32nd WEDC International Conference, Colombo, Sri Lanka, 2006

SUSTAINABLE DEVELOPMENT OF WATER RESOURCES, WATER SUPPLY AND ENVIRONMENTAL SANITATION

An auto irrigation system for home gardens in Sri Lanka

C. M. Navaratne, K. D. N.Weerasinghe and L. N. N. Jayasuriya, Sri Lanka

A subsurface pot irrigation system and a subsurface irrigation system with specially designed clay emitters were designed and tested to investigate the efficiency of the auto-irrigation systems for home gardens crop cultivation. The yield and development of curry chilies cultivated under the designed subsurface irrigation systems were compared with the yield and development of curry chilies under manual irrigation during three seasons; January – April, May - August and September – December. The yield obtained from the crop grown under designed irrigation systems is two times higher than the yield of crop grown under manual irrigation during dry seasons. The use of water under subsurface irrigation system with clay emitters was considerably less when compared with the subsurface pot irrigation. Both designed irrigation systems automatically control the water intake of soil when the soil is wet.

Introduction

Home gardens in Sri Lanka have small scale cropping systems. A well cultivated home garden supplies the family vegetables, fruits and other food without various poisons and impurities. It creates a friendly surrounding and provides mental satisfaction to the entire family.

The occurrence of unexpected dry periods due to uneven distribution of rainfall in most parts of the country emphasizes the requirement of irrigation water during cropping seasons. The common irrigation practice in home gardens is manual irrigation using water from the garden well or pipe borne water, which involves high labour cost and low water use efficiency and it is limited during dry seasons. Therefore, the development of an appropriate irrigation method, which has high water use efficiency and low labour requirement, has become an urgent need.

Water use efficiency and crop productivity are high under subsurface trickle irrigation systems compared with other irrigation systems (Brosz and Wiersma (1974), Goldberg et al (1976), Freeman et al (1976), Jenson (1980), Hoffman et al (1990), Lamm et al (1995), El-Gindy and El-Araby (1996) and Clancy (1996). Therefore, a subsurface trickle irrigation system with a suitable emitter for home gardens was designed.

Location of the experimental area

Field experiments were carried out at the research farm in the Faculty of Agriculture, University of Ruhuna at Mapalana in the Matara District. The Mapalana research farm lies in the mantle plain with an undulating topography rising from 9m to 30 m MSL. Based on the agro ecological map (2003), it is located in the agro-ecological region Low Country Wet Zone (WL4). The main soil group of the farm is Red Yellow Podsolic soils with soft or hard laterite. The annual rainfall, mean air temperature, annual pan evaporation and average relative humidity of the area are 2300 mm, 28 0C, 1560 mm and 73% respectively (Weerasinghe 1989).

Selection of suitable subsurface irrigators

Various types of emitters for subsurface drip irrigation systems were tested and practised by several researchers (Hiller and Howell, 1972; Keller and Karmeli, 1975; Wu and Giltin, 1980; Clark et al., 1993; Barth , 1995; Barth and Lamm, 1995). They reported that subsurface drip irrigation systems have high uniformity, efficiency and easy installation. Agodzo (1993) and Agodzo et al (1991) conducted both laboratory and field trials to find out the suitability of clay pots as subsurface irrigators. According to the above researchers the pot water supply was responsive to demand and it helped to increase the yield. In this study clay pots were selected as subsurface irrigators.

Design of clay pots

The round shaped clay pots (1.5 L) were identified as the best shape of subsurface irrigators among conical and drum shaped pots (Navaratne 2003). Further to round shaped clay pots a specially designed conical shape clay emittes (20 cm3) by Navaratne (2003) was used for the experiment. It was also planned to minimize the irrigation water loss. The conical shape was selected for emitters, as the depth distribution of moisture is high in conical shaped pots (Navaratne 2003).

Porous clay pots were automatically filled with water by a network of interconnecting pipes. Due to hydraulic permeability of the pot, the water flows into the soil surrounding the pot, thus providing a moisture supply to the root zone. The flow continues through the walls of the pot, and the rate of water released depends upon the difference in potential head between the pot and the soil. Therefore the irrigation system is able to respond automatically to changes in the rate of root water uptake.

Determination of wetting pattern

The wetting front and the volume of active root zone wetted were studied in the selected area under round shaped clay pots by Navaratne (2003). The results showed that the subsurface placement emitter wetted more soil volume than the surface placed emitter.

Design of auto irrigation systems

After selecting a suitable shape for the clay pot, subsurface irrigation systems were designed and tested in order to obtain the maximum yield with minimum irrigation requirement.

In the subsurface irrigation system with round shaped clay pots (pot irrigation), pots were connected to the main supply line by transparent tubes. Ten pots were buried in each plot (1.2x2m) with 50x50cm spacing which was determined by Navaratne (2003). Four plants were served by a single round shaped pot. Main supply line of the network of pots was connected to a supply tank of 220L volume. Amount of water depleted from the tanks was measured daily in the morning and filled to the original level subsequently.

In subsurface irrigation system with conical shaped clay emitters (trickle irrigation) were connected through transparent plastic tubes and connected to a supply bucket of 12 L volume. The system was arranged having plant spacing in the field so that each plant was served by a single emitter. The amount of water depleted from the buckets was measured daily in the morning and filled to the original level subsequently.

These irrigation systems were used to irrigate curry chilies (Capsicum grossum, Variety: Hungarian Yellow Wax). There were three treatments viz: subsurface pot irrigation, subsurface trickle irrigation and manual irrigation; and four replicates. The plots were arranged in the field based on complete randomized block design. The irrigation water requirement and physiological observations on the growth and development of the plant were measured in weekly intervals. At the end of the experiment the yield was collected after rejecting the borders and data statistically analyzed. The results under these irrigation networks were compared with each other during three seasons in January – April, May– August and September - December to test the adaptability and validity of designed irrigation systems.

Irrigation water consumption by curry chilies

Water consumption by curry chilies under each irrigation system during three seasons is given in Tables 1, 2 and 3.

It was revealed that total, maximum, minimum and daily average irrigation need of curry chilies under irrigation system with clay emitters was significantly less than the other two irrigation systems for all three seasons. When compared to two subsurface irrigation systems, the commanding wetted area was high in round shaped pots (diameter 56 cm and depth 25 cm) in the subsurface pot irrigation system whereas the commanding area of conical shaped clay emitters was low (8.8cm diameter and 22.8 cm depth). This may be the reason for higher water consumption under the subsurface pot irrigation system. As there is no concise method to measure the irrigation need for manual irrigation, the amount of water that needed daily for pot irrigation, was applied to manual irrigation plots everyday in the morning. Therefore, water consumed by curry chilies under the manual irrigation cannot be compared with the other two irrigation systems.

Table 1. Irrigation water consumption by curry chilies under three different irrigation systems in season I.

Irrigation system	Water consumption			
	Total (mm)	Max. (mm/day)	Min. (mm/day)	Av (mm/day)
Subsurface with clay pot	227	3.77	0.42	2.0
Subsurface with clay emitter	126*	2.69	0.33	1.1
Manual irrigation	227	3.77	0.42	2.0

*= significant at 1% level. CV = 14%

Table 2. Irrigation water consumption by curry chilies under three different irrigation systems in season II.

Irrigation system	Water consumption			
	Total (mm)	Max. (mm/day)	Min. (mm/day)	Av (mm/day)
Subsurface with clay pot	184	3.67	0.2	1.61
Subsurface with clay emitter	81*	2.1	0.1	0.71
Manual irrigation	184	3.67	0.2	1.61

*= significant at 1% level. CV = 5.9%

Table 3. Irrigation water consumption by curry chilies under three different irrigation systems in season III.

Irrigation system	Water consumption			
	Total (mm)	Max. (mm/day)	Min. (mm/day)	Av (mm/day)
Subsurface with clay pot	98	2.05	0.48	1.28
Subsurface with clay emitter	58*	1.37	0.13	0.76
Manual irrigation	98	2.05	0.48	0.28

*= significant at 1% level. CV = 9.2%

Table 4. Rainfall, Irrigation and water need of crop under different irrigation systems during three seasons.

Season	Effective Rainfall (mm)	Irrigation water used (mm)		Assumed water requirement (mm)	
		Pot	Trickle	Pot	Trickle
I	276.45	227	126	503	402
II	410.4	184	81	594	491
III	651.38	98	58	749	709

Table 4 shows the effective rainfall, irrigation need under pot and trickle irrigation systems and assumed water requirement (effective rainfall + irrigation need) for crops during three seasons.

Irrigation need under manual irrigation was not taken into account as the same amount of water used by pot irrigation system was applied.

It shows that the irrigated water intake by the crop under both irrigation systems is high during the seasons I and II, which experienced low rainfall compared with the season III. It can be revealed that when rainfall was low, water diffusion through clay pots and emitters to the root zone was high. A high amount of rainfall during season III kept the root zone wet and the wetness of soil may stop or limit passing water through clay porous walls of pots and emitters to soil. Therfore, soil wetness due to rain may control water diffusion through irrigation systems. This is a major advantage of these two irrigation systems for efficient use of water in home gardens as other irrigation systems released water to soil whether the root zone is moistened or not. Therefore, it can be clearly indicated that these two irrigation systems have good performances to save water in crop fields.

It was revealed that plants under the irrigation system with clay emitters consumed 44.5% less water in Season I, 56% less water in Season II and 40.8% less water in Season III than water consumed by pot irrigation.

Growth and development of the crop

Figs.1. 2 and 3 give the plant height at subsequent 8 weeks under different irrigation systems during the three selected seasons. The plant height difference among three irrigation systems was not significant during season III. During seasons I and II, plant growth under clay pot and clay emitter irrigation systems were significantly high, compared to manual irrigation. But the height difference was not significant. It can be indicated that the designed irrigation systems helped to develop plant growth during dry seasons.

Yield of crop

The cumulative yield of curry chilies under different irrigation systems during three different seasons is given in Figs 4, 5 and 6. The results revealed that the difference in yield of crop between pot and trickle irrigation during Seasons I and II is not statistically significant. However the crop yield under manual irrigation is significantly less compared to the other two irrigation systems.

During the period of Season III (September to December), the crop yield under trickle irrigation system was comparatively high. However the yield difference among irrigation systems was not statistically significant. The lowest yield was reported under manual irrigation. Therefore it can be indicated that even within the rainy season if the root zone can be moistened regularly, it would help to receive high a yield of crop.

It can be seen that the yield under manual irrigation is always less during three different seasons. This may be due to crops grown under manual irrigation received the same amount of water which were utilized by the plants cultivated under pot irrigation, once a day in the morning.

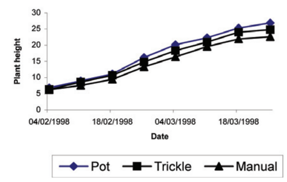

Figure 1. Plant height under different irrigation systems during season I

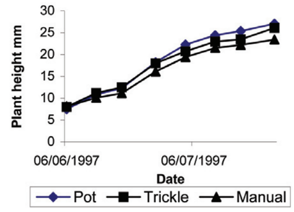

Figure 2. Plant height under different irrigation systems during three selected seasons in season II.

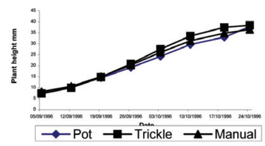

Figure 3. Plant height under different irrigation systems during three selected seasons in season III.

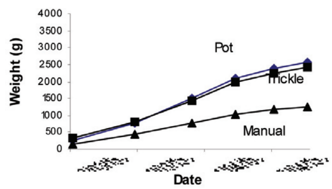

Figure 4. Cumulative yield of curry chilies under different irrigation systems in season I

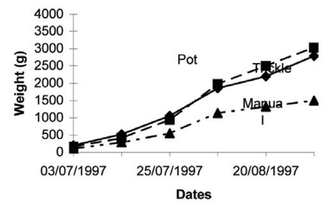

Figure 5. Cumulative yield of curry chilies under different irrigation systems in season II

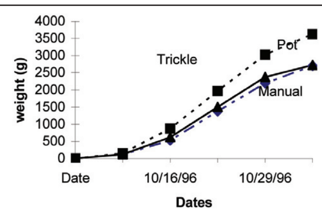

Figure 6. Cumulative yield of curry chilies under different irrigation systems in season III

Table 5. Reported yield and estimated yield under three irrigation systems during three seasons.

Irrigation systems	Yield kg/ha			
	Season I	Season II	Season III	Estimated
Pot	10708	12637	17267	10000 - 15000
Emitter	10113	11624	17961	
Manual	5260	6239	14254	

But, under designed irrigation systems, pots and emitters released water to the soil slowly within a 24 hour period. Therefore the plants can utilize water most effectively under these irrigation systems while water applied manually will lose due to evaporation, seepage and percolation. As a result, the automatic irrigation systems would produce more yield in home gardens.

Conclusion

The yield gained from the crop grown under designed irrigation systems is twice the yield of crop grown under manual irrigation during the dry seasons. The designed irrigation systems have high water use efficiency. They automatically control water intake by the soil when the soil is wet.

The use of water under the subsurface trickle irrigation system is considerably less when it compares with the subsurface pot irrigation. Irrigation water consumption by crops under trickle irrigation is 1.8 times less during January April, 2.2 times less during May – August and 1.7 times less during September – December

References

Agodzo S. K., 1993. Trickle irrigation using porous clay pot. PhD thesis, University of Newcastle upon Tyne, UK. 292 pp.

Agodzo S. K. Gowing J. W; Adey M. A. 1991. Use of porous clay pots as alternative trickle irrigation device. In Techniques for Environmentally Sound Water Resources Development, R Wooldridge (Ed), Pentech press. 10 pp.

Barth, H. K. 1995. Resource conservation and preservation through a new subsurface irrigation system. In Micro irrigation for a changing world: Conserving resources/preserving the environment. Proceedings of the Fifth International Microirrigation Congress. Orlando, Florida, USA.

Barth-H. K; Lamm-FR 1995.Resource conservation and preservation through a new subsurface irrigation system. Subsurface Irrigation Abstracts. 168-174; 6 ref.

Brosz,-D .D.; Wiersma,-J. L. 1974. Comparing trickle, subsurface and sprinkler irrigation systems. Subsurface Irrigation Abstracts Paper No 74-2045. 16p, 5 Fig, 7 Tab, 4 Ref.

Clancy, G. 1996. Australian experience with sub-surface drip irrigation. International Sugar Journal (Cane Sugar Edition) 98 (1170) 307-308 En, 2pl., also publ. in the Beet Sugar Edition T-systems International Inc., Australia.

Clark, G. A., Stanley, C. D., and Maynard, D. N. 1993. Surface vs. subsurface drip irrigation of tomatoes on a sandy soil. Proceedings of the Florida State Horticultural Society. 1993. Publ. 1994. 106: 210-212.

El-Gindy, A. M. And El-Araby, A. M. 1996. Vegetable crop response to surface and subsurface drip under calcareous soil. Evaporation and Irrigation Scheduling: Proceedings of the international Conference, Nov 3-6. pp1021-1028.

Freeman B. M, Blackwell J. and Garzoli K. V. 1976 Irrigation frequency and total water application with trickle and furrow systems. Agric. Water management 1;21-31.

Goldberg, D., Gornat, B. and Rimon, D. 1976. Drip irrigation; Principles, design, and agricultural practices. Kfar shmaryahu, Israel: Drip irri. Si. Publs. pp296.

Hiler-E. A; Howell-T. A, 1973. Grain sorghum response to trickle and subsurface Irrigation. Transactions of the ASAE, p 799-803, 5 fig, 3 tab, 18 ref.

Hoffman, G. J., Howell, T. A., Solomon, (1990). Management of farm irrigation systems. ASAE Monograph.ASAE, St. Joseph. MI. 1040 pp.

Jenson, M. E. 1980. Design and operation of farm irrigation systems. ASAE Monograph ASAE, St. Joseph, MI. pp 829.

Keller, J. and D. Karmeli. 1975. Trickle irrigation design. First Ed. Pub. By Rain Bird Manufacturing Co., Glendora, CA. 133 pp.

Lamm-F R; Manges-H L; Stone-L R; Khan-A H; Rogers-D H, 1995. Water requirement of subsurface drip-irrigated corn in northwest Kansas. Transactions-of the-ASAE. 38:2, 441-448; 29 ref.

Navaratne, C. M. 2003. Low Cost Auto Irrigation System For Home Garden Intensification To Minimize The Agro-Climatic Risk: A Case Study In Matara District PhD thesis, University of Ruhuna, Matara, Sri Lanka. 80 -128 pp.

Weerasinghe, K. D. N. 1989. The rainfall probability analysis of Mapalana and its application to agricultural production of the area. J. Natn. Sci. Coun. Sri Lanka 1989 17(2):173-186.

Wu J. P, Giltin 1980 Preliminery Concept of a drip irrigation network design. ASAE, Vol. 24 No:- 2 May-April 1980 p.p.330.

Contact addresses

C.M.Navaratne, Senior Lecturer
Department of Agricultural Engineering, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya.
Sri Lanka

K.D.N.Weerasinghe, Professor in Agronomy
Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya
Sri Lanka

L.N.N.Jayasuriya, Senior Lecturer
School of Civil and Chemical Engineering, RMIT University, Melbourne Australia
Australia