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CONCENTRATION OF SINGLE SUPERPHOSPHATE ON CLOGGING OF DRIP EMITTERS

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1 ABSTRACT

The localized irrigation systems are most suitable to fertigation uses, when compared to sprinkle, but are affected by the clogging of drip emitters, influencing the uniformity of the irrigation system. This study aims to analyze the susceptibility of on-line drippers under fertigation with single superphosphate to the clogging. This study was done at the Irrigation Laboratory of UNIVASF, Juazeiro-BA campus, Brazil. Two on-line non-pressure compensating drippers with different flow rates were used, both with the same operating pressure (150 kPa). The parameters analyzed were mean flow, relative flow rate, standard deviation, coefficient of flow rate variation, the CUC, DU, SUC and HUC, and clogging degree. The results show that the concentration used for single superphosphate showed no risk of clogging of the drip emitters during system runtime.

Keyworks: drip irrigation system, non-pressure compensating drippers, application efficiency

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2 RESUMO

Os sistemas de irrigação localizada são os mais indicados para uso na fertirrigação quando comparado com a aspersão, porém são afetados pela obstrução influenciando na uniformidade dos mesmos. Este trabalho tem como objetivo analisar a susceptibilidade ao entupimento de gotejadores tipo online sob fertirrigação com superfosfato simples. Esse trabalho foi realizado no Laboratório de Irrigação da UNIVASF, campus Juazeiro- BA. Foram utilizados dois emissores do tipo gotejadores online não autocompensantes com diferentes vazões, ambos com a mesma pressão de serviço (150 kPa). Avaliou- se os parâmetros vazão média, vazão relativa, desvio padrão, coeficiente de variação de vazão, os coeficientes CUC, CUD, CUE e CUH e

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grau de entupimento. Os resultados demonstram que a concentração utilizada de superfosfato simples não apresentou riscos de obstrução dos emissores durante o tempo de funcionamento do sistema.

Palavras chave: irrigação localizada, gotejadores não compensados, eficiência de aplicação

3 INTRODUCTION

The use of drip irrigation system is growing in the Northeast of Brazil (SOUZA et al., 2012). Localized irrigation is a breakthrough in technology and scale well results in the water and energy savings, that according to Boas et al. (2011), is due to the high efficiency on its use.

According to Dalri et al. (2015), the drip emitters constitute a major component of the localized irrigation system and, as specified by Saad and Jefery (2015), its performance is directly related to the efficiency of water application. The hydraulic characteristics of the emitter are important to define the quality of the product, especially when non-pressure compensating drippers are used.

The tendency of localized irrigation is always to provide additional technology to the field due to the need for alternative techniques that allow the interaction between irrigation water and other products (SILVEIRA et al., 2014). Sousa et al. (2011) affirmed that drip irrigation has many advantages, including the possibility of fertigation.

The method of drip irrigation has been used for fertilizer application because it improves the use efficiency of nutrients. Burt, O'cnnor and Ruehr (1995) state that fertigation is the most economical and efficient fertilizer application method, especially when it is used through localized irrigation systems. Phosphorus application from the use of single superphosphate fertigation, with localized irrigation using drippers, is a breakthrough technology (SCALCO et al., 2014). However, it is dependent on the use of drippers with a high degree of hydraulic design in relation to internal channel structures.

However, due to the small diameter of the orifice, the clogging of the emitters seems to be the biggest problem associated with drip irrigation operation (BRAUER, 2010). The combined use of fertilizers in water irrigation presents, in conformity with Frizzone et al. (2012), advantages and limitations. In accordance with Carvalho et al. (2015), in trickle irrigation, some drippers might have high susceptibility to clogging due to a particular characteristic of the localized irrigation method, which is the area of the drippers passage of water.

In compliance with Borssoi et al. (2012), the clogging of emitters can affect the uniformity of water distribution in the lateral line, from a small number of clogged drippers. Usually these obstructions cause reduction in the mean flow, increasing, consequently, the coefficient of flow rate variation of drip irrigation systems (SILVA et al., 2013).

On-line non-pressure compensating drippers, with flow rate of 2,58 and 4,85 $L.h^{-1}$, in function of the single superphosphate concentration in water irrigation, can show some clogging issues.

Thus, this study aimed to evaluate the behavior of the clogging of on-line non-pressure compensating drippers under laboratory conditions from use with high phosphorus concentrations in water irrigation.

4 MATERIAL AND METHODS

The study was developed at the Laboratory of Irrigation of the Federal

University of São Francisco Valley (UNIVASF), Juazeiro-BA campus, located in coordinates 9º23'18"S and 40º31'24"W. The city's climate is semi-arid, the average annual temperature is 24.2 °C and the average annual rainfall is 420 mm, which is concentrated in the months from November to March (INMET, 2013).

The experiment was conducted in a test bench installed in the irrigation laboratory of UNIVASF. The statistical analysis used was descriptive quantitative by measures of central tendency and data dispersion measurements considering the entire population.

The test bench for drippers had a closed cycle in relation to the water used in the tests, bringing the possibility to test different types of water quality and your effects on clogging emitters.

The bench had capacity for four lines side that worked simultaneously, and each line had 15 drip emitters, totaling 30 drippers for each studied flow, of brand Irritec model Idrop in blue (NC1) and green (NC2). The two dripper models used were on-line non-pressure compensating type, with nominal flow rate of 2.58 (NC1) and 4.85 (NC2) $L.h^{-1}$. They were subjected to an operating pressure of 150 kPa with a distance of 0.5 m between them. The drippers were endowed with tortuous labyrinths that allowed a turbulent flow regime in order to reduce the clogging of emitters.

The pressurization system used in the experiment consisted of a hydraulic pump with a power of 0.5 cv coupled to a water tank, 500 L. Following the pump, a disc filter was installed with 120 mesh. It used a Bourdon tube pressure gauge, installed at the entrance of each dripper line, allowing the pressure to be frequently checked and adjusted to the previously established pressure when it’s necessary.

The collectors used for flow rate calculation were coupled to the drip emitters evaluated over four lines, which was carried out a flow rate test every 48 hours of operation.

The single superphosphate followed the fertilizer recommendation for the state of Pernambuco of Brazil for two crops, melon (209.0 $mg.L^{-1}$) and grape (400.6 $mg.L^{-1}$). The phosphate has low solubility and can cause chemical clog in the drip emitters. However, such results have not been seen in research related to the drippers clogging analysis; so that fertilizer can be a viable possibility to use in water irrigation, whether manage fertilizer concentration correctly.

Initially, the drippers were submitted to 48 h of irrigation using treated water from the public-supply water (SAAE) of the Federal University of São Francisco Valley - Juazeiro / BA campus, in order to reference the drippers, operating at 150 kPa operating pressure. After that, the system was activated to simulate the cycles of the melon and grape crops with raw water from the São Francisco river and single superphosphate, in the following chronological order: a successive melon cycle followed by a grape cycle, in three repetitions for each one.

The NC1 emitter worked with a total irrigation time of 4584 hours, detailed as the following: melon cycle with 192h and grape cycle with 1320h; and NC2 emitter with a total irrigation time of 2280 hours, detailed as the following: the melon cycle 96 h and with the grape cycle 648h (Table 1).

Table 1. Operation time of the irrigation system in function of the single superphosphate concentrations ($Ca(H_2PO_4)_2.H_2O + CaSO_4.2H_2O$)

	Repetition 1		Repetition 2		Repetition 3	
			Irrigation time			
			Dripper NC1			
48h (0h)	192h (240h)[1]	1320h (1560h)	192h (1752h)	1320h (3072h)	192h (3264h)	1320h (4584h)
			Dripper NC2			
48h (0h)	96h (144h)[1]	648h (792h)	96h (888h)	648h (1536h)	96h (1632h)	648h (2280h)
			Concentration ($mg.L^{-1}$)			
0	209,0	400,6	209,0	400,6	209,0	400,6

[1] Sum

The parameters evaluated were: mean flow of drippers (Qm) Relative flow rate (Qr), standard deviation (σ), coefficient of flow rate variation (CVQ), clogging degree (GE) (Mélo, 2007). As well as the indicators of uniformity of water distribution expressing the variability of the water depth applied, from the following coefficients: Christiansen Uniformity Coefficient (CUC); Hart Uniformity Coefficient (HUC); Statistical Uniformity Coefficient (SUC) and Distribution Uniformity (DU) (ROCHA et al., 1999).

5 RESULTS AND DISCUSSION

The Table 2 shows the analysis of variables for the NC1 and NC2 drippers in function of irrigation times. The flow rate indicated by the manufacturer (catalog) of the drippers of this study are 2.58 and 4.85 L h^{-1} to a 150 kPa operating pressure. When subjected to the initial test at 48 h of irrigation using treated water, the mean flow values were 2.40 and 4.32 L h-1 to a 150 kPa, for NC1 and NC2 drip emitters, respectively. It is observed that the flow rates obtained in the initial test were lower than the manufacturer's flow. This result may be associated with fluctuations and uncertainty of the operating pressure. As well, according to Ribeiro, Coelho and Teixeira (2010), the water quality can influence the reduction of flow rate.

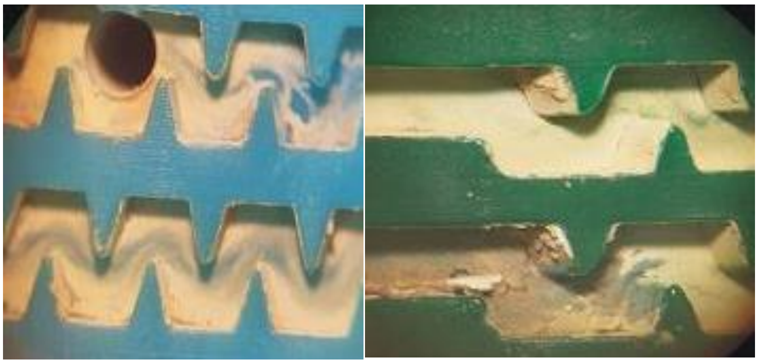
The NC1 and NC2 drippers showed 7 and 11% of flow variation with 48 hours of irrigation, respectively. This reduction can be attributed to a partial clogging of the drip emitters due to its initial use, to improper system dimensioning, or to the operating conditions of the experiment. Batista, Souza and Ferreira (2010) working with non-pressure compensating drippers observed a reduction of 4.56% in the mean flow after 120 hours of operation.

The mean flow for both drippers showed values close to the nominal flow rate, indicating good use conditions. However, only the NC1 dripper attend to the requirement of the Brazilian standard NBR ISO 9261 (ABNT, 2006), which requests a variation of 7%.

The relative flow rate of NC1 and NC2 drippers shows values close to 100%, with fluctuations following the increase of operating time. For NC2, initially observes a flow rate reduction on the order of 6.3% after 48 hours of operation, which, theoretically, is caused by the accumulation of particles inside the labyrinth of drip emitters. In general, the flow reductions were 15.1% and 12.6% for NC1 and NC2 drippers, respectively. This result is due to the increase of single superphosphate concentrations from the formation of insoluble compounds deposited inside the labyrinth in regions of circular flows and low speed (Figure 1). Carvalho at al. (2015) working with conventional drippers obtained values above 87% after 1368 hours of operation.

Figure 1. Labirinth internal view of NC1 (A) e NC2 (B)

A. B.



The standard deviation demonstrated a variable behavior of the flow rate to the NC1 and NC2 drippers that follows the increase of operating time, for the 30 drippers evaluated on each irrigation line. Then, it is observed reliable flow rate data to standard deviation values close to 5%, which explains a low variability and dispersion. That situation was more common for NC1 dripper than NC2 because, basically, of the existence of labyrinths with 0.6 mm, which promotes low flow rates and, consequently, a lower accumulation of sediments inside them. The NC2 dripper has labyrinths a thick of with 1.2 mm, and it can promote higher chances of accumulation of sediment deposits inside them.

Standard deviation values close to 20% of variation are unacceptable because it directly modifies the irrigation project design, especially, regarding the management of water use efficiency.

Table 2. Mean flow values in function of irrigation time for on-line non-pressure compensating drippers.

NC1 Dripper							
Var.	48h (0h)	192h (240h)	1320h (1560h)	192h (1752h)	1320h (3072h)	192h (3264h)	1320h (4584h)
Qm	2,4	2,35	2,36	2,27	2,3	2,23	2,06
Qr	98,6	96,6	97,1	93,3	94,6	91,6	84,9
Sq	0,04	0,14	0,04	0,04	0,03	0,12	0,20
CVq	1,8	6,2	1,8	1,9	1,4	5,7	9,8
NC2 Dripper							
Var.	48h (0h)	96h (144h)	648h (792h)	96h (888h)	648h (1536h)	96h (1632h)	648h (2280h)
Qm	4,32	4,56	4,49	4,52	3,99	4,14	4,05
Qr	93,7	98,7	96,6	97,7	86,6	89,8	87,4
Sq	0,09	0,08	0,13	0,07	0,15	0,15	0,23
CVq	2,2	1,9	3,1	1,6	3,8	4,5	5,9

(*) – Accumulated values

The coefficient of flow rate variation (CVQ) to NC1 and NC2 drippers showed values below 7% overall, attending the requirement of the Brazilian standard NBR ISO 9261: 2006 (ABNT, 2006), for non-pressure compensating drip emitters. According to Dalri et al. (2015), the CVQ evaluates the effect of the constructive factors of drippers; which explains the similarity of values between drippers because they present the same brand and model.

The CVQ variable may have direct influence on the internal hydraulic effects of drippers; Dalri et al. (2015) commented that the addition of fertilizers in irrigation systems can affect the hydraulic behavior of the drip emitters. In this study, the gradual increase of the single superphosphate concentration may have influenced the hydraulic behavior of water flow within the labyrinth for both drippers from the dimensional thinning of labyrinths, and from the accumulation and deposition of insoluble compounds inside them.

According to Batista et al. (2014), working with non-pressure compensate drippers and tortuous labyrinths obtained mean values of CVQ superior to 20% after 160 hours of operation, which does not attend the requirement of the Brazilian standard NBR ISO 9261: 2006 (ABNT, 2006). The same value was obtained by Silva et al. (2013) that, working with wastewater processing cashew, in non-pressure compensate drippers, it was observed that the CVQ value increased from 5% to 44% after 160 hours of operation.

The data relating to Christiansen Uniformity Coefficient (CUC), Distribution Uniformity(DU), Hart Uniformity Coefficient (HUC) and the Statistical Uniformity Coefficient (SUC) are shown in Table 3.

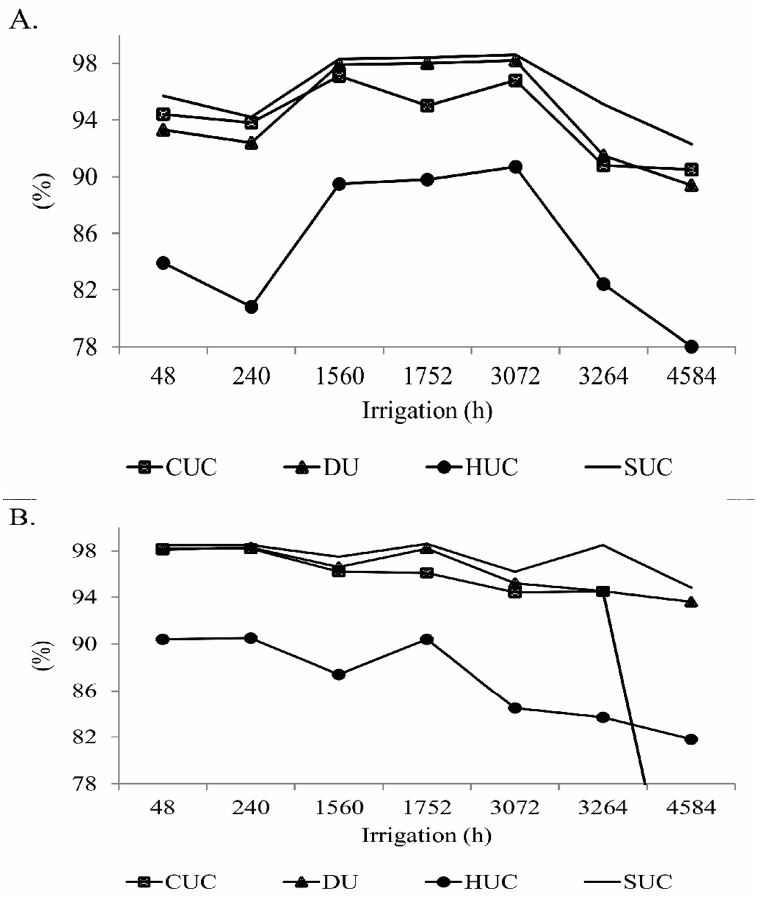
According to Table 3, the Christiansen Uniformity Coefficient (CUC) for NC1 and NC2 drip emitters were, generally, over 90%, demonstrating an excellent rating according to Mantovani (2002). The CUC shows the overall behavior of the samples in relation to the mean, explaining, in part, the low value found in 2280h for NC2 dripper from the standard deviation value for the same dripper. Santos et al. (2013), working with conventional drippers obtained CUC values equal to 83.1%, classified as a good value. On the other hand, Sandri et al. (2014), studying the Typhoon drippers, observed values inferior to 60% after 180 hours of operation. This value is classified as unacceptable, according to Mantovani (2002).

The values of the Distribution Uniformity (DU) were classified as excellent for both drippers, according to Mantovani (2002). Almeida et al. (2013), working with drip fertirrigation in CUD found low values. These values can be related to the precipitation of iron in the tube wall causing the increase of load losses and impairing the irrigation system. In contrast, in this study, the concentration of single superphosphate was not sufficientto generate low DU values.

From the results of CUC and DU, it can be affirmed that the clogging caused by single superphosphate was distributed along all the irrigation line. As a result, it is necessary new methods of system analysis related to the water distribution; recommending the use of dispersion statistical variables with the coefficients of uniformity for such analysis.

The Hart uniformity coefficient data (HUC) showed fluctuations in their behavior, which held off on the CUC values. It shows that the irrigation depth applied by drippers does not present a normal distribution. This behavior can be attributed to physical variations of the system, besides the operating time and the clogging caused by formation of insoluble compounds within the drip emitters.

Figure 2. Mean data referring to Uniformity Coefficients in function of irrigation time

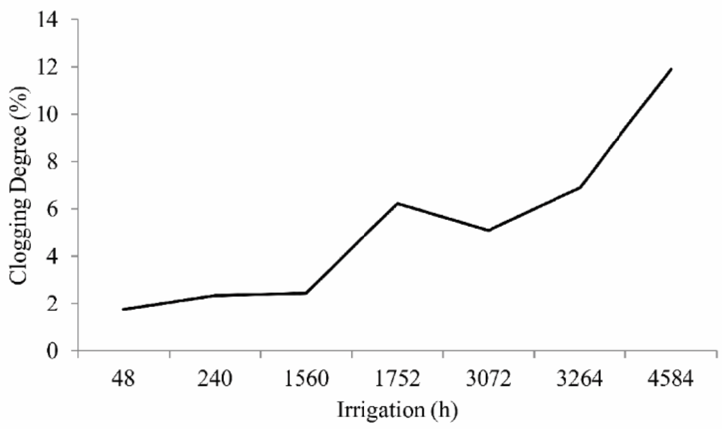


The values of Statistical Uniformity Coefficient (SUC), in general, are classified as excellent (MANTOVANI, 2002), and classified as good according to Mantovani (2002), in a drip irrigation system.

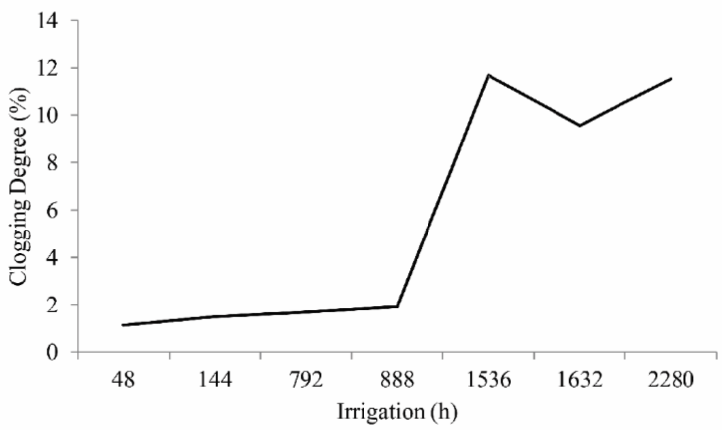
Table 4 shows the values for the clogging degree (GE) variable of the drippers NC1 and NC2, which are generally classified as low, according to Mantovani (2002). Despite these drippers have specific regions that promote sedimentation of insoluble compounds, it is not possible to measure hydraulically a drip emitter without providing a turbulent flow condition with the purpose of increasing friction losses and, hence, decreasing the output flow.

Figure 2. Evolution degree of obstruction in relation to the sum of hours of irrigation referring to the drippers NC1(A) e NC2(B)

A.



B.



Thus, the tortuous labyrinths and turbulent flow regime become important tools in the clogging control of drippers, having an important role within the labyrinth as the agitation of the physical and chemical particles. This situation may partially explain the clogging degree values, that were close to 10%. Also, it is observed that the concentration of single superphosphate was not sufficient to promote clogging of drip emitters, even with low solubility that could result in an increase of the chances of chemical clogging.

Ribeiro, Coelho and Teixeira (2010), working with conventional drippers, observed GE mean values lower than 8%, which is classified as low after 936 hours of operation when subjected to application of potassium chloride.

6 CONCLUSIONS

Single superphosphate concentrations of 1828.80 mg L-1 in water irrigation caused partial clogging (close to 10%) in on-line non-pressure compensating drippers in irrigation line under laboratory conditions.

Non-pressure compensating drippers with different flow rates did not differ in the chemical clogging caused by single superphosphate after a long period of irrigation system operation.

From the results of the uniformity coefficients, the clogging caused by single superphosphate occurs in a distributed manner in the irrigation line. Thus, it is necessary new methods of system analysis related to the distribution of water.

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