CHAPTER 1 : INTRODUCTION

Hydroponics is the technique of growing plants without soil. The roots grow either in air, which is kept very humid; in water, which is well aerated; or in some solid, non-soil medium, which is kept moist. The water around the roots contains a carefully balanced mixture of nutrients which provides food for the plant.

There are three main ways of growing plants hydroponically:

Aggregate culture

Small particles of chemically inert substances provide a suitable environment for the plant roots to grow through.

Rockwool culture

A fibrous sponge-like material made from molten rock provides an environment for the roots to grow through.

Water culture

Water, perhaps mixed with air (with no solid material), provides the environment in which the roots grow.

The aggregate, rockwool or water which is used to provide the root environment, supplies the physical needs of the roots.

The roots (and in fact the whole plant) also have chemical needs which must be catered to. The chemical needs are supplied by adding a carefully calculated solution of nutrients to the root zone, and maintaining the balance of chemicals in that solution at appropriate levels.

Hydroponics has also been called 'soilless culture', 'nutriculture' and 'chemiculture'.

rockwool culture

HISTORY

The word hydroponics comes from two Greek words: *hydro* meaning water and *ponos* meaning labour. This word was first used by Dr W.F. Gericke, a Californian professor who in 1929 began to develop what had previously been a laboratory technique into a commercial means of growing plants. Throughout the 19th Century a number of scientists undertook significant research into the nature of plant nutrition. Classical experiments conducted by German plant scientists, Sachs in 1860 and Knop between 1861 and 1865, led to our first understanding of what were essential plant nutrients. Chemical formulae developed by Sachs and Knop, and several other researchers who followed them, provided Dr Gericke with the knowledge to make an effective nutrient solution, thus overcoming the major restriction to the development of hydroponic culture.

Plants had been grown hydroponically before Dr Gericke, but only as laboratory experiments or (in the case of some earlier civilisations) without a proper understanding of the methods being used. Dr Gericke is credited with having recognised the commercial potential of what he had seen as a laboratory technique, and having conducted trials which inspired the development of a commercial industry in the following decades.

Scientists in North America, Europe and Japan, inspired by Dr Gericke's experiences, worked throughout the 1930s and 40s to refine our knowledge of hydroponic growing. The United States army used hydroponic culture to grow fresh food for troops stationed on infertile Pacific Islands during World War II. By the 1950s there were viable commercial hydroponic farms operating in America, Britain, Europe, Africa and Asia.

Interest in hydroponics developed in Australia throughout the 1960s, and in the 1970s many vegetable growers, inspired by tales of increased production, attempted to convert their operations to hydroponics. Unfortunately many of these people failed to do their 'homework', and embarked upon schemes without having a real understanding of the differences between soil and hydroponic culture. The result was many failures, and the development of an attitude in Australia that hydroponics doesn't really work.

In 1981 CSR Ltd established an Australian plant to produce horticultural grade rockwool for hydroponic production. CSR did their homework, promoted their product well and supported it with excellent technical information. As a result, Growool (as it is known) became widely accepted, and today is used extensively in the Australian cut flower industry.

At the beginning of the 21st century commercial crops of vegetables, berry fruit, and cut flowers are grown extensively by hydroponic culture in many countries. The most popular technique worldwide is rockwool culture, though NFT (Nutrient Film Technique), perlite and gravel bed culture are all very significant techniques in use in commercial hydroponics.

HOW PLANTS GROW

To understand and practice hydroponics successfully requires the grower to have an understanding of how plants grow.

Almost all plants grown in hydroponics are flowering plants. These plants have four main parts:

Roots – the parts which grow below the soil

Stems – the framework

Leaves – required for respiration, transpiration and photosynthesis

Reproductive parts – flowers and fruits.

Roots

Soil provides the plant with the following:

- Nutrients
- Water
- Air
- Support

Roots absorb nutrients, water and gasses, transmitting these 'chemicals' to feed other parts of the plant. Roots hold the plant in position and stop it from falling over or blowing away.

When we grow a plant in hydroponics, we must make sure that nutrients, water and air are still supplied and that the plant is supported, as would occur if it was growing in soil.

Nutrient supply in soil is a more complex matter than in hydroponics. Plant nutrients can be supplied, broadly speaking, in three different forms:

Water soluble simple chemical compounds

Nutrients in these compounds are readily available to plants (i.e. the plant can absorb them quickly and easily).

Less soluble simple chemical compounds

The nutrients in these compounds can be used by plants without needing to undergo any chemical change, but because they don't dissolve so easily in water they aren't as readily usable as the more soluble compounds. The diminished solubility may be because of the nature of the compound (e.g. superphosphate) or may be due to something else (e.g. slow-release fertilisers such as Osmocote, which is made by incorporating the simple chemicals inside a semi-permeable bubble – thus nutrients move slowly out of the bubble).

This second group of nutrients, when placed in soil, will last longer than the first group of water soluble nutrients.

Complex chemical compounds

These require chemical changes to occur before the nutrients can be absorbed by plants. They include organic manures and fertilisers which need to be broken down by the soil microorganisms into a form which they can use. They also include other complex fertilisers which need to be affected by natural acids in the soil, or heat from the sun, to become simple compounds which the plant roots can use.

Complex chemicals release their nutrients gradually over a long period of time, depending on the range of chemical changes needed to take place before the plant can use them.

Plants grown in a soil derive their nutrients from all three types of compounds. The availability of these compounds varies not only according to the group they come from but also with factors such as heat, water, soil acids and microorganisms present. Consequently it is impossible to control the availability of nutrients in soil.

This is one intrinsic advantage of hydroponics over soil growing. In hydroponics you can choose to use only simple, soluble compounds, and so you can determine the exact amount of each essential nutrient available to a plant at any point in time.

Stems

The main stem and its branches are the framework that support the leaves, flowers and fruits. The leaves, and also green stems, manufacture food by the process known as photosynthesis, and this is transported to the flowers, fruits and roots. The vascular system within the stem consists of canals, or vessels, which transfer nutrients and water upwards and downwards through the plant. This is equivalent to the blood system in animals.

Leaves

The primary function of leaves is photosynthesis, a process in which light energy is caught from the sun and stored via a chemical reaction in the form of carbohydrates such as sugars. The energy can then be retrieved and used at a later date if required in a process known as respiration. Leaves are also the principle plant part involved in the process known as transpiration whereby water evaporating, mainly through leaf pores (or stomata), sometimes through the leaf surface (or cuticle) as well, passes out of the leaf into a drier external environment. This evaporating water helps regulate the temperature of the plant. This process may also operate in the reverse direction whereby water vapour from a humid external environment will pass into the drier leaf.

The process of water evaporating from the leaves is very important in that it creates a water gradient or potential between the upper and lower parts of the plant. As the water evaporates from the plant cells in the leaves then more water is drawn from neighbouring cells to replace the lost water. Water is then drawn into those neighbouring cells from their neighbours and from conducting vessels in the stems. This process continues, eventually drawing water into the roots from the ground until the water gradient has been sufficiently reduced. As the water moves throughout the plant it carries nutrients, hormones, enzymes, etc. In effect this passage of water through the plant has a similar effect to a water pump, in this case causing water to be drawn from the ground, through the plant, and eventually out into the atmosphere.

Reproductive parts

Almost all plants grown in hydroponics are flowering plants. These reproduce by pollen (i.e. male parts) fertilising an egg (i.e. female part found in the ovary of a flower). The ovary then grows to produce a fruit and the fertilised egg(s) will grow to produce seed.

There can sometimes be difficulty in obtaining a good crop because insufficient pollen reaches the female parts, resulting in insufficient fruit forming. (This is discussed in chapter 11.)

blueberries

CLASSIFICATION OF HYDROPONIC SYSTEMS

There are two main groups of systems:

Water culture

Nutrients are dissolved in water which is brought in contact with the roots. Water is either aerated or roots are allowed to contact air as well as nutrient solution.

Trellis, wire mesh or some other support is provided above the nutrient solution

Examples

Nutrient tank

Standard jar

Nutrient film (NFT)

Mist systems

Aggregate culture

Nutrients are dissolved in water which is moved into the root area. The roots are grown in a solid, inert (nutrient-free) material, which is able to hold sufficient moisture but drain off the excess, allowing adequate aeration. The solid material which the roots grow in contributes towards (if not fully supplying) anchorage.

Examples

Beds and tier systems.

The Variables of a System

The types of hydroponic system that can be used vary for a range of reasons. The most common variables are:

1. *Solution dispensation* -closed or open (i.e. the solution is recycled or drained through and lost) -drip, slop, capillary feed, wicks, misting, dry fertilising etc.
2. *Automatic or manual operation*
3. *Type of medium* -gravel, vermiculite, perlite, sand, scoria, peat, expanded clay, a mixture etc.
4. *Construction materials* -concrete, fibreglass, plastic, glass, wood, masonry, metal, PVC, ceramic, polystyrene, etc.
5. *Rate and frequency of irrigation and feeding*
6. *Air injection* (in water culture, where air is pumped into nutrient solution to raise the oxygen level)
7. *Plant support* -trellis etc.
8. *Environmental controls* -temperature, ventilation etc.

OVERVIEW OF THE INDUSTRY

Commercial hydroponics is a successful and rapidly expanding industry. Industry growth has been particularly dramatic in the last decade. In the early 1990s there were around 5000 hectares of commercial hydroponic production worldwide. By 2001 there were an estimated 20,000 to 25,000 hectares under hydroponic production, and this strong growth in global commercial production is expected to continue over the next few years.[1]

Commercial production is centred in affluent countries with discerning customers – The Netherlands, Spain, Canada, UK, US, Australia, NZ, Italy and Japan. The major producer is Holland, with around 10,000 hectares under production, followed by Spain, Canada and France. Australia is ranked as the tenth major producer in the world, and the leading producer of fancy lettuce. Expansion in the US has been slower; in 1998 the US ranked as the sixteenth largest producer, although a recent surge in large commercial installations is likely to boost their production. [2]

Although, as this book shows, many crops can be grown successfully in hydroponics, worldwide commercial production is limited to a few crops: tomatoes, cucumbers, lettuce, capsicums and cut flowers (including roses, gerberas, carnations, chrysanthemums and lisianthus).

In most countries the majority of hydroponic crops are grown in greenhouses, the exception being Australia where more than 50% of hydroponic production takes place outdoors (due to the high proportion of lettuce grown). In Holland nearly all greenhouses have converted to rockwool and NFT culture as a consequence of soil depletion, salinisation, a build-up of soil-borne diseases, high water tables and good economic returns.

The most popular systems worldwide are NFT and rockwool culture, although other systems are used for commercial production. In all countries systems are moving towards recirculation, due to the potential environmental problems caused by run-to-waste systems.

Other sustainable practices such as 'organic hydroponics' (chapter 4) and Integrated Pest Management (IPM) are seen to be important strategies for future production. Currently more than 70% of Dutch hydroponic production relies on IPM (for tomatoes and capsicums it is more than 90%).[3]

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WHY PRACTISE HYDROPONICS?

Hydroponics has been practised by market gardeners and other growers since the 1940s. The advantages of hydroponics are many; however, the disadvantages should not be overlooked when you are deciding whether or not to set up a hydroponics system.

Advantages

1. You can grow anywhere

Crops can be grown where no suitable soil exists or where the soil is contaminated with disease.

2. Culture is intensive

A lot can be grown in a small space, over a short period of time. It is also possible to grow in multi-levels. Where transportation costs to the market are significant (e.g. in the centre of large cities), hydroponic farms may be viable irrespective of land values. For example, in Japan hydroponic vegetables are grown in supermarkets in the centre of large cities. The savings on transport costs and the benefits of having fresh produce offsets the increased cost of space in these cities.

3. Heavy work is reduced

Labour for tilling the soil, cultivation, fumigation, watering and other traditional practices can be reduced and sometimes eliminated.

4. Water is conserved

A well-designed, properly run hydroponic system uses less water than gardening. This is an important advantage in areas with poor quality or limited water supplies. In particular, hydroponics is seen to have potential benefits in controlling water pollution in developing countries.

5. Pest and disease problems are reduced

The need to fumigate is reduced. Soil-borne plant diseases are more easily eradicated in many nutriculture systems. This is particularly true in 'closed systems' which can be totally flooded with an eradicant. The chance of soil-borne human disease is also reduced. Though rare in developed countries, it is possible for diseases to be transmitted from animal manures or soil micro-organisms onto food plants grown in soil, leading to illness.

6. Weed problems are almost eliminated

Weeds are a major problem in most soil-based systems. Weeds are almost non-existent in hydroponic setups.

7. Yields can be maximised

Maximum yields are possible, making the system economically feasible in high density and expensive land areas.

8. Nutrients are conserved

This can lead to a reduction in pollution of land and streams because valuable chemicals needn't be lost.

[1] Hassall and Associates Pty Ltd, *Hydroponics as an Agricultural Production System*, RIRDC Publication No 01/141, November 2001.
[2] Steven Carruthers, A Global Perspective, *Practical Hydroponics*, Issue 42, 1998.
[3] Steven Carruthers, Hydroponics As An Agricultural Production System, *Practical Hydroponics*, Issue 63, 2002.

banana

9. The environment is more easily controlled

For example, in greenhouse operations the light, temperature, humidity and composition of the atmosphere can be manipulated, while in the root zone the timing and frequency of nutrient feeding and irrigation can be readily controlled.

10. Root zone chemistry is easier to control

Salt toxicities can be leached out; pH can be adjusted; EC (electroconductivity) can be adjusted. Also salts will not bind chemically to the majority of media used in hydroponics so problems of salt build-up that may occur in soils, particularly when highly soluble nutrients are used, are uncommon in hydroponics.

11. New plants are easier to establish

Transplant shock is reduced.

12. Crop rotation/fallowing is not necessary

All areas can be used at all times – you don't need to leave a paddock for a year to fallow every so often.

The amateur horticulturist can use hydroponic systems at home, even in high rise buildings. A nutriculture system can be clean, light weight, and mechanised.

Disadvantages

1. Initial cost is high

The original construction cost per hectare is great. This may limit you to growing crops which either have a fast turnover or give a high return.

2. Skill and knowledge are needed to operate properly

Trained plantsmen must direct the growing operation. Knowledge of how plants grow and the principles of nutrition are important.

3. Diseases and pests can spread quickly through a system

Introduced diseases and nematodes may be quickly spread to all beds using the same nutrient tank in a closed system.

4. Beneficial soil life is normally absent

5. Plants react fast to both good and bad conditions

The plants in hydroponics react more quickly to changes in growing conditions. This means that the hydroponic gardener needs to watch his plants more closely for changes.

6. Available plant varieties are not always ideal

Most available plant varieties have been developed for growth in soil and in the open. Development of varieties which are specifically adapted to more controlled conditions may be slow to occur.