Soilless Culture and Water Use Efficiency

Soilless Culture and Water Use Efficiency for Greenhouses in Arid, Hot Climates

S.W. Burrage
Wye College, University of London, Wye, UK

Abstract

Soilless cultivation is intensively used in protected agriculture to improve control over the growing environment and to avoid uncertainties in the water and nutrient status of the soil. It also overcomes the problem of salinity and the accumulation of pests and diseases.

Soilless culture is carried out in two main ways. Firstly, by using an inert substrate. Rockwool is the most widely used, although materials like perlite, sand, gravel and rock-like chippings are also used. Organic material such as peat is sometimes used. Secondly, true hydroponic techniques where there is a minimum of substrate and plants are generally grown in a recirculating nutrient solution.

In the past the substrate systems have been 'open' with the surplus nutrient running to waste. This has been wasteful of water and nutrients and has resulted in pollution of groundwater. Disposal of the used substrate has also resulted in an additional pollution problem. As a result of this there has been a reduction in the amount of substrate used and the development of 'closed' substrate systems. This has brought substrate systems closer to the true hydroponic systems like nutrient film technique.

Nutrient film technique (NFT) maximizes water-use efficiency by recycling all the water and nutrients not used by the plants. A thin film of nutrient solution maintained between two polyethylene sheets is provided to the plant roots, which grow into it. A pump delivers the solution to the higher end of the system, and the solution then flows under gravity back towards a storage trough (the system requires a minimum 1-in-100 gradient). Because of the risks of power and pump failure, most systems have both a back-up power supply and two pumps. Control of nutrient concentration is critical and tends to be automated via a conductivity meter; however, caution is required because of the risk of non-nutrient salt build-up giving false nutrition readings. The main requirement in changing from a soil-based system to NFT is the upgrade in

management skills—the whole system reacts much faster than conventional

agriculture, and so needs more careful monitoring and closer management.

Cucumber in a closed soilless system at Al Sulaiteen Agricultural Complex (Qatar)

Summary of Major Issues Arising and Discussion

Traditional techniques in protected agriculture may be highly productive but their relative use of water may be high due to run off and infiltration; thus, the water-use efficiency may be relatively low. In arid countries, rapid evaporation from the soil surface may also lead to salinity problems. Soilless techniques offer a way of improving water-use efficiency and obtaining better water management in crop production.

A good grower may achieve the same yield in soil as in soilless cultivation, but is likely to use 50–100% more water as a result of water losses from over-watering the soil and evaporation from the soil surface. If we consider yield per unit of water applied, soilless systems may increase yield substantially over soil-based systems.

There are two main types of soilless cultivation.

Open systems where the water and nutrients are supplied as in conventional soil culture and the surplus (about 25%) nutrient and water is allowed to run to waste. The attraction of this technique is its similarity to soil as a growing medium and many similar techniques have been developed using a variety of inert media such as rockwool, sand, vermiculite, perlite and pumice. The two most important features relating to the substrate are that it is inert and that it has a great water-holding/release capacity. The maintenance of an appropriate water and nutrient level within the substrate is essential to prevent plant stress.

Production of cucumber in sand bags—open soilless system, Ottoria Research Station (Qatar)

Waste substrates can be used as a soil conditioner but its use is very limited. Rockwool can be recycled (re-used) for up to three years, after which it loses its water-holding capacity.

A major disadvantage of open systems is that a proportion of the water and nutrients must be allowed to run to waste. This lowers water-use efficiency and contaminates groundwater supplies with salts. There is also a pollution problem arising from the need to dispose of the substrate on an annual or biannual basis.

Closed systems, such as nutrient film technique (NFT), where a film of solution is trapped between two sheets of polyethylene to form a growing channel. This provides a good contact between the recirculating solution and air, which is sufficient to maintain the oxygen level required by the roots without additional aeration of the solution. Because the solution is continually moving, there is very little short-term variation in salinity, unlike in the soil where salinity rises and falls with the water content. It is possible, therefore, to grow plants in much higher salinity in NFT solutions than would normally be used in soil-based production.

The main advantages of the closed systems over the open ones are the reduction in water and nutrient loss to the environment resulting in better water-use efficiency. Also, closed systems use minimal substrate, so the problem of pollution of the environment from its disposal is also reduced.

Advantages of soilless systems

Nutrients and water are applied more evenly to the plants, therefore reducing wastage and providing a situation closer to the ideal growing conditions.

Soilless cultivation has the capacity for increased yield. Improvement in crop production could be more than 10-fold.

Tube culture techniques for the production of strawberries on raised benches —an example of a closed system (Ottoria Research Station, Qatar)

The system can be automated to control and maintain the nutrient levels in the solution.

One important difference between NFT and soil-grown crops is that in NFT water and nutrients are brought to the roots as they are continually bathed in the solution, whereas in the soil the roots must grow through the soil to obtain water and nutrients.

Water-use efficiency can be at least doubled compared with soil-grown plants, since water is only introduced into the system when it is lost through the plant.

Allow precise monitoring and control over the nutrient solution which minimizes water and fertilizer usage and maximizes production.

Solution concentration may be used to control growth, e.g. a high-conductivity nutrient solution stresses the plant reducing vegetative growth.

The risks of disease spreading to the crops in NFT are relatively low. The use of chemical insecticides and fungicides in solution is an effective control measure.

In cucumber grown in NFT a small amount (<1%) of silica in the solution gives good protection against powdery mildew.

The initial investment in structure, troughs, etc., and control systems is returned by the improved efficiency in the use of water and the consistent quality and quantity of crops produced.

The biggest requirement when changing from conventional to soilless cultivation is the upgrading of management. Failure to do this can result in failure of the whole system. The simple reason is that, in traditional production the soil acts as a buffer to the decision-making process. In soilless growing there is less of a buffer, the reaction time of the crop to changes in nutrient-solution supply is less and decisions have to be taken at relatively short notice. The systems have to be actively managed.

Disadvantages of soilless systems

The main disadvantages of soilless systems are the initial cost and the increased technical demands on the management.

It is easy to adopt hydroponics technology. The pipe-work is standard. Equipment for measuring pH and conductivity, and (if possible) for conducting solution analysis is needed. Ready-made nutrient solutions for hydroponics are available on the market. Management of a hydroponics system is a mater of experience: it is advised that workers (researchers, extension workers and growers) should start small with soilless techniques and develop confidence in the system.

Future Activities and Research Priorities

Water-use efficiency is considered one of the most important issues for protected agriculture in the Arabian Peninsula (AP). It is mainly linked with growing techniques and systems. The use of cultivation systems appropriate to each condition (soil or soilless cultivation) is strongly advised, but consideration should be given to alternative techniques and to the development of related technologies.

Training

The participating countries recognized the importance of conducting training programs in water and water management for different target groups using local, regional and international resource persons.

Major issues for training include:

1. Management of greenhouse irrigation systems

2. Soilless culture techniques
3. Nutrient solution composition and management.

Applied Research and Experiments

Activities with research experiments were considered highly important for the AP. The major research issues that are highly recommended are:

Water requirements: conduct experiments to determine water requirements for various crops under different greenhouse conditions.

Irrigation systems and techniques: improvements on existing irrigation and fertigation systems with the aim of reducing water and fertilizer wastage.

Soilless culture: adaptation and development of suitable soilless culture. This would require many experiments on:
- Growing medium
- Nutrient solution composition and formulation
- Solution temperature
- Crop and cultivar responses.

Information and Technical Publications

There is a lack of up-to-date scientific and technical documentation specific for the region.

Write and publish technical handbooks and guidelines on:
- Modern irrigation systems for greenhouses
- Soilless culture techniques and management
- Plant nutrition and fertigation.

Study the economics and techniques of producing transplants in centralized nurseries using soilless techniques.

Economic assessment of different growing systems. This assessment should take into account production per unit of water, labor, and land.

Networking and Databases

Develop regional mechanisms to exchange experience and to transfer available technologies between the countries of the region.

Pooling available knowledge on:
- Crop water-requirements

Nutrient requirements and nutrient-solution composition
Control systems and automation.