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TECHNIQUES FOR IMPROVING WATER USE EFFICIENCY IN GREENHOUSE CULTIVATION IN CYPRUS

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SUMMARY - In Mediterranean region, there is an increasing concern about the effective and efficient utilization of water for agriculture and water conservation in general. The promotion of effective water use and on farm water management, were identified as an important contribution to the management strategy needed to address problems of water scarcity and practicing intensive agriculture on environmentally sound grounds. Recently particular emphasis was laid on protected cultivation and more specific on cultivation of vegetables and flowers on substrates and soilless cultures (closed systems and open with minimum drainage). New unites with soilless cultivation (mainly perlite, coconut and rockwool) have been established applying modern greenhouse technology and fully computerized irrigation-fertigation methods. The only way to increase productivity, improve quality and control growth and production, is through the application of modern greenhouse technology, new techniques of cultivation and integrated protection and production management. At the Agricultural Research Institute the use of local materials i.e. perlite, mixtures of perlite with pomace, almond shells, pine bark, gravel, etc. have been tried successfully. In this paper, results of the application of modern techniques, hydroponic cultures, re-circulation of irrigation water and nutrient solution in closed systems and control of the climatic conditions in the greenhouse (temperature, air humidity, CO_2, etc) will be discussed. The introduction of modern technology and soilless culture in greenhouse cultivations (vegetables and flowers) resulted in higher production, better quality, efficient and effective use of water and fertilizers and minimize the use of chemicals for pest and disease control. The use of closed recirculation systems has reduced the water needs of the cultivations close to the evapotranspiration levels of the crop. Ongoing research on using a green lagoon to de-nitrifigate the reject water from the closed system, when the undesired elements in it reach toxic levels, seems to be very promising. The grown Sudan-grass in the lagoon can be used as animal feed or as an energy plant.

Key words: soilless culture, hydroponic systems.

INTRODUCTION

In Mediterranean region, there is an increasing concern about the effective and efficient utilization of water for agriculture and water conservation in general. The promotion of effective water use and on farm water management, were identified as an important contribution to the management strategy needed to address problems of water scarcity and practicing intensive agriculture on environmentally sound grounds (Papadopoulos and Chimonidou, 1997, 2004).

In Cyprus, the irrigated land amounts to 35000 ha (16.2% of the total agricultural land) with provision to be expanded. The irrigated agriculture in semi arid countries like Cyprus demands large amounts of water and faces the serious challenge to increase or at least sustain agricultural production while coping with less and/or lower quality water (Papadopoulos and Chimonidou, 1997, 2004).

Recently particular emphasis was laid on protected cultivation and more specific on cultivation of vegetables and flowers on substrates and soilless cultures (closed systems and open with minimum drainage). New unites with soilless cultivation (mainly perlite, coconut and rockwool) have been established applying modern greenhouse technology and fully computerized irrigation-fertigation methods (Chimonidou 1999, 2003a, 2003b).

The demand for increased production and better yield quality, the lack of good quality water for irrigation and the need for protection and conservation of the environment require the implementation of new technologies in greenhouse cultivation. In this respect, the first measures to be taken are improvement of greenhouse structures and automation of the systems. Moreover, modern techniques have to be applied such as cultivation on artificial substrates, hydroponic cultures, re-circulation of irrigation water and nutrient solution in closed systems and control of the climatic conditions in the greenhouse (temperature, air humidity, CO2, etc). Apart from higher production of good quality (10 %-25 % yield increase in vegetables and up to 30 % in flowers), such technology would result in efficient and effective use of water and fertilizers and in minimizing the use of chemicals for pest and disease control, especially after the prohibition in using Methyl Bromide for soil sterilization. Moreover some cultural practices, like soil cultivation and weed control are avoided, and land not suitable for soil cultivation can be used (Polycarpou and Hadjiantonis 2004).

SOILLESS CULTURE

Recently particular attention was given in soilless cultivation and the area under soilless culture is rapidly expanding. The first soilless culture in Cyprus started with rose cultivation on rockwool in 1996 at the area of Monagrouli (Limassol) with 0.2 ha and expanded in 0.4 ha in 1997 with a fully automated computerized open system. Since then, the cultivation of roses on substrates has rapidly expanded. The application of soilless culture in vegetables (tomatoes, cucumber, lettuce, strawberries) came later due to the low and unpredictable market prices of the products.

The total area cultivated today in Cyprus using soilless techniques is about 11.6 ha. A break down of this area is given in Table 1. This area is expected to increase rapidly in the near future due to the grants schemes announced by the Ministry of Agriculture as a measure to improve the quality of the agricultural products as a result of Cyprus joining the European Community.

Soilless culture has some fundamental differences compared to growth on soil. Unlike soil culture, soil1754less cultivation starts with media free of soil born diseases and gives the grower flexibility to control growth by manipulating water and nutrient supply. The substrate can be chosen to have the desirable characteristics so that with the appropriate water and nutrient management yield can be maximized and quality be improved.

Table 1. Soilless Cultivation in Cyprus (Source: Department of Agriculture)

	Area of Soilless Culture in Cyprus (ha)		
Substrate	Flowers (Roses & Cerbera)	Vegetables	Total
Perlite	0.3	0.2	0.5
Coco Peat	3.8	1.6	5.4
Rock wool	0.7	5.0	5.7
TOTAL			11.6

However, there are some difficulties in soilless cultivation like:

- High initial installation cost
- High skill requirements on growers
- Sensitive system with no buffering capacity of nutrients – No error tolerance.

- High water quality requirements. Risk for environmental pollution if not properly managed.That is the reason for the slow application of the method until now.

EXPERIMENTAL WORK ON THE CULTIVATION ON SUBSTRATES

Roses on soilless cultivation

A lot of attention was given on the research on roses and experiments started since 1990 on the physiology of roses, the critical levels of development in relation to water stress and the effect of irrigation, shading and salinity on yield and quality (Chimonidou, 1996,1997,1998).

Experiments on soilless cultivation of roses started in 1997 using different substrates i.e. perlite, perlite (70%) + pomace (30%), Coconut, 100% rockwool and pine bark (70%) + straw (30%) as inert media. The aim was to compare different inert media (imported and local) and evaluate the cultivation in bags and containers using the technique of shoot bending. Irrigation based on the moisture content of the media, is kept constant at -5 to -8 kPa at the area of the root zone. The total amount of irrigation water was the same but the frequency was different according to the holding capacity of each substrate. The productivity and quality characteristics (stem length, fresh weight, flower bud diameter and height) have been recorded. Results were very encouraging for the local substrates tested.

Experimental work on the cultivation of Roses on soilless culture expanded in fully automatic greenhouses at different locations aiming at the use of new substrates to face the problem of low quality waters in Mediterranean climates using the minimum drainage and accumulate the salts at the periphery of the container.

A joint programme between the Agricultural University of Athens - Greece and the Agricultural Research Institute of Nicosia - Cyprus (2001-2004), aimed at studying the development and photosynthetic activity of roses cultivated in four different substrates and two irrigation regimes. Roses cv "Eurored" were cultivated on four different substrates in a heated greenhouse at the ARI using local materials i.e. perlite 100%, mixtures of perlite 50% with pomace 50%, perlite 50% with almond shells 50% and almond shells 50% with pine bark 50%. The two irrigation regimes applied, were 800ml (6 times/day X 2 min) and 530ml (4 times/day X 2 min).

The photosynthetic rate, stomatal conductance, CO2 concentration and transpiration rate of the rose plants grown in the four substrates and under the two irrigation regimes were measured as well as the total productivity and quality characteristics (stem length, fresh weight) of the roses produced. Results showed that concerning the interaction between substrate and irrigation level, higher production was recorded with the roses growing in the substrate pine bark 50% and almond shells 50% irrigated with the reduced irrigation level and the substrate of perlite 50% and pomace 50% irrespective of irrigation level. The quality characteristics of the roses produced under all treatments were marketable with mean stem length between 75-85cm.

No significant differences were observed concerning the photosynthetic rate, the stomatal conductance, the CO_2 concentration and the transpiration rate under the four substrates and the two level of irrigation. It seems that the lower irrigation level did not create conditions of water stress and did not affect negatively the physiological activities of the rose plants. Concluding remarks showed that the local substrates could be used successfully as substrates for the rose cultivation in the region.

Cultivation of Lysianthus (Eustoma) on substrates

Two different experiments on Lysianthus were conducted during the years 2002-2003 (at the Agricultural Research Institute and at Zygi experimental station), aiming at higher productivity and year round production.

The first experiment in cooperation with the Aristotle University of Thessaloniki was aimed at evaluating the productivity and quality characteristics of Eustoma grandiflorum on two substrates and two irrigation regimes. The substrates used were perlite 70% with coco 30% and perlite 50% with pomace 50%. The irrigation was performed using drippers of 4l/h and the irrigation intervals were: 6 times x 2 min (800 ml/ day) and 4 times x 2 min (530ml/ day = reduction 33%). The pH and the EC were kept constant at the levels of 6,5 and 1,7-1,8 DS/m respectively. Drainage for both cases was only 5%. Results showed that no significant differences were existed between the different substrates or the stressed and not stressed plants with respect to the total productivity (number of stems) or the quality characteristics (number of flower buds, stem length and fresh weight) of Lysianthus. Vase life of the plants was not affected by the cultivation in different substrates. On the contrary, the plants under the low level of irrigation lasted more days in vase with or without preservative (Chimonidou et al. 2003).

Greenery Cultivated in Different Substrates

Experiments on the cultivation of flowers and greenery on substrates started in 1995 with the Greenery Rumohra adiantiformis cultivated on four different substrates in comparison to the cultivation on soil in an unheated greenhouse at Zyghi experimental station. The aim was to increase productivity improve quality (particularly stem length with increasing shading levels) and avoid soil born diseases by improving soil structure and aeration of the root zone using local material (i.e. pine bark, mushroom compost, pomace etc.).

Results show that pine bark 30% with peatmoss 70% appeared to be the most promising substrate among those tested during 1995-97, concerning their quality characteristics (Chimonidou, 1999).

The experiment was extended in 1998 with the cultivation of greenery and other cut flowers on soilless cultivation. The species Limonium ottolepis, Rumohra adiantiformis, Gerbera jamesonii, and Pteris vitata, were tested in a mixture of perlite 70% and pomace 30% at the Agricultural Research Institute in Nicosia. The total productivity and the quality characteristics (stem length and fresh weight) as well as their keeping quality after harvest were studied. Results appeared to be very encouraging for all species tested and specially for Limonium ottolepis, concerning the total productivity and quality characteristics in comparison to previous research work carried out on soil (Chimonidou 1999).

HYDROPONIC SYSTEMS

The open system for soilless culture, Fig.1, is at present most favored commercially in Cyprus due to its simplicity, mainly in managing the nutrient solution.

Pollution of the environment (underground water), waste of fertilizers and water are though only some of the problems faced in open hydroponic systems. The leachate is usually collected in a reservoir and is used for the fertigation of open cultures or greenhouse cultivations in the soil. This results in approximately 30 % loss of fertilizers and water from the system.

For this reason ARI started a research program in order to develop a locally adopted closed hydroponic system (Fig. 2), using locally available inert substrates, like crashed gravel produced in a copper mine in Cyprus. The leach ate from the substrates is collected in a tank and is recirculated after being sterilized passing through a UV lamp. The EC and pH of the water are regulated using an automatic fertilizer-mixing unit as by the open system. The water consumption of a good managed closed system is reduced to the evapotranspiration level of the plants. The system requires water of very good quality that is difficult to find in Cyprus. At the coastal areas where greenhouse cultivation has developed due to the favorable climatic conditions, the ground water salinity ranges from 1.5 to 4 dS/m, whilst the salinity of water coming from dams is around 1 dS/m. The fresh water supplied to the closed system can be therefore rainwater collected from the greenhouses or water treated by a small reverse osmosis unit. Thus the need for replacing the nutrient solution due to the increasing concentration of chlorides and sodium is minimized. When the nutrient solution comes to the point that it has to be replaced, the possibility is studied to pass it through a green lagoon planted with sudan-grass is studied. By this method the water is denitrificated and can be safely disposed to the environment. The sudan- grass harvested from the lagoon could be used for animal feed or for the production of bio-mass for energy purposes. The experiments are carried out at the ARI research station at Zygi on tomato cultivation (Polycarpou and Hadjiantonis 2004).

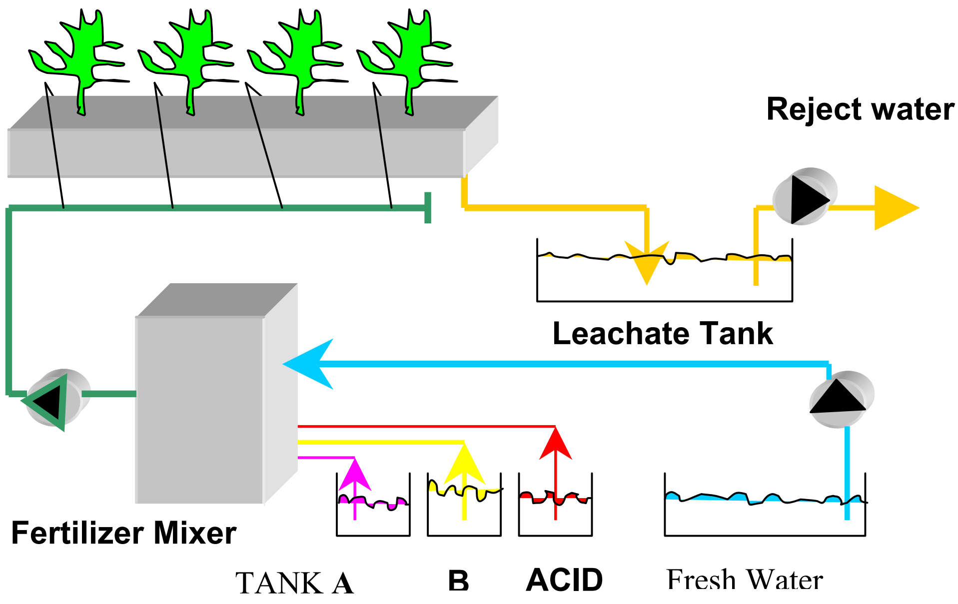

Fig. 1. Schematic diagram of an open hydroponics system applied commercially in Cyprus.

In addition, an open system using a mixture of locally available organic materials with perlite or peat moss as substrate is being studied in floriculture. In this “zero loss” system the nutrient solution is supplied to the plants, planted in big boxes (substrate volume 15 liters/plant), in such a quantity that leaching just starts. In this way the water and fertilizer loss from the system is minimal. The salts are pushed by the irrigation water away from the root zone and are accumulated in the outer volume of the substrate not affecting the growth of the plants.

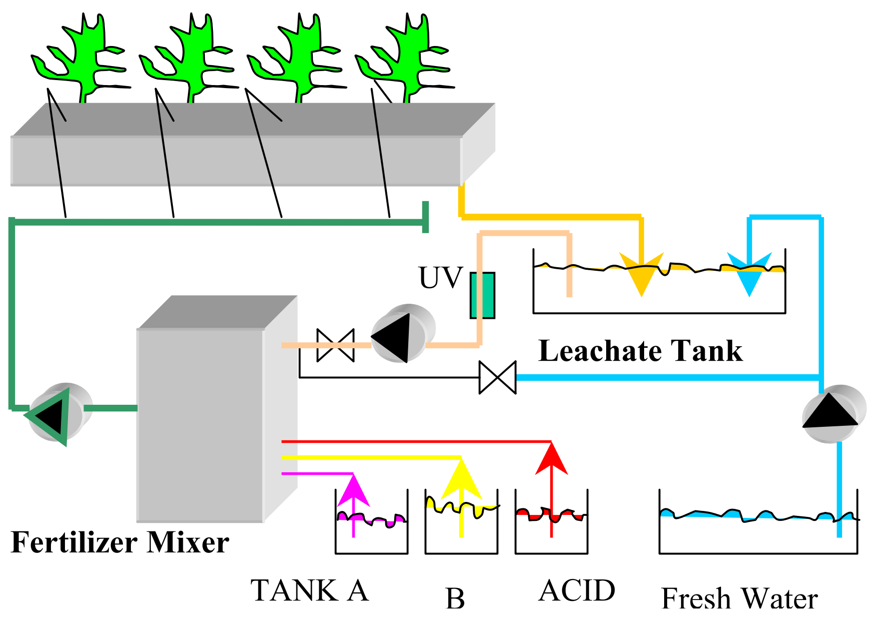

Fig. 2. Schematic diagram of a closed recirculating hydroponics system applied at the ARI in Cyprus.

In designing and operating such a closed hydroponic system the following main parameters are to be considered:

- Crop related matters such as the life span of the crop, the water and nutrient requirements (recipe), and the cultural practices needed.Method for fertilizer mixing and supply of irrigation water (Using simple volumetric fertilizer injectors or automatic fertilizer mixing units).
- Use of locally available inert substrates like perlite, coarse sand, crashed gravel vs. imported inert materials like rock wool.
- Climate Control in Greenhouses, like monitoring the aerial climate requirements (temperature, relative humidity, light, CO_2, etc), the root zone requirements (root temperature and O_2 supply in the root zone) and improving the PAR transmission of covering materials and lowering their NIR transmission.

Due to the advantages of the closed hydroponic system compared to the open one, ARI is investing a lot of effort in optimizing its parameters, simplifying its operation and training the growers in its effective management and utilization (Polycarpou and Hadjiantonis 2004).

CONCLUSIONS

- In Mediterranean countries where water is limited and of high cost, diversion to intensive irrigated agriculture, protected cultivation and soilless culture are promising alternative and innovative approaches.

- Soiless culture using locally available substrate materials (perlite, mixture of perlite + peat, pomace, pine bark etc) could be the solution. Experimental results so far in terms of yield, quality and water use efficiency are very encouraging.

- It is important that a suitable closed system is developed that is based on low cost local materials, which are both effective and easily disposable after use in order to avoid environmental pollution. The system should be easily adaptable to the growers according to their potential skills. The technology used should be locally supported in order to avoid long-term maintenance problems.

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