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SOILLESS CULTURE, A TOOL FOR MAXIMIZING THE UTILIZATION OF ARID LAND RESOURCES

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Abstract: Soilless culture techniques were developed under glass houses in order to overcome major agricultural problems such as nutrition, plant diseases and environmental pollution. The development of different types of soilless culture is summarized in the present paper. The development of simple low cost system for hydroponic was the main challenge to make soilless culture possible in Egypt. Several attempts to design and implement the different techniques of soilless culture were followed and were proved to be economically viable and environmentally safe. The utilization of such techniques resulted in improving water use efficiency to a great extent and helped to reduce the amount of chemicals used for pest and disease control to a considerable low level. The cost of production is relatively high but future research may be promising to reduce the cost and hence improve the applicability of these systems on a large scale in arid lands.

INTRODUCTION

The limited water resources and rapid increase in population were the major factors that drew the attention towards the use of intensive agriculture in Egypt. 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 through the use of hydroponic systems. (Zayed et, al. 1989).

The need for the use of soilless culture is becoming more important in Egypt than several years ago in order to increase the water use efficiency. (Zayed et, al. 1989).

Several possibilities and options of soilless culture are available to be used in Egypt. Nutrient film technique (NFT) and rockwool are the most expanded systems compared to the other systems. Even though it was found that rockwool should be replaced every other years, which means another additional cost compared to the nutrient film technique (NFT).

Several efforts have been made to introduce the nutrient film technique (NFT) in Egypt started initially in the tourist villages where the soil could not cultivated successfully. Never the less, there still be a good opportunity, to increase the water use efficiency by using other systems like the aeroponic systems.

DEFINITIONS

Soilless culture is a technology for growing plants in nutrient solution (water and nutrients) with or without the use of an artificial medium (e.g. sand, gravel, vermiculite, rockwool, peat moss, sawdust ...etc.) to provide mechanical support. Liquid hydroponic systems have no other supporting medium for the plant roots; aggregate systems have a solid medium of support. The term of hydroponic has used to described the growing plant in any media separated from the soil (Cooper 1979). Hydroponic systems are further categorized as open (i.e., once the nutrient solution is delivered to the plant roots, it is not reused) or closed (i.e. surplus solution is recovered, replenished, and recycled).

Some regional growers, agencies and publications persist in confining the definition of hydroponics to liquid systems only. This exclusion of aggregate hydroponics serves the blur statistical data and may lead to underestimation of the extent of the technology and its economic implications. Virtually all hydroponic systems are enclosed in greenhouse. Type structures in order to provide temperature control, to reduce evaporative water loss, to better control disease and pest infestations and to protect hydroponic crops against the elements of weather, such as wind and rain. Hydroponics are widely used to grow flower, foliage and bedding plants as well as certain high - value food crops but the vegetable crops are the most favorable crops growing in hydroponics in Egypt. (Jensen and Collins 1985).

HYDROPONICS CAN BE DIVIDED IN TWO CATEGORIES

Liquid (non aggregate) hydroponic systems
Aggregate hydroponic systems

LIQUID (NON AGGREGATE) HYDROPONIC SYSTEMS

Liquid systems are, by their nature, closed systems in which the plant roots are exposed to the nutrient solution, without any type of growing medium, and the solution is reused.

a. Nutrient Film Technique (NFT)

1. Definition :

NFT is the method of growing in which the plants have their roots in a shallow stream of recirculating water in which are dissolved all the elements required where there is no solid rooting medium.

A root mat develops which is partly in the shallow stream of recirculating water and partly above it. Thus, the stream is very shallow and the upper surface of the root mat which develops above the water, although it is moist, is in the air. So around the roots which are in the air, there is a film of nutrient solution - hence the name nutrient film technique (NFT). (Cooper 1979).

The key requirements in achieving a nutrient film situation are :

1. A uniform gradient down which the water flows is uniform and not subject to localized depressions - not even a depression of a few millimeters.
2. The inlet flow rate must not be so rapid a considerable depth of water flows down the gradient.
3. The width of the channels in which the roots are confined must be adequate to avoid any damming - up of the water by the root mat.
4. The base of the channel mat be flat and not curved, because there will be a considerable depth of liquid a long the center line of a channel with a curved base merely because of the shape of the base. (Cooper 1979).

2. Description

The nutrient film technique was developed during the late 1960, by Dr. Allan Cooper at the Glasshouse Crops Research Institute, Littlehampton, England (Winsor et al., 1979), a number of subsequent refinements have been developed at the same institution (Graves 1983). In a nutrient film system, a thin film of nutrient solution flows through plastic lined channels, which contain the plant roots; the walls of the channels are flexible, to permit them being drawn together around the base of each plant to exclude light and prevent evaporation. The nutrient solution is pumped to the higher end of each channel and flows by gravity past the plant roots to catchment pipes to the catchment Fig.(1). The solution is monitored for replenishment of salts and water before it is recycled. Capillary material in the channel prevents young plants from drying out, and the roots soon grow into a tangled mat.

3. Design of NFT channels for use on a prepared surface

In the design of a universal channel, a rigid base was incorporated as part of the design. If a universal channel is not used it is essential to prepare the surface of the ground so that, it has a smooth, permanent, sloping surface that will not change. Cooper (1979) reported that compacted soil is not suitable because it will be subject to uneven settlement when it becomes wet, subsidence will occur irregularly and localized depressions will develop. Covering the prepared surface with a layer of concrete, or with strips of concrete on which the NFT channels rest, is an obvious possibility, but concrete is expensive. The author reported that there is a need for some development work to determine the cheapest possible method of treating the surface of the ground to provide a permanent, smooth slope free from localized depressions in the context of NFT cropping. Mr. Robert Power, a pioneer NFT grower in Barbados, has covered his site with sand of a sufficient depth give a smooth slope and has then spread on top of the sand a one centimeter lager of a coarse sand : cement mix of 5:1. By moistening the surface, rolling it with a vibrating roller and allowing it to set, a permanently smooth slope was achieved. Maintenance of the surface was, however, necessary because cracks developed which had to be filled without delay by hand.

Mr. Len Dingemans, a pioneer NFT lettuce grower in England, has even formed the NFT channels in the lager of concrete with which he covered his site. Every 23 centimeters (9 inches) there is a flat bottomed channel in the concrete which is 10 centimeters (4 inches) wide and 2.5 centimeters (1 inch) deep. In these channels in the concrete the places small compressed soil blocks which support the young lettuce plants.

After a while the roots grow out into the channel, down which the nutrient solution is recirculating, and the plants become self - supporting. The leaves eventually spread out as the lettuces heart - up and form a "lid" over the channel which prevents any further water loss by evaporation and, by cutting out the light, kills out the algae which initially grew in the recirculating solution while it was exposed to the light.

In Egypt, Zayed et al., (1989) has developed a simple method of NFT greenhouse as described in Fig.2. Two catchment tanks with holding capacity of $3m^3$,each were placed in a trench dug across the middle of the greenhouse. The ground was prepared to have five ridges 29m long, 1m wide, in each side of the tanks. The ridges had a uniform slope of 1 in 100 either side made from a compacted soil. A thin layer of sand was added to the surface of the ridges to reduce depression. The gullies were laid on top of the ridges, two gullies per ridge, in parallel lines down the slope, the gullies were made from strips of black on white polyethylene, 80 cm wide. The two edges of the strip were raised, to from a trough, and stapled together between the plants. Tanks were filled with nutrient solution, which was circulated by two submersible pumps, one for each tank. Solution was passed into one meter PE. hose to the top ends of the gullies which the solution was allowed to flow by down gravity. The solution was collected in a 6 in PVC pipe at the end of the gully and returned to the catchment tank for recirculation.

On the other hand, in the sandy soils in North Sini where, the soil is sandy, for preparing the slope. The greenhouse divided in two parts. The slope had made from the end of the greenhouse middle. The space between the sloped ridges were filled with sand to reduce the collapse of the ridges Fig

(3&4). Some soil was mixed by the sand to make the sand more rigid to reduce also the collapse of the ridges. The solution was collected by a sloped channel made from cement to a catchment tank which made also from the cement outside the greenhouse to increase the efficiency of using the space in the greenhouse. (El-Behairy 1996).

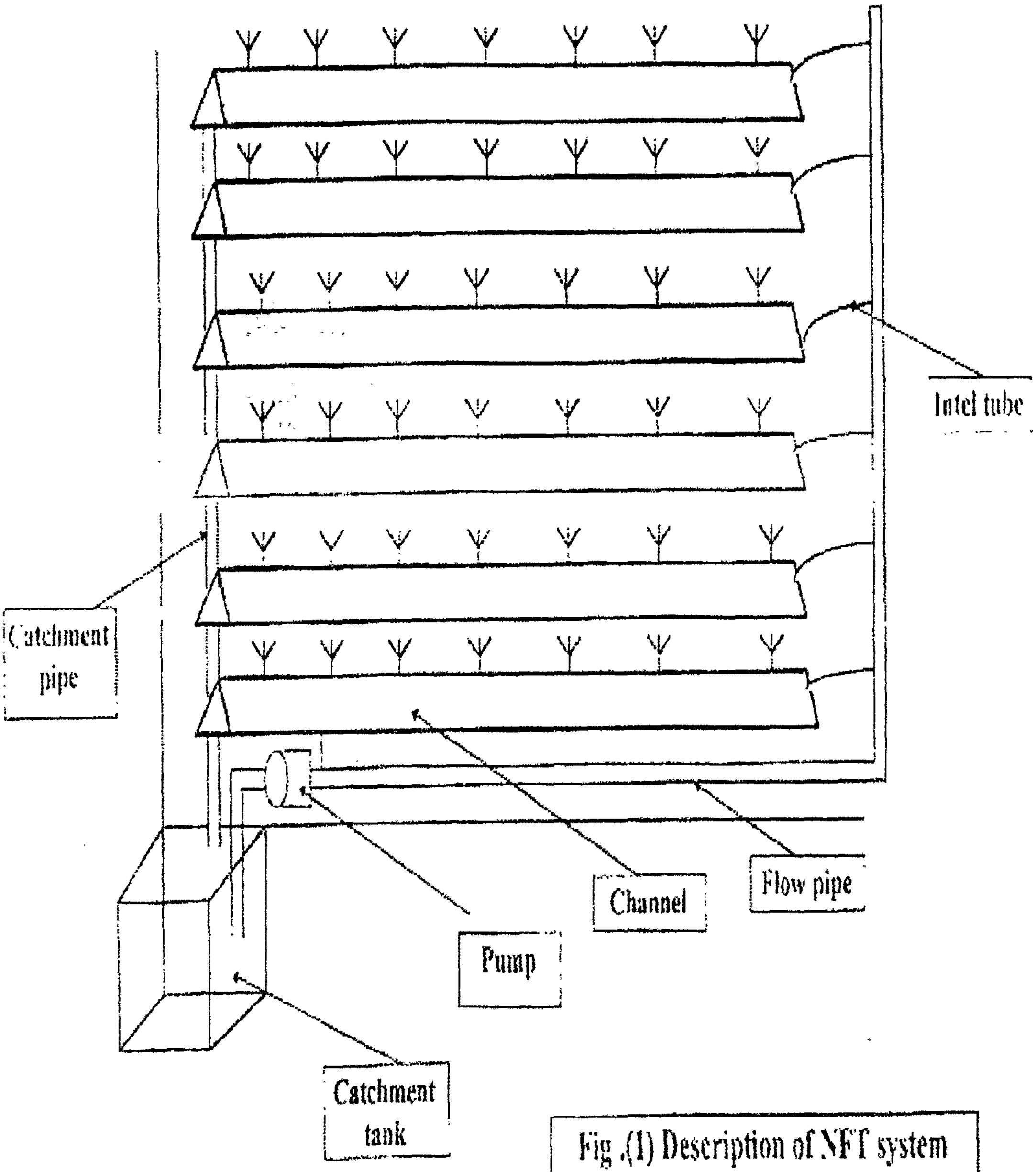

Fig .(1) Description of NFT system
Source Cooper (1979)

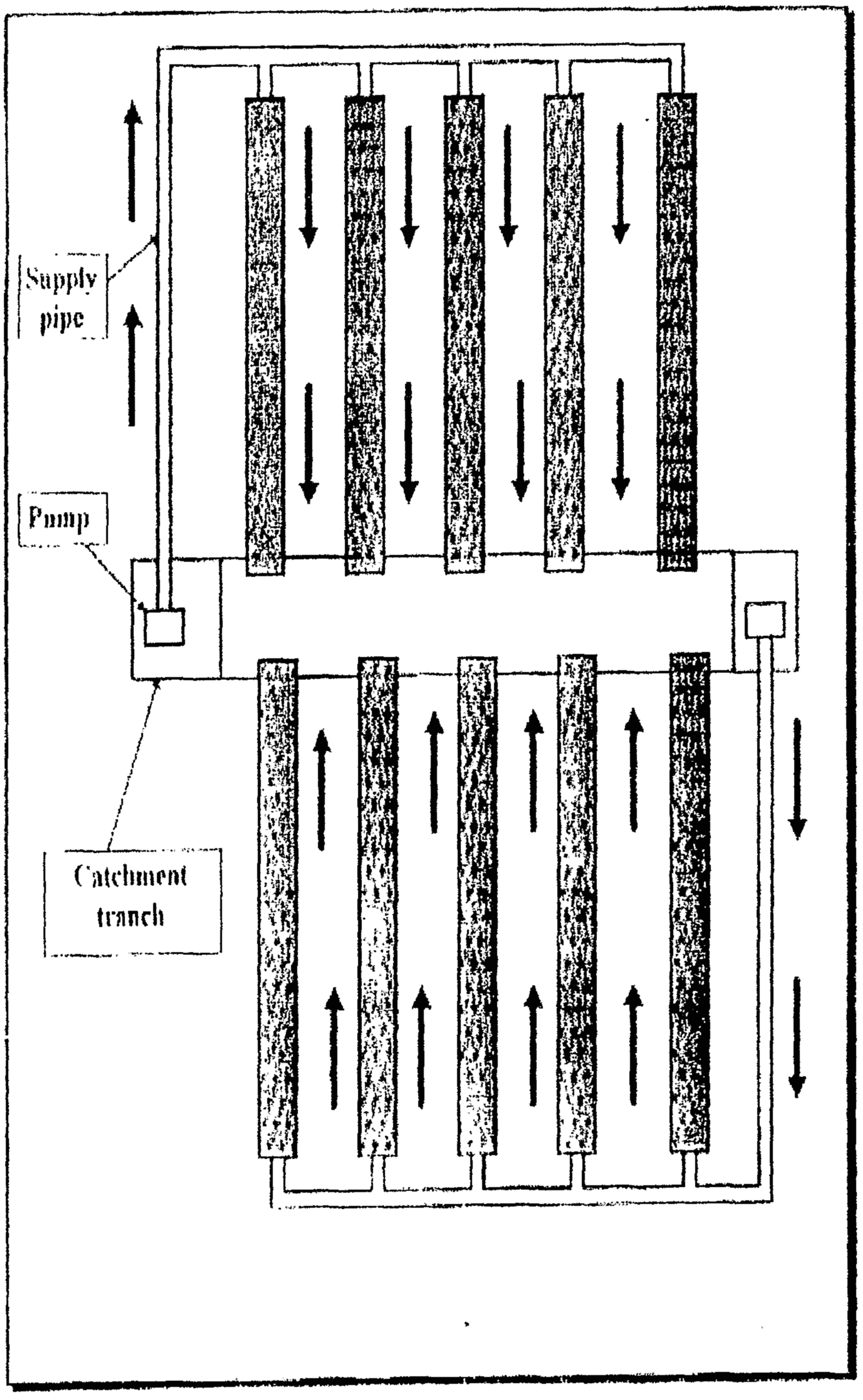

Fig. 2. Description of simple NFT system design in Egypt (Source: Zayed et al., 1989)

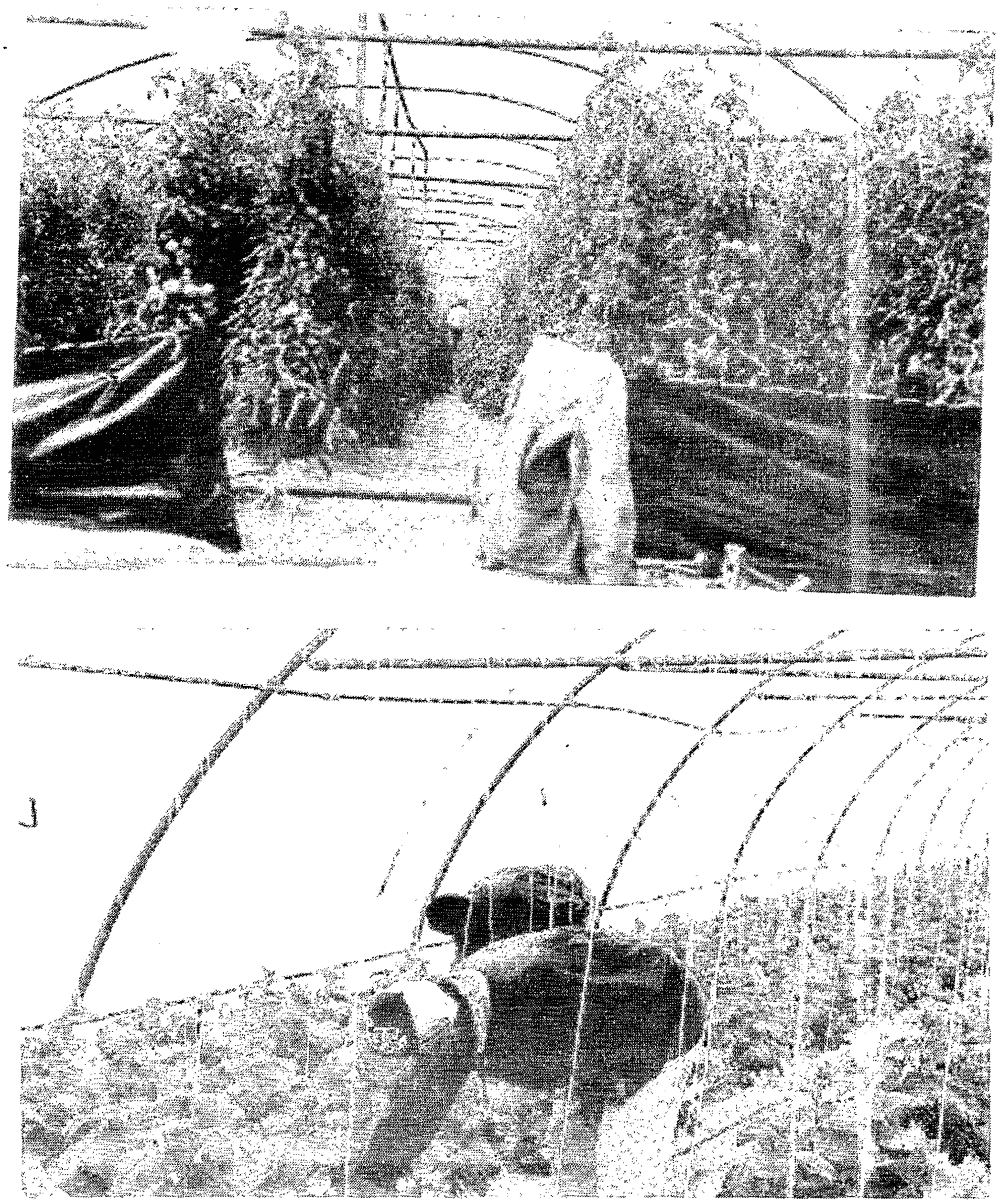

Fig. 3. Tomato and cucumber production using NFT in North Sinai
Source : El-Behairy (1996)

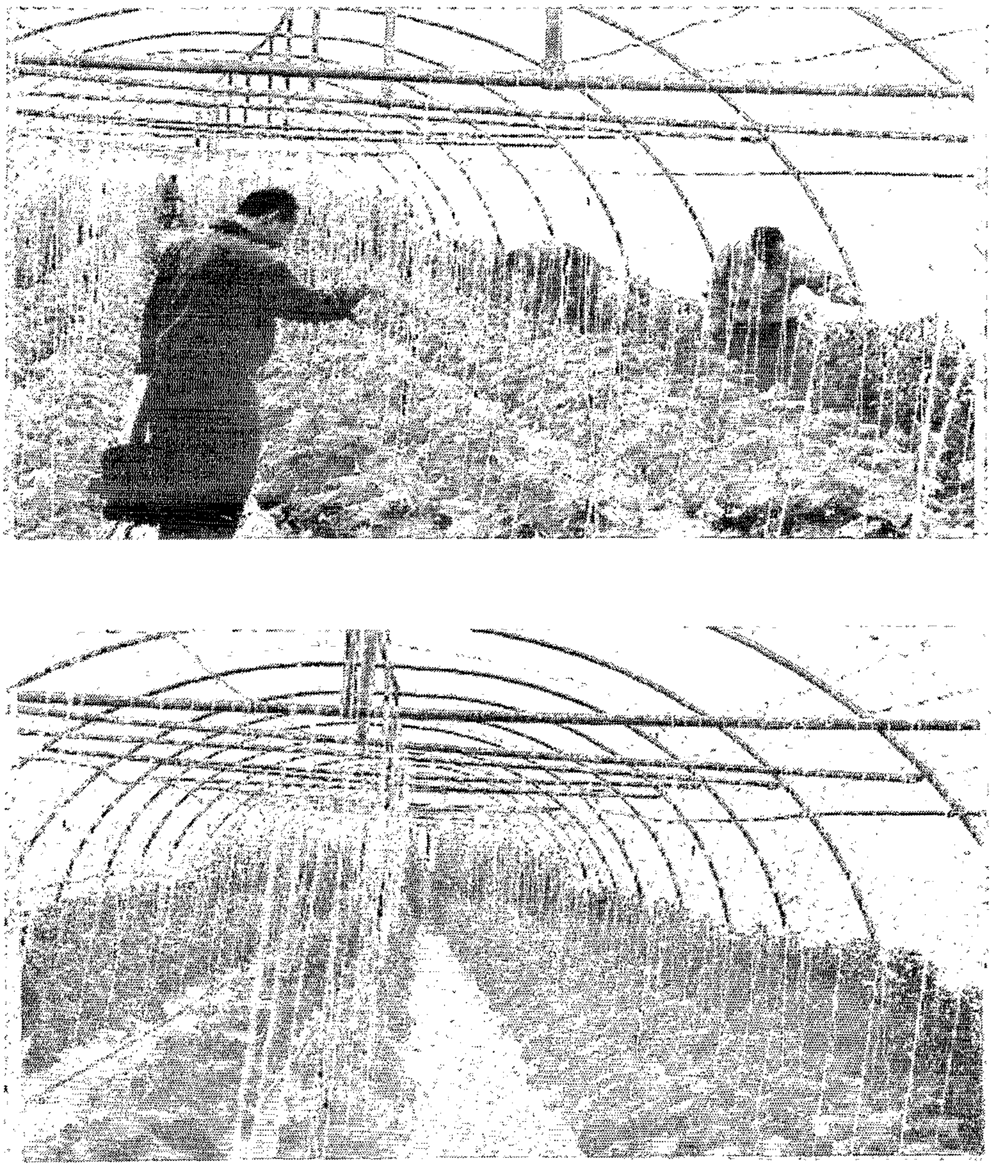

Fig. 4 Vigorous cucumber plants grown in NFT North Sinai
Source : El-Behairy (1996)

Water quality control :

The best water for NFT 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 an NFT installation with the make - up water. An economy in the use of this often 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 in the NFT installation. 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.

Cooper, (1979) 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. But this method is very expensive.

On the other hand, Molyneux (1988) suggested a method for deciding when the nutrient solution can be discharging when the hard water was used. This method is used successfully in Egypt when the ground water used in the NFT system.

The author suggested that the two most common salts dissolved in the hard water are calcium and magnesium. Electrical conductivity, monitored as CF, increases as nutrient salts are dissolved in the solution. It follows then that natural salts dissolved in water added to the CF. The CF of the water before nutrients are added is known as the base CF. Use the conductivity meter to measure base CF 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)	0 - 3 CF	follow soft water instructions
2)	4 - 8 CF	follow hard water instructions
3)	9 or above	refer to special adaptations

The conductivity program using hard water (Base CF 4 - 8) :

The sum of the affects of using hard water make - up supplies is that, after nutrients additions to a predetermined level, desired CF, subsequent changes in solution CF do not solely reflect the removal of nutrient from the solution by the plants. This situation manifests itself as stable solution CF when make - up water CF additions more or less equate with nutrient losses, or as rising solution CF when make - up water CF additions are greater than nutrient losses. Sometimes, the solution CF 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.

At System Start - Up :

Fill the circulation tank with clean water, begin circulation and bring the system to operating capacity. Check, and note, the base CF of the water in the circulation 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 CF depending on the crop and use the following equation :

$$\text{Target CF} = \text{Desired CF} + {}^{1}/_{2}\ \text{Base CF}$$

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

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

The following examples illustrate this procedure :

Base CF of make - up water	6	
Solution volume in circulation	210	liters
Original target CF	13	
Make - up water used	70	liters

Therefore, make - up water volume is ${}^{1}/_{3}$ rd. of solution volume and contributes proportionally to the solution CF i.e., 6 divided by ${}^{1}/_{3}$ = 2.

$$\begin{aligned}\text{Target CF} &= \text{Desired CF} + {}^{1}/_{2}\ \text{Base CF}\\ &= 13 + {}^{1}/_{2}\ (2)\\ &= 13 + 1 = 14\end{aligned}$$

The new target CF = 14 then add nutrients A & B to bring the solution to the new target CF.

Discharging the solution :

Eventually the target CF 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 CF of the make - up water.

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

Some monocrop growers a dot the procedure of discharging the solution when the target CF reaches twice the desired CF.

The special program for using very hard water (9 or above) :

The principal problems with very hard water supplies, base CF 9 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 CF, already high due to high base CF, is quickly increased by make - up water and acid additions, and there is reduced scope to assign these CF increases to useful nutrients.

The practical significance is that the full base CF must be allowed at system start - up when calculating a target CF and when maintaining nutrient levels in the solution by setting a new target CF. Accordingly, when using very hard water supplies, calculation of target CF uses the following equation:

$$\text{Target CF} = \text{Desired CF} + \text{Base CF}$$

And then it follow the same procedure as described in the hard water (CF 4 - 8).

Interrupted flow of the nutrient solution :

The use of intermittent flow technique with hydrophilic plants has so far been restricted to early management. It is inappropriate to cut off the flow during the daytime during any period of rapid growth once roots have extended into the channels, except for very short duration such as at discharging. However, switching off the flow during periods of reduced or insignificant growth can be a very useful technique because it provides an opportunity for reducing excess moisture around the base of the stem and the root, thereby restricting the possibility of disease. Additionally, the technique is known to promote root growth and may beneficially affect root activity. Periods of reduced or insignificant growth include the hours of darkness and other periods when temperatures or light are inadequate. As a result the circumstances where the flow may be advantageously interrupted are quite varied, but note also, that many times excellent results have been achieved without any interruptions to flow.

Wilting, as a result of insufficient root or root death, may be alleviated by switching off the flow at night. Of course, as this condition usually occurs in summertime during long days, the opportunity for switching off is limited, but is nevertheless useful. If a crop is open to receive early morning sunshine then, it is imperative that the flow is reinstated before dawn. Some growers institute night time shutting off as standard procedure because, it is felt it acts as a preventative of excessive root death as well as ensuring adequate root quantity. The evidence for this is not conclusive. However, during the later season when growth rate has declined and with it the demand for water, there is an opportunity for switching off flow each night to allow the propagation blocks to dry and to reduce dampness surrounding the plants. Similarly, if plants are over wintered in the nutrient solution, especially lettuce and other plants set out late for early production the following season, then it is advantageous if the flow is switched off at night and indeed at other times where there is no possibility of growth and where some reduction of root zone and atmospheric moisture is desirable. The greatest difficulty of interrupted flow regimes is the complication of switching off and on. On some sites, there is no difficulty, but in the domestic situation it can be an unnecessary chore unless the operation is automated. Where automation is introduced ensure that the stopping and starting of flow is compatible with any solution heating program simultaneously employed.

In the countries where the whether are stable it is possible to use an electric timer for switching on and off the flow but in the countries where the whether are unstable it is recommended to use a solar meter connected with computer to count the accumulation of the short wave radiation to the

0.3 MJ^{-2}, then the flow will switch on for 15 minutes. By experience the flow can be switched on for 15 minutes 3 to 5 times in the cloudy whether El-Behairy (1990). This can save the energy, the pump and the water.

Where the hydrophobic plants occupy channels especially prepared with aggregate, intermittent flow is the rule rather than the exception. Here the on - flow time is gradually increased to allow for increased water uptake due to larger plants and improvement of the season, so that by mid - summer the on - flow time may be all day. Later, as the season declines, the on - flow time is reduced so that by late autumn or early winter, just an hour or two on - flow per fortnight is ample in poor conditions. There is no doubt that these desirable changes in on - flow times do worry inexperienced NFT growers, especially as it is not possible to give precise day by day or week by week instructions. Occasional failure to switch off at night in mid - summer or failure to switch on promptly at other times is most unlikely to have a noticeable affect on the plants. Two parameters are utmost. Always allow the propagation block to dry, at least at the top, before restarting flow and judge the effectiveness of the regime by the growth of the plants.

Aeroponics :

The idea of the aeroponics is to grow the plants in holes in panels of expanded polystyrene or other material with the plant roots suspended in mid air beneath the panel and enclosed in a spraying box. The box is 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 is normally turned on for only a few seconds every 2 - 3 minutes. This is sufficient to keep the roots moist and the nutrient solution aerated.

Aeroponic systems of this type, with inclined polystyrene surfaces, were first described in detail in 1970 by Massantini (1973) in Italy. Similar systems were developed subsequently by M.H. Jensen in Arizona for lettuce, spinach and even tomatoes, although the latter was judged not to be economically viable. In fact, there are no known large - scale commercial aeroponic operations in the United States, although several small companies market systems for home use. For some types of advanced horticulture, such as rooted cuttings of imported foliage plant materials without soil, aeroponics may prove to be suitable.

The A. frame aeroponic system developed in Arizona for low, leafy crops may be feasible for commercial food production. Inside the structure, the frames are oriented with the inclined slope facing east - west. The expanded plastic panels are standard - sized (1.2m X 2.4m), mounted length wise, and spread 1.2m at the base to form an end - view equilateral triangle. The A - frame rests atop a panel - sized watertight box, 25 cm deep, which contains the nutrient solution and misting equipment (Jensen 1980). Young transplants in small cubes of growing medium are inserted into holes in the panels, which are spaced at intervals of 18 cm on center. The roots are suspended in the enclosed air space and misted with nutrient solution as described previously.

An apparent disadvantage of such a system is uneven growth resulting from variations in light intensity on the inclined crops (Giboney 1980) further studies on variance of slope are therefore indicated. An advantage of this technique for lettuce or spinach production is that twice as many plants may be accommodated per unit of floor area as in other systems, i.e., as with vine crops, the cubic volume of the greenhouse is better utilized. Unlike the small test systems described here, larger plantings could utilize A - frame more than 30m in length, sitting atop a simple, sloped trough that collects and drains the nutrient solution to a central sump; greenhouses, furthermore, could be designed to be much lower in height.

Another potential commercial application of aeroponics, in addition to the rooting of foliage plant cuttings, would be the production of leafy vegetables in locations with extreme restrictions in area and/or weight. This would specifically include very large, manned space vehicles for extended occupancy. Jensen`s (1980) work has included the development of aeroponic systems in a revolving "space drum" that simulates extraterrestrial gravity. Later, the Boeing Co. further developed these concepts.

Abou- Hadid et. al. (1994) had done a preliminary studies on the use of aeroponics for vegetable crops under Egyption condition. They described the system by using expanded polystyrene sheets arranged in the " A " shape with a dimension of 1.8 m long, 0.55 m basal width and the height of each side was 0.9 m (Fig.5). The polystyrene sheet thickness was 2.5 cm and covered with black on white polyethylene film, 200 μ, for extra radiant insulation. The plants were inserted into holes spaced 25 cm apart in 4 rows, with total of 30 plants on each side. Plant density of 41.67 plants/m^2 was obtained . For nozzles, 40 cm apart, were used for each unit which were served by a non- submersible pump of 1.8116 Amps. The structure was sloped towards the solution tank which served as a catchment tank at the same time. The nutrient solution spraying was controlled using a pre-set timer which turned-on for five minutes and off for five minutes from 7.00 am to 8.00 p.m. and continuously off from 8.00 p.m. to 7.00 am.

The authors confirmed that the possibility of using the aeroponic technique for further investigations to study the economics of some other vegetables and the water use efficiency

AGGREGATE HYDROPONIC SYSTEMS

In aggregate hydroponic systems, the plant has to grow in a solid medium. To chose the best aggregate materials to be suitable for the hydroponic system, there are some key characteristics have to be provide by the materials :

1. It has to be solid to support the plants.
2. It has to be inert "not contain any nutrient element.
3. It can hold enough water.
4. It can hold enough oxygen at the same time with holding the water.
5. It is not contain any toxic component to the plants.
6. It is not contain any disease.

In all aggregate hydroponic system, the nutrient solution is delivered directly to the plant roots. Also the aggregate system may be either open or closed, depending on whether, once delivered, surplus amounts of the solution are recovered and reused. Open systems do not recycle the nutrient solution, closed system do.

Open systems :

In most open hydroponic systems nutrient solution is recovered; however, the surplus is not recycled to the plants but is disposed of in evaporation ponds or used to irrigate adjacent landscape plantings or windbreaks. Because the nutrient solution is not recycled, such open systems are less sensitive to the composition of the medium used or to the salinity of the water. This in turn has given rise to experimentation with wide range of growing media and development of lower cost designs for containing them. In addition to wide growing beds in which a sand medium is spread across the entire greenhouse floor, troughs, trenches, and bags are also used, as well as, slabs of porous horticultural grade rockwool.

Fertilizers may be fed into the irrigation water with proportions or may be mixed with the irrigation water in a large tank or sump. Irrigation is usually programmed through a time clock, and in larger installations, solenoid valves are used to allow only one section of a greenhouse to be irrigated at a time.

1. Trough or Trench Culture :

Some open aggregate system involve relatively narrow growing beds, either as above grade troughs or sub grade trenches, whichever are more economical to construct at a given site. In both cases the beds of growing media are separate from the rest of the greenhouse floor and confined within waterproof materials. For ease of description, this will hence forth be called trough culture.

Concrete is a traditional construction material for permanent trough installations (It may be covered with an inert paint or epoxy resin); fiberglass or plybord covered with fiberglass is also used. To reduce costs, polyethylene film, at least 0.01 cm in thickness, is now commonly used. The film, usually in double layers to avoid leakage, is placed atop a sand base and supported by either planks, cables, or concrete blocks (Jensen 1968; Sheldrake and Dallyn 1969).

The size and shape of the growing bed are dictated by labor efficiencies rather than by engineering or biological constraints. Vine crops such as tomatoes usually are grown in troughs only wide enough for two rows of plants, for ease in pruning, training, and harvesting. Low flowering plants are grown in somewhat wider beds, with a midpoint a worker can conveniently reach at arm's length. Bed depth varies with the type of growing media, but about 25 cm is a typical minimum; shallower beds of 12 - 15 cm are not uncommon but require more attention to irrigation practices. Length of the bed is limited only by the capability of the irrigation system, which must deliver uniform amounts of nutrient solution to each plant, and by the need for lateral walkways for work access. A typical bed length is about 35m. The slope should have a drop of at least 15 cm per 35m for good drainage, and there should be a well- perforated drain pipe of agriculturally acceptable material inside the bottom of the trough beneath the growing medium.

As open systems are less sensitive than closed systems to the type of growing medium used, a great deal of regional ingenuity has been displayed in locating low - cost inert materials for trough culture. Typical media include sand (Jensen 1971), Vermiculite (Harris 1976), sawdust (Adamson and Maas 1981; Maas and Adamson 1981), perlite, peat moss (Maher 1976), mixtures of peat and vermiculite (Jensen 1968), and sand with peat or vermiculite (Smith 1982). One of the most effective of these materials is a mixture of peat moss and vermiculite developed at Cornell University (Sheldrake and Boodley 1965) to provide trough growers with a sterile soil. The peat moss - vermiculite medium is customarily used with drip or trickle irrigation systems.

2. Bag Culture :

Bag culture is similar to trough culture, except that the growing medium is placed in plastic bags, which in lines on the greenhouse floor, thus avoiding the costs of troughs or trenches and complex drainage systems. The bags also may be used for at least two years and are much easier and less costly to steam sterilize than bare soil.

The bags are typically of UV - resistant polyethylene, which will last for two years (Sheldrake 1981); they have a black interior. The exterior of the bag should be white in deserts and other regions of high light levels in order to reflect radiation and inhibit heating the growing medium; conversely, a darker exterior color is preferable in northern, low - light latitudes to absorb winter heat. Bags used for horizontal applications are usually 50 - 70 liter in capacity. Growing media for bag culture include peat, vermiculite, or a combination of both to which may be added polystyrene beads, small waste pieces of polystyrene, or perlite to reduce the total cost. When used horizontally, bags are sealed at both ends after being filled with the medium.

The bags are placed flats on the greenhouse floor at normal row spacing for tomatoes or other vegetables (Judd 1982) although it would be beneficial to first cover the entire floor with white polyethylene film. M.H. Jensen demonstrated with trough culture in New Jersey that 86 % of the radiation falling on a white plastic floor is reflected back up to the plants compared with less than 20 % of the light striking bare soil. Such a covering may also reduce relative humidity and the incidence of some fungus diseases. Paired rows of bags are usually placed flat, 1.5m apart (from center to center) and with some separation between bags. Holes are made in the upper surface of each bag for the introduction of transplants, and two small slits are made low on each side for drainage or leaching. Some moisture is introduced into each bag before planting. Less commonly, the bags are placed vertically with open tops for single - plant growing; these have the disadvantages of being less convenient to transport, requiring more water, and maintaining less even levels of moisture.

Drip irrigation of the nutrient mix is recommended, with a capillary tube leading from the main supply line to each plant. Plants growing in high - light, high temperature conditions will require up to 2 liters of nutrient solution per day. Moisture near the bottom of the bagged medium should be examined often (Sheldreke 1981).

The most commonly grown crops in bag culture are tomatoes and cucumber (also cut flowers). When tomatoes are grown, each bag is used for two crops per year for at least 2 years. It has not yet been established how many crops may be grown before the bags must be replaced or steam sterilized, but the latter is performed by moving the bags together under a tarpaulin, at an estimated cost of less than $ 1000/ha (Sheldrake 1981).

3. Rockwool Culture :

Rockwool is making a major impact on horticulture around the world, of which only the tip of the iceberg has yet been recognized. Since it was first seriously considered as an inert substrate for glasshouse crops only a little more than a decade ago, the interest which has been generated in rockwool has expanded year by year. Developed initially in Denmark, it was quickly taken up by the Dutch and eventually moved into Britain and France. Now, there are a rapid expansion both in Europe and further afield, including the USA, Canada, New Zealand and Australia. In all these centers of horticulture experience will be gained which, when pooled, will eventually make rockwool the most widely researched plant medium since soil.

The main use for rockwool, and the use which makes the most of its unique characteristics, is as a substrate in its own right. For this purpose, the material is formed into slabs or blocks, into which the crop is rooted.

The characteristics of rockwool which make it so suitable as a growing medium are as follows :

* The most important features of rockwool are those which relate to the way it responds to watering and feeding.
* It is to all intents and purposes totally inert chemically except for some minor effect on pH, it does not modify any nutrient solution which is applied to it, and neither does it inhibit the availability of any of these applied nutrients to the crop.
* It has a massive pore space which can hold both nutrient solution and air to supply the roots. When rockwool slabs are fully watered the ratio of water to air in the substrate is ideal for root growth it cannot be over watered.
* The plants can take out a much greater proportion of the nutrient solution in the medium much more easily than they can from other substrates such as soil or peat.
* The rockwool can safely be over watered, large volumes of solution can be used to flush out unwanted nutrients such as sodium from the rooting zone without at the same time water logging the roots.
* Rockwool is a completely sterile medium and that it is ideally suited to temperature regulation (Smith 1987).

a- Requirements for rockwool culture :

To make a success of rockwool culture, it is necessary to have certain facilities to hand. Basically, these are :

1. A source of good quality water which is available in adequate quantities throughout the growing season. Poor quality water can be cleaned, but only at considerable expense, and this will certainly not be economic for an area of less than 1 - 2 acres.
2. An analytical service capable of providing a quick results turn -round for input and slab solution samples, and preferably also for plant analysis.
3. Portable monitoring equipment to allow the grower to check daily the pH and conductivity of the input and slab solutions.
4. A source of advice to provide information and local experience of the crop which is to be grown in rockwool.

b- Sources and types of rockwool :

There are at least five manufacturers of rockwool for horticultural use whose products are available internationally. Some of these market directly, while others use horticultural suppliers in various countries to distribute their products. The first company to produce rockwool materials for the horticultural industry was Grodania of Denmark, whose a products have been trailed in Europe since the mid 1970's, and until now distributed around the world. Other manufacturers have followed Grodania's lead as the potential for the substrate has become more recognized. Of these, the following brands are the only ones likely to be encountered outside Holland at present : Capogro, Basalan, Cultura and Cultilene. Most suppliers now offer two ranges of slabs, one for long - term use and a low density version for single season use. The slabs are either 90 or 100 cm long and are available in various widths (generally 15 - 45 cm) and depths of 5, 7.5 or 10 cm. Wrapped or unwrapped slabs are usually offered and sometimes Paris of slabs wrapped together to give a 180 - 200 cm long unit.

c- Rockwool systems :

The use of horticultural rockwool as the growing medium in open hydroponic systems has been increasing rapidly; such systems now receive more attention from a research standpoint than any other type in Europe (Hanger 1982).

Cucumbers and tomatoes are the principal crops grown on rockwool; in Denmark, where rockwool culture originated in 1969 (Verwer 1976), virtually all cucumber crops are grown on rockwool. This technology is the primary cause of the rapid expansion of hydroponic systems in Holland, which increased from 25 ha in 1978 to 80 ha in 1980, and increased again to more than 500 ha by the end of 1982 (Van Os 1983). Rockwool, first developed as an acoustical and insulation material, is made from a mixture of diabase, limestone, and coke that is melted at high temperature, extruded in small thread and pressed into sheets weighing about 80 kg/m^3. Insulation rockwool is inappropriate for horticulture. For use as a growing medium, rockwool must be modified in process that has remained confidential (Hanger 1982).

In open hydroponic systems, plants are usually propagated by direct seeding in small (40 m m^3) rockwool cubes that have a small hole punched in the top and are saturated with nutrient solution. These cubes are usually transplanted into larger rockwool cubes (75 m m^3), manufactured specifically to receive the germinating cubes, and side wrapped with black plastic film. The larger cubes are subsequently placed atop rockwool slabs placed on the greenhouse floor. The slabs are usually 15 - 30 cm wide, 75 - 100 cm long, and 75 mm thick.

A typical layout for open - system rockwool culture by leveling the ground and covering it with white polyethylene film for good hygiene and light reflection. A bed normally consists of two rows of rockwool slabs, each individually wrapped in white film, with the rows spaced 30 cm apart. The slabs should have a slight inward tilt toward a central drainage swale. If bottom heat is required, the slabs are placed atop polystyrene sheets, grooved in the upper surface to accommodate hot water pipes. Because of the porosity of the rockwool, almost all of the nutrient solution remains in the slab for plant use if an appropriately modest irrigation schedule is used; if there is a surplus, it will drain out of the slab and into the shallow channel.

Before seedlings are transplanted, the rockwool slabs are soaked with nutrient solution. The plants, remaining in the small rockwool cubes in which they were established, are simply set atop the slabs through holes cut in the plastic film. If the root system is well developed in the cubes, the roots will move into the slab within 2 - 3 days. Each plant receives nutrient solution via individual drippers, with irrigation rates varied as a function of plant demand and environmental conditions.
Rockwool has several inherent advantages as an aggregate :

1. It is light weight when dry.
2. Easily handled.
3. Simple to bottom heat.
4. Easier to steam - sterilize than many other types of aggregate materials.
5. It permits accurate and uniform delivery of nutrient solution.
6. Required less equipment, fabrication and installation costs; and entails less risk of crop failure due to the breakdown of pumps and recycling equipment.

On the other hand, the obvious disadvantage is that rockwool may be relatively costly unless manufactured within the region.

In Egypt, there is no rockwool manufactured and all the rockwool are imported from Europe. For the cost of the shipment and the customs the rockwool is very expensive and the rockwool culture is not economic.

Medany et. al., (1995) had tested different local materials to be used as a substrate. He used a date - palm fibers (Leaf); dried shredded date - palm leaflets (Karena), nylon threads (NT), rockwool (RW) and the control "without any media". They reported that the leaf and karena treatments gave 50 % yield of cucumber higher than the rockwool and 100 % higher than the control. They also reported that the increase of the yield with the reduction of production cost by eliminating the expensive imported rockwool, makes the local palm fibers reasonable alternative substrates for vegetable production. They related these results to the better active distribution between the material and the surface of solution, or to the positive effect of the organic composition of the leaf and karena.

d. Sand Culture :

Concurrent with the beginning of rockwool culture in Denmark in 1969, a type of open system aggregate hydroponics using pure sand as the growing medium was under development by researchers at the University of Arizona, initially for desert application (Fontes et al., 1971; Jensen 1973). It was logical to investigate such a potential. Because other types of growing media must be imported to desert regions and may require frequent renewal, they are more expensive than sand, a commodity usually available in profuse abundance.

The Arizona researchers designed and tested several types of sand based hydroponic systems. The growth of tomatoes and other greenhouse crops in pure sand was compared to their growth in nine other mixtures (e.g. sand mixed in varying ratios with vermiculite, rice hulls, redwood bark, pine bark, perlite, peat moss), there were no significant differences in yield (Jensen 1973; Jensen 1975).

Unlike many other growing media, which undergo physical breakdown during use, sand is a permanent medium; it does not require replacement every one or two years.

Pure sand can be used in trough or trench culture. However, in desert locations, it is often more convenient (and less expensive) to cover the greenhouse floor with polyethylene film and a system of perforated drainage pipes, and then back fill the area with sand to a depth of approximately 30 cm. If the depth of the sand bed is shallower, moisture conditions may not be uniform and plant roots may grow into the drain pipes. The areas to be used as planting beds may be level or slightly sloped; supply manifolds for nutrient solution must be sited accordingly.

e. The sand types :

Different types of desert and coastal sands with a variety of physical and chemical properties were used successfully by the University of Arizona workers. The size distribution of sand particles is not critical, except that exceptionally fine material, such as mortar sand, does not drain well and should be avoided. The particle size distribution of sand typically used in this technology is given in Table(1).

Table 1. Particle - size distribution of typical sand used in hydroponic systems

Particle Size (m m)	Size distribution (%)
over - 4.760	1
2.380 - 4.760	10
1.190 - 2.380	26
0.590 - 1.190	20
0.277 - 0.590	25
0.149 - 0.277	15
0.074 - 0.149	2
less than 0.074	1

Source Jensen (1971)

Standard drip or trickle irrigation systems are used. In the larger Arizona - type systems, fertilizer proportions usually are used and irrigation is programmed through a time clock system. If the sand used is highly calcareous, increased amounts of chelated iron must be applied to the plants. Sand growing beds should be fumigated annually because of possible introduction of soilborne diseases and nematodes.

In considering any new location for a closed hydroponic facility a water agricultural suitability analysis must be done. It is important to know the sodium absorption ratio, salinity and pH of the water, and whether any undesirable elements (boron or fluoride) are present. Irrigation water containing more than 500 ppm (approx. 0.78 mhos/cm/10^3) of salts not used by plants in large amount should be avoided.

Irrigation practices are particularly critical in the desert during the high - radiation summer months, when crops may have to be irrigated up to eight times per day. Proper irrigation is indicated by a small but continuous drainage (4 - 7 % of the application) from the entire growing area, Evaporation of water around small summer tomato transplants is often high, which can lead to a slight buildup of fertilizer salts in the planting beds. Extra nitrogen causes excessive vegetative growth, decreasing the number of marketable fruits; this can be avoided by reducing the amount of nitrogen in the nutrient solution from the time of transplant until the appearance of the first blossoms.

Drainage from the beds should be tested frequently, and the beds leached when drainage salts exceed 3000 ppm.

In the United States, the principal crops grown in sand culture systems are tomatoes and seedless cucumbers. Yields of both crops have been high (Jensen 1980).

In the Middle East, a wider variety of table vegetables has been grown in sand culture installations (Fontes 1973).

In Egypt Ibrahim et. al., (1989) had design a sand culture under plastic tunnels at Dokki Protected Cultivation Center, Cairo.

The design was as follow :

Five 0.8 X 38m 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 (Jensen and Hicks, 1973). The profile of the trench was adjusted to 1 (V) shape. The trench was lined with a water proof polyethylene sheet (200 μ) to prevent plants from rooting into the original soil (Jensen, 1971). The surface of the bed was sloped to be parallel to the bottom of the trench.

There inches corrugated perforated plastic pipe was placed a long the bottom of each trench. The drains were connected at the lower end to a main drain that sink into a 9 m^3 nutrient tank. Once the drain pipes are in place, washed coarse sand obtained from Cairo - Alex. desert road (km 40) was 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 was 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 (Resh, 1981). A float valve was 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 (Johnson 1979) 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 was run along each plant row. The emitters were placed in these lateral lines 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 (Cooper, 1982).

Tomato grown in this system were propagated in a peat vermiculite mixture 1:1 (v/v) (Larsen, 1971). The formulae of chemicals added per m^3 of propagation medium was as follows :

250 g ammonium nitrate,	150 g potassium sulphate,
50 g magnesium sulphate,	250 g super phosphate,
4000 g calcium carbonate,	50 g penlate as a fungicide (El-Beltagy, 1988).

It was reported earlier that the best time to plant tomatoes in the plastic tunnel in Egypt is during October and November. Such plants, will be ready to yield during February, March and April before the open - field tomatoes appear on the market (Abou - Hadid et al., 1986 and Nassar and Corandall, 1987).

The results should that there were saving for water and nutrients consumption and improving of the yield.

From all the previous works in the hydroponic systems in Egypt, it can be concluded that, the hydroponic is the main feature of Egypt for the expansion of growing vegetables in the state of the shortage of water.

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