Water Quality and Uniformity in Trickle Irrigation Systems: A Case Study of Antalya, Turkey

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The clogging of emitters is a common problem in trickle irrigation systems. Partial or complete clogging adversely affects uniform water distribution, as well crop yield. Despite the quantity of research cited in previous studies about the quality treatment and distribution uniformity of irrigation water, the problem still present. The research was performed to determine effects of water quality on emitter clogging and uniformity of water for 11 different trickle systems installed at greenhouses in Antalya, Turkey. The results showed that the pH varied from 7.14 to 8.11. Electrical conductivity (EC) varied from 432 to 866 μhos/cm and irrigation water used in 6 trickle systems (55 %) it was lower than the 750 μhos/cm and had low hazard effect on greenhouse plants. In water samples used in five systems (45 %), had moderately hazard. The uniformity coefficient (UC) varied between 62.2 and 95.1 %, the average of 88 %. The UC values show excellent uniformity in 63.6 % of the systems, good in 27.3 % and poor in 9.1 %,

Key Words: Trickle, Water, Quality, pH, Electrical conductivity, Clogging, Uniformity.

INTRODUCTION

Water quality is a major concern in management of trickle irrigation systems. In fact, partial or complete clogging reduces uniformity of water distribution and as a consequence, decreases irrigation efficiency. Well-designed trickle systems should apply the water uniformly, in such a way that the different emitters discharge almost the same rate. A good management must maintain uniformity, that is easy to quantify[1,2]. In study on clogging and mitigation procedures, Nakayama and Bucks[3] established that these processes are closely related to the quality of irrigation water. The clogging of emitters can be caused by physical, chemical or biological contaminants. Physical clogging is caused by suspended inorganic particles (such as sand, silt, clay, plastics), organic materials (animal residues, snails, *etc.*) and microbiological debris (algae, *etc.*)[4,5]. Chemical problems are due to dissolved solids when they interact with each other to form precipitates and the precipitation of calcium carbonate in waters rich in calcium and bicarbonates. Injected chemicals during the plant growth such as fertilizers and pesticides are also responsible for clogging. In most cases, chemical clogging can be solved by acid treatment or injection through the system by reducing pH of water[6]. The biological clogging can be solved with the injection of a biocide followed by flushing to clear the system of organic matter.

Water analysis prior to system design, a preventive maintenance program and field evaluation of clogging and uniformity are strongly recommended[1,7]. Up to now, no water quality evaluation method capable of representing potential emitter clogging has yet been developed. The causes of clogging vary from location to location and for the same water, clogging depends on other local conditions, such as water temperature and on emitter features. In the early 1980s, Bucks *et al.*[4] proposed a classification scheme for water quality to indicate clogging potential and little change has been made since then. Available methods for field measurement of irrigation uniformity are both time and money consuming. Uniformity coefficient (UC) for localized irrigation systems, based on emitter flow measures is highly recommended[1,8,9]. It is a useful indicator, which shows the water uniformly. Tüzel[10] classified the water distribution level in accordance to uniformity coefficient. These were; UC > 90 %-excellent water distribution; 80 % < UC < 90 % - good water distribution; 70 % < UC < 80 %-moderate water distribution; 60 % < UC < 70 % - poor water distribution; UC < 60 %-unacceptable water distribution. The uniformity coefficient varied from 78 to 96 % in a study of vegetable irrigated trickle systems at Konya, Turkey[11]. According to the result, water distribution was in the range of moderate to excellent.

This study was therefore, carried out to determine the effects of water quality on emitter clogging and water distribution uniformity for 11 different trickle systems located in Antalya, Turkey. Protected cultivation is very popular in research area and trickle systems are highly preferred to the potential advantages in green houses. The irrigation water resources mainly wells and some of canals.

EXPERIMENTAL

The research was carried out to determine the effect of water quality on emitter clogging and uniformity of water in 11 different trickle systems in Antalya, Turkey under greenhouse conditions. The study area is situated close to Mediterranean and the trickle systems have been used in one to 17 years for mainly irrigating of tomato, pepper, cucumber and egg plants. For determination of irrigation water quality used in trickle systems, samples were collected in 1 L clean plastic bottles. The samples were taken form wells after the well operated for at almost 20 min and below the water surface in canals.

The trickle system consisted of polyethylene laterals of 16 mm obtained from different companies laid parallel to crop rows and each lateral served only one plant row. The emitters with 2-4 L/h flow rate were in-line type and placed on laterals 0.35 to 0.80 m apart depending upon the plants. All the systems were equipped with screen-filters which were common to all the systems in the research area. The research was conducted during April-June 2007 periods. Water quality data were evaluated by use of Table-1[12,13].

TABLE-1
SOME PROBLEMS MET IN TRICKLE SYSTEMS AND
WATER QUALITY RELATIONSHIPS [Ref. 12]

Problems and causes	Level of problem		
	Low	Moderate	High
Clogging [pH]	< 7	7-8	> 10
Hazard of plants [EC (µhos cm^{-1})]	< 750	750-3000	> 3000
Specific ion hazard [Cl (ppm)]	< 142	142-355	> 355
Soil permeability [EC (µhos cm^{-1})]	> 500	200-500	> 200

The discharge of a significant sample of emitters was measured by the standard procedure[9]. It was measured by a graduated container 200 mL and pressure by a precision pressure gauge graduated in 15 mH_2O and 20 mH_2O. The emitter discharge were measured in 24 emitters, located in a representative subunit of each system; 8 laterals were chosen for each subunit; three emitters (the nearest to the inlet, the middle one and the last) were tested for each lateral (**Scheme-I**). The volumetric method[14] was used for computing the uniformity coefficient (UC) of trickle irrigation system (eqn. 1).

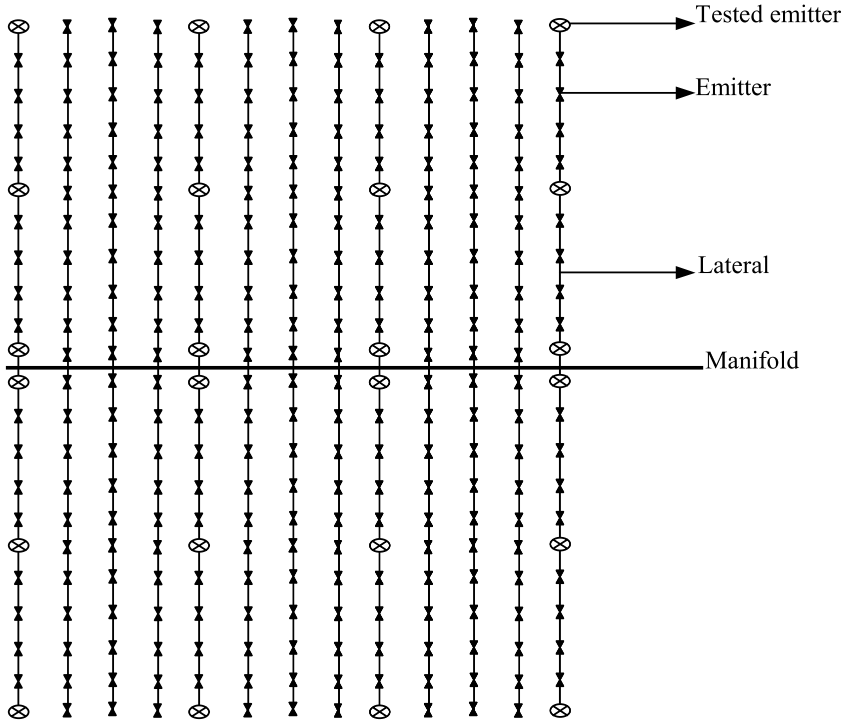
$$UC = 1 - \left(\frac{\Delta q}{q}\right)$$

where; q-the mean emitter discharge rate (L/h) and Δq-mean deviation of the emitter discharge from mean value. The results were evaluated by Tüzel[10] and Goyal[15].

RESULTS AND DISCUSSION

It is obvious from the Table-2 that the pH values of irrigation water varied from 7.14 to 8.11. In irrigation water used in system 4, pH was higher than 8 but, it was near to the threshold level of 8. Under such conditions, water quality used in most trickle systems (91 %) had moderately hazard to the emitter clogging. Due to the periodically injection of acid as a liquid fertilizer form, pH could be reduced successfully.

Table-2 also shows that electrical conductivity varied from 432 to 866 µhos/cm and irrigation water used in 6 trickle systems (55 %) had lower than the 750 µhos/cm. This water had low salinity hazard on plants. In irrigation water used in other 5 systems (45 %), it was in the range of between 750 to 3000 µhos/cm. This means that this water had moderately salinity hazard to those greenhouse plants. This water may increase the soil salinity in areas where the poor drainage conditions. In Antalya province, greenhouses have poor drainage system and are covered by glass or plastic covers. To reduce the soil salinity level of not harmful for most plants, rainfall should be diverted to the greenhouses in winters or leaching should be performed during the inactive plant growth periods.



Scheme-I: Emitters tested in the subunit

TABLE-2
WATER QUALITY PARAMETERS OF IRRIGATION WATER

Trickle system	Water supply	pH	EC (µhos cm^{-1})	Ca (ppm)	HCO_3 (ppm)	Cl (ppm)
1	Lined well	7.44	690	6.1	5.22	0.95
2	Canal	7.59	792	7.0	6.35	0.85
3	Canal	7.76	862	7.6	7.56	0.90
4	Canal	8.11	432	4.2	4.00	0.20
5	Unlined well	7.52	572	5.4	4.35	0.50
6	Unlined well	7.36	597	5.5	4.10	0.65
7	Unlined well	7.28	696	6.4	4.70	0.75
8	Lined well	7.59	749	6.6	6.00	1.05
9	Lined well	7.24	810	7.7	5.57	1.00
10	Unlined well	7.14	769	7.2	5.56	1.20
11	Unlined well	7.33	866	8.1	5.91	0.90

To examine the EC effect on soil permeability, only irrigation water used in 4th system had lower than 500 µhos/cm salts, whereas it was higher than this value in others. According to the results, EC had low harmful effect on soil permeability in irrigation water used in 10 trickle systems. In irrigation water used in system 4, however, had the moderate harmful effect on soil permeability[12].

Table-2 also shows that the calcium concentration varied from 4.2 to 8.1 ppm that was lower than 40-60 ppm in all water samples. Magnesium and carbonate concentration were measured zero ppm (not given in Table-2) in all water samples. Bicarbonate concentrations varied from 4 to 7.56 ppm that was lower than the 122 ppm and almost all pH values were near to 7.5. Therefore, calcium carbonate precipitation was not present on all emitters[13].

The same data (Table-2) show that the Cl content was very low in all researched irrigation water samples. According to the results, none irrigation water used in those systems had the specific ion hazard and all water supplies were suitable for trickle irrigation.

The improvement of the uniformity of water application is one of the easier ways to sustain water resources at the farm level. In research, the summary of the UC results are given in Table-3. The Table-3 showed that UC varied from 62.2 and 95.1 %, the average of 88 %. The UC values (Table-3) show excellent uniformity in 63.6 % of the systems, good in 27.3 %, poor in 9.1 % and unacceptable in 0 %[10,15]. The results were higher than those findings of Orgaz *et al.*[6] and are in agreement with the findings of Acar[16,11]. Although in most trickle systems (60 %) were older than 7 years, higher UC in such systems might be resulted from the periodically maintenance and properly design of systems. In greenhouses, plant production was only the income of those farmers, so they have a great effort for obtaining the higher and good quality production. Almost whole production has exported to the foreign countries. On the other hand, there were a much differences between maximum and minimum emitter discharges in one system measured low UC. The possible reason should be clogging in emitters or deformation in lines. To prevent clogging of emitters, farmers in practice have applied some liquid fertilizers as acid form that were useful for plants. It is well-known that the acid injection through the system causes reduction in pH and dissolves calcium carbonate precipitation in emitters. The injected liquid fertilizer doses were observed different in research greenhouses. In trickle system 2, irrigation interval was observed 3 d and 5 L/ ha H_3PO_4 and 15 L/ha HNO_3 were applied in each irrigation during the periods May-June 2007. Similarly, some farmers have applied 20 L/ha/15-20 d H_3PO_4 and 20 L/ha/month HNO_3 depending on the severity of clogging. The treatments were observed efficient way for preventing the emitter clogging resulted from chemical composition of irrigation water and meeting the plant nutrients.

In general, pressure in laterals was measured 15 and 20 mH_2O and higher than the optimum acceptable level of 10 mH_2O. Use of high pressure increases the emitter discharge as well energy consumption. Whole pumps used in trickle systems in research area were worked by use of electricity. Due to subvention of electricity by government, farmers do not care the higher electric consumption. This is not suggested in agricultural lands especially for field crops irrigated by trickle systems under use of oil in Turkey. In Turkey, petroleum products are expensive and increase the production costs of plants.

TABLE-3
UNIFORMITY COEFFICIENTS AND WATER DISTRIBUTION LEVELS

Trickle system	Water supply	UC (%)	Water distribution
1	Lined Well	93.8	Excellent
2	Canal	83.7	Good
3	Canal	95.1	Excellent
4	Canal	90.5	Excellent
5	Unlined Well	91.1	Excellent
6	Unlined Well	83.1	Good
7	Unlined Well	93.3	Excellent
8	Lined Well	91.8	Excellent
9	Lined Well	62.2	Poor
10	Unlined Well	88.6	Good
11	Unlined Well	95.0	Excellent
Average		88.0	

In Antalya province like the other parts of the Turkey, all greenhouses do not have drainage system. To reduce the soil salinity level that is not harmful for plant growth, rainfall should be diverted in winters to the greenhouses or leaching should be performed during unvegetated periods.

Conclusion

In present research, non-irrigation water had the serious calcium precipitation problem. In areas where the chemical precipitation exists, the usual treatment for calcium precipitation is to acidify the water by lowering the pH to 7.0 or lower with continuous injection.

The uniform coefficient (UC) values varied from 62.2 to 95.1 %, the average UC of 88 %. Most trickle systems were older than 7 years and higher UC in most systems might be resulted from the proper design, good management and periodically maintenance of trickle systems.

In general, pressure in laterals was 15 and 20 mH_2O that was higher than the optimum acceptable level of. For sustainable energy use, pressure of 10 mH_2O is strongly recommended.

To determined the UC more accurately, emitter flow rate should be measured more than 24 (if possible all emitters) points in emitters.

Trickle systems are strongly recommended to the arid and semi-arid areas of the world for sustainable use of water resources under well design, good management and maintenance. Water analysis prior to system design, a preventive maintenance program and field evaluation of clogging and uniformity are strongly recommended.

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