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Investigating the Effects of Fertigation on the Clogging and Uniformity Distribution of Emitters

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Abstract: Emitter clogging is one of the drip irrigation systems' main challenges, which the water quality plays a crucial role in this regard. So, in the current study, a suitable physical model for implementing fertigation in drip irrigation system was established. The hydraulic performances of three types of emitters (labeled type 1 to 3) having discharge rates of 4 L/hr were evaluated. For this purpose, the amounts of manufacturing variation coefficient, pressure-discharge relation, application uniformity and Christiansen's Uniformity Coefficient (UC) were determined. Additionally, some experiments were conducted for evaluating the emitter clogging in fertigation with different urea concentrations of 0, 50, 150 and 250 g/m^3, during 480 hrs. It was revealed that the emitter type 3 had superior performances in comparison with two other emitters in most cases. Moreover, according to the obtained results, the percentage of emitter clogging was increased by increasing the time duration of the experiment and the concentration of urea. As a conclusion, the emitter type 3 was recommended for implementing fertigation in drip irrigation systems due to its high distribution uniformity and more resistance against clogging in comparison to others.

Keywords: Drip irrigation, Emitter clogging, Fertigation, Hydraulic performance

Introduction

The water crisis is one of the essential issues in arid and semi-arid regions such as Iran. This condition has gotten worse in recent years due to occurring successive droughts. Considering the indices of the water crisis, Iran's water resources have a very critical condition. Therefore, proper management of water allocation is vital in these resources. Moreover, the section of agriculture is the primary water consumer in Iran. In another point of view, trickle irrigation is one of the irrigation methods which its high abilities in water saving and labor cost reduction have been mentioned in the literature.

Different factors such as emitter clogging, manufacturing variation and temperature and pressure fluctuations affect the emitter discharge and distribution uniformity and may decrease the efficiency of the system (Keller and Bliesner, 1990). So, emitter clogging is one of the main problems for the optimum utility of drip irrigation systems in the orchards and fields. Emitter clogging causes non-uniform distribution of water in the fields and decreases the crop yield (Dehghanisanij et al., 2005).

Bozkurt and Ozekici (2006) studied different effects of the fertigation on emitter clogging and concluded that fertilizers containing calcium and phosphate led to sever clogging of emitters. Nakayama and Bucks (1981) categorized emitter clogging by the physical, chemical and biological factors. Haijun and Guanhua (2009) investigated the performance of three types of long-pass, on-line and pressure compensating emitters using fresh

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water and treated sewage effluent. Results indicated that the water quality, emitter type and irrigation duration influenced the emitter clogging and distribution uniformity. Bo Zhou et al. (2015) examined drip irrigation emitter clogging using reclaimed water and then the effect of different irrigation frequencies on dynamic emitter's outflow was studied. The results indicated that emitter clogging increased with shorter drip irrigation intervals.

The objective of the current research is to evaluate the resistance of three types of emitters against clogging in fertigation with different concentrations (0, 50, 150 and 250 gr/m^3) of Urea by the nominal emmission rate of 4 L/hr.

Methods

A physical model was constructed to investigate the performance and hydraulic characteristics of the emitters including the manufacturing coefficient of variation, pressure-discharge relation, distribution uniformity and emitter clogging by applying different levels of Urea concentration. The mentioned model was consisted of a 150L reservoir tank and 48 emitters as depicted in Figure 1.

Figure 1. Constructed physical model

Three types of common emitters in Iran were selected for experiments (Figure 2). The apparatus was operated under the pressure of 10 m-H_2O and then the discharges of emitters were measured.

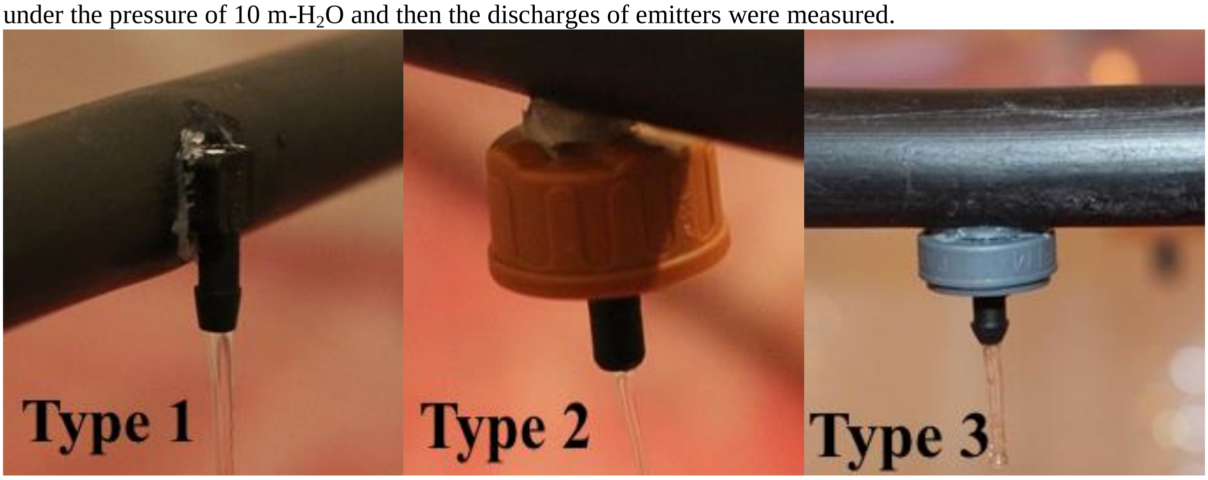


Figure 2. Three types of utilized emitters in the experiment.

The experiment was implemented with four concentrations of Urea (0, 50, 150 and 250 gr/m^3). Water temperature during the experiment was almost constant at 20 °C. Furthermore, the system was operated 8 hours per day during 60 days of experiment. The average discharge of each emitter during its application was determined at the end of every day.

Gene Expression Programming (GEP)

Gene expression programming (GEP) is an algorithm that utilizes populations of individuals and chooses them based on their fitness, and it can apply genetic changes by the usage of genetic operators (Ferreira, 2001a, b). The first stage in the GEP algorithm concerns creating a primary population of solutions. Next, the chromosomes represented as a tree expression, which assessed according to a fitting function. According to the selection, the best individuals have more chances of having children. The whole process is repeated for some generations, and as the new generations appear, it is expected that population quality improves on average.

Evaluation parameters

The performances of GEP models were evaluated by Correlation Coefficient (CC), Root Mean Square Error (RMSE), Willmott's Index of agreement (WI) and Mean Absolute Error (MAE). These statistics are presented as follows:

$$CC = \frac{\left(\sum_{i=1}^{n} O_i P_i - \frac{1}{n}\sum_{i=1}^{n} O_i \sum_{i=1}^{n} P_i\right)}{\left(\sum_{i=1}^{n} O_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} O_i\right)^2\right)\left(\sum_{i=1}^{n} P_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} P_i\right)^2\right)} \quad (1)$$

$$WI = \left|1 - \left[\frac{\sum_{i=1}^{N}(O_i - P_i)^2}{\sum_{i=1}^{N}\left(\left|P_i - \bar{O}_i\right| + \left|O_i - \bar{O}_i\right|\right)^2}\right]\right|, 0 \le WI \le 1 \quad (2)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(P_i - O_i)^2} \quad (3)$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|P_i - O_i\right| \quad (4)$$

where O_i and P_i are observed and predicted i^{th} value.

Results and Discussion

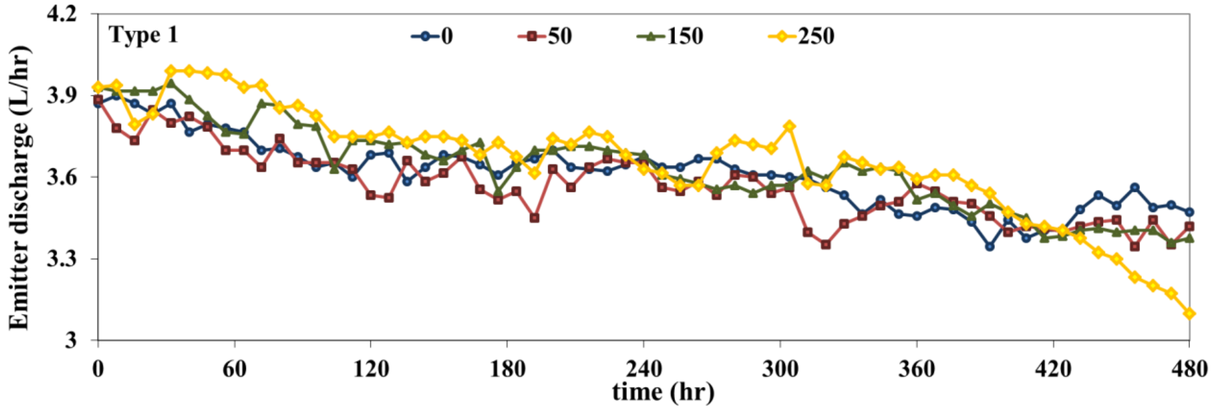
The hydraulic charachtersitics of the three emitter types were determined in different pressures during the experiments as presented in Table 1. The nominal discharge of the emitters was 4 L/hr, but real measured discharges measured during the experiments were a little different. Although the distribution uniformity of the emitter type 2 was a little higher than emitter type 3, emitter type 3 may be recommended because of its lower differences from nominal discharge of 4L/hr. Meanwhile, it can be comprehended from Table 1 that discharge of emitter type 3 was less sensitive to the pressure variations and had an acceptable performance comparing to other studied emitters.

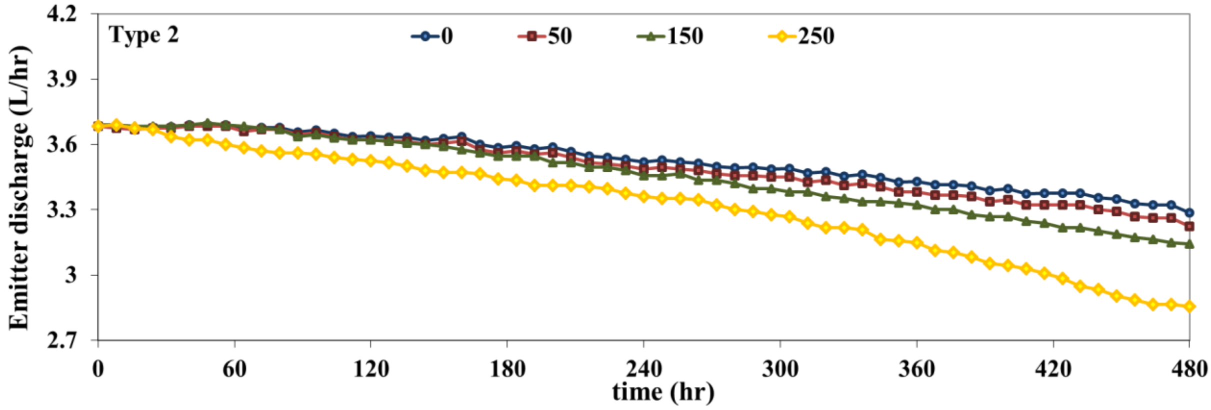
Table 1. Hydraulic characteristics of utilized emitters

Hydraulic characteristic	Emitter type	Pressure (m-H_2O)		
		8	10	12
Average discharge (L/hr)	1	3.82	3.90	4.14
	2	3.82	3.68	3.75
	3	4.14	4.04	4.10
manufacturing variation coefficient	1	0.041	0.074	0.035
	2	0.025	0.024	0.024
	3	0.024	0.032	0.027

	1	96.50	95.19	97.10
Christiansen's Uniformity	2	97.94	97.97	97.95
	3	98.00	97.44	97.63
distribution uniformity	1	94.99	91.15	95.65
	2	97.15	97.25	97.40
	3	96.73	96.47	96.80
Discharge variation	1	-4.5	-2.5	3.5
	2	-4.5	-8.0	-6.3
	3	3.5	1.0	2.5

In the second stage of the experiment, the clogging of the emitters was investigated by applying four different concentration of 0, 50, 150 and 250 g/m^3 Urea during 480 hrs and the obtained results are illustrated in Figure 3. According to the results, the discharges of all emitters were decreased during 60 days of experiment. The performance of emitter type 3 was better than other emitters. As can be seen from Figure 3, emitter type 3 has lower discharge decreasing trend in comparison with other types.





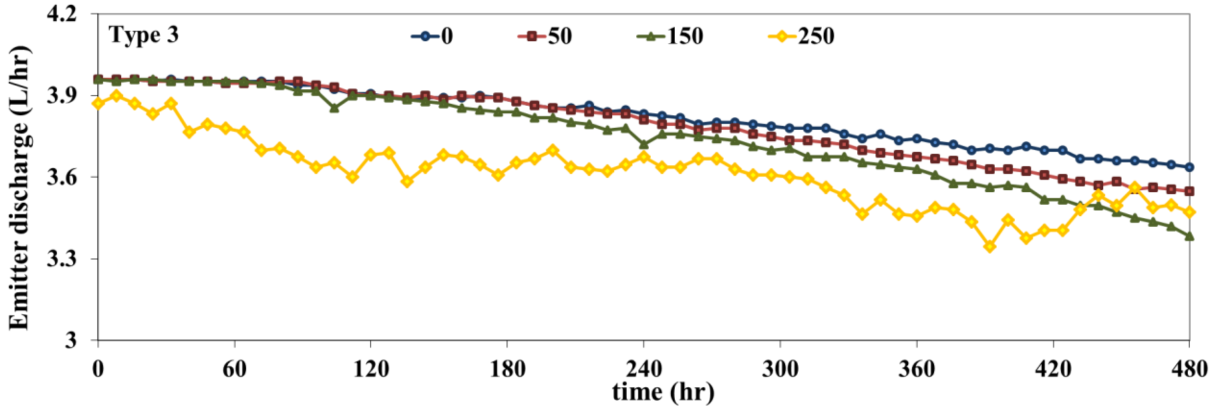


Figure 3. The comparison of emitter discharges under different concentrations of Urea fertigation.

For extracting mathematical formulations for each emitter, the discharge rates of them were collected and sorted randomly. Then, 70% and 30% of data were used for the calibration and validation process of GEP models, respectively. The obtained statistical results for the three studied emitters are presented in Table 2.

Table 2. Statistical parameters for each emitter

Emitter type	Statistical parameters			
	RMSE	MAE	CC	WI
1	0.116	0.087	0.726	0.838
2	0.047	0.038	0.969	0.984
3	0.088	0.05	0.864	0.992

It can be comprehended from Table 2 that the predictions of emitter type 2 are more accurate than other emitters. Additionally, the resulted formulations of the GEP model for the emitter types 1 to 3 are presented with equations 5 to 8, respectively.

$$Q = ArcTan[\frac{1}{\sqrt{(1+(4.939+0.100384T)^2)}}]^{1/6} + ArcTan[\frac{1}{\sqrt{(1+(6.17999+0.119143T)^2)}}]^{1/6} + ArcTan[(-17.2247+2C-T)^2]^2 \quad (5)$$

$$Q = 3.25949+0.581383\cos[0.185307T^{1/3}]-0.00100826(-9.97263-T)\times\sin[9.2905-C]^3 \quad (6)$$

$$Q = 3.20105-\frac{\sin[5.88669-T^{1/3}]}{8.46362-\sqrt{C}+C}+\sin[\sin[e^{\sin[T^{1/4}]^3}]]-\tan[0.006224\tan[0.003112T]] \quad (7)$$

where, Q is the emitter discharge (L/hr), T is time (hr) and C is the Urea concentration (g/m^3).

Overall results indicated that the emitter type 3 showed the best performance against clogging. Therefore, it may be a right choice for the application of fertigation by drip irrigation systems.

Conclusion

In the current research, three emitter types were examined for their resistance against clogging. For that purpose, four different concentrations of Urea including 0, 50, 150 and 250 g/m^3 were injected during 480 hrs to the system and temporal discharge rates of emitters were measured. The obtained results indicated that the clogging rates were increased during 60 days of the experiment. Moreover, the emitter type 3 showed the best performance and was selected as the superior emitter type.

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