite, mulches and other organic matter, blood and bone, seaweed fertilisers, fish emulsion etc.

- 'Chemical' inputs are minerals that have been chemically treated (frequently with acid) to make them more soluble, or more available to the plant. Commercial fertilisers most frequently consist of chemically treated nutrients. Even chemical fertility inputs work best in association with the addition of organic matter.

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; we may end up doing the wrong thing to the soil. If we only take a sample from the top centimetre or half inch; we may be only sampling the fertile topsoil. The soil below may be totally different.

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.

Organic Matter and Living Soil Organisms in the Soil
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 % 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 don't 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; and
- plants should be fed with manure (preferably well decomposed)

SOIL WATER
Three forces are responsible for water movement on soil:

Gravity is the principal force in saturated soil causing the water to move downwards under tension.
Adhesion is the force of attraction between two unlike molecules i.e. soil particles and water are attracted to each other.

Cohesion is the force of attraction between two like molecules in this instance water and water.

Adhesion and cohesion are the two forces that can cause water to move by capillary action (capillarity) in any direction i.e. up and down or laterally. They are the two principal forces that move water in unsaturated soil.

Why is Water Important to Plants?
Plants absorb more water then any other material, most of it entering the plants through its root system from the soil.

- Seeds require water to initiate enzyme activity required to activate germination
- Water is used in photosynthesis and all other metabolic processes associated with plant growth and development
- Lowers the temperature of the plant's leaves when water is dissipated through transpiration
- Water dissolves nutrients before they are up-taken by plants.
- Water functions as a transport system within the plant moving nutrients to sites where they are converted into products of photosynthesis, and then transports the synthesised materials to sites of storage or use within the plant

Water Loss from Soils
Water is lost from soil due to three factors:
Percolation (gravitational water)
Water becomes unavailable to plant roots by moving in and down through the soil in response to the force of gravity.
b. Transpiration by plants
Growing plants cause a considerable losses of soil water through transpiration i.e. water lost through the plant's living tissue (mainly leaves). Transpiration will continue even if soil water is no longer available resulting in wilting.
c. Evaporation from the soil
The sun heats the surface of the soil causing evaporation. Wind moving over the soil surface also contributes to evaporation of water from the soil. The extent of evaporation depends on the depth of the soil.

Improving Water Retention
In light soils that have a low water holding capacity but with a high percolation rates, materials can be added to help prevent or lessen water loss by improving soil structure and physically holding water in the soil within the materials added:

- Manures
- Peat moss
- Straw
- Pine bark
- Mushroom compost
- Aged sawdust
- Compost etc

Weed control to prevent competition for water and mulch to protect the surface are other very effective ways of retaining water. This also has the additional benefit of adding to soil fertility and nutrient availability.

Hygroscopic Water
Soil becomes hygroscopic when all the water is emptied from the macropores and all but the smallest micropores within the soil, any further water loss would make the soil air dry. When this occurs all the liquid is gone except for a thin, tightly bound layer around the soil particles this water becomes unavailable to the plant and is termed hygroscopic water.

Gravitational Water
Is the term for water that moves through the soil due to gravity (gravitational pull). The process of water movement through the soil from saturation point to field capacity is called gravity drainage

Field Capacity
Soil is said to at field capacity when excess or gravitational water has run off and percolated down to the water table. The potential for access by plant's roots is high. The amount of water soil holds at field capacity is dependent on its texture i.e. clay has high water holding potential, sand low.

Plant Available Water
Once soil reaches field capacity there is little water movement within the soil. The water in the soil is then lost through absorption by plants roots and surface evaporation. The water held in the soil eventually may reach the point where there is so little left available to the plants that they reach wilting point. The remaining water is unavailable as we saw earlier (hygroscopic water). Plant available water is therefore the water held in the soil between field capacity and permanent wilting point.

Permanent Wilting Point
As we saw in the last section permanent wilting point is reached when the plant can no longer obtain water from the soil. This occurs when the water potential of the soil is the same or lower then the water potential of the plant. The water left in the soil at this point depends on the type of soil and also the species of plant growing in it. The plant is usually beyond recovery at this point even if the conditions are humid.

Saturation
The soil is saturated when excess water is present. The water takes up all the available pore spaces some of which will usually be occupied by oxygen. Fine textured, badly drained soils with smaller pore spaces are more susceptible to saturation. This type of soil will contain a lot of water and little oxygen at field capacity. Impermeable sub-soils can also lead to saturation of upper well structured soil levels. The clay in such substructures impedes the gravitational downwards flow of water from the large pore spaces and creates a water table. The soil below the water table is waterlogged and the soil pore spaces fill with water causing saturation.

The amount of water held in a soil and the amount that is tightly bound will vary from soil to soil. The following table indicates typical soil moisture quantities for some different soils expressed as a percentage by weight of dry soil.

Moisture Quantities For a Number of Soil Types

Soil Type	*Saturation*	*Field Capacity*	*Permanent Wilt Point*	*Available Water*
Fine sand	15-20%	3-6%	1-3%	2-3%
Sandy loam	20-40%	6-14%	3-8%	3-6%
Silt loam	30-50%	12-18%	6-10%	6-8%
Clay loam	40-60%	15-24%	7-10%	8-14%
Clay	40-70%	25-45%	12-20%	13-20%

MEASURING WATER AVAILABLE TO PLANTS

Tensiometer

The tensiometer is used to gauge soil moisture characteristics. A field tensiometer can be used to determine when irrigation is required by monitoring the soil moisture content. A vacuum gauge alerts the user as to when watering is needed, using predetermined calculations particular to the soil type. Clayey soils may cause problems as it shrinks around the tensiometer on drying. The use of tensiometers is restricted to high soil moisture conditions.

Calculating Field Capacity

1. Wet a soil sample to near saturation. Cover to reduce evaporation. Let it drain for 2-3 days.
2. Take a sample of the soil and weigh it.
3. Place the soil sample in an oven at between 100-105 Degrees Celsius for 16 hours. Weigh and record this second weight after drying. Do not heat at a higher temperature as this can destroy organic material and give a false reading.
4. Calculate Field Capacity with the following formula:

$$\text{Field Capacity} = \frac{\text{Loss in Weight}}{\text{Final Dry Weight}} \times 100$$

Calculating Permanent Wilting Point (PWP)

1. Fill a pot with the soil to be tested.
2. Grow a plant in the pot until its roots penetrate most of the soil and are visible at the bottom of the pot.

Use a plant which shows signs of wilting easily when wilting point is reached – for example, a petunia, tomato, sunflower or fuchsia.

3. Now cease watering until wilting occurs. When the plant wilts, seal the surface of the pot with a sheet of plastic to prevent further loss of water through evaporation.
4. Now place overnight in a humid enclosure (i.e. either a humid greenhouse or plastic tent). If permanent wilting has not occurred the plant will recover. If the wilting persists in the morning, you have then reached permanent wilting point.
5. Now calculate moisture content by drying the soil at 100-105 degrees centigrade for 16 hours then separate the roots from the soil to find the final dry soil mass.

$$\text{PWP} = \frac{\text{moist weight - dry weight (incl. roots)}}{\text{Final dry weight}} \times \frac{100}{1}$$

Soil Moisture Calculations

Available moisture range = Field capacity minus permanent wilting point. Typical results are as follows:

Soil Type	*Field Capacity*	*Permanent Wilting Point*
Clay	45%	30%
Clay loam	40%	25%
Sandy loam	28%	18%
Fine Sand	15%	8%
Sand	8%	4%

In field situations the following factors are used as constants for calculations.

Soil type	*Available water (mm/m of soil)*
Clay	165 mm
Clay loam	150
Sandy loam	120
Fine sand	80
Sand	55

The following table can be applied to a feel test to estimate soil moisture level.

How Moist?	*What It Feels Like*	*Moisture of Field Capacity*
Dry	Powdery and dry	0%
Low	Crumbles and doesn't adhere into a ball, even loosely.	Below 25%
Reasonable	Crumbles but will adhere in a ball.	25 to 50%
Good	Adheres into a ball with a little pressure.	50 to 75%
Excellent	Forms a pliable ball which can be rolled into a cylinder	75 to 100%
Too wet	When squeezed, water drips from the soil	Over 100% (Over field capacity)

IMPROVING INFILTRATION OF WATER INTO THE SOIL

Infiltration can be improved by:

1. Overcoming compaction of the soil.
2. Improving soil structure.
3. Breaking up impermeable layers in the soil such as heavy clays.
4. Breaking or opening up impermeable surface layers.
5. Overcoming the water-repelling characteristic of some soils i.e. fine sands.

Methods that can be used to overcome these problems include:

Cultivation

Surface crusting, impermeable layers and compaction can be rectified to some degree by either machine or hand cultivation. For small jobs, hand cultivators can be used to overcome surface crusting and spades can be used to break up the upper soil layers. For large areas, and problems deeper in the soil profile, machinery is the best option. Deep ripping cultivators such as mole ploughs can be very effective.

Rotary hoeing of the topsoil is generally ineffective (particularly on silt soils). This method can make soil more workable in the short term, but may increase drainage problems in the long term by causing a hard impermeable layer below the level of cultivation. In cases where sub soil drainage is installed, it may be necessary to undertake special sub soil cultivations.

Mixing in Soil Additives
These are materials which are mixed with the soil to improve its physical structure with respect to drainage ability.

- Sand with an ideal of 70% of soil content being medium or fine sand particles (usually added at rates of 250 tonnes per acre or more).
- Organic matter such as peat, compost etc. These materials can be of value mixed with topsoil at the rate of about 25 tonnes per acre or more.
- Other Gritty material can occasionally become available which can be used as a sand substitute (eg. perlite, expanded clay etc). Often these alternatives are too expensive.

Chemical Treatments
These are substances which are applied to improve the soil's chemical characteristics with respect to drainage ability.

- Lime does the same job as clay breaker, but also has side effects. It raises the level of calcium (which can sometimes be a problem) and it makes the soil less acidic (raises pH). Unlike clay breaker, lime should be physically dug in.
- Gypsum has the same effect as lime, but doesn't alter pH.
- Dolomite lime does the same as lime but also adds the nutrient "magnesium" to the soil, which can be an advantage in some situations, and a disadvantage in others.

NB: All treatments above require moist soil conditions over several months to have an effect, so don't expect instant results.

IRRIGATION
Water is essential to plant growth and is often the major limitation to plant growth. Irrigation is common in horticulture. However, depending on the climate, the value of the crop, the value of the land and its suitability for irrigation, the cost, reliability and quality of the water supply, irrigation may or may not be possible or feasible.

Irrigation may enable a crop to be grown in a dry climate where it would not otherwise be possible, or it may supplement the existing rainfall and improve yields by extending the growth period of the crop or by ensuring there is adequate moisture during critical periods when the crop is growing most rapidly.

The value of irrigation can vary greatly from year to year depending on the distribution of rainfall during the growth season. Irrigation at appropriate times may also improve the quality of the product.

Infiltration and Drainage

As covered earlier infiltration refers to process of water entry into the soil and is influenced by:

- Soil type and soil texture. Sandy soils generally have higher long term water penetration rates than clayey soils.
- The condition of the surface soil. Water will enter faster if the soil surface is friable and open or is extensively and deeply cracked. Compacted or crusted soil with few cracks reduces infiltration.
- The stability of the surface soil. Low water stability means that the soil crumbs do not stay together when wetted. Low water stability results in slow water penetration unless the soil is sandy. Also, it often results in the formation of a surface crust as the soil dries which will reduce infiltration at the next irrigation.
- Depth of soil above an impermeable layer. For example, if a soil consists of light loamy topsoil over a clayey subsoil or parent material, any water up over the impermeable layer reduces water penetration.

Poor drainage can result in temporary waterlogging and loss of productivity. In the longer term, it can cause permanent waterlogging and high salinity levels if irrigated. Conversely, soils with excessive drainage are undesirable because of the large amount of irrigation water necessary to keep them moist. Thus a slowly permeable clay layer at a depth of one metre is desirable. Observations of the effect of heavy rain on bare soil can indicate how well a soil will behave under irrigation. Does ponding occur quickly? Does the surface soil structure remain the same when it dries out or does a crust or blocky layer develop? Since observations together with laboratory tests such as those which can be done by the Department of Agriculture or relevant Government department in your region, can greatly assist in the choice of suitable land for irrigation. In order to determine the physical aspects which make a soil suitable for irrigation, one needs knowledge of soil composition, texture, structure and the moisture characteristics of soils.

Types of Irrigation

There are two main types of irrigation systems which are available to the home gardener - sprinkler systems which spray water over plants and trickle systems which drip water directly onto the ground. Sprinkler systems are particularly appropriate for applying water to lawn areas, shrubs and flower beds, while trickle irrigation systems can be used in garden beds, under treed areas, in pots and containers, and hanging baskets. Trickle systems use less water and are particularly valuable in areas with limited water supply.

DO-IT-YOURSELF MICRO IRRIGATION SYSTEMS

These consist of three main types of components:

1. Black plastic pipe. When the ends are soaked in hot water, this becomes pliable and can be simply pushed over connectors to join it to other sections of pipe or attachments to a tap.
2. Connectors, with two, three and four way joints used to connect sections of pipe together.
3. Outlets made of moulded plastic which discharge the water either as a spray or a drip. A hole is simply poked in the pipe wherever you want to discharge water and a nozzle (sprinkler) or dripper (trickle outlet) is pushed or screwed into the hole. Believe it or not, it will hold in that position and not leak when the water is turned on.

Trickle Systems
Trickle irrigation systems apply water at low pressure through a system of polyethylene micro-tube outlets. Although the design of systems varies greatly, the basic components of all trickle systems include an automatic controlling device, a pressure regulator (to ensure water pressure is even between droppers), filter, control valves, and drippers.

Trickle irrigation is used more by home gardeners because it:
Conserves Water
Water is directed exactly where the plant needs it most - the plant roots. Loss of water from wind and excess runoff is minimised, giving a saving on water rates and conserving increasingly scarce water supplies.

Saves Labour
Although tickle systems are initially time consuming to set-up and occasionally require some ongoing maintenance, trickle systems are permanent fixtures which can be fully automated. Busy work schedules and holidays are no longer a problem with such a system.

Doesn't place water where it isn't wanted
People, paths, furniture, etc close to the water outlet aren't wet when the system is on.

Reduces Weeds
Weeds have less chance of germinating because less area of the soil is moist.

Reduces Disease
Trickle systems don't wet the foliage and flowers. Wet foliage and flowers are more susceptible to diseases.

HOW TO USE A WATERING SYSTEM
Don't water at regular intervals (such as daily or weekly) for any long period of time. A plant's needs will change at different times. Not all plants will need to be watered at the same intervals. You should decide when to water according to the following criteria:

Climatic Conditions
Water loss increases with increased sunshine intensity, air temperature, wind speed, and decreased humidity.

Soil Structure
The texture of a soil will determine the soil's ability to hold water.
Clay soils which have fine particles and small pore spaces hold water better than sandy soils which have large particles and large pore spaces. You need to achieve a soil moisture level which provides sufficient moisture for plant growth without causing water-logging.

Proximity to Other Plants
Large shrubs and trees will compete for the available water. The depth and spread of their roots may make it difficult to grow shallow-rooted plants such as lawn grasses.

The Species Being Watered
Generally speaking, native plants and plants from arid countries require less water than plants which come from areas of high rainfall with well-structured soils.

Knowing when to water is therefore extremely important in achieving a healthy garden. Over and under watering can be equally detrimental to plant growth. Plants suffering a shortage of water will exhibit the following symptoms:

- Leaves wilt, especially in new growth.
- Leaves turn yellow.
- Leaves burn and sometimes drop off the plant.
- Stunted growth, poor flower and fruit set. This will be more evident in plants which have been stressed without water over a long period.

Over watered plants will appear leggy, brittle stemmed and have lush, or even rank, new growth. Flowering will be reduced at the expense of leaf and stem growth. General plant health will be reduced as soil nutrients are leached from the soil, and disease problems will increase, particularly root and leaf fungus. Observing stress symptoms should be a last resort in deciding when to water.
A simple test that involves simply feeling a sample of soil can indicate soil moisture levels. The sample should be taken from the root zone of the plant.

Degree of Moisture	*Feel of Soil*	*Amount of Moisture*
Dry	Powdery	none
Low	Crumbly, does not stick together	25% or less
Fair	Crumbly, but does hold together	25%-50%
Good	Will form a ball with some pressure	50-70%
Excellent	Pliable ball which sticks together readily; some clear water can be squeezed from it	75-100%
Too wet	Sticky ball which water can easily be squeezed from.	100%

Sophisticated instruments such as tensiometers can be used to accurately gauge the moisture condition of the soil. The best time to water the garden is the early morning. Evening watering tend to encourage leaf fungus problems as the leaf stays wet throughout the night. Midday watering is often inefficient as evaporation rates are high.

Maintaining Appropriate Water Levels
Consider the soil where a plant is growing. If a plant is getting too wet, perhaps the soil should be more freely draining. If the plant is getting too dry, perhaps the soil should have a better capacity to retain moisture.
- Consider the frequency of watering. Maybe you need to water more often or less often.
- Consider water penetration. Does the water you apply get absorbed into the soil or does it run off and get lost? Does it land on the leaves of plants and get deflected away from the soil? Does the sun or wind remove it before the plant gets to use it?
- Is the plant in a shaded situation? Is it in a very hot situation?
- How much natural rainfall has it been getting?

Rate of Watering

The amount of water which is applied at irrigation depends on:

- the plant's needs
- what you expect to achieve from your garden
- the capacity of the soil to hold water
- the system you are using

Deep, infrequent irrigations will produce better results than frequent and shallow watering. Light watering encourages plant roots to proliferate in the moist upper soil layers. During dry periods when the surface layers dry out, the roots die.

The number of days between irrigations can be calculated by the amount of moisture in the root zone divided by the average moisture lost through evapotranspiration every day. (See tables below)

Rate of Evapotranspiration

Climatic Conditions	Rate of moisture lost from soil through evapotranspiration (mm) per day
Cool and humid	2.5
Cool and dry	3.8
Mild and humid	3.8
Mild and dry	5.1
Hot and humid	7.6

Amount of Moisture in the Plant Root Zone (per 100 mm soil depth)

Type of soil	Average amount of moisture (mm)
Clay	18
Clay Loam	16
Loam	14
Sandy loam	10
Sand	7.5

Period of Watering

- In sandy soils you can apply a lot of water quickly and it will be absorbed.
- In heavy clay soils you must water slowly over a long period (Heavy applications will not soak in, and a lot will be lost as run off).
- Deep rooted plants such as trees should be watered slowly over a long period, so as to wet the soil to a great depth.
- Deep rooted plants can be watered less often.
- Shallow rooted plants such as annual flowers and vegetables need frequent watering, but of a shorter duration at each watering.

AUTOMATIC SYSTEMS

There are many different devices available which can control switching the flow of water off, or both on and off.

The simplest and cheapest device is a manually operated clock which allows water to flow for the period of time it is adjusted to and then switches off: this lets you switch your watering system on and then forget about switching it off.

The most complex systems are computer controlled and allow you to set the time of day and duration you wish water to be applied. This type of controller will turn on and off several different lines of sprinklers, whether you are at home or not. Though complex in the number of tasks they can perform, these controllers are easy to operate and for the average home handyman, relatively easy to install.

MAINTENANCE OF WATERING SYSTEMS

Regular maintenance of your watering system will increase both the efficiency of water distribution and the life of the system.

Check:

- *Plastic components.* These will eventually deteriorate through exposure to ultra-violet rays. Replace parts which show signs of splitting, aging, etc.
- *Metal components.* Prevent rust formation. Oil parts which begin to rust.
- *Filters*. Filters in trickle systems should be flushed out regularly to prevent blockages occurring through build ups of soil particles and growth of algae.
- *Pipes and nozzles in trickle systems*. If blockages do occur flush the system with a chlorine-based solution (eg. liquid sodium hypo chloride - 10% chlorine) to destroy bacteria.
- *Controllers* (ie. time clocks, etc) need to be tested every few months to make sure they are working properly.

PLANT 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.

More details on plant nutrition will be covered in lesson 3.

SOIL LIFE

Earthworms

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 micro-organisms, 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 reproduction. 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 high organic matter content. The most commonly available worm varieties are *Lumbricus rubellus* (Red Worm) and *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 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 tree's growth by increasing the tree root's absorptive area. Eventually infected roots are shed by the tree and the fungus utilises them as food.

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

Techniques to Help Create a Healthy Garden

Gardeners can adopt techniques that will help them to create a healthy high production garden. See the following suggestions:

Crop Rotation
Crop rotation means that one type of crop creates suitable growing conditions for the following year's crop. For example, the nitrogen added to the soil by peas and beans will create suitable conditions for growing leafy green vegetables. Crop rotation also discourages the build up of pathogens in the soil. More details on crop rotation can be found later in this lesson.

Green Manures
Green manures are crops that are grown specifically to mow or cultivate back into the soil, to improve the structure, organic matter content, and fertility of the soil. Green manure crops usually include legumes and crops that provide bulky organic matter. Many genera and species of beans, peas and other legumes are used, along with a wide variety of grasses and broadleaf plants.

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 micro-organisms, such as Rhizobium bacteria, that live in swellings on the roots of legumes plants. These plants can be a valuable source of nitrogen to a soil.

Legumes need to ‘nodulate’ in order to fix nitrogen. Nodulation is the growth of rhizobium bacteria on the roots of legume plants. These bacteria extract nitrogen from the air, and supply this to the plant. In some circumstances, legume seed is ‘innoculated’ with rhizobium spores to ensure good nodulation.

Legumes should be mown down or cultivated into the soil when the plants begin to flower. It is also important to know that known organic matter ‘volatilises’ or ‘releases’ nitrogen and other nutrients into the atmosphere as it dries out. This is one reason why organic growers frequently cultivate green manures into the soil, in preference to simply mowing them down. Leaving mown green manures on the soil surface can prevent erosion, however.

Sheet Composting
Certified organic growers use a soil development method known as sheet composting. This process involves spreading the compost materials, such as manure and hay, over the production area, then sowing the area to green manure. The green manure utilises the ‘raw’ nutrients in the manure, and stores it in a biological form. When the green manure is cultivated back into the soil, or mulched back onto the soil surface, the plant materials decompose, holding the nutrients in a stable but plant-available form known as humus. The inclusion of the green manure crop prevents commercial crops from coming into direct contact with the raw manure. Certification standards vary in their requirements, but some standards require two or more green manure crops to be grown following application of raw manure.

Before deciding how to (or even whether to) improve a soil, you need to know whether a soil is good or bad, or if it has other characteristics that need improvement.

Drainage
Drainage 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, add some to see how it drains and then saturate the soil and add some more water to the top. You will often note slower drainage on saturated soil.

Soil nutrition is (to some extent) indicated by the vigour of plants growing in a soil. Soil structure 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 - 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 in soil can damage this characteristic of a gradation in soil structure through the soil profile by destroying the structure at the surface. Such a situation can be very bad!!

The improvement of soil structure may use two approaches. First, 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 normally give the best long term results.

However, where soils have been leached and have become very acid, 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 replace Sodium ions in the soil with others (principally Calcium and Magnesium). These help flocculate clay particles and so produce some initial structure which will allow the soil to be worked as above.

GETTING STARTED IN YOUR VEGETABLE GARDEN

Once you have decided that you want to grow your own herbs and vegetables the next step is to choose the right site in your garden.

The vegetable garden should be situated where:

- it receives maximum sunlight (not shaded by trees and buildings)
- it has good soil which is well drained
- it is relatively free from weeds and other competing plants
- it has access to a suitable supply of water
- it is sheltered from any prevailing winds

Some compromises may have to be made depending on what you have available.

Some of the culinary herbs such as parsley, basil and coriander require similar conditions to vegetables and therefore can be included in the vegetable garden. Perennial herbs such as chives, winter savoury, and thyme are useful as borders to edge the vegetable beds. Rosemary, sage and lavender make lovely enclosing hedges and bay topiaries could be used as focal points throughout.

The size of the vegetable plot will depend to a large extent on how much space you have available, the size of your family, the vegetables they prefer to eat and the amount of time you have to tend the garden. As a general guide an area of 80-100 sq. metres can provide a family of four with an adequate yearly supply of fresh vegetables if you grow two or more crops in most parts of the plot each year.

Which Do You Want to Grow?

What you grow will depend a great deal on your own preferences, as well as environmental factors (e.g. soil, climate), however when deciding what to grow it is worth considering the following:

- Some vegetables such as radish produce prolifically in a short time, while others like artichoke will be slow to mature. Some vegetables such as asparagus can occupy a space for a very long time.
- Use most of your plot for high yield vegetable varieties if you want to harvest large quantities of produce. Alternatively you could opt to plant gourmet varieties that are more expensive to buy but give a lower yield.
- Some vegetables and herbs lose flavour and nutritional value if stored for even short periods. Such vegetables are best eaten fresh and include tomatoes, lettuce, beans, cauliflowers, basil, coriander and parsley. These vegetables are therefore worth growing yourself.

What Quantities of Vegetables and Herbs Can You Consume and Store?

When deciding what and how much to grow, consider the following points:

- Do you want to produce all of your own vegetable needs, or will you also buy some? Do you eat a lot of vegetables or not?

- Do you have sufficient space and suitable conditions (i.e. refrigerators, freezers, and preserving facilities) to store your produce?
- Can you trade or barter your produce with others?

How Much Time Do You Have?
Remember that once you have prepared and planted your garden, you need to have the time to do all the necessary tasks at the right time, such as fertilising, weeding, watering, pest and disease control, harvesting, processing and storage.

Pests need to be monitored and controlled before they ruin a crop, and quality produce means harvesting at the right time. A small well managed vegetable plot will often give bigger and better yields then a large, poorly maintained one.

Planning for a Continuous Harvest
Plan for a continuous harvest, as this avoids the feast and famine situation so often experienced by novice gardeners. Here are some ways to ensure a year 'round supply of produce:

- Stagger the plantings. Most vegetables can be planted over a three to four month period and achieve relatively even yields for each planting. Try planting small quantities of each crop at two-week intervals. This is easiest for varieties grown directly from seed, as the seed can be stored until needed. This way you can also grow two or three seedlings at a time (of cabbage for example). When using seedlings you may need to plant a full punnet at each planting of 6-8 week intervals. Seedling punnets do however contain 8-10 plants, and that amount of cabbages all maturing at once for example, may be too much for your family.
- When selecting seeds look for early, mid and late season varieties of each vegetable or fruit. This will stagger harvest times over the entire season.
- Some vegetables can only be grown at specific times of the year. Plant these at the appropriate time. Others can be grown over extended periods, or even throughout the year. Grow these when the other crops are not available.

GETTING THE BEST OUT OF YOUR GARDEN

Provide Good Drainage
Good drainage is vital for a successful vegetable and herb garden. If you have clayey soil or if your site is in a low-lying area, prepare a raised growing bed 30 cm above the natural ground level. Use retaining materials such as sleepers, bricks, treated pine or hardwood timber. Provide sufficient drainage holes at the base of the retaining material so water can readily drain out from the bed. Slotted drains (agricultural pipes) may be needed if poor drainage prevails, but remember that you need to design the garden so that the water has somewhere to fall to.

Prepare the Vegetable Bed
It is important to prepare the vegetable bed properly. The following will help establish the best soil conditions from the outset:

- Thoroughly cultivate the soil and mix in compost to a depth of 15 cm.
- Leave for a week then ideally test for pH (simple pH test kits are available from your local nursery). The ideal pH for healthy vegetables is between 6 and 8. More information on soil pH is provided later this lesson.

- Correct the pH if necessary by incorporating lime or dolomite into the soil to raise pH or sulphur to lower it.
- Continue cultivation with a fork, cultivator or rake to kill all weeds and produce a fine crumbly textured soil.

Root crops such as carrots and parsnips may need the soil cultivated deeper or to be grown in a raised bed with additional soil.

In poor soils it is beneficial to grow a cover/green manure crop to improve the soil fertility and structure. However do not grow root crops such as carrots and parsnips after the addition of manure or a cover crop as it makes them fork. Grow and harvest leafy crops first, then sow carrots/parsnips (without any more additives) as the following crop.

Green Manure/Cover Crops
Green manure or cover crops help your soil by improving fertility, increasing the amount of organic matter present, holding more water, and suppressing weeds. Sow a green manure crop in fallow beds (ie. beds that are resting between crops) in autumn or winter and dig the crops in before they flower in spring or just leave them on top of the soil as mulch.

As discussed earlier soil bacteria have a symbiotic relationship with legumes. The bacteria (rhizobium) infect the root system of legumes and change atmospheric nitrogen into a form that is usable by plants. This nitrogen is contained in root nodules produced by the rhizobium. When the plant is dug in or allowed to decompose on top of the ground the available nitrogen will feed the following crop. Not all soils contain the necessary rhizobium, so in some cases you may need to buy inoculated seed or inoculants.

What to grow to improve the soil:
- Legumes (tic peas, field peas, broad beans, lupins, vetch and alfalfa) add nitrogen and organic matter. Lupins and alfalfa are deep rooted and also help to break up heavy soils allowing deep rooted crops such as tomatoes and corn, to penetrate to lower levels for water and nutrients.
- Clover adds nitrogen and also acts as a weed suppressant when grown as a living mulch under other crops
- Barley increases phosphorus uptake of the following crop and also provides excellent mulch. (It is an excellent crop to precede tomatoes.)

Manage Weeds
Spending time and effort on weed control early on; before they have a chance to take hold will mean less work later and ultimately a better crop. Dig out and remove the entire root system of perennial weeds, particularly bulbs from weeds such as oxalis, nutgrass and onion weeds. Remove annual weeds as they appear and are just large enough to handle. Don't let them flower as this increases spread.

Crop Rotation
Periodically, crops grown in a plot should be replaced with a different crop, preferably from a different plant family. Crop rotation is used to improve various aspects of crop and soil health for the following reasons:

- It helps help reduce disease and pest problems. Each plot should be planted with crops from a different family group each year, for example, potatoes shouldn't follow tomatoes which are in the same family. Cabbages shouldn't follow mustard (also in the same family). Also try to choose disease-resistant varieties or plants that are not prone to the diseases and pests that the previous crop is prone to.
- It helps minimise weed problems. Grow crops that suppress weeds, for example crops with large leaves which exclude light, before growing crops that are sensitive to weed competition in the same plot. Grow crops that can cope with weeds at the end of the rotation when weeds may have built up.
- It makes optimum use of the fertilisers and soil conditioners (including compost) you add to the soil by growing crops with different fertility requirements successively. For example, follow leaf crops which use nitrogen with carrots, which require phosphorus for good development.
- It helps maintain and improve soil quality by growing plants with differing root structures and by increasing the amount of organic matter returned to the soil.

Crop Rotation Systems
There are various types of crop rotation systems. It all depends on your needs and the size of your garden. Crop rotations generally have intervals of three to five years duration.

The following are different types of vegetable rotations that will help prevent the build up of pests, diseases and weeds in soils, as well as effectively utilising soil fertility:
1. Plant a gross feeder (eg. tomato), then a legume (eg. beans), then a light feeder (eg. coriander), then a green manure, then a gross feeder again.
2. Plant a flower crop (eg. broccoli), followed by fruit crop (eg. peas), followed by a leaf crop (eg. lettuce), and followed by a root crop (eg. carrot).
3. Grow a crop or crops for half of the year, and graze the same area the remainder of the year.
4. Fallow areas between crops (i.e. do not graze or grow a crop).
5. Grow cover crops for green manure at least annually to revitalise the soil.

Rotations should also be designed so that crops from the same family, genus, or species do not follow one another (in some cases, gaps even of several years may be necessary to get rid of pest or disease problems). In order to develop these kinds of rotations properly, it is necessary to know a little about the scientific names of the plants you are growing.

Mulch the Garden
Mulching helps to control weeds, prevent erosion of the soil from around the vegetable roots, and reduces water requirements. Organic mulches also provide nutrients as they break down and increase the soil population of beneficial organisms such as earthworms. Mulch material should not have direct contact with the stems of vegetables, as this may result in pest and disease problems such as stem or collar rots.

Organic mulches suitable for the vegetable garden are straw, lucerne hay, compost, green manure, seaweed and composted or aged animal manure. Most organic mulches which haven't been composted will draw nitrogen from the soil as they rot and break down. A side dressing of blood and bone or other nitrogenous fertiliser will compensate for the nitrogen loss.

Don't Overcrowd Plants
Resist the temptation to plant small seedlings too close together as this will result in less than satisfactory growth, even with good soil preparation. Plants starved for space and light will rarely produce a good crop. Spacing is important for sunlight and for root spread. Overcrowding will also reduce ventilation around the plants, making them more susceptible to disease, such as fungal rots.

Select and Use Top Quality Seed and Seedlings
Always check expiry dates on seed packets and choose strong, green seedlings. Some seedling producers "starve" their plants purposely to keep them becoming root bound when contained in punnets. Such plants are often leggy and pale in colour (i.e. they are nitrogen deficient). Treat starved seedlings by spraying the foliage with a liquid plant food such as a soluble seaweed fertiliser.

Use Disease Resistant Varieties
Select seed varieties for disease resistance. It is much easier to choose the right variety than try to control a disease which is destroying all your hard work.

Feed Your Plants
Annual vegetables grow rapidly and use a lot of plant food. The compost you incorporated in your seed bed preparation may not be released fast enough to keep up with the plant's capacity to grow. Top-dress the soil of your vegetable plot with a suitable organic fertiliser. Plant leaves absorb nutrients very quickly and therefore applying foliar plant food is an ideal way to boost plant growth. This is particularly effective for leafy crops such as lettuce, cabbage, cauliflowers and silver beet.

Control Pests and Diseases Promptly
Regular inspection of your vegetables is a must. The early sighting of pest and disease problems can prompt early action and control with appropriate natural control methods.

Harvest and Process Produce at the Right Time
One of the real joys of growing your own vegetables is being able to pick, pull or cut vegetables when you need them on a day-to-day basis. Daily inspections and tasting will determine when they are ready to harvest.

Excess harvest means you can store the "fruits" of your efforts. Select the method (freezing, bottling or drying) and prepare some days in advance to enable you to harvest and process at the optimum time. Some vegetables need to be harvested regularly to maintain the quality of the produce and increase the productive life of the plant. Zucchinis, squash, cucumbers and asparagus are good examples of these kinds of vegetables.

Remember:
- Root crops such as carrots and parsnips may need the soil cultivated deeper or a raised bed with additional soil.
- In poor soils it is beneficial to grow a cover/green manure crop to improve the soil fertility and structure. However do not grow root crops i.e. carrots and parsnips after the addition of manure or a cover crop as it makes them fork. Grow and harvest leafy crops first then sow carrots/parsnips (without any more additives) as the following crop.

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 minimize 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.

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 conditions of compost you need to be aware of are:

- Moisture, which should be between 40 and 60%. Take a handful of the composting material from at15 or 20cm deep into the heap/mound of composting material, and squeeze it. It should be about a 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, which is incorporated by aerating and turning the heap over occasionally.
- Temperature, which should be between 40 and 60 degrees Celsius.
- pH, which will change during the stages of maturity. Generally you need not do anything to alter pH.
- A Carbon to Nitrogen ratio (C/N ratio) (see below for explanation) 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 loose some nutritional value.

What is the C/N ratio?
For effective composting to occur, the micro-organisms 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 percent carbon (C) in the materials, to the percent 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.

How Do You Make Compost?
If left long enough, any material that is of plant or animal origin will eventually rot away, but composting speeds up the rate of decomposition. Good compost will add fertility and humus to your garden.

For the best results, the compost should have the following:

- A mixture of organic materials. Ideally, the compost should contain around 25 times more woody materials that are high in carbon (branches, leaves, sawdust, paper) than moist, green materials which are high in nitrogen (grass clippings, kitchen scraps, green plants, manure).
- Oxygen to speed up the rates of decomposition. Oxygen can be added to a compost heap by using ventilated pipes running through the centre of the heap or by turning the compost regularly.
- A moisture level between 40 and 60%. Like a squeezed sponge, damp but not soggy. If water builds up at the base of the heap, install drainage pipes underneath to help remove excess water. If it's too dry, sprinkle water when you turn the heap.
- A temperature range between 40 and 60 degrees C. A heap of 1 to 3 cubic metres will provide ideal temperature conditions. Usually the centre of the heap is the warmest and, for this reason, it is advisable to mix up the contents of a heap from time to time.

What Can be Put into Compost
Compost can consist of: kitchen scraps (but not meat), lawn clippings, weeds, leaves, newspaper, seaweed, pruning off-cuts, straw and manure. For quicker results, use small pieces of plant material, shred or chip large branches and tree trunks. Branches, corn stalks, dead bedding plants, should be cut or shredded to 5-10 cm. pieces. Avoid plants that have been sprayed with weedicides or diseased plant material (eg. mummified fruits). Exclude thorny or spiky plant material to prevent injury when hand weeding or when spreading your compost.

How to Build a Compost Heap
The easiest way to build a compost heap is simply to pile up the materials in a heap around 1.5m wide and 1.5m tall. The heap can be left open or surrounded by bricks, timber, wire netting or other similar materials.

Use a variety of organic materials and place them in layers between 5cm and 10cm thick. Moist or juicy material should be in thin layers (no more than 3cm thick) covered by dry organic material such as dry straw or shredded paper. Between every second or third layer, add a small amount of soil, as this will help introduce the micro-organisms necessary for the decomposition process.

If using a large amount of cooked food, or dry material such as straw, sawdust or paper, add some manure to boost levels of nitrogen in the compost. Every week or so, turn the heap with a garden fork. In rainy weather, cover the heap with plastic, and in hot dry weather spray it lightly with water. In warm conditions the heap will be ready in around 4 weeks; in colder weather it can take several months.

Compost Bins

There is a range of plastic compost bins available from garden centres, local councils and hardware shops. These are useful for composting small amounts of waste and for making compost in small gardens where you don't want to look out at an open heap of rotting waste. Fixed bins can be difficult to aerate, and are prone to becoming too dry or too wet. Rotating bins are more expensive but provide quicker, more reliable results.

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 be still intact.)
- It should drain well, but still have good moisture holding capacity.
- It should be dark in colour.
- It should smell earthy, not rotten or mouldy.
- The high temperatures which occurred in the centre of the heap during decomposition should have dropped.
- There should be few if any disease organisms or weeds left alive in it.

How to Use 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 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.
- Don't plant in pure compost alone. Compost is good for most plants, but doesn't have everything a plant needs. Soil is necessary too.
- A potting soil made from loam and compost is still likely to require some fertiliser, particularly phosphorus.

COLD AND THE GARDEN

Understanding frost

- Frost is most likely to occur or be at its worst just before dawn.
- Frost moves and settles lower down a slope, so plants higher up the slope are less likely to be affected.
- On a frosty night the air is colder at ground level. Frost can occur on the ground while not occurring on foliage a couple of metres high.
- A wall or fence can provide protection from frost for a distance of up to half the height of the wall.
- Increased ventilation stops frost settling. In some orchards, growers even install huge fans to prevent frost damage.

Watch out for flushes of new growth. Sometimes an abnormal warm spell is followed by a cold snap and tender new growth is MOST sensitive to cold.

There are three ways to make the backyard warmer:
1. Trap heat by creating suntraps or heat banks
2. Create heat by mulching to keep plants warm
3. Stop cold coming in by planting windbreaks and building fences; by putting guards around cold-sensitive plants

Protecting Trees and Shrubs
Newly planted evergreen trees and shrubs are most at risk. At the start of winter, place tree guards (made from Hessian or plastic) around susceptible plants.

Protecting Fruit
Excessive cold might not cause any obvious damage to fruit trees but if you look carefully, you may see that the fruit buds have withered or dropped, and that can significantly affect your crop in the coming season.

Some cold is good though. Many fruit trees need a cold spell to get the fruit buds to form; but the same fruit trees can suffer if a frost occurs late in winter, especially if the buds have started to swell or open.

Protect fruit trees by covering with shade cloth, applying thick layers of mulch, using irrigation at times of frost, or using fans to generate warm air.

Cold Weather Checklist
- Watch the weather report daily.
- Move cold-sensitive indoor plants away from windows. Unless you have double glazing, frost can even move a few inches inside a heated house or greenhouse.
- Move susceptible tub plants under a shade tree or the eaves of the house.
- At the start of winter, put tree guards around newly planted trees and shrubs.
- Ensure good ventilation in the garden to minimise frost.
- Put a thick layer of organic mulch around cold-sensitive plants (as the mulch rots it generates heat, so mixing in manure can help generate even more heat). Note that while mulches insulate the soil, they can attract frost as well.
- Cover seedlings with a cloche (a small portable frame, covered with plastic or glass) or bell jar (use an old plastic drink bottle with the neck cut off).

COMPANION PLANTING
Some plants are thought to have beneficial effects upon other plants around them; such as helping deter pests or diseases, improving the soil, or even simple things like providing protection from wind or excessive sun. These plants are called “Companion Plants”. However it must be noted that the evidence to back-up the efficacy of companion planting is mostly from folk-lore rather then hard scientific evidence.

General Principles

- In nature, shrubs growing around a tree trunk may protect it from damage by animals. Many animals will at times eat the bark of certain trees.
- Large hardy plants growing beside smaller less hardy ones will provide protection from strong winds, frost and excessive heat. They create a more humid environment beneath the foliage, and can help dampen the effect of dry air in some situations.
- Avoid planting two plants side by side if they are attacked by the same pest or disease. This applies even to the same variety. For example, it is better to alternate cabbage plants with onions in a row, rather than having all the onions together and all the cabbages together.
- Planting decoy plants to attract insects away from the vegetable area.
- Planting a diverse range of plants to 'confuse' insects
- Planting species known to have a beneficial effect on neighbouring plants ie. Chamomile.

Some Companion Planting Associations

Marigold

Marigolds repel nematodes which attack narcissus (daffodils) and other types of bulbs. Plant a crop in a bed then remove before planting bulbs; or plant alongside bulbs.

Calendula

Calendulas attract a range of beneficial predator species including hoverflies, and repel some pest species such as the asparagus beetle and tomato hornworms.

Lavender

The scent and oil helps control a variety of insects but attracts bees. A poor lime soil results in stronger oil content. A fertile acid soil may grow healthy plants but oil levels and companion plant value is reduced. Wallflowers and lavender are mutually beneficial in the production of flowers

Nasturtiums

These contain oil that insects are attracted to in preference to cabbages and cauliflowers, which have similar oil. Nasturtiums may become infested, but your vegetables growing alongside them can be cleaner than they would otherwise be. Nasturtiums act as a trap crop for aphids.

Pyrethrum

Though this little flowering annual contains a chemical insecticide, as a companion its use is limited. It is effective in controlling pests when planted amongst strawberries. It will also tend to repel flies when planted in large quantities.

Roses

Alliums (Garlic, Chives, etc), planted below roses will help protect against black spot and mildew, and can repel some insects. Parsley helps control aphis on roses.

Sweet Peas

These fix nitrogen in the soil and are therefore beneficial adjacent to most plants but there are a few exceptions: notably Alliums (eg. onions and chives) and other members of the Lily family.

Sunflowers

Squash and cucumber grow well under sunflowers but potatoes do not. Sunflowers can attract lacewings and wasps which are beneficial insects. Lacewings help control various pests including thrip, mealy bug, white fly and aphis.

WHAT CAN BE GROWN TO TRADE OR SELL

Horticultural crops can include a wide variety of things: fruit, berry fruit, nuts, vines, vegetables, cut flowers, bulbs, container plants, loose rooted plants, herbs and their products, seed, fibres, tea and coffees. Any of these crops may be grown either on a large scale, commercially; or on a much smaller scale either to sell, trade or for home use.

For small scale production horticulture it is very important to be sure of your market or intended use and grow for that market or use. It is difficult for the small scale producer to compete with the large scale grower for the open market.

How Do You Decide What to Grow?

Are you producing for your own needs, for a market, or for both?

A. Producing for your own needs, known as a subsistence crop

Your market is assured here. It is difficult to go wrong provided you do the following: You must have or must develop the skills required. Check and be sure that you can grow each particular crop cheaper than what you might buy the product for. BEWARE, even though it may seem ridiculous, it is often possible to buy something for less than it might cost you to grow it.

B. Growing for a Market:

Your market is rarely assured, and when it is, there are disadvantages attached to the advantage of a guaranteed market.

- Study the demand of alternative crops under consideration and select high demand crops.
- Consider the crop's keeping quality. Crops which keep for short periods only (eg. peaches) are more of a risk than ones which keep well (eg. almonds).
- Consider when the crop will be sold and the likely changes in demand throughout the year.
- Consider the relationship between cost outlay and return. Some crops require large capital outlay before any return can be obtained (eg. walnut orchard property and labour etc. can be tied up for up to 10 years before reasonable crops start to be obtained from the trees).
- Consider the scale on which that crop is normally grown commercially. Crops grown on large scales (eg. wheat) are subject to scale economies ie. They need to be grown on large scales to achieve reasonable cost efficiency.
- Consider how well established that particular sector of the horticultural industry is, and study what other people growing that crop are doing. If everyone plants a particular crop because there has recently been a high demand next year may result in an over production of that crop, and very cheap prices.
- How suitable is that crop to the soil and climate of your area.
- Consider your own experience and technical ability in relation to the ease of production of the particular crop being considered. Some crops are very difficult to grow; others are easy. If you are inexperienced, start with the easy ones.
- Consider likely transportation and marketing of crops

- Consider the time the crop takes to mature and length of production of the particular crop considered (eg. radishes can be harvested 4 to 6 weeks after sowing if grown right. Pear trees take 4 years before you get a worthwhile crop, but will keep bearing for over 100 years).
- What are your existing resources (eg. manpower, machinery area available, money etc) and what crops are these resources suited to.
- Consider market presentation and preferences before beginning a venture. Some crops require a larger capital outlay to package and present at market than others (eg. some fruits need to be packed in special boxes). Red apples sell better in some places than green apples. Container plants sell better in plastic containers than in tins.

Where to Get Helpful Information

There are numerous organisations and agencies which can be of great assistance to anyone growing a crop. These agencies and organizations are common in most states and countries, particularly in capital cities or large regional towns.

- The place to start is your nearest government Agriculture or Rural Industries Office. You can check on the nearest office by contacting your local member of parliament, or even looking in the telephone book.
- Government and private research stations which operate in the areas of agriculture and horticulture. Addresses of these can be found in the telephone book.
- Contact them as you want information on a specific crop. They should be able to help, even if it's only to forward you onto another unit, department or individual.
- Professional Associations or Garden Clubs can be very helpful when entering into a new field, horticulture or anything else. There are general associations such as Institutes of Horticulture or more specific associations such as groups representing fruit growers, berry growers etc. You can obtain contacts for such groups through your government Agriculture Department, through individuals already involved in that area, or through trade magazines.
- Magazines, Information bulletins and Books can keep you up to date with new research, better methods and new products.
- Field Days and Agricultural Shows are places where you can get a wealth of knowledge and assistance if you are starting out in a new profession or even just commencing to grow something new for your own use. Government departments, Horticultural Schools and Colleges or people involved working in the field should be able to tell you something of what field days or shows are on and when they are on.
- If you are serious about the crop or crops you are going to grow, it is essential that you should maintain an effort to keep yourself informed; know what are the latest techniques; what are the market trends; what are the latest varieties etc. To keep yourself up to date you have to maintain contact with the other people and organizations. You should contact and keep a contact with all of the resources mentioned above and more!

STATISTICS

Governments regularly collect and publish facts and figures which will tell you what was grown where and when. These production figures are valuable in helping you understand the potential of a crop you might consider. Collect figures for several years and study the trends (growths and setbacks) in crops you might be considering. Find the relevant department in your phone book or via an internet search.

Suggested Magazines:

- 'Grower Magazine'
- 50 Doughty St, London, WC1N 2LS, U.K.
- 'Good Fruit and Vegetables' crn Wellington and Gipps Sts, Collingwood, 3066, Australia.
- 'Commercial Horticulture' Ruddick Publishing Co. P/O Box 766, Toowoomba, 4350, Australia.
- Government Department of Agriculture Journals.

Suggested Books:

- 'Growing Vegetables' by Mason and Lawrence (Kangaroo Press, Australia)).
- 'Commercial Hydroponics'' by John Mason (Kangaroo Press, Australia)
- 'Natural Gardening' by Hodges (Viking O'Neill)

OTHER CROPS

Fruit

Citrus

These require a large area, take at least 3 years from planting to production of any worthwhile crop and full production takes a lot longer; trees can remain productive for a hundred years or more. There has been a boom in citrus fruit production in some countries due to the demands for packaged orange juice etc. Another development in the past decade has been a steady trend towards mechanisation in the citrus industry (You may consider lack of finance a serious limitation to efficient production of citrus. You might need to mechanise in the future to be competitive!). Citrus fruit keep and transport well. Products include fresh fruit, juice, marmalade, rind/peel, and some canned and candied fruits. Small areas of ½ acre or so have been a productive unit in the past.

Berry Fruits

These are highly productive for the area cultivated. A couple of acres of berries can support a small family. Tree fruits may require 20 acres or more to bring a similar return. Most berries produce good crops within the first few years (blueberries are an exception, taking several years to begin giving any significant crop). Some berries last only a few seasons (eg. strawberries). Fruit doesn't keep fresh for very long. Products include: fresh fruit, jams, syrups and some frozen fruit.

Nuts

Nuts require a relatively large area for a worthwhile crop. Most nuts grow on trees and take at least 4 years from planting to the time when significant crops are produced (some 10 years or more). Keeping qualities are good if kept dry. Require at least a couple of acres to produce marketable quantities.

Vines

Vines require a medium to large area (more than berries, less than nuts or citrus). Most of the world crop is dried or used for wine; less than 10% is eaten as fresh fruit. Growing for drying is only worthwhile in low rainfall areas; growing for wine can be profitable in a wide range of areas (high to low rainfall). Dried fruit or wine keeps well, but fresh fruit does not keep very long. Vines require a lot of attention and take several to bear bearing fruit.

Pome Fruits
Include apples, pears, quinces etc. An average apple orchard supporting a family might be between 25 and 35 acres. Smaller acreages can provide a profitable sideline. Will grow in a wide range of areas on a wide variety of soils provided reasonably drained and watered, with temperatures which include reasonably cold nights during winter (commercial orchards are found across a much greater variety of climates than some other fruits) keeping quality up to 6 months or so in cold storage.

Stone Fruits
Include apricots, peaches, plums etc. These are a little less hardy than pome fruits, but still adaptable to a wide range of conditions. Drainage is more critical. Fruit does not keep as long as pome fruits. It is important to get the appropriate variety to suit your particular climate. Both stone and pome fruits take up to 5 years to come into commercial bearing from planting time.

Vegetables
These have a small to medium space requirement; some vegetables can be worthwhile as a cash crop, but market forces are volatile in the vegetable industry. It is best to grow several different types of vegetable at once (unless growing for a contract). This way, if prices drop on one crop, you may still make a profit on another crop. Cultivation is intense as much attention is required to be given to the plants. One method of decreasing the risk is to grow in a plastic tunnel house (inexpensive greenhouse) so the crop matures early.

Cut Flowers
This industry is bigger than most people realise. A wide variety of plants can be grown for cut flowers, some take a lot of expertise to grow; others are relatively easy. Some produce very high profits relative to the area they require others need many acres to have any chance of bringing similar profits. Some cut flowers are perennial crops, producing for many years from the same plant (eg. roses) while others produce only one crop and then must be replanted (eg. stocks). Cultivation required is relatively higher than other horticultural crops (eg. weed control, feeding, watering, pest control, pruning etc). Keeping quality is usually not good (with some exceptions). Violets, for example, must be sold as soon as harvested, though orchids will keep for a few weeks. Recent research into holding some flowers by cool storage or freezing has shown flowers can be stored for periods beyond what was previously thought possible.

Bulbs
These provide a double headed return. You can sell the flowers as well as the bulbs. Returns can be good, particularly with some types (eg. tulips, hyacinth, gladioli) but market demand does vary and prices fluctuate.

Container Plants
This field has boomed in recent years. Even in a depressed economic climate, the nursery industry always seems to survive and in fact, do better than most other sectors of the economy.
The nursery industry comprises growing plants in three main ways:

- The first method has been to grow loose rooted plants (plants which are grown in the ground and dug up at time of sale, with roots that may be surrounded by soil or perhaps free of soil, either way, not in a container).
- The second method has been to grow annual and vegetable seedlings in trays or punnets (here many plants are grown in the one container).

- The third method has been growing single plants in a single container. This 'container plant' branch of the nursery industry is the area which the majority of the nursery industry is concerned with today.

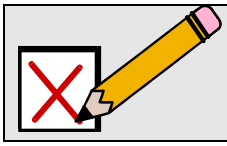
Herbs
These can produce a wide variety of saleable products. These include; dried herbs, oils, herbal sprays, powders, potpourri essences, seed, herb teas etc. This is a minor horticultural industry, nevertheless an expanding industry. Herbs are currently in vogue, and while this situation remains, there is profit in growing herbs and herb products on a small scale. Herbs are highly productive for the area they require.

Fibres
The commercial feasibility of small scale production of fibres is questionable in many countries and climates. There are some plants which will produce fibres in cooler climates: New Zealand flax, kadzu vine, Jerusalem artichoke, chugar vine, reeds, rushes etc. Cotton requires a warm climate. There may be more value in raising a sheep or two for fibre than growing horticultural crops on a small scale.

Oils and Essences
Many plant oils and essences have value in industry. Most are usually grown on a large scale, though some are rare and expensive and may have value on a small scale. Know your market before you start (eg. some seed oils such as sunflower may be uneconomical to grow on small scale, but some perfumes/herbs could be more worthwhile). Uses for these products include; cooking oils, perfumes, medicines, tans and dyes, lubricants, fuel oils, concentrated foods (vitamins etc).

Seeds
Production of grass seed, vegetable and flower seed is well organised, often mechanised and competitive. These types of seeds may not be economical to grow on a small scale. Production or collection of tree and shrub seed is perhaps a more promising area to consider.

Other Plants
Plants can be grown for a variety of other uses not mentioned above; timber, cane, tea, coffee, rubber etc. Most of these things are usually grown on a large scale and may not be economically feasible on small properties.



SELF ASSESSMENT
Perform the self assessment test titled ‘Test 2.1’.
If you answer incorrectly, review the notes and try the test again.

SET TASK

1. Visit a local nursery and inspect the food plants which are available in your locality. Talk to the nursery manager/staff and find out what types of food plants will become available at other times of the year.

2. Make a list of food plants which can be grown in your locality.
(If you are an isolated location, write to your state government Department of Agriculture and request information on food plants which will grow in your locality).

3. Build a compost bin and send in a photo of the finished bin.

ASSIGNMENT
Download and do the assignment called ‘Lesson 2 Assignment’.