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AVALIAÇÃO DE DESEMPENHO DO MICROASPERSOR EM LINHA LATERAL E SIMULAÇÃO MATEMÁTICA DE SEU GRADIENTE DE ENERGIA

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1 RESUMO

Objetivou-se avaliar o desempenho do microaspersor Agropolo modelo MC20 em diferentes condições hidráulicas, gerando informações para um melhor dimensionamento de sistemas de microirrigação e manejo da água em áreas irrigadas. A condução do projeto hidráulico para simulação do gradiente de energia em linhas laterais, considerou-se informações determinadas através da escolha de componentes do projeto. Foram extraídos do catálogo comercial do fabricante os pares de valores referentes a vazão e a pressão e, a partir destes, gerou-se a curva vazão-pressão, onde a simulação foi feita pelo Método Algébrico - Christiansen (MA) e Método Iterativo (SBS) – Back-Step. Para ambos métodos o microaspersor se comportou de maneira semelhante, quando submetido a condições sugeridas pelo fabricante, num espaçamento entre emissores de 5,2 m, usando tubos de polietilenos de diâmetro interno de 13 mm e uma pressão de serviço de 20 mca, admitindo uma variação de 10% da pressão. Foram calculados os coeficientes de uniformidade de pressão (CUp) e de vazão (CUq), ambos com valores superiores à 95%, demonstrando a excelência no desempenho do emissor.

Palavras-chave: hidráulica, modelagem matemática, coeficiente de descarga.

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PERFORMANCE EVALUATION OF THE SIDE LINE MICROSPARENT AND MATHEMATICAL SIMULATION OF ITS ENERGY GRADIENT

2 ABSTRACT

The objective was to evaluate the performance of the Agropolo model MC20 microsprinkler under different hydraulic conditions, generating information for a better design of micro-irrigation systems and water management in irrigated areas. The conduction of the hydraulic project to simulate the energy gradient in lateral lines, considered information determined through the choice of project components. The pairs of values referring to flow and pressure were extracted from the manufacturer's commercial catalog and, from these, the flow-pressure curve was generated, where the simulation was performed using the Algebraic Method -

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Christiansen (MA) and Iterative Method (SBS) – Back-Step. For both methods, the microsprinkler behaved similarly, when subjected to conditions suggested by the manufacturer, in a spacing between emitters of 5.2 m, using polyethylene tubes with an internal diameter of 13 mm and a working pressure of 20 mca, admitting a 10% pressure variation. The uniformity of pressure (CUp) and flow (CUq) coefficients were calculated, both with values above 95%, demonstrating the excellence in the performance of the emitter.

Keywords: hydraulic, mathematical modeling, discharge coefficient.

3 INTRODUCTION

Knowledge of the hydraulic characteristics of emitters is essential for the correct sizing and operational management of irrigation systems (KELLER and BLIESNER, 1990). The hydraulic parameters of emitters in localized irrigation consider the following characteristics: relationship between flow and pressure at the inlet; localized head loss with their insertion in the pipe; flow regime; manufacturing uniformity; effective wetting radius; and uniformity of spatial water distribution (ABNT, 2004; ABNT, 2006).

The hydraulic performance of the emitter is determined by the variation in flow as a function of the response to pressure variations, which is determined by the exponent x (discharge coefficient) (LIMA, 1991). According to Azevedo (1986) and Abreu et al. (1987), for x equal to zero, the flow is constant regardless of the pressure variation, making the emitter self-compensating. Regardless of the precision of the manufacturing process, emitters present millimetric differences, the consequences of which are reflected in the values of the discharge coefficient, 'k', and the discharge exponent, 'x' (AZEVEDO, 1986). According to Dantas Neto et al. (1997), small differences between two apparently identical emitters can cause significant variations in the system flow. In general, the low efficiency of localized irrigation projects is related to the nonuniformity of water distribution (BARRETO FILHO et al., 2000).

The applied water depth can be affected by variations in the emitter flow rates within the project area. Among the factors that influence this are the nozzle diameter, orifice geometry and roughness, and jet inclination and velocity (SILVA and SILVA, 2005). Abreu et al. (1987) stated that the hydraulic performance of an emitter is determined, among other factors, by the manufacturing coefficient of variation, which is a measure of flow variation caused by variations in the manufacturing process. The manufacturing coefficient of variation can directly affect a properly dimensioned design (OLITTA, 1986). Nakayama and Bucks (1981) cite the main causes of manufacturing variation as follows: variations in water pressure and temperature; heterogeneity of the material used; and the emitter design itself.

According to Pizarro Cabello (1986), a perfect emitter would have the exponent $x = 0$ (self-compensating), those in a laminar regime $x = 1$ and those in a turbulent regime $x < 1$; for Frizzone et al. (2012), the perfect emitter must have an exponent “x” equal to zero, negating the effect of pressure variation on the emitter flow. Keller and Karmeli (1974) consider emitters with exponent $x = 1$ to be in a laminar regime and those with $x = 0.5$ to be in a turbulent regime.

The objective of this work was to evaluate the performance of the microsprinkler Agropolo model MC20 with a yellow nozzle and a 2.0 mm diameter under different hydraulic conditions to generate information that can contribute to the sizing of systems and the management of areas irrigated with this emitter.

4 MATERIALS AND METHODS

Data processing and calculations were performed in a spreadsheet. Table 1 shows the microsprinkler data , taken from the manual provided by the manufacturer, used to determine the flow–pressure curve via the Keller and Karmeli (1975) equation.

Table 1. Points of the flow-pressure equation for commercial microsprinklers.

Agropolo MC20 – Nozzle 2.00 mm R. 5.2 m	
Pressure (mca)	Flow rate m³/h
10	153.9
15	189.8
20	220.8
25	247.5
30	271.5
35	293.8

Source: Authors (2021).

Table 2 shows the data used to dimension the lateral line. As a criterion, an admissible variation of 20% in the lateral line pressure was adopted.

Table 2. Input data for hydraulic simulation of the lateral line.

Input data		**Unit**
Operating pressure (Ps)	20	mca
Acceptable flow variation (q)	10	%
Emitter spacing (se)	5.2	m
Proportionality constant (k)	46.89	dimensionless
Discharge exponent (x)	0.5165	Dimensionless
Inner diameter (Di)	13	mm
M	1.75	Dimensionless
F	$46{,}50.10^{-6}$	Dimensionless

Source: Authors (2021).

Blasius equations were used to determine f (friction factor); the Reynolds number, which determines the flow regime; and the Darcy and Weisbach equation (equation (1)), which is recognized as one of the most accurate ways to predict pressure loss.

$$hf = \frac{8.C}{\pi^{(2-m)}.9{,}81} . \left(\frac{4}{v}\right)^{(-m)} . \left(\frac{q}{Se}\right)^{(2-m)} . Di^{-(5-m)} . L^{(3-m)} . F \quad (1)$$

where hf is the allowable pressure loss in the lateral line (mca); C is the tabulated coefficient of friction (dimensionless); m is the Blasius coefficient (dimensionless); v is the kinematic viscosity of water ($m^2\ s^{-1}$); q is the nominal emitter flow rate ($m^3\ s^{-1}$); Se is the spacing between emitters (m); Di is the lateral line diameter (mm); L is the lateral line length (m); F is the correction factor (dimensionless); and Q is the total lateral line flow rate ($m^3\ s^{-1}$).

The lateral line was sized for a polyethylene pipe, i.e., a smooth conduit with an internal diameter of 13 mm. For greater practicality, the Blasius and Reynolds number equations were substituted into the universal pressure loss equation, and a single equation was obtained through algebraic manipulations. The correction factor proposed by Wu and Gitlin (1975) was used for pressure variation along the lateral line.

For the algebraic method (AM) of Christiansen, the data extracted from the flow-pressure equation (k = 46.889 and x = 0.5165) were used, and the prefixed values (spacing between emitters, pipe internal diameter, discharge exponent and service pressure) were considered. Given this, the following parameters were calculated: nominal flow (qn), lateral line length (L), number of emitters (n), adjusted lateral line length (Lajust), allowable head loss (hf') and corrected internal diameter (Di). In the application of the iterative method (SBS) – back step, the same values fixed in the previous methodology were considered in the calculations. Initially, on the basis of the estimate of the allowable head loss (hf'), the initial pressure of the parcel (Ho) was estimated, and then the pressure at the end of the line was calculated (Hn = H1). The value of K, used in the hf equation in the sections, was also calculated.

For greater accuracy in the calculations of the pressure drop in the lateral line, the variation in velocity, the Reynolds number and the variation in discharge of the emitter at each position (n) were considered. However, the application of the Blasius method was fixed to estimate hf', using iterative calculations under the condition that, if $H_n < H_0$, n = n + 1 continues to increase until $H_n / H_0 = 1$.

A priori, on the basis of the estimate of the allowable head loss (hf'), the initial pressure of the portion (Ho) was estimated, and then the pressure at the end of the line (Hn = H1) was calculated. Notably, although the calculations begin section by section with H1, this pressure is the pressure received by the last sprinkler. This can be better observed in the energy gradient (Figure 2). Therefore, the value of K, which was used in the hf equation in these sections, was also calculated.

The uniformity parameters for both flow (q) and pressure (p) were calculated to verify the standardization of water application in the simulation via equation (2).

$$CU\ (\%) = (1 - CV)\ x\ 100 \qquad (2)$$

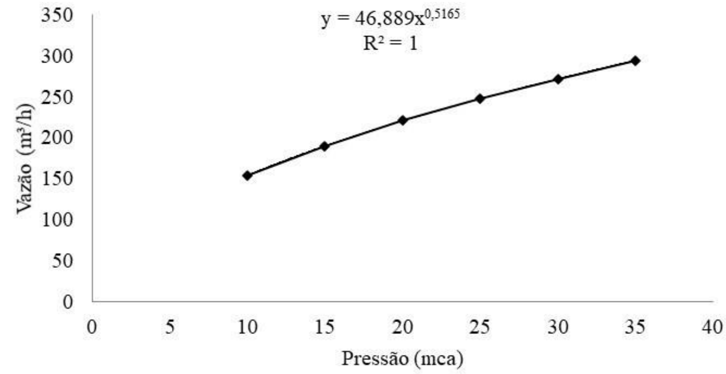
where CU is the uniformity coefficient (%) and CV is the coefficient of variation (dimensionless).

5 RESULTS AND DISCUSSION

The adjustment of the potential flow equations as a function of the operating pressure and nozzle diameter showed a high correlation between the flow and pressure values, which can be confirmed by the value of the coefficient of determination ($R^2 = 1$), as shown in Figure 1.

The micro sprinkler Agropolo MC20 with a yellow nozzle presented an exponent of 0.5165, classifying it as a turbulent regime. According to Frizzone et al. (2012) and Schimitd (2014), the emitter must have an exponent "x" close to or equal to zero (self-compensating), as it has low sensitivity to pressure variation and better uniformity of water distribution. When the coefficient x is equal to 1, there is a laminar flow regime, and below this range, the regime is characterized as turbulent (PIZARRO CABELLO, 1996).

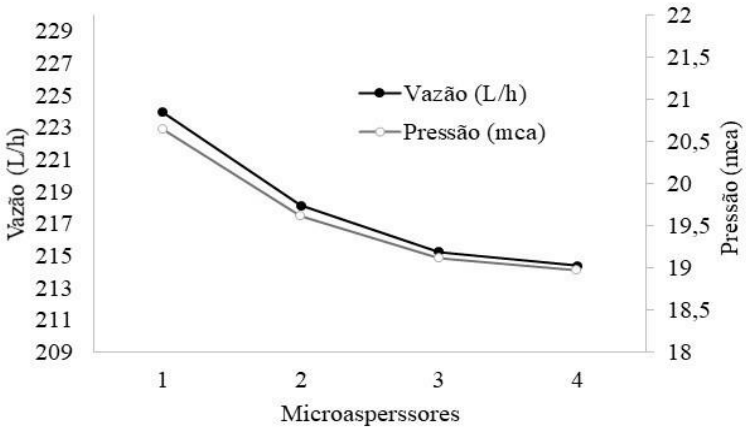
Figure 1. Flow-pressure curve of the Agropolo MC20 emitter with a yellow nozzle.



Source: Authors (2021).

Figure 2 shows a pressure variation along the lateral line of 8.1% and a flow variation of 4.3%. Thus, the hydraulic criteria were met, allowing good operability if this scenario was implemented. The total frictional head loss in the lateral line was 3.40 mca.

Figure 2. Variation in pressure and flow in the lateral line as a function of the position of the microsprinklers.



Source: Authors (2021).

The flow–pressure relationship as a function of the distribution of the number of microsprinklers decreased along the lateral line (Figure 2) (Table 3). Similar results were obtained by Polycarpo et al. (2019) and Franco et al. (2020). For Silva and Silva (2005), the uniformity of irrigation depth application along the lateral line in localized irrigation systems is directly related to the variation in pressure and flow of the emitters. Thus, changes in pressure caused by head loss lead to variations in flow. This behavior is associated with energy loss caused by friction and the insertion of microsprinklers along the line, in addition to being influenced by their manufacturing processes (PINHEIRO et al., 2019). Therefore, the hydraulic simulation performed on the commercial microsprinkler demonstrated good energy gradient performance when the lateral line was sized, providing data that can be used as a decision-making tool when this equipment is used in the field.

Table 3. Indices of the elements of vectors (H) and (q) for the scenario simulated by the SBS method.

Issuer	H (mca)	q (L/h)	Q (L/h)	hf (mca)
-	22.37	233.47	1,105.17	-
1	20.64	223.96	871.67	1.7293
2	19.62	218.13	647.73	1,0284
3	19.11	215.23	429.6	0.5013
4	18.97	214.37	214.37	0.1485

Source: Authors (2021).

Table 4 shows the parameters obtained when the flow and pressure uniformity test was applied to the simulation. The flow uniformity coefficient was 98.01%, and the pressure uniformity coefficient was 96.14%. Moreover, the uniformity parameters obtained excellent values, considering that the system is localized, ensuring standardized water application if this scenario is reproduced in practice.

Table 4. Flow and pressure uniformity parameters obtained in the simulation.

Emitter Flow Rate		Pressure from Issuers	
Average	217.92	Average	19.59
Size	4.00	Size	4.00
Minimum	214.37	Minimum	18.97
Maximum	223.96	Maximum	20.64
Total Amplitude	9.59	Total Amplitude	1.67
Standard Deviation	4.33	Standard Deviation	0.76
Coefficient of Variation	0.019890205	Coefficient of Variation	0.038640258
CUq	98.01	Cup	96.14

Source: Authors (2021).

With respect to the acceptable flow rate variation criterion, which is 10% (LUIDWIG, 2012), the corresponding percentage was 4.28%. Therefore, the microsprinkler used in the study met the hydraulic criteria necessary for a good water application response to the system. Notably, in addition to this mathematical evaluation of the emitter and the lateral line where it was installed, field testing is required to validate the theoretical behavior of the system.

6 CONCLUSIONS

The mathematical model proved to be effective in measuring the pressure and flow gradient along the lateral line, in addition to enabling an assessment of the performance of the localized irrigation system (microsprinkler), serving as a method to aid decision-making in choosing the emitter to be used.

The micro sprinkler, the yellow nozzle Agropolo system, presented a turbulent regime with less influence from pressure variations on the flow rate. This result may be related to the water distribution along the lateral line. A uniformity above 96% indicates that, if the scenario is implemented, the emitter will have good standardization of water application in the irrigation system.

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