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in

Hamdy A. (ed.), Monti R. (ed.).
Food security under water scarcity in the Middle East: Problems and solutions

Bari : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 65

2005
pages 357-362

RATIONALIZATION OF THE USE OF WATER IN VEGETABLE AND NURSERY CROPS

A. Colombo*, A. Rizzi*, A. Tosca* and G. D'Angelo*
* Fondazione Minoprio, Vertemate con Minoprio, Italy. E-mail: mirtserv@fondazioneminoprio.it

SUMMARY – The rational use of water in agriculture is an urgent aim, since there is a lack of water in many places in the world. The evolution of more efficient irrigation systems in vegetable and nursery crops growing has been remarkable. There has been a change from gravity irrigation systems, such as flowing irrigation, with rather low efficiency index, to pressure irrigation systems, such as sub-irrigation, overhead and localized irrigation. In order to exploit the sub-irrigation advantages new cultivation systems are developed. These new systems are based on the sub-irrigation, adjusted by the use of special mats with high water retention capacity. These irrigation systems guarantee the retention of water and nutrients which, in the older systems, have been lost during irrigation.

Keywords: water, micro-irrigation, sub-irrigation, vegetables, nursery crops, closed system

1. INTRODUCTION

The situation of the environment at the beginning of XXI century is not favourable. Natural resources, which in the past were unlimited, are now gradually running out. This could be dangerous for future generations that depend on a sustainable use of resources by the preceding generations.

Water is one of the resources whose future availability is at risk: its value is known by everyone, and it cannot be replaced by any alternatives.

Regarding the use of water, agriculture is the field where water is mainly consumed: in fact about 70% of the water used in the world is employed in agriculture. An increase of 14% of this percentage is expected for next 30 years, if irrigated areas increase by 20% (United Nation World Water Development Report, 2003). For this reason it seems essential to study solutions for increasing the efficiency of irrigation systems and the re-use of waste water coming from agriculture and other activities.

For this purpose, modern irrigation practices aims to:

- maintaining an optimal moisture content in the soil in order to secure the necessary amount of water for the plants;
- decreasing costs by reducing the preparation of the soil;
- improving the irrigation system by minimizing both the water and energetic inputs;
- minimizing work loads in the production by utilizing automation systems.

Other problems related to the use of water in agriculture include the concern or the possible pollution of groundwater resources by fertilizers, pesticides and waste-water. A shortage in water supply involves increasing costs for using clean water: it will be necessary to identify irrigation systems with a high agronomic and engineering efficiency.

Today the best efficiency is obtained with localized irrigation, especially if joined with a closed system. This type of system enables the re-use of irrigation water not consumed by the crop and, thus, reduces water losses.

In this paper both irrigation techniques actually employed in vegetable and nursery crops and experiments carried out at Fondazione Minoprio are discussed.

2. THE DEVELOPMENT OF IRRIGATION SYSTEMS IN VEGETABLE AND NURSERY CROPS

The present techniques in use at growers, both in the production of vegetables and in the nursery cultivations, are based on overhead and localized irrigation. The last one is able to give a higher efficiency than traditional irrigation systems (gravity or flowing irrigation). Low efficiency of traditional irrigation systems is linked to the great quantity of water lost during irrigation, because the water supply is much larger than plant absorption and soil retention capacities.

By localized irrigation these problems are minimized; the main handicap of this system is the high installation costs. However, the increased return will pay the investments by means of greater crops and better qualities in the productions.

In the next sections the characteristics of principal types of irrigation systems in use in horticulture (overhead and micro-irrigation) will be discussed.

2.1. Overhead irrigation

This system is frequently used in vegetable growing. It has a lower efficiency than localized irrigation because of the greater volumes of water required, but the efficiency is greater than for surface irrigation (flowing and border irrigation). Other positive aspects of this system are:

- Possibility of watering the ground without levelling (operation extremely expensive);
- Decrease in soil erosion and less damage to the soil structure, by operating with an adapted water amount and drop size;
- Decrease in water run-off and fertilizers losses: in fact this system allows to use only about a half the water volumes of the gravity systems at the same effect for the crop. Normally, with overhead irrigation water consumption goes from about 500 m^3ha^{-1} in clay soils with localized irrigation, to about 1300 m^3ha^{-1} with flowing irrigation. (CDA, 2003);
- Possibility to influence temperatures, both to decrease damages from frost and stresses caused by heath;
- Possibility to distribute pesticides by the irrigation system.

In sum, these positive aspects decrease problems of enough water supply in windy weathers and the costs for maintenance of the sprinklers.

2.2. Micro-irrigation

Micro-irrigation seems to be the most effective system to reach the above listed goals. It localizes the water directly to the soil where the root systems are, wetting only a portion of the soil and use low pressure (1-2 bar); this requires pipes with a small diameter and thus is easy to handle and is inexpensive. The localization of the water to where the roots are, leads to a decrease in water waste and therefore increase the efficiency.

Other benefits of localized irrigation are:

- Reduction of costs for the preparation of the soil;
- Possibility of doing cultural operations such milling or harrowing because the space between rows is not occupied by irrigation pipes and sprinklers;
- Possibility to fertilize plants near their roots, promoting an easier absorption of nutrients.

Naturally there are also some disadvantages as, for example:

- Cost of materials (pipes, irrigators);
- Need of maintenance of drip emitters, especially using salty waters;
- A good know-how by the grower for the maintenance of the right pressure and density of drip emitters.

Even if micro-irrigation is usually adopted above soil surface, it can be realized also underground. In the first case it is named “micro-irrigation”, in the second one “sub-surface irrigation”. Both systems can be realized by the use of drip emitters. The function of the drip emitters is to reduce the pressure inside the pipes by dispensing little quantities of water. This can be achieved in most cases by means of a labyrinth inside the drip emitter.

2.2.1. Micro-irrigation above soil surface

These systems can be placed both directly above the ground and on supporting structures.
Different drip-pipes are used in vegetables growing, also under a plastic mulch. These can be more or less rigid. Examples of flexible dripping pipes are: the perforated hose, double-cavity hose and pipes with external drip emitters, whereas rigid systems are "*in-line pipes*" and "*integral-pipes*" (the first containing drip emitters filling the whole section of the pipe, the second containing emitters welded inside, filling only a part of the section of the pipe).

For improving the distribution efficiency of water, self-compensating emitters maintaining a constant pressure of supplied water have been developed. In some cases these emitters are joined with capillary mats able to hold 1-3 lm^{-2} of water. This association allows saving a lot of water and nutrients, compared with the oversupply in other systems (as related to the capacity of absorption by the crop/plants).

2.2.2. Sub-surface irrigation

Though initially expensive and not suitable for many areas, the economical advantages of drip irrigation can be further enhanced by placing the irrigation pipes about 10 centimetres below the surface. Thus, the water really goes straight to where it's needed, i.e. to the roots of the plants. Evaporation is greatly reduced, and there is no opportunity for surface runoff. This system can also be used for the efficient supply of fertilizers.

3. EXPERIMENTAL CLOSED-SYSTEM NURSERY AT FONDAZIONE MINOPRIO

In 2003 Fondazione Minoprio, in co-operation with M.A.C. S.r.l. (Minoprio Analisi e Certificazioni S.r.l.) and with Swiss nurseries (Alberto Stierlin e Manetti Vivai), built an experimental nursery, with the aim to decrease and rationalize the use of water and nutrients for nursery container plants. This project was made within the "Across-the-border programme", P.I.C. Interreg III A I-CH 2000-2006.

In the nursery the rational use of resources depends on the possibility to catch and re-use rainwater and runoff water through the use of innovative technologies, enabling the increase in water and fertilizer use efficiency (Marzialetti & Pardossi, 2003). Another aim is to obtain an efficient and high-quality production.

3.1. The nursery

The experimental nursery extends on a surface of 1000 m^2 with a longitudinal and transversal inclination of 1.5%. It is divided into three shaded sectors. In every sector of 322 m^2 (35m x 9.2m) a different irrigation system is applied: in the first a traditional irrigation technique, in the second a closed-system irrigation and in the third sub-irrigation with a special mat called Aquamat System ™.

In the first (control) and second sector overhead irrigation with sprinklers is used, but in the second sector water is recycled by means of collecting drainage water into a basin of 50 m^3. In the case of heavy rain there are sensors for directing the water elsewhere.

In the third sector the mat Aquamat System™ is placed. It is composed of a watertight polyethylene layer at the bottom and a polyester mat with a heavy absorbent value (about 11 $l\ m^{-2}$). On top of this is a light cover preventing water evaporation and a UV-resistant permeable woven textile sheet. The irrigation system with drip emitters is placed under the textile sheet.
In the control sector (the first) on levelled ground a layer of gravel has been covered with a permeable textile sheet. In this area lysimeters collect samples or the analysis of the drain water of the soil.

3.2. The trial

In the first year of experimentation (2003) four species of shrubs were cultivated (2.500 plants/species): *Abelia x grandiflora*, *Photinia x fraseri* 'Red Robin', *Prunus laurocerasus* 'Rotundifolia' and *Viburnum tinus*.

Plants were potted in pots with diameter of 15 cm (1.5 l of volume). For each sector a different cultural technique was adopted.

In the sector 1 (control) a substrate composed by peat, ground and pumice v/v ratio 2:1:1 fertilized with Nitrophoska Gold (1.3 kg/m^3) and Phycote (2 kg/m^3) was used. During the cultivation period irrigations were carried out only with pure water, without mineral fertilizers.

In the sector 2, with the closed system, a substrate composed by peat and pumice v/v 4:1 was employed, whereas in the sector 3, with Aquamat System™, a mixture of peat, compost and pumice v/v ratio 2:1:1 was used. Both these two substrates were not fertilized, but were amended with calcium carbonate until a pH of 5,6. In sectors 2 and 3 a continuous fertigation was managed using a nutrient solution with a N:P:K ratio of 17:11:17 and an E.C. of 0,8 mS cm^{-1}.

In the second year (2004) another trial was carried out by using only one type of substrate for the three cultivation sectors: peat, compost and pumice (ratio 2:1:1) and the same type of pots.

The cultivated species were *Photinia x fraseri* "Red robin", *Thuya plicata excelsa*, *Pyracantha* 'Soleil d'or', *Pyracantha* 'Orange Glow', *Pyracantha coccinea* 'Red Column', *Prunus laurocerasus* 'Rotundifolia' (2.200 plants/species).

Plants in the test sectors were cultivated in a substrate added with the slow-release fertilizers Nitrophoska (1.3 kg m^{-3}) and Triabon (2 kg m^{-3}) and irrigated with pure water.

Plants in the sectors 2 and 3 were fertigated with a nutrient solution with a N:P:K ratio of 22:6:13.

In both trials principal chemical parameters (macronutrients, pH, EC) of pure water, nutrient solutions, sewage from the basin, solutions from lysimeters and cultural substrates were analysed. In addition to this, the used water volumes were measured weekly.

To evaluate the growth of the cultivated plants also the dry weight and the growth (height and diameter) of plants were measured.

3.3. Results and discussion

At the end of the first year of experimentation (2003) data collected showed that the best growth of cultivated plants have been obtained with the closed system and the Aquamat System™ (sectors 2 and 3), with the exception of *Photinia*, where results obtained with Aquamat System™ have been less favourable than in the control treatment (Fig. 1). Dry weight of plants was not different among the different irrigation systems, probably because of the short cultivation time (Fig.2).

Water analysis showed that the water in the basin collecting runoff had a N:P:K ratio of 4,2:1:2,8, while in the starting solution the ratio was 1,5:1:1,5; Despite this, after the control of the nutrient solution in the closed system, the N-P-K ratio was more similar to the starting solution (1,9:1:1,6).

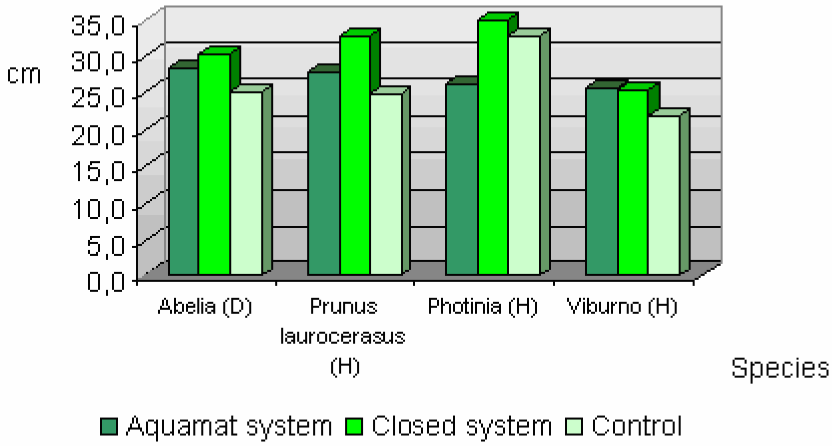

Figure1. Year 2003: Plant growth (D = diameter); (H = height) in the three sectors

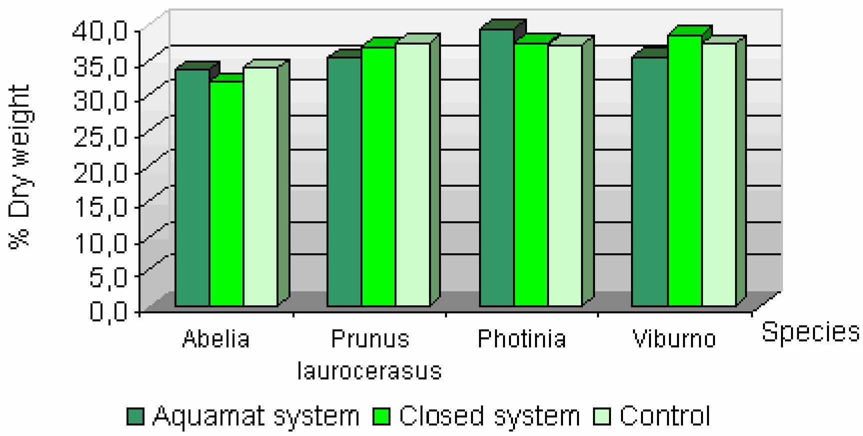

Figure 2. Year 2003: Dry weight of plants cultivated in the three sectors

The water used was much less in the closed system and with Aquamat System™ : In this system water used was only 1/5 of that in the control treatment, while the closed system used 1/3 of that in the control treatment.

In the second year (2004) data will be collected in November. However, preliminary results show that also this year, the water use in the Aquamat System™ has been lower than in the other two systems (Tab.1). Thus, the results show that the quantities of water lost with a traditional irrigation system is very high.

Table 1. Water balance from May to September 2004 (m^3).

	Sector 1 (Control)	Sector 2 (Closed system)	Sector 3 (Aquamat System ™)
Supplied water	223	224	166
Re-used water	0	110	2
Water consumption	223	114	164

Also in this second year the N:P:K ratio was analysed, and after the use of the solution the concentration was about similar to that at the beginning (3.6:1:2.1), in spite of the different N:K ratio checked in the water contained in the basin (6.5:1:3 = N/K 2.2).

Regarding an economic evaluation, the traditional system has lower costs (27 €/m^2) than Aquamat System™ , which is 55% (42 €/m^2) more expensive. But the most expensive system is the one of sector 2 (overhead irrigation with closed system) with a cost of 63 €/m^2. In this evaluation, the cost of fertigation system was not included, because it depends on the size of the nursery.

In summary; the Aquamat System™ is best both for the plant quality (Caron, J. 2002), for the reduction of water use and decrease of the potential pollution risk. The costs are relatively low, and can probably be decreased further in the future, by simplifying and adapting this idea to the nurseries.

4. CONCLUSIONS

In order to implement the sub-irrigation advantages also in the nursery, where sprinkling or micro-irrigation are at present normally in use, new systems are developed. These new systems are based on the sub-irrigation, adjusted by the use of special mats with high water retention capacity. These irrigation systems guarantee the recovery of water and nutrients that have not been held by the crop during irrigation.

Although localized irrigation implies rather high installation costs, the decision on which system to choose must include an evaluation of manpower, energy and water costs saved by using the improved new systems.

REFERENCES

Beeson Jr, R. 2002. Comparison of Laval University capillary mats to other landscape nursery irrigation systems. Mid Florida Research and Education Center, Univ. of Florida.

Caron J. *et al*. 2002. Showing signs of improvement. *American Nurseryman* (7):32-34.

Centro Divulgazione Agricola 2003. Metodi di irrigazione-Gestione delle risorse idriche in agricoltura 94-95.

Colombo, A. *et al*. 2004. Razionalizzazione dell'uso delle risorse idriche nel settore del florovivaismo in contenitore. Fondazione Minoprio.

Marzialetti, P. & Pardossi, A. 2003. La gestione dell'irrigazione e della concimazione nelle colture florovivaistiche.

United Nation World Water Development Report 2003. Water for people – Water for life 17-19.