Ciência Rural, Santa Maria, v.47: 07, e20151605, 2017

http://dx.doi.org/10.1590/0103-8478cr20151605

ISSNe 1678-4596

RURAL ENGINEERING

Non-pressure compensating emitters using treated sewage effluent for irrigation

João Alberto Fischer Filho[1*] **Alexandre Barcellos Dalri**[1] **Miquéias Gomes dos Santos**[1] **José Renato Zanini**[1] **Rogério Teixeira de Faria**[1]

[1]Departamento de Engenharia Rural, Faculdade de Ciências Agrárias e Veterinárias, Universidade Estadual Paulista (UNESP), Via de Acesso Prof. Paulo Donato Castellane, s/n, 14884-900, Jaboticabal, SP, Brasil. E-mail: joaofischer16@gmail.com. [*]Corresponding author.

ABSTRACT: *This study aimed to evaluate the obstruction of non-pressure compensating emitters using treated sewage effluent (TSE) for irrigation. A drip irrigation system with six models of emitters (encoded) was installed in level field conditions. TSE coming from a sewage treatment station was used as irrigation water after being filtered through a disc filter (120 mesh). Seven flow rate evaluations of drippers operating at 100kPa were performed (0, 100, 200, 300, 400, 500 and 600h of operation). The experimental design was randomized in a 6×7 factorial arrangement (6 models and 7 times), with four repetitions, and Tukey's test was used to compare means. Relative flow rate (Qr), the flow rate coefficient of variation (CVQ) and degree of clogging (GE) were determined. There was a reduction in flow rate in five dripper models, which are susceptible to clogging. The model with rated flow stood out against the others, showing a Qr of 100.52%, CVQ of 2.76% and GE of 0.49%. The use of TSE changed the Qr of the drippers after 600h of operation.*

Key words: *wastewater, trickle irrigation, clogging, water saving.*

Gotejadores não autocompensantes usando efluente de esgoto tratado para irrigação

RESUMO: *Objetivou-se avaliar a obstrução de gotejadores não autocompensantes utilizando efluente de esgoto tratado (EET) para irrigação. Um sistema de irrigação por gotejamento com seis modelos de gotejadores (codificados) foi instalado em nível e em condições de campo. Como água de irrigação foi utilizado EET, originado de estação de tratamento de esgoto, filtrado por um filtro de disco (120 mesh). Foram realizadas sete avaliações da vazão dos emissores (0, 100, 200, 300, 400, 500 e 600h de funcionamento), operando a 100kPa. O experimento foi montado em delineamento casualizado, com arranjo fatorial 6x7 (6 modelos e 7 tempos), com 4 repetições e teste de Tukey para comparação das médias. Foram determinados a vazão relativa (Qr), o coeficiente de variação de vazão (CVQ) e o grau de entupimento (GE). Observou-se redução na vazão em cinco modelos de gotejadores, sendo estes suscetíveis ao entupimento. O modelo com maior vazão nominal destacou-se perante os demais, apresentando Qr de 100,52%, CVQ de 2,76% e GE de 0,49%. A utilização de EET alterou a Qr dos gotejadores após 600h de funcionamento.*

Palavras-chave: *reuso de água, emissores, grau de entupimento, economia de água.*

INTRODUCTION

The consumption of water in agriculture in Brazil is approximately 70% of total (ANA, 2015). This significant demand, coupled with the scarcity of water resources in Brazil's populous regions and the need for alternative sources of plant nutrients, indicates that agriculture should be given priority in the reuse of treated sewage effluent (TSE).

Instead of contaminating surface water and groundwater with nutrients in sewage effluent, its use as irrigation water can meet the water and nutrient requirements of crops. Drip irrigation is used for applying TSE and has advantages such as saving water, high efficiency and low contamination of the agricultural product (DAZHUANG et al., 2009), and it is characterized by low flow rate, with minimal environmental, health and economic impact.

The presence of highly variable amounts of microorganisms in wastewater, which can agglomerate with mineral or organic particles in suspension and chemicals in the water, such as iron and sodium, can cause obstruction of drippers. Clogging of drippers is a serious problem associated with drip irrigation, compromising the uniformity of water application (NAKAYAMA & BUCKS,

Received 12.11.15 Approved 03.29.17 Returned by the author 04.28.17
CR-2015-1605.R2

1991), the main disadvantage of using TSE in a drip irrigation system.

In assessing the obstruction of emitters with TSE (LIU & HANG, 2009) reported that the characteristics studied were affected by the type of emitter and operating time. Although, important studies on the subject have already been carried out, there is a need for additional studies to evaluate technical aspects and irrigation equipment, especially with the use of non-pressure compensating emitters, which had a lower cost but showed a higher prevalence of obstruction in relation to other irrigation systems.

This study aimed to evaluate the obstruction of six models of non-pressure compensating emitters using TSE for irrigation.

MATERIALS AND METHODS

The study was carried out at an experimental farm of FCAV-UNESP Jaboticabal Campus (21° 14’ 41,9”S and 48° 16’ 25,2”W), and the TSE used was collected from the sewage treatment station in the municipality of Jaboticabal, SP, Brazil. Under appropriate conditions, similar to those of an operational unit of localized irrigation, a field experiment was set up in a flat area, and the test consisted of six side lines (LL) of different models of non-pressure compensating drippers, spaced 0.5m apart, in which TSE was used for irrigation.

TSE was subjected to analyses of chemical and physical characteristics and total coliforms, which resulted in pH = 7.1, total nitrogen = 53.0mg L^{-1}, total iron = 0.52mg L^{-1}, sedimentable solids = 0.2mg L^{-1}, sodium = 58.3mg L^{-1} and total coliforms = 47.433MPN $(100mL)^{-1}$. Solids present in the wastewater were removed using a disc filter (130µm = 120 mesh) (Azud®) installed near the entrance to lateral lines, which was cleaned every day.

The non-pressure compensating drippers used in the experiment and their main technical characteristics are presented in table 1. To avoid possible bias, positive or negative, drippers used were coded E1 to E6, since the tests conducted were not standardized.

The first evaluation was performed with clean water and occurred after the experiment was set up. In the first test, which was considered standard, six flow rate tests were performed in the same drippers, previously identified, every 100h. Sixteen emitters were evaluated in each LL, and four emitters served as replicates; thus, there were four replicates per LL. During the flow rate test, the pressure at the beginning of the LL was maintained at 100kPa using a pressure regulator and monitored using Bourdon manometers and a mercury manometer. The system was turned on for 6h per day, from Monday to Friday, totaling a time of use of 600h and 140 days at the end of the experiment.

In the evaluations, collectors were placed below the drippers to collect the TSE. Each dripper was isolated using a string for the proper collection of TSE. Time of collection was 4min. The collected liquid was then weighed on an electronic scale, and later, the mass was transformed to L h^{-1}, using a density of 1g cm^{-3} for TSE.

Performance of drippers was evaluated by calculating the relative flow rate (Qr) using equation 1, flow rate coefficient of variation (CVQ) using equation 2 and degree of clogging (GE) using equation 3, as described below:

$$Qr = \frac{Qa}{Qi}100 \tag{1}$$

where: Qr is relative flow rate, %; Qa is actual flow rate, L h^{-1}; and Qi is flow rate at the beginning of the experiment, L h^{-1}.

$$CVQ = \frac{S}{q_m}100 \tag{2}$$

where: CVQ is flow rate coefficient of variation, %;

Table 1 - Main technical characteristics of the non-pressure compensating dripper pipes evaluated.

Manufacturer	Model	Spacing (m)	Pipe diameter (mm)	Pressure range (kPa)	Flow rate (L h^{-1})
Drip-Plan	Drip-Tec	0.50	17	100	2.30
Petroisa	Durázio	0.30	16	100	1.70
Irritec	P1	0.25	16	100	1.50
Chapin	Chapin	0.30	16	70	1.24
Petroisa	Tiquira	0.30	16	70	2.00
Netafim	Dripline	0.75	17	*	2.00

*Data not supplied by the manufacturer.

S is standard deviation of the sample, L h^{-1}; and q_m is mean flow rate of the sample, L h^{-1}.

$$GE = \left(1 - \frac{Qa}{Qi}\right)100 \quad (3)$$

GE is degree of clogging, %.

Since there is no norm to characterize the susceptibility of a dripper to clogging, the criterion suggested by BARROS et al. (2009) was adopted for the main analysis of the susceptibility of emitters to clogging with the use of TSE, and the index suggested by MORATA et al. (2014) was used in the analysis of the degree of clogging.

The experimental design was randomized in a 6×7 factorial arrangement (six models and seven times), and when the effect of the treatments was significant, means were compared by the Tukey test (1%). The analyses were performed using the computational program Assistat.

RESULTS AND DISCUSSION

Relative flow rate (Qr)

There was a reduction in Qr in five of the dripper models studied at the end of the experiment at 600h (Figure 1). The E4 model stood out with the lowest Qr (88.05%), showing the highest negative effect of using TSE.

The E2 model showed virtually constant flow during the study period, and its final value was slightly increased (100.35%). The emitters E1, E3 and E6 varied little in flow rate during the experiment, ending at 600h with Qr equal to 99.51, 98.44 and 98.91%, respectively. The dripper E5 showed a reduction in flow rate during the running time, but this reduction did not occur sharply, with Qr equal to 95.78% at 600h, differing statistically ($P<0.01$) from the others.

According to the criterion of susceptibility of the emitters to reduced flow (BARROS et al.,

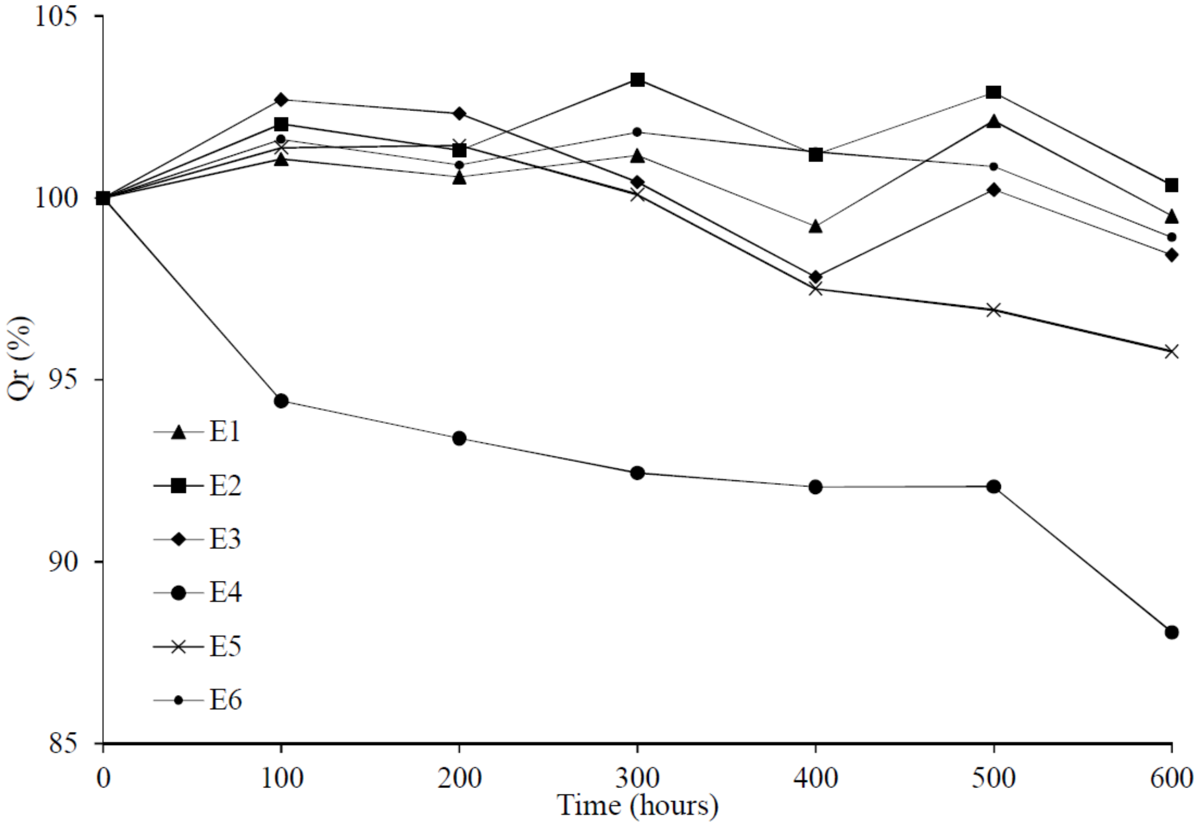

Figure 1 - Relative flow rate (Qr) of six models of non-pressure compensating drippers using treated sewage effluent as irrigation water as a function of the time of use.

2009), it appeared that only the emitter E4 showed variation, with Qr exceeding 10%, characterized as being susceptible to flow rate reduction. According to CUNHA et al. (2013), uniform water application in a drip irrigation system is related to hydraulic factors and the quality of emitter, in addition to water quality and fertigation with salts that can cause clogging of emitters.

Analysis of variance and comparison of means indicated that there were statistically significant differences between models of drippers evaluated after 600h of operation (Table 2). Best performances were obtained by the models E1, E2, E3 and E6, which did not differ and showed relative flow rates close to 100%. The E4 dripper had the lowest mean Qr among the drippers during the 600h of operation, with a mean reduction in flow rate of 6.80%; this dripper had low nominal flow, which may have contributed to a greater reduction in mean Qr.

As to the effect of time of use of the effluent on the drippers, there was no significant effect on the flow rate of the drippers up to 500h of TSE use (Table 2). With 600h of TSE use, statistically different flow rates were obtained from 0 to 300h. Although there was no significant difference in flow rate between 400, 500 and 600h, there was a reduction in mean discharge rate with this time of use. In studying the clogging of drippers using water with a high content of calcium and magnesium, MÉLO (2007) noted that relative flow rate was 87.05 to 95.94% after 360h.

To determine the risk of clogging in emitters, AYERS & WESTCOT (1994) proposed a water quality rating. On the basis of this classification, it was found that, according to values of the chemical analysis of TSE, a slight to moderate restriction in the use of TSE could occur due to the pH being between 7 and 8 and the iron level being between 0.1 and 1.5mg L^{-1}. These water conditions might have caused a reduction in flow rate in some drippers, impairing their efficiency.

Table 2 - Analysis of variance and the Tukey test of the mean values of relative flow rate (Qr) for six non-pressure compensating drippers using treated sewage effluent.

Factor	Relative flow rate – Qr (%)
----------Test F----------	
Emitter (E)	29.89^{**}
Time (T)	4.59^{**}
E x T	1.34^{NS}
Emitter (E)	
E1	100.52 ab
E2	101.58 a
E3	100.28 ab
E4	93.20 c
E5	99.02 b
E6	100.76 ab
----------Time (T)----------	
0	100.00 a
100	100.53 a
200	99.98 a
300	99.86 a
400	98.18 ab
500	99.18 ab
600	96.84 b
CV (%)	2.99

^{NS}: Not significant ($P>0.05$); **: Significant ($P<0.01$); CV: Coefficient of variation.

Flow rate coefficient of variation (CVQ)

There was an increase in CVQ in five of the dripper models studied, but to different degrees (Figure 2). Only the dripper E2 showed lower CVQ at the end of the experiment (5.24%), compared to the beginning of the experiment (6.12%). CVQ indicated the change in flow rate for a given sample of irrigation emitters. It is the result of the issuing of the project, the material used in its manufacture, the quality of its manufacturing and the conditions of use during irrigation (KELLER & BLIESNER, 1990).

The dripper E5 showed a CVQ more than 12% in all evaluations, ending at 600h with 12.44%, with values being greater than the 7% ceiling set by the standard (ABNT, 2006), which is characterized as medium quality from a manufacturing point of view. Dripper E6 showed a CVQ value over 7% only in the evaluation at 600h (8.83%), so the use of TSE affects the variation in flow rate between emitters after 600h of use.

According to the criterion of susceptibility of the emitters to a reduction in flow rate proposed by BARROS et al. (2009), the dripper E5 was characterized as being sensitive throughout the study period, and the E6 dripper showed sensitivity to reduction in flow rate after 600h of operation.

Dripper E1 stood out with the lowest CVQ in all evaluations, ending the experiment with 2.76%. The E2 dripper always showed values between 5 and 6%, but at 600h, it was not characterized as sensitive

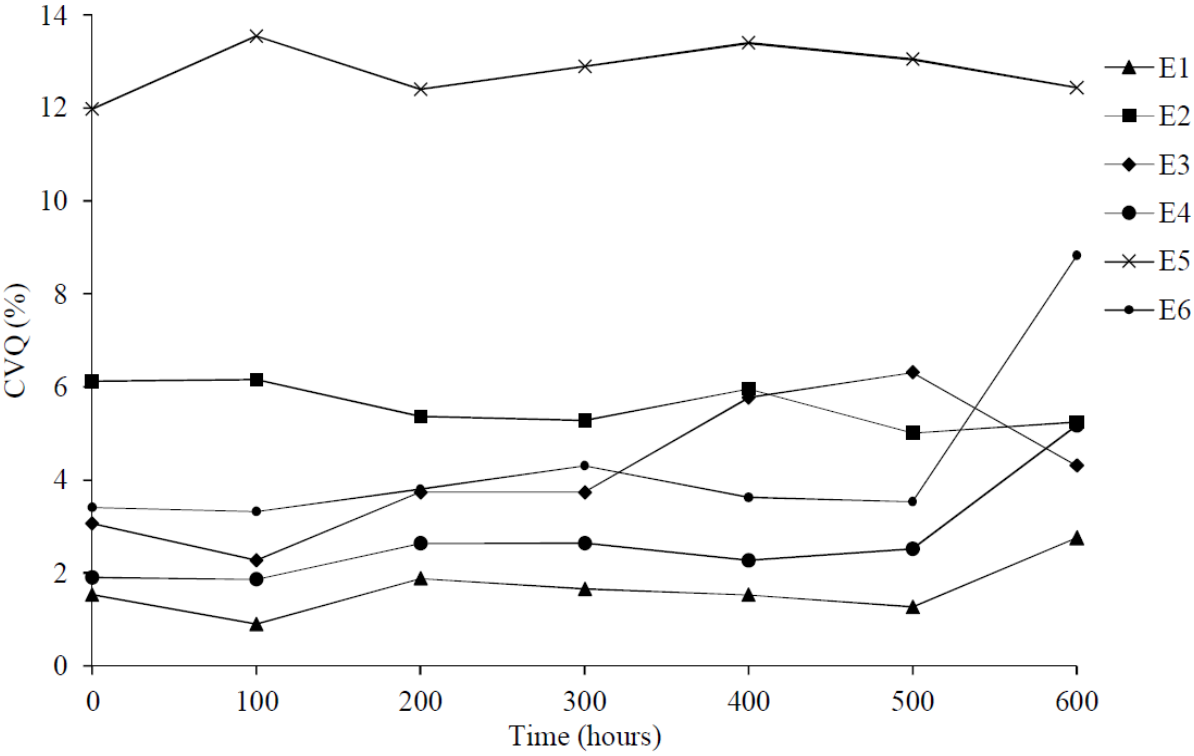

Figure 2 - Flow rate coefficient of variation (CVQ) of six models of non-pressure compensating drippers using treated sewage effluent as irrigation water as a function of time of use.

to reduced flow. The drippers E3 and E4, despite showing values below 5.5% (maximum according to BARROS et al., 2009), displayed a gradual increase in CVQ with operation time, ending the experiment with 5.24 and 4.30%, respectively. Therefore, these emitters can be considered as being of optimal manufacturing quality, according to ABNT (2006), due to values below 7%.

Degree of clogging (GE)

Only the E2 dripper showed no clogging but rather increased flow rate (Figure 3), in all evaluations, displaying the best performance among the dripper models studied for this evaluation.

The emitters E1, E3 and E6 showed obstruction after 600h of operation with a degree of clogging of 0.49, 1.56 and 1.09%, respectively. They were characterized as having low severity of clogging at the end of the experiment, according to MORATA et al. (2014), with values lower than 10%.

The dripper E5 showed clogging after 400h of use of TSE, increasing linearly up to 600h, when the experiment ended with 4.22% clogging, rated as having low susceptibility to clogging (MORATA et al., 2014). Dripper E4 was susceptible to clogging as early as the second evaluation (100h), when there was clogging of 5.58%, increasing until the end of the experiment, giving a final value of 11.95%; E4 showed medium severity of clogging and underperformed the other dripper models studied, corroborating the results of BATISTA et al. (2012), who reported a reduction in dripper flow rate using effluent primary treated sewage, primary and secondary of 62, 22 and 61%, respectively.

CONCLUSION

The use of TSE changed the relative flow rate of the drippers after 600h of operation. The dripper models showed performances varying in the degree of clogging and CVQ, and the dripper with rated flow (2.30L h^{-1}) was better than the others. The use of non-pressure compensating drippers can be recommended for the application of TSE up to 500h of operation, without the occurrence of severe clogging.

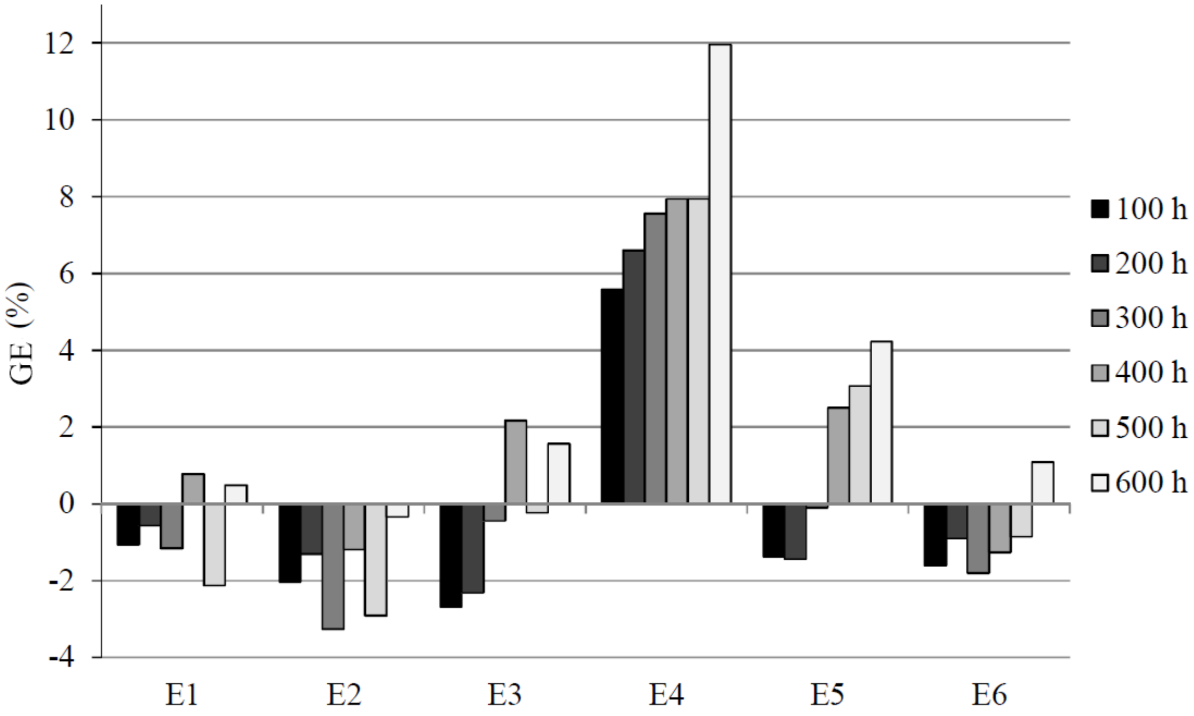

Figure 3 - Degree of clogging (GE) of six models of non-pressure compensating drippers using treated sewage effluent as irrigation water as a function of time of use.

REFERENCES

ABNT (ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS). **NBR ISO 9261**: equipamentos de irrigação agrícola. Emissores e tubos emissores. Especificação e métodos de ensaio. São Paulo, 2006. 17p.

ANA (AGÊNCIA NACIONAL DE ÁGUAS). **Conjuntura dos Recursos Hídricos no Brasil**. Uso da Água: irrigação. Available from: <http://conjuntura.ana.gov.br/uso.html>. Accessed: Sept. 23, 2015.

AYERS, R.S.; WESTCOT, D.W. **Water quality for agriculture**. Rome: FAO Irrigation and Drainage Paper, 1994. 97p.

BARROS, A.C. et al. Entupimento de gotejadores em função da aplicação de superfosfato simples e ácido nítrico. **Engenharia Agrícola**, v.29, n.1, p.62-71, 2009. Available from: <http://www.scielo.br/scielo.php?pid=S0100-69162009000100007&script=sci_arttext>. Accessed: May 10, 2015. doi: 10.1590/S0100-69162009000100007.

BATISTA, R.O. et al. Desempenho hidráulico de sistema de irrigação por gotejamento aplicando água residuária de suinocultura. **Agropecuária Científica no Semiárido**, v.8, n.3, p.105-111, 2012. Available from: <http://150.165.111.246/ojs-patos/index.php/ACSA/article/view/239>. Accessed: May 05, 2015.

CUNHA, F.N. et al. Variabilidade temporal da uniformidade de distribuição em sistema de gotejamento. **Revista Brasileira de Agricultura Irrigada**, v.7, n.4, p.248-257, 2013. Available from: <http://www.inovagri.org.br/revista/index.php/rbai/article/view/177>. Accessed: Apr. 27, 2015. doi: 10.7127/rbai.v7n400177.

DAZHUANG, Y. et al. Biofilm structure and its influence on clogging in drip irrigation emitters distributing reclaimed wastewater. **Journal of Environmental Sciences**, v.21, p.834-841, 2009. Available from: <http://naldc.nal.usda.gov/download/45102/PDF>. Accessed: May 10, 2015. doi: 10.1016/S1001-0742(08)62349-9.

KELLER, J.; BLIESNER, R.D. **Sprinkle and trickle irrigation**. New York: Van Nostrand Reinhold, 1990. 652p.

LIU, H.; HUANG, G. Laboratory experiment on drip emitter clogging with fresh water and treated sewage effluent. **Agricultural Water Management**, v.96, n.5, p.745-756, 2009. Available from: <http://www.sciencedirect.com/science/article/pii/S0378377408002795>. Accessed: May 18, 2016. doi: 10.1016/j.agwat.2008.10.014.

MÉLO, R.F. **Dinâmica e controle do entupimento de gotejadores em função de precipitados químicos e fitoplâncton**. 2007. 189f. Tese (Doutorado em Irrigação e Drenagem) - Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo, Piracicaba, SP.

MORATA, G.T. et al. Entupimento de gotejadores com uso de efluente de esgoto tratado sob dois sistemas de filtragem. **Revista Brasileira de Agricultura Irrigada**, v.8, n.2, p.86-97, 2014. Available from: <http://www.inovagri.org.br/revista/index.php/rbai/article/view/227>. Accessed: Apr. 30, 2015. doi: 10.7127/RBAI.V8N200227.

NAKAYAMA, F.S.; BUCKS, D.A. Water quality in drip/trickle irrigation: a review. **Irrigation Science**, v.12, p.187-192, 1991. Available from: <http://link.springer.com/article/10.1007/BF00190522>. Accessed: May 20, 2015. doi: 10.1007/BF00190522.