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RESPONSE OF ON-LINE EMITTER TO DIFFERENT WATER TEMPERATURES AND PRESSURES

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Abstract

This research was conducted in hydraulic laboratory of Irrigation Department, Suleyman Demirel University, Isparta, Turkey. Different water temperatures (20, 30, 40 and 50°C) and operating pressure (80-200 kPa) were applied to determine emitter discharge equations ($q = kH^x$*), standard temperature discharge index (TDI, standard temperature is 20*^oC*), coefficient of manufacturing variation (CV) and uniformity parameters such as Christiansen uniformity (Cu) and emission uniformity (CUE). On-line pressure compensating emitter with 2 *Lh^{-1}* discharges at system pressure of 100 kPa according to the manufacturer recommended, was used. Emitters were placed at 20 cm interval on the laterals with 16 mm diameter. Discharge equations related to temperatures were obtained as *$q=2.01H^{0.00}$*, *$q=1.96H^{0.00}$*, *$q=1.61H^{0.04}$* and *$q=1.54H^{0.05}$* respectively. Increased water temperature decreased the emitter discharge. The rate of emitter discharge decreased average 2.5% by increasing of water temperature from 20 to 50°C. TDI values decreased with increasing of water temperature (*$p<0.001$*). CV, Cu and CUE values of the emitters under different water temperatures ranged between 0.027-0.033, 97.3-98.5% and 89.2-96.7%, respectively.*

Key words: *discharge, on-line emitter, pressure, water temperature.*

INTRODUCTION

The amount of water resources used in agriculture is rapidly decreasing in last decades. Therefore, more efficient irrigation methods are required. Drip irrigation systems provides the highest efficiency compared to other irrigation methods and high efficiency in these systems depend on uniformity of emitter discharge. The implementation of a drip irrigation system with successful water distribution uniformity depends on the physical and hydraulic properties of the lateral. Factors affecting uniformity in drip irrigation are: a) manufacturing variability; b) head loses formed along the pipeline; c) pressure variations due to the change in height; d) sensitivity of the emitter to the irrigation water temperature and the pressure; e) emitter clogging (Mizyed and Kruse, 1989; Rodriguez-Sinobas et al., 1999; Clark et al., 2005; Dutta, 2008). Manufacturing variability and temperature are uncontrollable and variable parameters affecting the discharge and uniformity of emitters in drip irrigation systems. Drip irrigation laterals and emitters used in the field may have full or partial exposure to the sun in summer period. Therefore, viscosity, density and emitter flow passage can be affected by temperature changes (Peng et al., 1986; Rodriguez-Sinobas et al., 1999).

The aim of the study was to evaluate the effects of different water temperatures and pressures on discharge, standard temperature discharge index, coefficient of manufacturing variation and uniformity parameters such as Christiansen uniformity and emission uniformity of the on-line pressure compensating emitter.

MATERIALS AND METHODS

The research was conducted in hydraulic laboratory of Irrigation Department, Suleyman Demirel University, Isparta, Turkey. Laterals were placed in the emitter testing bench without inclination. Sensitive graduated cylinder and manometers were used to determine discharge of the emitters and to measure pressure. Water was supplied from a 216 L capacity reservoir with the aid of a small pump having 3.4 m^3h^{-1} discharges at 4.2 bars. The water was heated by two 1500 watts resistance and water temperature was monitored both by temperature control panel and by a digital thermometer measured from emitter output accurate to ± 1^oC. In the research, pressure compensating on-line emitter with 2 Lh^{-1} discharges at system pressure of 100 kPa, according to the manufacturer recommended, was used. Emitters were placed on the laterals with 16 mm diameter at intervals of 20 cm. Water temperatures from 20 to 50°C and pressure values from 80 to 200 kPa were used to determine the effects of different water temperature and pressures on emitter discharge equations, standard temperature discharge index (TDI), coefficient of manufacturing variation (CV), Christiansen uniformity (Cu) and emission uniformity (CUE).

Each test was conducted by measuring the discharge of 24 emitters placed on laterals in testing bench under a constant temperature and different pressures. Before each test, the system was operated for 5 minutes to reach constant pressure then discharge was measured volumetrically and these values were converted to Lh^{-1}. For the water temperature test, temperature was changed from sensor screen and waited about 30 minutes to reach the desired temperature (Rodriguez-Sinobas et al., 1999; Clark et al., 2005).

Regression test procedures were used to determine coefficients (k) and exponents (x) of discharge equations ($q = kH^x$) and correlation coefficients for each temperature. In addition, standard temperature discharge index (TDI), standard variation (S), coefficient of manufacturing variation (CV), Christiansen uniformity (Cu) and emission uniformity (CUE) were calculated using Equation 1-5 (Bralts and Edwards, 1986; Christiansen, 1942; ASABE, 2003).

$$TDI = \frac{qt^0}{qt^0_{20}} \tag{1}$$

$$S = \left[\frac{\sum_{i=1}^{n}(q_i - q_{mean})^2}{n-1}\right]^{1/2} \tag{2}$$

$$CV = \frac{S}{q_{ort}} \tag{3}$$

$$Cu = 100\left(1 - \frac{\Delta q_0}{q_{mean}}\right) \tag{4}$$

$$CUE = 100\left[1 - \frac{1.27CV}{\sqrt{n}}\right]\frac{q_{min}}{q_{mean}} \tag{5}$$

where:

- qt^0 is the emitter discharge (Lh^{-1}) at the test water temperature;
- qt^0_{20} is the emitter discharge (Lh^{-1}) at the 20°C;
- S is the standard variation;
- q_i is the emitter discharge (Lh^{-1});
- q_{mean} is the average emitter discharge (Lh^{-1});
- n is the total number of emitters;
- Δq_o is the absolute deviation of the average (Lh^{-1});
- q_{min} is the minimum discharge obtained from minimum pressure (Lh^{-1}).

RESULTS AND DISCUSSIONS

The x values for different water temperature were determined close to 0 as expected, which is consistent with flow regime of the pressure compensating property belong to the manufacturer's data.

According to emitter discharge and pressure relationships, while regression analyses were found to be significant at 40 and 50°C ($p<0.001$), they were not significant at 20 and 30°C (Figure 1). It was observed that the discharges of the pressure compensating on-line emitter increased by increasing pressure at 40 and 50°C (r = 0.79, 0.85). Although discharge was stable under low water temperature, there was a slight increasing trend in emitter discharge with pressure under high temperature.

These results are similar to the previous studies in that discharge in pressure compensating on-line emitter varied not clear (Rodriguez-Sinobas et al., 1999; Nasrolahi et al., 2011).

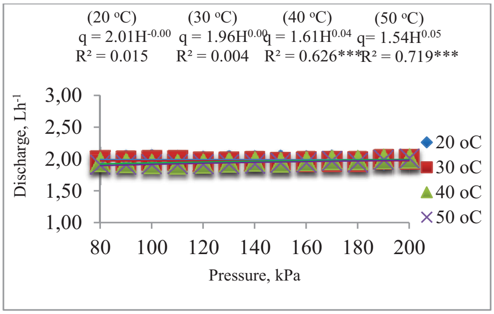

Figure 1. Emitter discharge - pressure relationships at different water temperatures

The average discharge variations in temperature changes from 20 to 50°C were illustrated in figure 2. Linear regression was obtained between emitter discharge and water temperature in pressure compensating on-line emitters ($r \approx 0.99$). As the temperature increased, the discharge of the emitter decreased.

The rate of emitter discharge decreased average 2.5% due to increased water temperature from 20 to 50°C. Some other researchers explained that the relationship between water temperature and discharge with linear regression similar to our study and water temperature tend to decrease discharge of some pressure compensating emitters (Zur and Tal, 1981; Dogan and Kirnak, 2010; Nasrolahi et al., 2011).

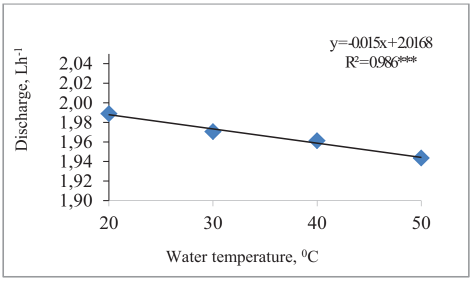

Figure 2. Water temperature - emitter discharge relationship

Standard temperature discharge index (TDI) values were calculated from discharges from standard water temperature (20°C) and different water temperature (30, 40 and 50°C). Then, regression analyses were done (Figure 3). Strong linear relationship between TDI and water temperature was found ($r \approx 0.99$).

This data is consistent with some previous researches (Zur and Tal, 1981; Von Bernunth and Solomon, 1986).

TDI values for the pressure compensating on-line emitter were significantly decreased with an increase in water temperature ($p<0.001$).

The result is similar to the studies by Parchomchuk (1976) and Dogan and Kirnak (2010).

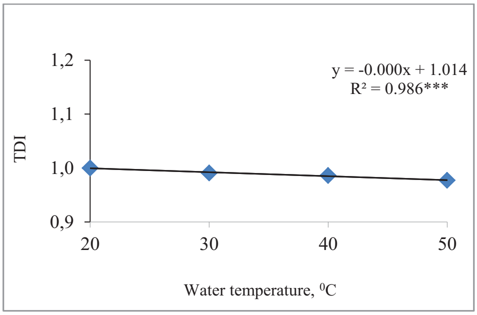

Figure 3. Water temperature- standard temperature discharge index (TDI) relationship

CV values ranged from 0.027 to 0.033 and were lower than 0.05. They were ranked in „excellent” class under pressure changes for different water temperatures (ASABE, 2003). CV values of the emitter were not affected from changes in water temperature. Our results are similar with Clark et al (2005) and Dogan and Kirnak (2010) indicated that there was no relationship between CV and water temperature.

Cu values of the emitter tested changed between 97.3 and 98.5% under different pressure and water temperatures. Cu≥95% condition recommended by Wu and Gitlin (1979) was provided in all temperatures and pressures and Cu values also provided almost the condition as Cu≥98% suggested by Perold (1977) in generally.

CUE values varied from 89.2 to 96.7%. In all water temperature and pressure, CUE values classified as „good - excellent” class according to ASABE (2003) stayed between 87 and 94 %. However, CUE values exceeded 94 % and took place in the „excellent” class at recommended for operating pressure of 100 kPa. CUE values of pressure compensating on-line emitter had a downward tendency with increased water temperature ($p<0.05$), while there were no relationship between CV and Cu values and water temperature (Figure 4).

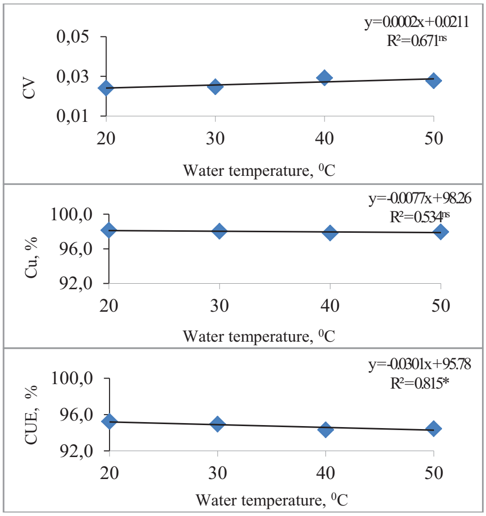

Figure 4. Effect of water temperature on uniformity parameters

CONCLUSIONS

In the study, according to regression analyses between emitter discharge and pressure, although discharge was stable under low water temperature (20 and 30°C), there was a slight increasing trend in emitter discharge with pressure under high temperature (40 and 50°C). The x values of the emitter discharge equation for different water temperature were obtained as 0 in accordance with the flow regime of the pressure compensating property. Linear relationships were observed between both emitter discharge and TDI and water temperature. Both emitter discharges and TDI values were decreased with the increase of water temperature.

The data indicated that while the water temperature had no significant effect on CV and Cu, CUE values had a downward tendency with increased water temperature.

In conclusion, temperature may have a significant effect on the emitter discharge under the sunlight conditions during the summer period. Therefore, manufacturer should provide the information to drip irrigation system designers and users about responses of water temperatures and pressures to emitter discharges.

In addition, users should measure water temperature and pressure and make associated correction when the irrigation system is operated in the field for high efficiency.

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