J. Int. Environmental Application & Science, Vol. 4 (1): 79-85 (2009)

Evaluation of Trickle Irrigation Systems for Some Vegetable Crops in Konya-Turkey[#]

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Received January 13, 2009; Accepted February 12, 2009

Abstract: This study was conducted to evaluate randomly selected 11 trickle irrigation systems, 4 in plastic greenhouses and 7 in open fields, for some vegetable plants at Konya province of Turkey. The present work covered mainly determinations of uniformity coefficient (UC), root lengths of vegetables, evaluation of working pressures of systems and also system components. The UC varied from 79.2% to 94.5%. The root length of processing tomato varied from 53cm to 58cm and 34cm to 38cm under field and greenhouse conditions, respectively. The working pressures varied between 0.6 and 0.9 atm. that were lower than the optimum working pressure of 1.0 atm.

Key Words: *Trickle irrigation, vegetables, uniformity coefficient, root length.*

Introduction

Irrigation is needed for successful crop production where stored soil moisture and natural precipitation is insufficient to meet the crop water requirement (Hassan *et al*. 2002). Efficient water use by irrigation system is becoming increasingly important especially in arid and semi-arid climate regions. Some authors (Shmueli & Goldberg, 1971; Kadam, 1993; Sanders *et al.* 1989; Acar, 2001) have reported the advantages of trickle irrigation. They reported that trickle irrigation has a greater water economy in such regions under good management conditions. It also has the potential to increase yields of crops even with reduced irrigation water application. Trickle irrigation reduces evaporation and deep percolation, controls soil water content more precisely (Bernstein & Francois, 1973).

In general, excess water applications in agriculture results in low irrigation efficiencies. The use of trickle irrigation is inevitable in the near future because of the scant of water supply and salinity problem caused by traditional irrigation methods at arid and semi-arid regions (Şimşek *et al*. 2004).

The potential of trickle irrigation systems in reducing energy use, water and plant nutrients losses and improving efficiency has long been studied (Bresler, 1977; Nakayama & Bucks, 1986; Keller & Bliesner, 1990; Burt & Styles, 1994; Dasberg & Or, 1999). The properly designed irrigation system applies the amount of water desired at the appropriate time while providing for leaching requirements, agronomic operations, and environmental considerations (Hoffman & Martin, 1993). Trickle irrigation management is based on the frequent replenishment of water loss by evapotranspiration. Goldberg *et al.* (1971) reported that high irrigation frequency may reduce evaporation and deep percolation and establish a favourable soil moisture and oxygen condition in the root zone throughout the crop period. To calculate the frequency and duration of irrigations, the depth of the active root zone of the crop being monitored should be known. It was noted that to maintain a healthy, well distributed root system, it is very important to apply irrigation water to the some area of soil to the same depth every time (Anonymous, 1999). The crop root zone depth can be limited by shallow soils, compaction layers, and dry soil. All of them reduce amount of available water to the crop, thus requiring more frequent irrigation intervals. In practice, it is possible to schedule the irrigation by using the soil moisture tensiometer because of the ease of use and the immediate results. Smasjtrla *et al.* (1985) demonstrated that to reduce deep percolation and to maintain nearly constant high soil water potential; high frequency (multiple applications per day) irrigations should be

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[#] *This research was a partial MSc Thesis of Muhammed Cüneyt Bağdatlı.*

suggested. Goldberg & Shmueli (1970) indicated that yields of cucumber (*Cucumis sativus* L.) planted in sandy soil would be reduced if irrigation frequencies were beyond one day.

Irrigated agriculture provides higher crop yield but the performance of many irrigation projects has far from the expectations as a result of poor water management at farm and system levels (Islam *et al.* 1990). Trickle irrigation systems sometimes may be managed poorly so such systems would be inefficient. Over watering of plants in agriculture leads to the leaching of some plant nutrients lower part of the root zone. Under excess water application conditions, some nutrients like nitrogen may reach to the ground water and result in ground water contamination. To sustain the water resources and prevent the ecology, irrigation water resources should be managed properly.

The study evidence suggests that different emitter arrangements, discharge rates, irrigation amounts, and soil types resulted in different patterns of crop yield (Colombo & Or, 2006). Ortega *et al.* (2002) reported that the most important problems detected were caused by low working pressure and occasionally, by an excessive variation of pressure within the subunit. To determine the systems properly operated or not, such systems should be tested in some periods.

The aim of this study was, therefore, to evaluate the some trickle irrigation systems installed in green houses and open field's conditions for vegetable plants at Konya province of Turkey.

Materials and Method

The research was conducted during the periods Spring-Autumn 2005 at Konya province of Turkey. The study region has savanna ecology and environment is described as almost arid. The long term weather records show that total annual rainfall in Konya is almost 300mm and only 130mm of it precipitates during the crop growth period (Anonymous, 2004).

The data in Table 1 and 2 present information on the physical and chemical properties of the soils in research farms. Predominantly sandy-loam (SL) in texture and the soil is acidic in reaction.

Table 1. Some physical properties of soils in research farms

Farms	Soil Depth (cm)	Bulk Density, γt, (g/cm^3)	Field Capacity, FC, (%)	Wilting Point WP, (%)	Available Water Capacity, AWC, (%)	Soil Texture
1	0-30	1.63	28.42	14.78	13.64	Sandy-Loam (SL)
	30-60	1.65	28.54	14.31	14.23	Sandy-Loam (SL)
	60-90	1.60	28.51	14.84	13.67	Sandy-Loam (SL)
2	0-30	1.58	26.93	14.49	12.44	Sandy-Clay-Loam (SCL)
	30-60	1.59	27.11	13.89	13.22	Sandy-Clay-Loam (SCL)
	60-90	1.58	28.89	14.89	14.00	Sandy-Clay-Loam (SCL)
3	0-30	1.46	28.95	12.32	16.63	Loam (L)
	30-60	1.58	28.60	15.98	12.62	Sandy-Loam (SL)
	60-90	1.56	28.39	15.46	12.93	Sandy-Loam (SL)
4	0-30	1.60	27.75	13.97	13.78	Sandy-Loam (SL)
	30-60	1.62	28.33	13.69	14.64	Sandy-Loam (SL)
	60-90	1.64	27.89	14.16	13.73	Sandy-Loam (SL)
5	0-30	1.56	26.35	13.29	13.06	Sandy-Loam (SL)
	30-60	1.48	28.29	12.01	16.28	Loam (L)
	60-90	1.60	27.08	14.26	12.82	Sandy-Loam (SL)
6	0-20	1.45	22.73	11.26	11.47	Silty –Loam (SiL)
	20-40	1.41	20.55	10.14	10.41	Silty –Clay-Loam (SiCL)
7	0-20	1.40	24.35	12.42	11.93	Silty –Clay-Loam (SiCL)
	20-40	1.38	22.68	11.78	10.90	Silty –Clay-Loam (SiCL)
8	0-20	1.42	20.61	10.21	10.40	Silty –Clay-Loam (SiCL)
	20-40	1.40	20.25	10.94	9.31	Silty –Clay-Loam (SiCL)
9	0-20	1.41	19.38	11.04	8.34	Silty –Clay-Loam (SiCL)
	20-40	1.43	20.10	10.45	9.65	Silty –Loam (SiL)
10	0-30	1.42	24.60	12.45	12.15	Silty –Loam (SiL)
	30-60	1.40	23.13	11.78	11.35	Silty –Loam (SiL)
	60-90	1.39	28.51	11.02	17.49	Loam (L)
11	0-30	1.40	28.56	11.10	17.46	Loam (L)
	30-60	1.46	23.78	11.24	12.54	Silty –Loam (SiL)
	60-90	1.48	23.90	11.74	12.16	Silty –Loam (SiL)

Irrigation water quality is presented in Table 3 and generally is second (**C_2**) or third (**C_3**) class in terms of the salinity hazard (Farook, 1998a).

Table 2. Some chemical properties of soils in research farms

Farms	Soil Depth (cm)	PH	Salt Content mmhos/cm	$CaSO_4$ (%)	Lime Class
1	0-30	7.12	0.54	12.96	Moderately
	30-60	7.02	0.56	14.09	Moderately
	60-90	7.04	0.75	17.09	Excess Lime
2	0-30	7.21	0.44	21.04	Excess Lime
	30-60	7.22	0.45	21.41	Excess Lime
	60-90	7.36	0.47	21.79	Excess Lime
3	0-30	6.93	0.66	10.52	Moderately
	30-60	6.96	0.89	10.70	Moderately
	60-90	6.99	0.90	10.89	Moderately
4	0-30	7.11	0.51	10.89	Moderately
	30-60	7.17	0.69	12.96	Moderately
	60-90	7.18	0.89	14.27	Moderately
5	0-30	7.46	0.64	10.89	Moderately
	30-60	7.47	0.66	11.08	Moderately
	60-90	7.49	0.73	14.96	Excess Lime
6	0-20	6.76	0.52	3.69	Low
	20-40	6.84	0.42	3.86	Low
7	0-20	6.84	1.21	2.95	Low
	20-40	6.92	1.44	3.01	Low
8	0-20	6.79	1.22	0.74	Low
	20-40	6.82	1.33	0.81	Low
9	0-20	6.40	1.15	0.73	Low
	20-40	6.22	1.20	0.78	Low
10	0-30	7.24	1.12	3.46	Excess Lime
	30-60	7.10	1.17	3.93	Excess Lime
	60-90	7.13	1.35	3.72	Excess Lime
11	0-30	7.14	1.19	3.25	Excess Lime
	30-60	7.12	1.25	3.72	Excess Lime
	60-90	7.24	1.48	4.07	Excess Lime

Table 3. Quality of water supplies used in irrigation practices.

Farms	Water Supply	PH	Salt Content; EC micrommhos/cm	Sodium Adsorption Ratio, SAR	Water Quality Class
1	Deep Well	7.9	592	4.91	$C_2 S_1$
2	Deep Well	7.6	580	5.33	$C_2 S_1$
3	Deep Well	8.0	1269	5.99	$C_3 S_1$
4	Deep Well	7.7	439	3.16	$C_2 S_1$
5	Deep Well	7.5	500	3.14	$C_2 S_1$
6	Pond	7.7	410	0.69	$C_2 S_1$
7	Pond	7.5	484	1.19	$C_2 S_1$
8	Pond	7.9	285	0.60	$C_2 S_1$
9	Pond	7.6	304	1.34	$C_2 S_1$
10	Deep Well	7.4	1095	5.26	$C_3 S_1$
11	Deep Well	7.4	1956	9.50	$C_3 S_1$

The research was conducted in randomly selected 11 farms [(four in plastics green houses (farm no of 6, 7, 8 and 9)] and seven in open (farms no of 1,2,3,4,5,10 and 11) fields. The trickle system consisted of polyethylene laterals of 16 mm obtained from different companies laid parallel to crop rows and each lateral served two rows of plant. Farm size, growth conditions and of vegetables with planting spaces are presented in Table 4.

The flow rate of a significant sample of emitters and pressure head (Capra & Tamburino, 1995) were measured by a graduated container (100 and 200 mL of capacity) and manometer, respectively. Almost 24 emitters were tested, located in a representative subunit of each system, eight laterals in each subunit, and three emitters in each lateral (Figure 1).

In all in-line emitters of 2-4 L h^{-1} capacity was tested (Farouk, 1998b) and following equation was used for computing the uniformity coefficient (UC);

$$UC = 1 - \left(\frac{\Delta q}{q} \right) \qquad (1)$$

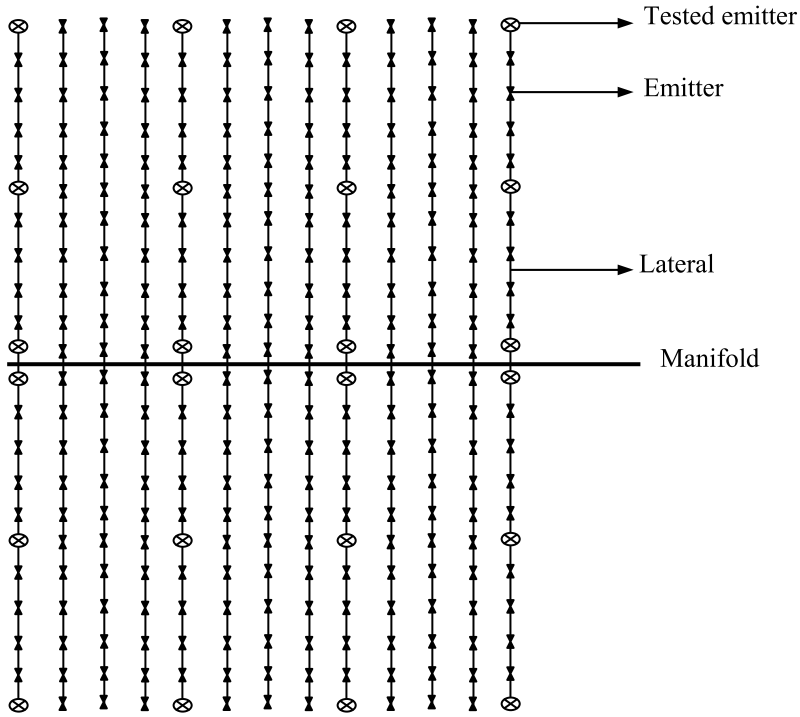

Figure 1. Scheme of tested emitters in the subunit for determination of UC

Table 4. Some design properties of vegetables in research farms.

Farms	Farm Size, (ha)	Growth Conditions	Plants	Plants	
				Row Space, (m)	Space Between plants, (m)
1	2.73	Open Field	Processing Tomato	1.50	0.40
2	4.50	Open Field	Processing Tomato	1.80	0.50
3	7.50	Open Field	Processing Tomato	1.70	0.30
4	1.70	Open Field	Cabbage	0.45	0.30
5	1.50	Open Field	Processing Tomato	1.80	0.50
6	1.80	Greenhouse	Cucumber	0.45	0.30
7	0.074	Greenhouse	Cucumber	0.55	0.40
8	0.20	Greenhouse	Processing Tomato	0.40	0.30
9	0.0552	Greenhouse	Processing Tomato	0.55	0.40
10	2.10	Open Field	Processing Tomato	1.40	0.60
11	4.0	Open Field	Pepper	0.20	0.30

Where; q- the mean emitter discharge rate (L h^{-1}) and Δq- mean deviation of the emitter discharge from mean value (L h^{-1}). The results were evaluated by Tüzel (1993) and Bralts (1986). For root length measurement, plants were harvested with most care. The sides of plants, 60cm from each side, were dug in 1m deep and the plant along with the soil was lifted (Habib, 1988).

Results and Discussions

Emitters are one of the most important components of trickle irrigation systems. In examined farms, clogging problem was observed low in majority of the systems. The UC values varied from 79.2% to 94.5%. According to the results, UC values (Table 5) showed excellent uniformity in most of the systems according to Tüzel (1993) and Bralts (1986). Yavuz (2008) reported that UC values were between 62.2% and 93.8% in Antalya province of Turkey for greenhouse conditions and these were lower than our study results. In this research, pressure variations mainly affected the UC of the systems and this is in line with the findings by Capra & Scicolone (1998).

Table 5. Uniformity coefficients of tested trickle irrigation systems

Farm no	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
UC, %	87.5	92.0	93.0	87.6	87.5	93.5	93.3	91.5	94.5	89.5	79.2

The root lengths was variable, ranging from 53 to 58cm (Table 6) for processing tomato under field conditions and the highest root length with 58cm was obtained from farm 10. However, it varied from 34 (farm 8) to 38cm in greenhouse conditions (farm 9). Yavuz (2008) reported that root length varied from 0.30 m to 0.43 m for processing tomato under greenhouse conditions in Antalya province of Turkey. The study result was similar to findings of Yavuz (2008). The root lengths of cabbage and pepper were measured as 52 and 45cm, respectively under field conditions. This increased in open field by comparison to greenhouses conditions, since soil depth was shallow in green houses. The growth conditions possibly affected root lengths of the vegetables and the vertical root growth of vegetables was observed lower in greenhouses. Similar result was demonstrated by Kramer & Boyer (1995).

Table 6. Root lengths of plants in research areas.

Farms	**Plants**	**Root Lengths (cm)**
1	Processing Tomato	56
2	Processing Tomato	53
3	Processing Tomato	55
4	Cabbage	52
5	Processing Tomato	54
6	Cucumber	37
7	Cucumber	32
8	Processing Tomato	34
9	Processing Tomato	38
10	Processing Tomato	58
11	Pepper	45

The distribution components of control unit are presented in Table 7. In that Table, manometer was not present in 1, 6, 8 and 9 farms. According to the results, farmers did not control the working pressure of those systems. This could be caused the non-uniform water distribution to the plants and could be affected the system performance adversely. The hydrocyclone was not present in most farms (1, 2, 4, 6, 7, 8 and 9 farms) although it was vital important for obtaining irrigation water from unlined wells. The filters, one of the most important components of trickle system, were present in most farms.

Table 7. Components of control unit in researched systems

	Components of Control Unite		
Farms	**Manometer**	**Hydrocyclone**	**Filter**
1	-	-	+
2	+	-	+
3	+	+	+
4	+	-	+
5	+	+	+
6	-	-	+
7	+	-	+
8	-	-	+
9	-	-	-
10	+	+	+
11	+	+	+

The present study showed that lateral length was chosen suitable in 10 examined farms. The highest lateral length was measured 30m (in farm 1) and this was higher than suggested by firm guide (22m) for present design condition. The UC value was measured lower than the most other tested farms (87.5%). To improve the uniformity of water distribution, laterals should be laid equal or slightly shorter than the maximum lateral lengths as suggested by Acar (2001).

The working pressure varied from 0.6 to 0.9 atm and was lower than optimum pressure of 1.0 atmosphere in all tested systems. The low pressures affected the water distribution uniformity in farms 1, 4, 5 and 11 so some plants might be received more water than the others. This problem can be solved by a proper regulation of the installations, automated when possible, and proper design as recommended by Ortega *et al.* (2002).

In present study, none farmers have measured the soil moisture content. Therefore, they did not know whether the soil moisture content in root zone depth is sufficient or not for optimum crop growth. To solve the problems associated from non-uniform water application, soil water content should be measured and right amount of water should be applied. In practice, at least soil moisture tensiometer may be used by farmers to determine the time and duration of irrigation.

To increase the water distribution uniformity, maintenance and repair works of systems also should be done regularly. To sustain the water resources or prevent the harmful effects to the environment associated from excess water application in agriculture, irrigation water should be managed properly.

Conclusion and Recommendations

- Due to clogging problems, few trickle irrigation systems have suboptimal application uniformity. To increase the water distribution uniformity, maintenance and repair works of systems also should be done regularly.
- Soil moisture content should be controlled after the irrigation in root zone depth. At least, soil moisture tensiometer for this purpose may be used by farmers in practice to determine time and duration of irrigation.
- It should be noted that more water does not result in higher crop yield. Excess water application adversely affects the balance of water-air in root zone depth. As a result of this, in general crop yield reduces.
- Excess water should not be applied to the plants. This water also carries to the plant nutrients like nitrogen to the ground water. Under this condition, groundwater resources are contaminated.
- The water resources are like a backbone of the nation so it should be used with most care in all sectors.

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