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## Simple Substrate Culture in Arid Lands

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Additional information is available at the end of the chapter

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### 1. Introduction

The limited water resources are the major factor that drew the attention towards the use of intensive agriculture in arid land. Protected cultivation was the first step, which started initially at late seventies and intensified at mid-eighties. Maximizing crop yield per square meter of soil as well as per cubic meter of water could be achieved using soilless culture systems [12]. The need for the use of soilless culture is becoming more important in arid lands than several years ago in order to increase the water use efficiency. In addition, continuous cultivation of crops resulted in poor soil fertility, which in turn has reduced the opportunities for natural soil fertility build up by microbes. This situation has led to poor yield and quality. In addition, conventional crop cultivation in soil (conventional open field agriculture) is difficult as it involves large space, large amounts of water and a huge number of labors [1].

Soilless agriculture means growing plants in the absence of land as the normal agricultural, where soil not used as a medium for agriculture but used as a support to the system. This technique can be an alternative to the conventional cultivation in the soil which has problems and difficult. In addition, soilless culture is possibly the most intensive method of crop production in today's agricultural industry in combination with greenhouses.

In protected cultivation, the high levels of crop and continuous cropping inevitably leads to problems of pests and diseases in the soil. The accumulation of these problems leads to a loss of yield and eventually of the crop. Cropping can only continue if some form of sterilization of the soil or rotation of crop can take place. Steam sterilization is not economically viable & not efficient, the use of methyl bromide banned in many European states, and it will band. For production to continue there is inevitably a move towards some form of soilless culture or soil replacement cultivation.

The use of soilless culture has substantially increased during the last decade as it contributes to the intensification of horticultural production and provides high crop yields even in areas with adverse growing conditions [12].

This chapter will discuss the importance of soilless culture in arid land, the constraints of using this type of cultivation, the type of soilless culture used in arid lands and the suitable types of substrate culture for arid lands.

## **2. Importance of soilless culture in arid land**

Soilless culture technique provides a large number of advantages that could be summarized as follows [9]:

- Standardization of the culture, and of the root environment in particular.
- Excluding soil infection and hence the danger of disinfectant residues.
- Drastic reduction of energy input for the conditioning of the root environment.
- Crop production where the soil is unsuitable.
- Drastic reduction of the water consumption.
- Efficient use of nutrients.
- Better control of vegetative and generative plant development.
- Earlier and higher production.
- Qualitatively better production.
- Rationalization of labor.
- More possibilities for culture mechanization and automatic control.

## **3. Why we have to move to this type of cultivation in arid lands**

Most of the growers in the arid region now a day should move to the soilless culture for the following reasons:

### **3.1. Increase productivity**

The matter of increased yields with the application of soilless culture should be examined carefully. It is true that precise control of nutrition to the plants grown in soilless cultures will result in higher yields and quality, but this does not necessarily mean that yields from the best cultures in soil are inferior. Nevertheless, it is difficult to believe that the fast increase in area in soilless culture in the Netherlands and other European countries would have occurred

unless commercial growers were confident of some yield increase to help offset the additional cost of soilless culture.

It is of course understandable that if there are soil problems, (i.e. poor soil, saline soil, toxic soil, etc.), then soilless culture will produce much better crops. Many reports published during the last 15 years presenting results on comparison of soilless methods and soil. Most of them show advantages towards the soilless systems, but this was usually been due to a combination of factors such as reduction of labor, higher yields and the greater uniformity of quality due to them or uniform conditions of growth. However, it must be mentioned that in many experiments the management of crops in the soil is not controlled properly [9].

### **3.2. Control of plant nutrition**

The accurate control of plant nutrition compared to soilless culture is also one of the most important advantages of soilless culture. This can be seen from: the point of view of the controlled concentrations, which can be applied to the various crops, various environments, stage of plant growth, etc. In addition, harmful elements to plants, above certain concentrations can be kept within safe concentrations (i.e. Mn, B, Zn, Cu, Pb, etc.)

Another important advantage related to plant nutrition in soilless culture, is the uniformity with which nutrient elements can be supplied to the substrate. This is particularly true with water culture and the more sophisticated systems and less true for the aggregate cultures, especially the simplest ones using surface drip irrigation systems (sand culture, etc.).

When using water cultures or aggregate cultures with inert substrates the level of nutrients, supplied to the new crops those chosen by the manager. This is not the case with soil cultures where in many cases excess nutrient levels in the soil from the previous crops produce salinity.

Another advantage of the soilless culture related to plant nutrition is the ability to control the pH and the E.C. of the nutrient solution according to the requirement of the crop and the environmental conditions. Similar control in soil cultures is very difficult and expensive [9].

### **3.3. Water economy and control**

Water is the most important factor for crop production. Protected crops require large amounts of water due to exclusion of rainfall when crop production is required in hot, arid regions of the world; water is like to be a limiting factor not only of availability but also of quality and cost.

The advantage of soilless culture related to the ease of irrigation applies mainly to certain soilless systems, such as NFT and other true hydroponic systems (where the plants have their roots immersed into the nutrient solution) and to sub-irrigated substrate culture, and is not fully applicable to the rest of the soilless cultures using various inorganic or organic substrates. In fact, watering the later, the frequency and duration of irrigation is much more critical substrates with low water holding capacity, compared to soil.

With reference to water saving, certain soilless systems, for instance the closed or recirculated ones, undoubtedly economize water because drainage and evaporation from the surface

eliminated by the design and operational scheme of the systems (NFT, “closed” systems, sub-irrigated soilless culture). In addition, with soilless culture, more accurate water supply control practiced.

Furthermore, water culture and sub-irrigated substrate systems save much labor in the time consuming task of checking and cleaning irrigation nozzles. On the contrary, crops grown on substrates and soil, require frequent examination of trippers as these can easily be blocked by calcium carbonate or other compounds especially with a “hard” water supply. The blockage problem can be eliminated either by acidification of nutrient solution or by pretreatment of irrigation water [9].

### **3.4. Reduction of labor requirement**

Out of soil production exclude all cultural practices associated with the cultivation of the soil, sterilization of soil, weed control, etc. Labor requirement for soilless culture is not similar to all soilless systems. Therefore, the system itself, the degree of automation, the type of substrate, the number of crops raised on each substrate, etc. but in any case, generally speaking, there is a saving in labor impute when soilless culture employed [9].

### **3.5. Sterilization practices**

The greenhouse soil must be free from any soil-borne pathogens before the establishment of any new crop. Sterilization is a difficult and costly operation, but necessary and of great importance. It is justified because the greenhouse business require high investment in structures, facilities, plant materials, running costs, etc. and the need to obtain maximum yields and returns, is obvious to have an economically viable operation. The most effective method of soil sterilization is by steaming, but the method is expensive due to the high cost of energy and labor, therefore its application eliminated. Chemical sterilization is less expensive but not without disadvantages, i.e. the use of formaldehyde had the problems of fumes which are highly phytotoxic and the most important chemical, methyl bromide, a very toxic material to handle, has the problem of chemical residues (bromide ions taken up by the crop) and environmental pollution.

It is therefore, of great advantage the cultivation of crops outside of the soil as there is no need for sterilization when materials and substrates used only for one time, because spreading of diseases avoided. When “closed” soilless culture used depending on the system, the need for sterilization varies, i.e. to clean “true hydroponic” culture structures, following the removal of all debris, etc., a dilute rate of formaldehyde used, followed with clean water. In the NFT system, the film that forms the gullies can be replaced. When solid substrates are used, steam or chemical sterilization should be applied if the material is to be used again. In this case, the application of both is easier and economic but in any case, sterilization of soilless culture systems is easier than soil sterilization [9].

### 3.6. Control of root environment

Possibilities for more accurate control of root temperature, root oxygen supply are more easily to achieve in soilless cultivation[9].

### 3.7. Multiple crops per year

Due to the absence of the cultivation techniques, operations like soil cultivation, soil sterilization etc., the number of crops per year is increased, in a given production area, because the time interval between crops is nearly short [9].

### 3.8. Unsuitable soil

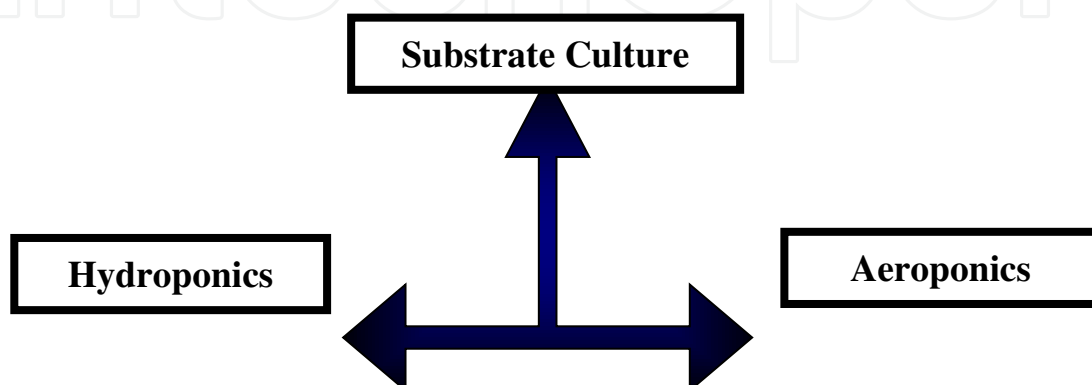
Soilless culture offers an ideal crop alternative to soil culture when there is no soil available at all, or there is no suitable soil for crop production, when soil salinity is higher or there are toxic substances into the soil and finally there is an accumulation of soil pathogens into the soil [9].

## 4. The constraint points for soilless culture in arid lands

- The high temperature most of the year.
- The availability of the soft water.
- The needed water for the cooling.
- The availability for the equipment in the country.
- The availability of the fertilizer for making the nutrient solution in the country.

## 5. Soilless culture system for producing vegetables in arid lands

Soilless culture divided into three major branches according the root growing media



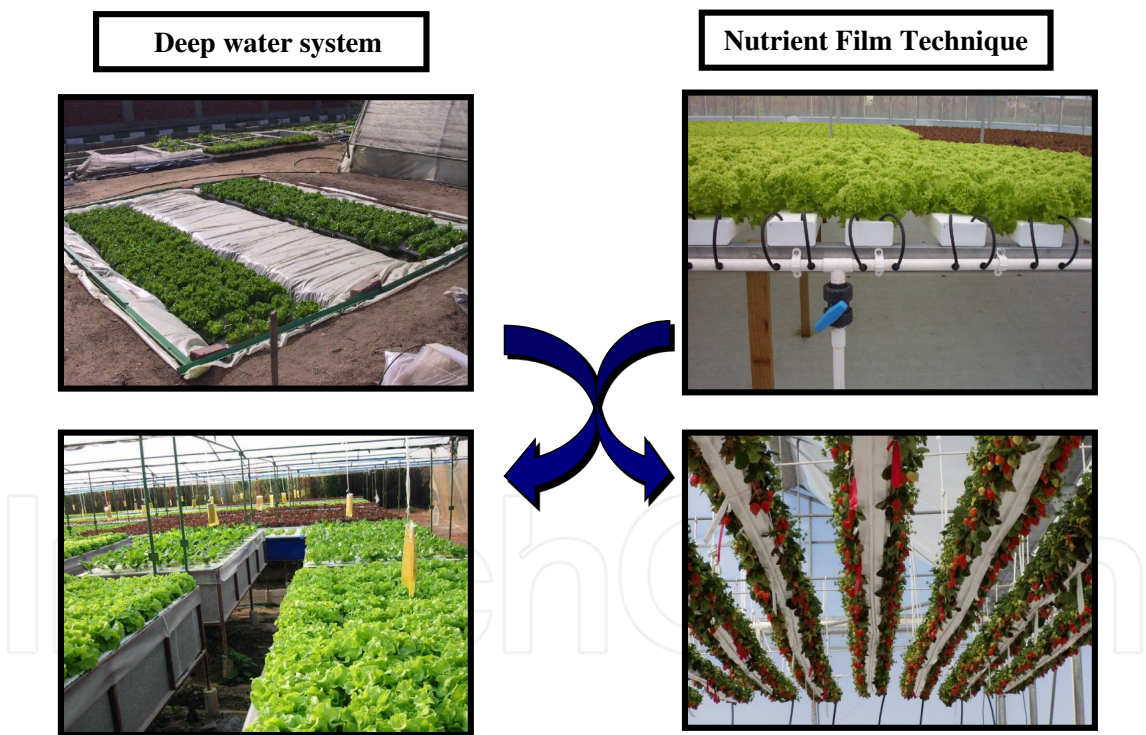
Hydroponics is a technology for growing plants in nutrient solutions (water containing fertilizers). There are different types of hydroponics according the movement of the nutrient solution and the two main systems as follow:

**5.1. Deep water culture**

The plant roots grow in containers filled with water containing fertilizers (static water). In this system water mixed with nutrient solution and oxygen applied to the plants through nutrient solution using air pump or by mixing water with air. The plants are flouting on the nutrient solution using polystyrene sheet.

**5.2. Nutrient Film Technique (NFT)**

In this system, the roots of the plants grow in a shallow film of water and nutrient solution inside cultivation channel or tube. The plants inserted in polyethylene (black on white) channel laid on a slope bed. The nutrient solution pumped into the channels in a thin film of nutrient solution and the excess nutrient solution collected and returned to the catchment tank.



**Figure 1.** Different systems of deep-water culture and nutrient film technique

**5.3. Aeroponics**

In this system, nutrient solution sprayed as a fine mist in sealed root chambers. The plants are grown in holes in panels of expanded polystyrene or other material. The plant roots suspended in midair beneath the panel and enclosed in a spraying box. The box sealed so that the roots

are in darkness (to inhibit algal growth) and in saturation humidity. A misting system sprays the nutrient solution over the roots periodically. The system normally turned on for only a few seconds every 2-3 minutes. This is sufficient to keep roots moist and the nutrient solution aerated [1].



**Figure 2.** Aeroponic system for producing lettuce

#### **5.4. Substrate culture**

In this system, a solid medium provides support for the plants. As in liquid systems, the nutrient solution delivered directly to the plant roots. The substrate culture divided according to drainage procedure into two major systems according to drainage procedure

#### **5.5. Open system**

The open system is that when the nutrient solution applied to the system with the plants grow and then drained off as waste.

Because the leached or drained solution is not recirculated to the feeder tank, it does not require monitoring and adjustment. Once mixed, it is generally used until depleted. In addition, the quality of the irrigation water is less critical. A content of up to 500 ppm of extraneous salts is easily tolerated, and for some crops (tomatoes, for example) even higher salinities are permissible, although not desirable. It is advisable to monitor the growing medium, particularly if

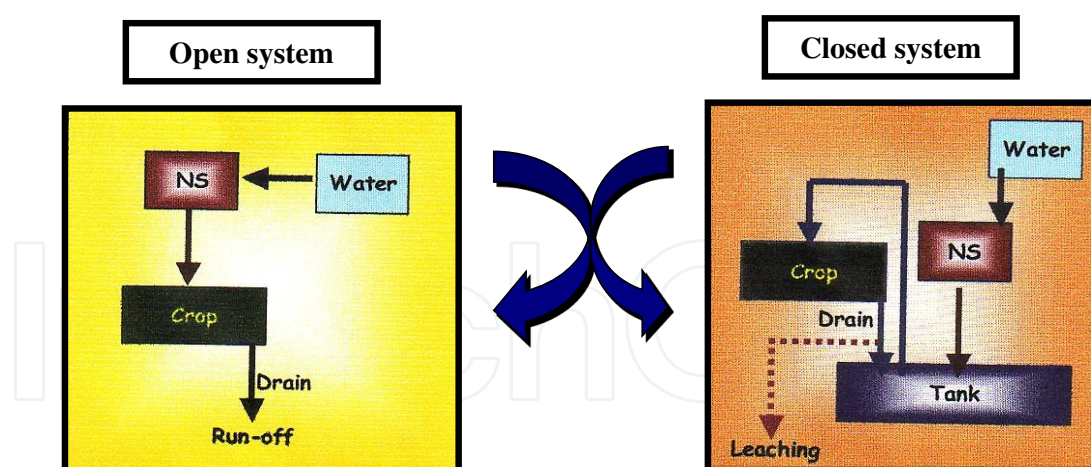


Figure 3. Scheme of the open and closed system for substrate culture systems

the irrigation water is relatively saline or if the operation is located in a warm, high sunlight region. To avoid salt accumulation in the medium, enough irrigation water is used to allow a small amount of drainage or “leaching” from the bags. This drainage should be collected and tested periodically for total dissolved salts [1].

### 5.6. Closed system

Closed system works in the same way as open system with one important difference that nutrient solution which run-off after each application is collected and recirculated to be used in successive irrigation times.

Closed systems are economical in the use of nutrients, but require frequent monitoring and adjustments of the nutrient solution. Measuring (EC) is a convenient check of total salt concentration, but provides no data on the concentration of major elements, and it is virtually unaffected by the amounts of trace elements present. Periodic chemical analyses are required, usually every two or three weeks for major elements and every four to six weeks for trace elements.

Small farmers commonly practice this regime: Begin with a new solution; at the end of a week add one-half of the original formula to the solution. At the end of the second week, dump the remaining mixture from the tanks or sumps and start all over again [1].

## 6. Growing media used for growing horticulture crops in the arid lands

### 6.1. Function of growing media

- Serves as a reservoir for plant nutrients
- Serves as a reservoir for water available for plants
- Must provide gas exchange between roots and the atmosphere outside the root substrate

- Provides support for the plant.

Some individual materials (substrates) can provide all four functions, but not at the required level of each. For example, sand provides excellent support and gas exchange but has insufficient water-and nutrient supplying capacity [9].

## 6.2. Characteristics of appropriate substrates

- Capacity to hold water

The capacity to hold and drain surplus water depends on the texture of the medium, the size and form of its granules and the permeability. The smaller granules have more surfaces, are close to each other, and therefore, can hold more water. Also the uneven form of granules has a surface area more than granules of even or round form thus the first has higher capacity to hold water.

Consequently, the size of granules should be appropriate so that it can hold proper quantity of water suitable to the crop to be grown [1].

- The substrate should have good aeration and good drainage capacity

The substrate should have a good drainage capacity for draining surplus water and therefore, ensures good aeration around roots. Therefore, we should avoid substrate/medium with fine granules which impedes the movement of oxygen through such granules, reducing the overall aeration condition in the growing environment and leads to asphyxiation of plant roots [1].

- The substrate should be free from harmful or poisonous materials

The substrate should be free from any material, which may cause harm to plant roots or affect plant growth such as sand and small stones of lime origin (contain calcium carbonate). This should be avoided as it can increase the nutrient solution pH to more than 7. This increase leads to sedimentation of iron and phosphorus causing a symptom of deficiency although they exist in the solution.

- The substrate should be supportive to plants growing in it

The substrate should be acting to fix the plants properly. This depends on the texture of the substrate, which should be medium-heavy to fix plant roots [1].

- To be free from diseases incitements

The substrate should be free from different pests and insects so that it would not form a source of infecting plants by different diseases [1].

- To be free from salinity

The substrate should be free from salinity to avoid affecting the growing plants. For instance, the medium made of wood dust usually contains high concentration of sodium chloride due to soaking the wood in salt solution for long periods [1].

- The substrate should be free from weed seeds

This is to avoid being a source of weeds, which will grow and compete with the main crop for nutrition and water. In many cases, weeds would also be a host for some diseases, which would infect and damage the growing plants [1].

- To be slow in the decomposition process

In case of using organic medium, it would preferably be of slow deteriorating nature so that it continues to be in the best condition for the longest period possible. This will reduce the cost of changing the substrate annually [1].

- To be easily transported, handled, and less expensive

There are many kinds of substrates but it is important that the selected one be available in several locations to facilitate its handling and transportation. This would result in reducing the cost of transportation and hence, the preliminary cost of establishing the roof garden. The price of the substrates should be appropriate and acceptable so that the system adopted by all categories of the society [1].

### 6.3. Types of growing media

Growing media "substrates" can be classified as follows:

**Inert media:** A solid inert material for supporting the plant and provides air and water availability conditions to the roots such as perlite, sand, Rockwool, volcanic gravel, pumice...etc.

**Organic media:** A natural organic material for supporting the plant such as peat moss, coconut fibers, coco peat, rice husk, wood bark...etc.

There are several raw materials, which are used as substrates for roof farming. Such materials differ from one another about its physical characteristics. Due to variations and multiplicity in the forms and types of materials available in the surrounding environment, there is a need for particular criteria, which enables us to select the appropriate material for an agricultural medium (substrate) [9].

#### 6.3.1. Organic substrates

##### 6.3.1.1. Peat moss

The Peat moss is considered the most common substrate and widely used at global level. It is a decomposed organic material available in humid locations of the globe called Peat moss mines. This material is used separately or mixed with other substrates such as vermiculite or sand.

The peat moss is characterized by the following:

- Large capacity to absorb water about 8 folds of its weight at saturation level and drains surplus water.
- Low acidity level.



- High percentage of organic matter (94-99%).
- High porosity (95-98%)

#### 6.3.1.2. *Rice husk*

The characteristics of rice husk presented below:

- Very light weight.
- Provides necessary aeration for roots of different plants. If mixed with a substrate of bad aeration, it can improve airing and drainage capacity.
- Has a medium capacity to hold water.



#### 6.3.1.3. *Coconut fibers*

The coconut peat and fibers have recently used as substrate for soil-less agriculture. It obtained from the coconut fruits.

##### **Characteristics of coconut fibers:**

- Possibility of use for more than one year without any change in its physical characteristics.
- Its decomposition slow therefore, it would not deteriorate quickly.
- Has capacity to hold water.
- Can provide enough airing to the substrate.



### 6.3.2. *Non-organic substrates*

#### 6.3.2.1. *Sand*

Sand considered one of the best and oldest materials used as a solid substrate for growing plants. It is preferable not to use sands containing lime due to the high rate of calcium carbonate, which acts as a welding material for sand granules and changes the physical characteristics of sand. It is also advisable not to use coast sands due to its high content of salt. It is preferable to use sands of granite or silicone origin as agriculture substrate. The diameter of sand granules is an important factor for successful preparation of agriculture substrate with sand. The coarse sand cannot hold enough quantity of moisture and very fine sand does not allow a sufficient rate of aeration. Sand characterized by good drainage capacity but its ability to hold water is weak. Therefore, it is preferable to mix it with peat moss or compost.



#### 6.3.2.2. *Vermiculite*

It is dehydrated iron, aluminum and magnesium silicate, which obtained from metallic chips from Mica mines in Africa, Australia, and America. The material to use as a substrate obtained by treating the raw element with a temperature of 1000 centigrade. Therefore, the humidity transforms to vapor which creates an increasing pressure inside its layers, which in turn fragmented to small light pieces of good porosity and characteristics appropriate to soil-less agriculture.

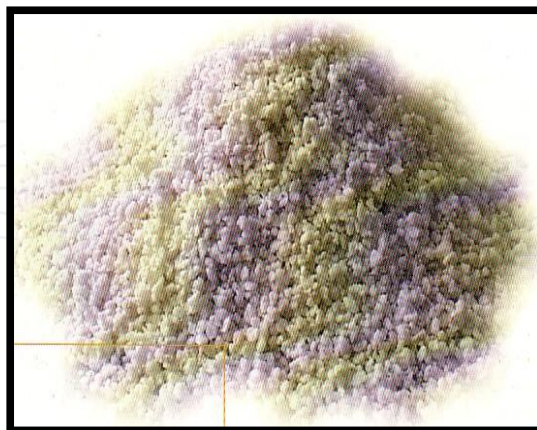


Some characteristics of Vermiculite are:

- High capacity to hold water.
- Contains magnesium and potassium in an absorbable form for the benefit of plants. It has noted that vermiculite is a good water absorption material and therefore, continues to be wet most of time; hence, it is preferable to mix it with other materials to reduce such permanent wet condition so that it would be more appropriate for plant growth.

#### 6.3.2.3. Perlite

This is a volcanic stone originated from volcanic lava of color graded from grey to white and consist of Aluminum Silicate + Sodium and Potassium, which is grinded and heated to high temperature from 900-1000°C. This results to swelling due to exodus of hot air forming air gaps, which cause large expansion, and swelling of granules.



Some characteristics of Perlite are:

- A material of stable physical consistence with no capacity of cationic alternation.
- A light weight material.

- Good drainage capacity while holding enough water. However, irrigation is preferred several times per day to guarantee the water and nutritional elements needed by the plants.
- A substrate of good airing conditions.
- A material of good capillary porosity which facilitates its irrigation by sub-surface method.
- Perlite is widely used either separately with good results or in a mix with other substrates like peat moss to grow several vegetable crops, seeds, flowers, and indoor ornamental plants.

#### 6.3.2.4. *Calcined or Expanded clays*

Heating montmorillonitic clay minerals to approximately 690°C forms calcined clays.

The pottery-like particles formed are six times as heavy as perlite.

Calcined clays have a relatively high cation exchange as well as water holding capacity.

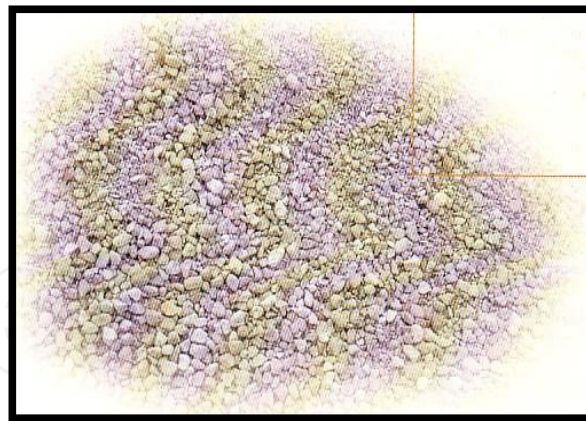
This material is a very durable and useful amendment [11].



**Expanded Clay**

#### 6.3.2.5. *Pumice*

Pumice is direct product of acidic volcanism. It is a highly vesicular volcanic glass, silicic in composition and occurs as massive blocks or unconsolidated, fragmented material. The vesicles are glass-walled bubble casts, which give pumice a low density compared to natural glass. Pumicite, the commercial term for fine-grained, fragmented pumice with shards under 2mm in diameter, may be deposited some distance from the source. Pumice is formed from silicic lavas rich in dissolved volatiles, particularly water vapor. On eruption, sudden release of pressure leads to expansion of volatile which, in turn, generates a frothy mass of expelled lava. This mass may solidify on contact with the atmosphere as a vent filling or flow, or may be shattered by a violent eruption. Pumice has many advantages such as high strength-to-weight ratio, insulation and high surface area, which result from the vesicular nature of this rock [11].



**Pumice**

Some characteristics of pumice

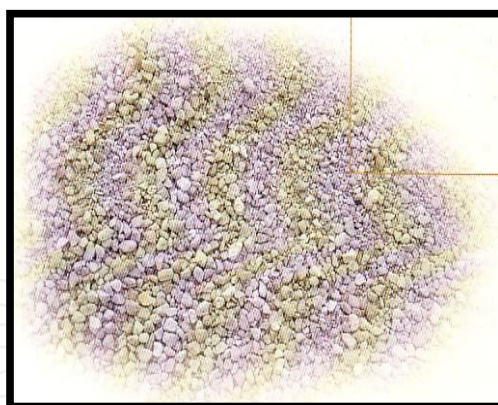
- Pumice a material similar to Perlite from the chemical point except that it contain calcium carbonate which make a problem which react with acid leading to a reduction in the size of the particle. This reduction of particle after using for longer time, the substrate can be compacted.
- It differ than perlite in physical characteristics, where this material is heavier.
- Does not absorb water easily and does not hold it for a long period.
- A substrate of good airing condition.
- Easy to clean and purify [11].

#### 6.3.2.6. Foamy rock

This is a silicon rock of volcanic origin, contains Aluminum, Potassium, Sodium, traces of Iron, Calcium, and Magnesium. The material has several gaps, which formed because of hot vapor exodus before the volcanic lava cools down. This material is available in its natural form and does not need heating but only breaking and grinding to the appropriate size of granules.

Some characteristics of Foamy rock are:

- Foamy rock is a material similar to Perlite from the chemical point of view but differs in physical characteristics, as the first material is heavier.
- Does not absorb water easily and doesn't hold it for a long period.
- A substrate of good airing condition.
- Easy to clean and purify.



#### 6.3.2.7. Rockwool

The use of rockwool has quickly spread in agriculture particularly in Europe where it used to produce many vegetable and ornamental crops.

It is a fiber produced from volcanic rocks and contains Diabase (60%), Lime stone (20%) and Coal (20%).

This mix heated to very high temperature for melting together. The melted material is transformed to fine threads of 5-micron diameter after treatment with fast centrifugal machine and cooling. The threads are then compressed and divided into the required sizes. During the cooling process, the phenol material added to help sticking the rocky wool into a substrate of good porosity.

#### Important forms and uses of rockwool

- **Germination cubes:** This could be in a single or aggregated form.
- **Seedlings blocks:** To accommodate the small germination cubic's with its contents of plants or the young seedlings directly.
- **Agricultural slices:** To which seeds of proper size transferred, where plant completes its life cycle.
- **Loose (unpacked) rock wool:** This used as substrates for cultivation in pots or mixed with other substrates to improve the characteristics of airing and water holding.

#### Some characteristics of rockwool are:

- Dry material does not contain any nutritional or non-nutritional solution.
- Sterilized material free of pests, insects, and disease.
- Very light but solid material. This facilitates its preparation and processing.
- A material of high porosity (97% of the total size) which facilitates drainage.
- Facilitates disposal of salt sediments through adding water only in the open system for leaching.

- Easy to sterilize and could be used for more than a year.



The above substrates used separately or in the form of mixture of more than one substrate.

#### 6.4. Substrates mixtures

The above-mentioned substrates could be used in a separate form as agricultural substrate or may be mixed together to attain the best characteristic for the plants to be grown.

The substrate characteristic has a strong impact on success of agricultural operation because it determines the balance between water needed for plant growth and the air necessary for root's breathing. It is therefore, necessary to have small gaps to help holding of water needed for plant life and large gaps required to ensure air necessary for its growth. Some of the most important characteristics, which assessed, are:

- Substrate's weight
- Capacity to hold water
- Acidity (PH)
- Concentration of salts
- Apparent density of substrate
- Cation exchange capacity
- Degree of stability

The above characteristics show the importance of mixing more than one substrates together to achieve the required mixtures. Some of such mixtures were tested and showed good results. Ratios of some mixtures summarized below:



**Figure 4.** Cucumber grown in sand culture under green house

Substrates	Rate of mixing
Peat moss: Perlite: sand	2:2:1
Peat moss: Perlite	1:1
Peat moss: sand	1:3
Peat moss: sand	3:1
Peat moss: vermiculite	1:3
Peat moss: perlite	1:4

**Table 1.** Some substrates mixtures. [9]

**7. The Recommended substrate system in arid lands**

**7.1. Sand culture in Egypt**

[4] had design a sand culture under plastic tunnels at Dokki Protected Cultivation Center, Cairo.

The design was as follow:

Five 0.8 \* 38rn trenches for each tunnel were excavated to a depth of 20 or 40 cm. The bottom of each trench was first leveled and graded to a slope of 12 cm per 40m [5]. The profile of the trench was adjusted to 1 (V) shape. The trench was lined with a water proof polyethylene sheet (200 p) to prevent plants from rooting into the original soil [6]. The surface of the bed was sloped to be parallel to the bottom of the trench.

There inches corrugated perforated plastic pipe placed along the bottom of each trench. The drains were connected at the lower end to a main drain that sink into a 9 m<sup>3</sup> nutrient tank. Once the drain pipes are in place, washed coarse sand obtained from Cairo - Alex. Desert road (km 40) filled to a depth of either 20 or 40 cm.

The nutrient tank was 2.0 m length X 1.5 m width X 3.0 m height with 30 cm thick concrete construction, coated with bituminous paint. This tank divided into two equal parts each designed to hold a volume of 30 to 40 % greater than maximum volume required for daily irrigation of each tunnel [10]. A float valve attached to a water refilling line in order to maintain the water level in the tank. The system is designed to recirculate the nutrient solution frequently from the nutrient tank by means of a submersible pump (1 Hp, 220V, and 2 inch in diameter outlet pipe) that was operated by a time clock, one or two times daily.

Some solid particles could be released into the recirculating solution, therefore filtration would be necessary. In fact, the tank acts as a sedimentation tank for the solid particles, which released from the main underground water supply or from recirculated nutrient solution. In addition, two filtration systems were used:

1. A coarse filter "Nylon stocking" was fitted on the outlet of the main drain pipe before the nutrient tank.
2. 150 mesh screen filter were fitted between the circulation pump and the inlet pipe to the main irrigation pipe, in such a way that it is easily removed for cleaning.

The filtration units particularly the screen filter have to be cleaned and replaced fairly frequently because solid particles retained on the screen will progressively reduce the flow rate through the screen.

A drip irrigation system was used with this sand culture [7] with excess nutrient solution (over 50 % of the total applied) to maintain recycling. Such system is termed as a closed system. The drip irrigation system feeds each plant individually by the use of two-liter emitter.

Drip irrigation system of each plastic tunnel contains 50 mm in diameter polyethylene header line. From this header line, 18 mm polyethylene pipe run along each plant row. The emitters were placed in these lateral lies at the base of each plant (50 cm distance between successive plants).

It is worthily to mention that, emitters, pipes fittings of drip irrigation system used for both soil or sand culture and the cover of nutrient tank should be black to prevent algae growth inside the piping system or the nutrient tank.

It is essential that materials used to construct the closed sand culture should not be phytotoxic. In other words, they should not have any harmful effect on the plants. No phytotoxicity has been reported from the use of concrete, bituminous pipes or sheets [5].

## **7.2. Polystyrene pot system**

There are two main systems for the polystyrene pot system:



**Figure 5.** Vertical pot system (Condensing system)

#### 7.2.1. Vertical pot system (Condensing system):

Different production systems for different crops introduced to small growers in the APRP region by ICARDA-APRP. For production of cash crops such as strawberries and beans, the vertical soilless production system was adapted to maximize growing space by growing the crops vertically. Such technique for strawberry has been investigated for last four years in Bahrain, Kuwait, Oman and Saudi Arabia and currently in Egypt has proved promising from the view point of productivity, cost and water saving. The fundamental structure of the system is the columns, which consist of 8-12 growing containers made from polystyrene on top of each other as seen in the photo. These column of polystyrene pots installed in sloped channel lined by polyethylene sheets to collect the excess of nutrient solution. At the end of the channels there is a PVC tube to collect the return nutrient solution delivering them to filter then to the nutrient solution tank. The column supported by one inch PVC tube from inside the pots. The pots filled substrate (peat moss: perlite 1:4 v/v). The crops are planted in the 4 corners of these containers. The irrigation water and nutrition solution applied to the plants using the drip irrigation and the excess of irrigation recirculated in closed system. The growing containers made locally and the system could be installed in any greenhouse or even in the open field.

#### Main advantages of the system

The production of strawberries in the vertical hydroponics system was quite successful. The hydroponics system showed followings advantage over the traditional soil-bed production system:

1. 30-50% savings in the cost of the production materials;

2. More yield per unit of water;
3. Double yield per square meter of land area;
4. Longer production season;
5. Increased income due to early season production when prices are high; and
6. Far less incidence of pests and deceases. As a result, lesser chemicals used and higher quality produces obtained.

#### 7.2.2. Simple pot system

For production of cash crops such as tomato, pepper, cantaloupe...etc, the recirculation pot system adapted to maximize growing space by growing the crops in polystyrene pots. Such technique for the cash crops has been investigated for last four years in Bahrain, Kuwait, Oman and Saudi Arabia and currently in Egypt has proved promising from the view point of productivity, cost and water saving. The fundamental structure of the system is simple containers made from polystyrene inserted in a sloped channel lined by polyethylene as seen in the photo. The crops are planted in these containers in substrate consists of perlite: peat moss (4:1 v/v). The irrigation water and nutrition solution applied to the plants using the drip irrigation and the excess of irrigation recirculated in closed system.



**Figure 6.** Simple pot system cultivated with tomato seedlings



**Figure 7.** Simple pot system cultivated with cucumber

### 7.3. Polyethylene containers

There are different types of containers suitable to substrate culture in arid lands. Also, the different containers shapes create different substrate systems as follow:

#### 7.3.1. *Open topped container (Vertical containers)*

This type of containers suitable for substrate can hold the water because it can allow a longer column of substrate for the big plants and allowed the water to be drained by gravity.

The idea for these containers to have a holes at the lowermost of the container (5 cm from the bottom) to allow the water to drain. The container filled with small gravel in these 5 cm and then by the chosen substrate. If the open system is used, the containers installed on a bed covered by polyethylene sheets and the drain water is collected and used in another use. If the closed system is used, there a gutter is installed and the containers are installed inside these gutter. The drain water collected and delivered to the nutrient solution after filtering to the nutrient solution tank.

#### 7.3.2. *Horizontal bags*

The idea of these bags is use for the substrate cannot hold the water like perlite. These bags have a short side and there are holes at the lowermost to drain the excess water. When these bags filled with water, part of these holes will be blocked and keep some water at the bottom of the bags to be a pool can supply the roots with water and nutrient.



**Figure 8.** Container system using polyethylene bags



**Figure 9.** Container system using polyethylene pots



**Figure 10.** Container system using polyethylene containers



**Figure 11.** Strawberry and sweet pepper cultivated in Horizontal bags

## 8. Water quality control in the arid lands

The limited water resources and rapid increase in population were the major factors that drew the attention towards the use of substrate in the arid lands.

The best water for substrate cropping is rainwater or water condensed from moisture - laden air. Water from these two sources has virtually no dissolved substances in it. Consequently, there is no build - up of excess ions coming into the substrate installation with the make - up water. An economy in the arid lands, the use of this scarce water can be obtained, if it is mixed with less pure water to provide a blended water in which the concentration of dissolved substances is still acceptable. If the water, that is being used has dissolved in it a substance that is being supplied by the make – up water at a faster than the crop is removing it, then an excess will accumulate in the recirculating solution. If the build - up of the excess is not too rapid, then it is quite realistic to pump out the nutrient solution from the installation after a period of time that was not sufficient duration for an adverse concentration to build up.

[2] suggested to obtain an analysis of the water supply in ppm for the following ions : nitrogen phosphorus, potassium calcium magnesium iron manganese boron, copper, molybdenum, zinc, sodium, chlorides and sulphate. From an inspection of the analytical data it should be possible to decide which ion, or ions, may build up to adversely high concentrations.

Arrangements should then be made for weekly analyses to enable the concentration of the suspect ion (or ions) to be plotted on a graph as the concentration build up. Close observation of the crop will indicate when appearance of the plants begins to be not quite right. However, this method is very - expensive.

On the other hand, [8] suggested a method for deciding when the nutrient solution can be discharging when the hard water was used. This method used successfully in Egypt when the ground water used in the substrate system.

The author suggested that the two most common salts dissolved in the hard water are calcium and magnesium. Electrical conductivity, monitored as EC increases as nutrient salts dissolved in the solution. It follows then that natural salts dissolved in water added to the EC. The EC of the water before nutrients added is known as the base EC. Use the conductivity meter to measure base EC taking care to use a representative sample, i.e., from a pond or other open water source. Collect from "open" water not from puddle edges, from the tap; run the tap for a minute before collecting the sample. If your CF meter is not 'temperature compensated adjust the sample temperature to around 20 °C before taking a reading. The author divided the water to:

1. The EC between 0 to 0.3 m.. mohs follow soft water instructions
2. The EC between 0.4 to 0,8 m.mhos follow hard water instructions
3. The EC over 0.9 m.mohs refer to special adaptations

## **9. The conductivity program using hard water (Base EC 0.4 – 0.8 m.mhos)**

The sum of the effects of using hard water make - up supplies is that, after nutrients additions to a pre-determined level, desired EC subsequent changes in solution EC don't solely reflect the removal of nutrient from the solution by the plants. This situation manifests itself as stable solution EC when make - up water EC additions more or less equate with nutrient losses, or as rising solution EC when make - up water EC additions are greater than nutrient losses. Sometimes, the solution EC may fall if marginally hard water is used. Irrespective of the manifestation, the effect is a gradual decline of the nutrient status of the solution. This decline must be arrested and the following procedure demonstrates how this is done

### **9.1. At system start - up**

Fill the nutrient solution tank with clean water, begin circulation and bring the system to operating capacity. Check, and note, the base CF of the water in the nutrient solution tank. Add the acid to reduce water pH close to desired pH "between 6 - 6.5". The amount of acid used will depend on the hardness of the water. It is useful to keep a record of the amount of acid required so that future treatment of the same volume, after solution discharges, will be rapidly accomplished. Do not overdose; avoid lowering the pH much below 6.0.

Determine desired EC depending on the crop and use the following equation:

$$\text{Target EC} = \text{Desired EC} + 1/2 \text{ Base EC}$$

Add nutrient stock solution A & B in equal volumes, unless specifically desired to do otherwise, to achieve target EC.

Add nutrient A first and allow this to disperse a little before adding B. Allow time between nutrient additions and monitoring EC for the nutrients to disperse throughout the system. This process may be encouraged by stirring the solution in the circulation tank. When target EC achieved check solution pH and adjust if necessary.

The following examples illustrate this procedure :

- Base EC of make - up water 6
- Solution volume in the nutrient solution tank 210 liters
- Original target EC 1.3
- Make – used water up 70 liters
- Therefore, make - up water volume is  $\frac{1}{3}$  rd. of solution volume and contributes proportionally to the solution EC i.e.,  $6 \text{ divided by } 3 = 2$ .
- Target EC = Desired EC + Base EC =  $1.3 + \frac{1}{2} (2) = 1.3 + 0.1 = 1.4 \text{ m.mhos}$
- The new target EC = 1.4 m.mhos then add nutrients A & B to bring the solution to the new target EC.

## 9.2. Discharging the solution

Eventually the target EC will be raised to an unacceptably high value. Generally, this occurrence dictates the time the solution should be discharged. The frequency of discharging will be regulated by the rate of water removal by the plants of course, but also and particularly by the hardness, manifested as base EC of the make - up water.

The general advice, found to have great practical utility, is to allow the rise in EC to continue until it passes a value 50 % greater than the original EC. When it reaches this value you have to discharge the nutrient solution.

Some mono crop growers adopt the procedure of discharging the solution when the target EC reaches twice the desired EC.

## 10. The special program for using very hard water (0.9 or above)

The principal problems with very hard water supplies, base EC 0.9 m.mhos or above, are these:

First, because of the very high level of natural salts present, there is a large oversupply of those which are also nutrient salts, so that a smaller proportion are removed from the system due to take up by the plants.

Second, large amounts of acid are required to neutralize the salts. The result is that start - up solution EC, already high due to high base EC, is quickly increased by make - up water and acid additions, and there is reduced scope to assign these EC increases to useful nutrients. The practical significance is that the full base EC must be allowed at system start - up when

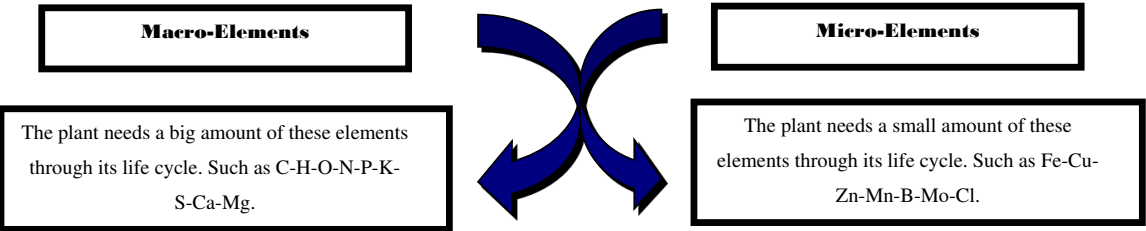
calculating a target EC and when maintaining nutrient levels in the solution by setting a new target EC. Accordingly, when using very hard water supplies, calculation of target EC uses the following equation:

Target EC = Desired EC + Base EC

Then it follow the same procedure as described in the hard water (EC 0.4 – 0.8 m.mhos)

## 11. Nutrient solution composition

Plants require 16 essential elements for their growth and development. Without these nutrients, plants cannot complete their life cycles and their roles in plant growth cannot replaced by any other elements. These 16 elements divided into micro and macro element categories as sketched bellow.



All the nutrient elements required for plant growth have to be present in the nutrient solution for soilless culture systems. Some of the elements may be present in adequate quantities as in the water supply. Other elements will have to be added to the water. These usually are:

N – P – K – Ca – Mg - Fe- Mn – B – Cu – Zn - Mo.

**\*\*Ideal Concentrations (ppm) of Elements in Nutrient Solution for tomato is given below as an example**

Elements	Symbol	Concentrations
Nitrogen	N	200
Phosphorus	P	60
Potassium	K	300-350
Calcium	Ca	170
Magnesium	Mg	50
Iron	Fe	3-6
Manganese	Mn	0.5-1.0
Boron	B	0.3
Copper	Cu	0.1
Molybdenum	Mo	0.2
Zinc	Zn	0.05

## 12. Conclusion

It is clear to solve the problems in the arid lands as shortage of water and lack of technology and the limited income of the grower that using simple but the high technology substrate culture can be a substitute of the soil cultivation. This is because that most of the equipment produced locally, the prices of this equipment's is reasonable and can be afforded by the medium class grower special the grower is producing for export. This technique is saving water, there is no need of soil sterilization, there is no for land reclamation.

The most system of the simple substrate system is the column polystyrene pot system for the small plants and the single polystyrene system for the big plants, which can isolate the plants from the high temperature.

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