

AREIA BRANCA DE CAMPINARANA COMO ELEMENTO FILTRANTE PARA FILTRO DE AREIA EM SISTEMAS DE MICROIRRIGAÇÃO¹

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1 RESUMO

Em sistemas de microirrigação é fundamental que a água seja corretamente filtrada para a retirada de impurezas que possam comprometer o funcionamento e o manejo do sistema. Nesse sentido, o objetivo geral desta pesquisa foi avaliar a qualidade da areia branca de Campinarana (ABC) da região de Mâncio Lima, Acre, localizada na Amazônia Ocidental brasileira como elemento filtrante para filtro de areia. Avaliou-se o coeficiente de uniformidade, massa específica, diâmetro equivalente, porosidade, esfericidade e eficiência de remoção de sólidos em suspensão por um sistema de filtragem e retrolavagem construído a partir de tubos e conexões em PVC rígido. Os parâmetros avaliados demonstraram que a ABC com diâmetro médio das partículas de 0,6 mm ou 1,2 mm podem ser utilizadas como elemento filtrante do filtro de areia em sistemas de microirrigação. Entretanto, partículas da ABC com diâmetro médio de 0,6 mm retiveram até 12% a mais de sólidos em suspensão em relação às partículas com diâmetro médio de 1,2 mm.

Palavras-chave: filtro alternativo, irrigação localizada, Amazônia Ocidental.

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WHITE SAND OF CAMPINARANA AS A FILTERING ELEMENT FOR SAND FILTER IN MICROIRRIGATION SYSTEMS

2 ABSTRACT

In microirrigation systems, it is essential that the water is correctly filtered to remove impurities that may compromise the functioning and management of the system. In this sense, the general objective of this research was to evaluate the quality of the white sand of Campinarana (WSC) from the region of Mâncio Lima, Acre, located in the Western Brazilian Amazon as a filtering element for sand filter. The uniformity coefficient, specific mass, equivalent diameter, porosity, sphericity, and removal efficiency of suspended solids were evaluated by a filtration and backwash system built from pipes and connections of rigid PVC. The evaluated parameters demonstrated that the WSC with average particle diameter of 0.6 mm or 1.2 mm can be used as a filtering element of sand filter in microirrigation systems. However, WSC particles with an average diameter of 0.6 mm retained up to 12% more suspended solids than particles with an

average diameter of 1.2 mm.

Keywords: alternative filter, localized irrigation, Western Amazon.

3 INTRODUCTION

In recent years, in the state of Acre, there has been an increase in crops irrigated by microirrigation (drip and microsprinkler), including passion fruit, papaya, vegetables, Canephora coffee and açai in dry land areas.

Generally, raw water sources with high concentrations of suspended particles are used to irrigate these crops (SERRANO *et al.*, 2018b). Furthermore, the water used for irrigation may contain suspended biological material resulting from the decomposition of forest vegetation, forcing irrigators to filter the water in their irrigation systems to avoid clogging the emitters.

This high concentration of particles is common in rivers in sedimentary basins, such as the Acre River basin, where concentrations of suspended particles can reach 840 mg L^{-1} , which, in addition to clogging emitters in irrigation systems, can also cause abrasion corrosion in the rotors of suction pumps (SERRANO *et al.*, 2018a).

The operational parameters established for the correct use of filters are often not met, as there are few references on the subject,—and technical information on

equipment operation for Brazilian conditions is usually scattered and/or insufficient. This factor, combined with limited technical assistance, is a problem that farmers must address and can consequently lead to their dissatisfaction, as it results in poor irrigation system performance, leading to increased maintenance costs (TESTEZLAF, 2008).

In this sense, the general objective of this research was to evaluate the quality of white sand from Campinarana in the region of Mâncio Lima, Acre, which is located in the western Brazilian Amazon, as a filter element for sand filters in microirrigation systems.

4 MATERIAL AND METHODS

The research was carried out at the Mechanization Laboratory of the Federal University of Acre in Rio Branco from March to June 2020. Initially, the granulometric characteristics of the white sand of Campinarana (ABC) were evaluated (Figure 1), followed by the removal of suspended solids from the irrigation water.

Figure 1. Images of white sands from Campinarana with different sieve diameters during the granulometric determination process.



Source: Authors (2020).

Two 50 kg samples of ABC were collected in the Mâncio Lima region, Acre, for physical characterization of the material and removal of suspended solids. For the granulometric characterization of ABC, the method described by the Brazilian Association of Technical Standards NBR 11799 (BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS, 2016) was adopted. The ABC was dried at 105°C in an oven for 3 hours, after which 100 g was removed for sieving by shaking. The sieves used had openings of 2.36 mm, 2.00 mm, 1.70 mm, 1.40 mm, 1.18 mm, 1.00 mm, 0.85 mm, 0.71 mm, 0.60 mm, 0.50 mm, and 0.42 mm.

This procedure was performed in triplicate, and the values computed for each particle size were used to calculate their respective averages. After sieving, the retained masses were determined and converted into percentage values to plot the particle size curve to estimate the effective grain diameter that allowed the passage of 10% and 60% of the material, D_{10} and D_{60} , respectively. With these data, the uniformity coefficient (CU) was calculated according to Equation 1 (BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS, 1995).

$$CU = \frac{D_{60}}{D_{10}} \quad (1)$$

where CU is the sand uniformity coefficient (dimensionless); D_{60} is the diameter, in mm, of the sieve that allows the passage of 60% of the material; and D_{10} is the diameter, in mm, of the sieve that allows the passage of 10% of the material.

The specific gravity (ρ_s) was quantified from 20 g of the dry sample, which was transferred to a 50 mL volumetric flask and, subsequently, with the aid of a burette, filled with absolute ethanol until it covered the sample. The material was then homogenized to remove bubbles, taking care not to leave granules above the meniscus of the glassware. The material remained at rest for 15 min and was stirred again after this period, after which the sample was left to rest for 24 h. After this period, 50 mL of alcohol was added, and the total volume used was recorded. With this information, the specific gravity was calculated via Equation 2 (AMERICAN SOCIETY OF TESTING AND MATERIAL, 2007).

$$\rho_s = \frac{m_g}{V_b - V_a} \quad (2)$$

where ρ_s is the specific mass (g cm^{-3}); m_g is the mass of the grains (grams); V_b is the volume of alcohol (cm^3); and V_a is the volume occupied by the sand (cm^3).

To determine the equivalent diameter

(D_{eq}) of the sand, the method of Cleasby and Fan (1981) was used, where the masses of 200 grains were measured for samples with diameters less than 1.0 mm and 150 grains were measured for those with larger diameters. The equivalent diameter was then calculated according to Equation 3.

$$D_{eq} = \left[\frac{6}{\pi} * \frac{m}{\rho_s} \right]^{\frac{1}{3}} \quad (3)$$

where D_{eq} is the equivalent diameter (mm) and m is the average mass of the grains (g).

Porosity (ε) was calculated according to the method described by the American Water Works Association (1999), by which porosity can be determined by measuring the volume of 200 cm³ of the sample with the aid of a graduated cylinder and funnel, taking care to maintain the uniformity of the material's fall and subsequently determining its mass. The procedure was repeated five times, and the average of these repetitions was used to calculate this variable via Equation (4).

$$\varepsilon = \left(\frac{V_t - \frac{m_g}{\rho_s}}{V_t} \right) * 100 \quad (4)$$

where ε is the porosity (%); V_t is the total volume (cm³); and m_g is the mass of the 200 cm³ sample (g).

Sphericity was determined according to the methodology of Di Bernardo and Dantas (2005). First, 23 grains of sand were removed from the previously dried samples and placed on graph paper. With the aid of a stereoscopic microscope, visual classification was subsequently performed.

To perform the suspended solids removal tests in the water, two sand filters constructed from rigid PVC pipes and fittings were assembled (Figure 2). The filters had a 75 mm diameter and a nominal pressure of 80 mca. The filters were installed in sequence to allow backwashing. Pressurization was provided by a 0.5 HP motor pump set with a total head of 28 mca and a maximum flow rate of 1,800 L h⁻¹, which was connected to a 1,000 L reservoir.

Figure 2. Images of the sand filters constructed from rigid PVC material used to evaluate the removal efficiency of the suspended solids present in water.



Source: Authors (2020).

A pressure gauge was installed at the pump outlet to check the operating pressure. The system flow rate was calculated by timing the time it took to fill a 20-liter reservoir (SALCEDO, 2010) and controlled by opening a valve installed between the pump and the reservoir. The adjusted flow rate for the filtration tests was 760 L h^{-1} . The removal efficiency, for the specific case of total suspended solids, was calculated via Equation 5 (AMERICAN SOCIETY AGRICULTURAL AND BIOLOGICAL ENGINEERS, 1994).

$$E_r = \left(1 - \frac{SST_2}{SST_1}\right) * 100 \quad (5)$$

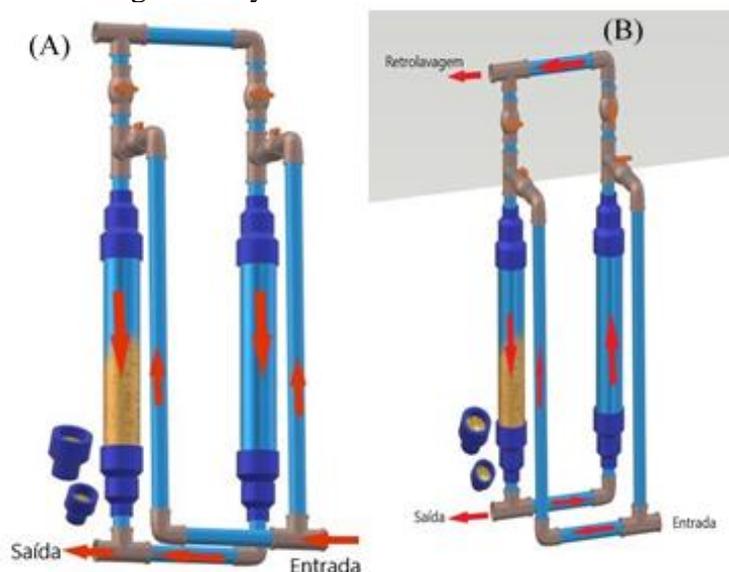
where E_r is the removal efficiency (%); SST_2 is the concentration of total suspended solids in the filter influent (g L^{-1}); and SST_1 is the concentration of total

suspended solids in the filter effluent (g L^{-1}).

During the 60 minutes, every 10 minutes in the effluent flow, three water samples were collected in a plastic container, which were then dried in an oven at $105 \text{ }^\circ\text{C}$ (BAIRD; EATON; RICE, 2017).

The removal efficiency of the filtration system was determined for two ABC particle sizes, 0.6 mm and 1.2 mm, for a 25 cm sand column. For sand with a diameter of 0.6 mm, a suspension material composition of 2.5, 3.5, or 5.0 g/L was used, and for sand with a diameter of 1.2 mm, a composition of 2.5, 5.0, or 10.0 g/L was used under constant manual agitation in the reservoir. After each evaluation, the filtration system was backwashed with clean water to remove the material retained in the sand column. This process was performed by reversing the water flow in the system (Figure 3).

Figure 3. Water flow in the filter during suspended solids removal tests (A) and water flow during backwashing of the system to remove solids retained in the sand layer (B).



Source: Authors (2020).

A descriptive analysis of the data was performed, and the removal efficiency of the suspended solids present in the water as a function of the operating time was analyzed graphically and by Student's t test to compare the means.

5 RESULTS AND DISCUSSION

The operating pressures and pressure drop of the sand filters were not evaluated. The backwash system worked properly, allowing the material retained by the sand column to be removed (Figure 4).

Figure 4. Sand layer of the filter element after water filtration (A) and after backwashing (B).

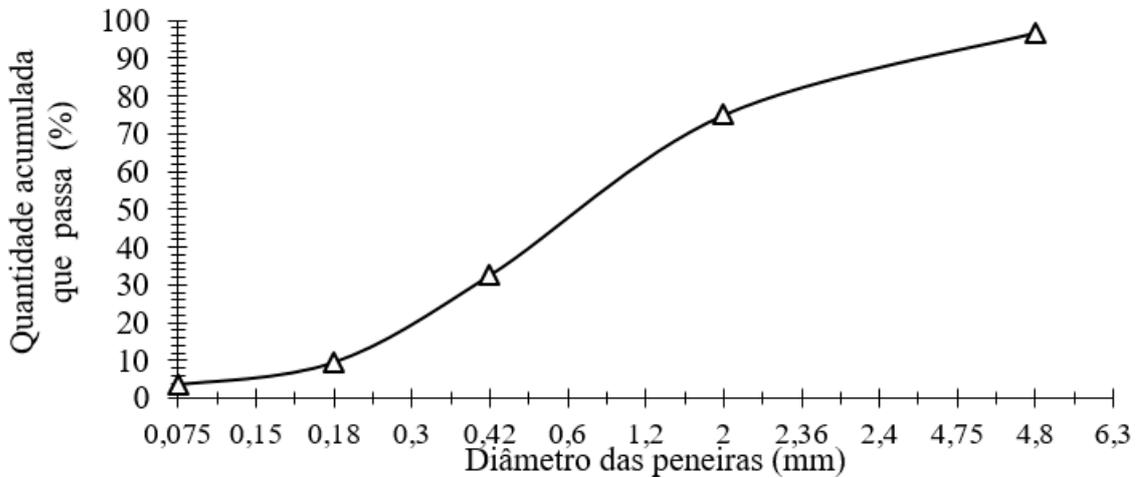


Source: Authors (2020).

The ABC composition contained 28% gravel, of which only 3.2% was classified as medium, and the remainder was classified as fine. The sand fraction, which represented 71.4% of the ABC composition,

consisted of 28.6% coarse sand, 28.4% medium sand, and 14.4% fine sand. The 0.6% fraction that was not retained in the sieves can be classified as silt according to the granulometric curve (Figure 5).

Figure 5. Granulometric curve of the white sand from Campinarana in the Mâncio Lima region, Acre.



Among the ABC fractions analyzed, grain diameters ranging from 0.42 mm to 4.8 mm can be used as filtering elements for sand filters, which translates into an estimated 60% utilization of the granulometric profile, with the coefficient of variation of the distribution of fractions in the samples ranging from 6.76 to 15.87. This shows that the material is uniformly distributed throughout the mine, with the exception of those with diameters above 2.4 mm, which are present in smaller quantities; therefore, the simple occurrence of these fragments in the sample already increases variability.

This particle size profile presented a uniformity coefficient of 7.22, classified by ABNT NBR 6502/95 as moderately uniform, which is not suitable for use in filters.

Therefore, it was necessary to separate the sample into particle size bands, from which two were selected. The first band was defined as the grains that passed through the 1.2 mm sieve and were retained in the 0.6 mm sieve. The second band was the grains that passed through the 2.4 mm sieve and were retained in the 1.2 mm sieve and were named "sand 0.6" and "sand 1.2".

With this separation, the samples became uniform (Table 1), which is also in accordance with the recommendations of Testezlaf, Deus and Mesquita (2014), who state that the result of the uniformity coefficient must be between 1.4 and 1.6 for the material to be used in sand filters, since these values improve water permeability, as they reduce the compaction of the filter bed.

Table 1. Parameters of Campinarana white sand separated for use as a filter element for sand filters in microirrigation systems.

Parameters	Sand 0.6	Sand 1.2
Uniformity coefficient	1.43	1.44
Specific mass (g cm ⁻³)	2.60	2.60
Equivalent diameter (mm)	0.53	0.84
Porosity (%)	14.83	18:00
Sphericity	0.85	0.85

The specific gravity remained the same for both sand grain sizes. This characteristic demonstrates that the grain sizes have the same geological origin and have undergone similar weathering due to being deposited in nearby locations, thus undergoing identical formation processes and possessing identical concentrations of the forming minerals (MESQUITA, 2014).

The average porosities of the 0.6% and 1.2% sand samples were 37% and 38%, respectively. This value differs from the results obtained by Chang *et al.* (1999), who evaluated sand with diameters between 0.5 and 1.5 mm and reported porosity values between 40% and 43%. This difference in porosity is due to the sand particles having rounded points, which allows better fitting between the grains, reducing the number of empty spaces (MESQUITA, 2014).

The average sphericity value of the two ABC particle sizes was 0.85. This result corroborates the result obtained by Mesquita (2014), who obtained a sphericity of 0.82. According to the author, the value found is in accordance with the values verified for silica sand, which is commonly used in

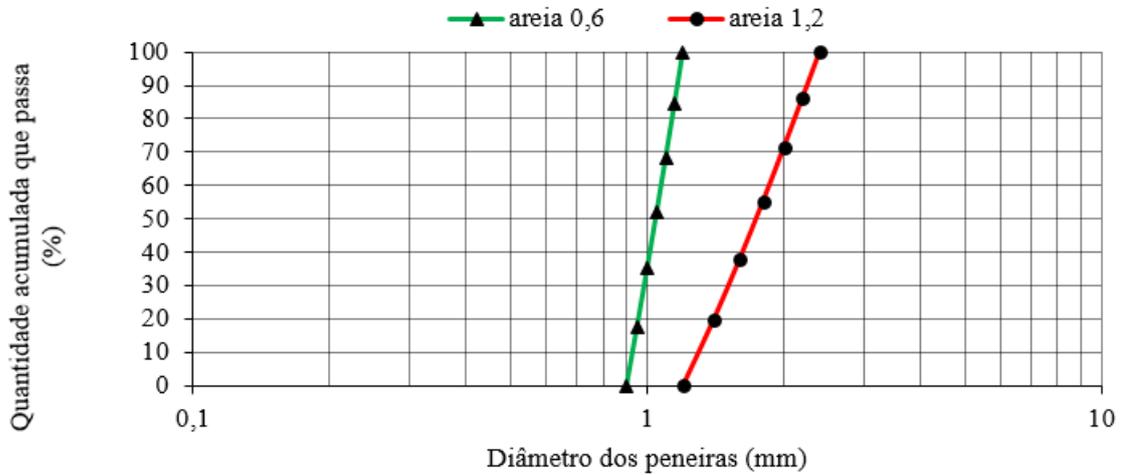
water filters for irrigation. Given this result, it is inferred that sands with this sphericity are spherical in shape (FAIR; GEYER; OKUN, 1968; RITTENHOUSE, 1943).

According to Phillips (1995), the sands suitable for use in irrigation filters are those with edges but are not sharp or angular, which can reduce filtration efficiency. This characteristic favors backwashing, as dirt particles are released more easily, increasing the cleaning efficiency of the filtration system.

Thus, the ABC of the Mâncio Lima region, Acre, located in the western Brazilian Amazon, meets the necessary requirements that accredit it as a filter element for sand filters in microirrigation systems.

When plotting the granulometric curve of the samples (Figure 6), the “S” curve, characteristic of this type of data, was not presented because of the reduction in the variability of the grain size; however, a straight line with a slightly inclined (curved) position was observed, again indicating the uniformity of the samples.

Figure 6. Granulometric curves of Campinarana white sand selected for use as a filter element in sand filters for microirrigation systems.



After the ABC particle size was characterized and separated, tests were performed to remove the suspended solids from the water via sand with particle diameters of 0.6 mm and 1.2 mm. Figures 7 and 8 show the results of the removal efficiency of the suspended solids. The removal efficiency gradually increased as the influent presented a greater quantity of

suspended solids. A total suspended solids content of less than 50 mg/L (0.05 g/L) poses a low risk of dripper clogging (BUCKS; NAKAYAMA; GILBERT, 1979). An increase in the retention of suspended solids on the order of 3.21% was also observed for every 0.5 g L⁻¹ of suspended solids present in the water.

Figure 7. Suspended solids in water were removed from Campinarana white sand with a diameter of 0.6 mm and a 25 cm column, with a filtration flow rate of 760 L h⁻¹.

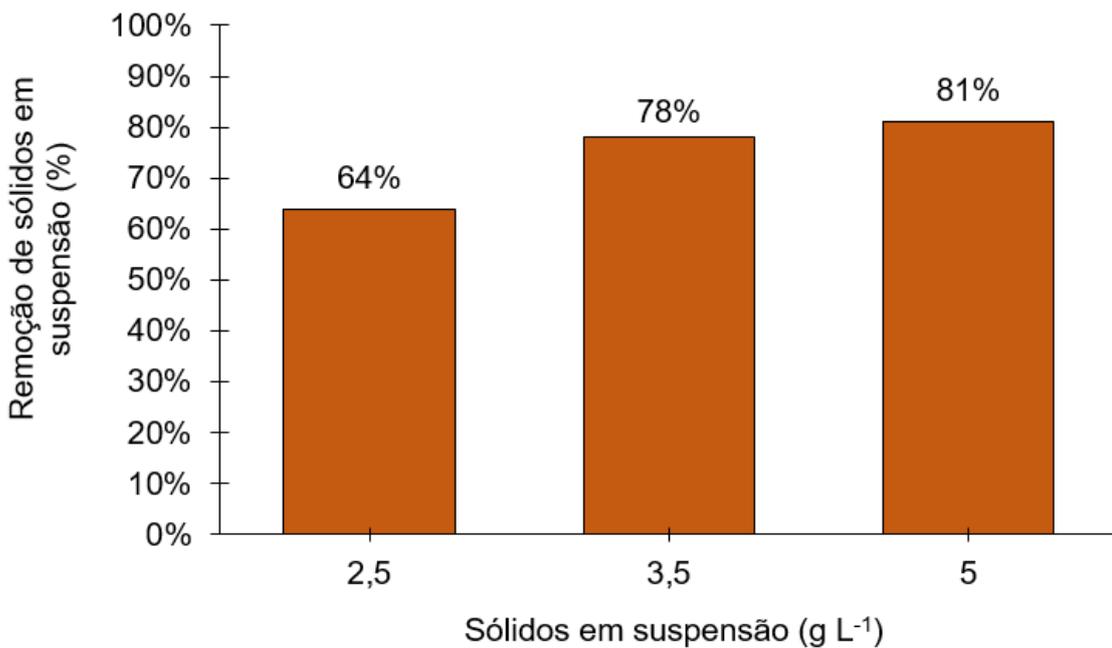
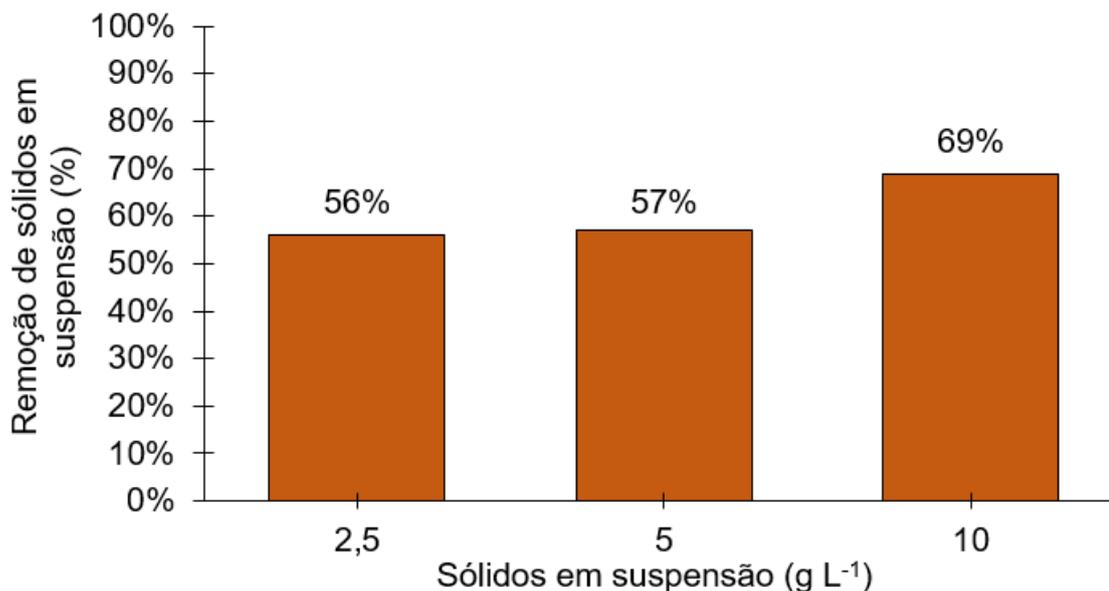


Figure 8. Suspended solids in water were removed from Campinarana white sand with a diameter of 1.2 mm and a 25 cm column, with a filtration flow rate of 760 L h⁻¹.



An analysis of the results in Figure 8 revealed that the percentage of suspended solids removed was, on average, 56.5% for the 2.5 and 5 g L⁻¹ doses present in the irrigation water. As the amount of suspended solids increased to 10 g L⁻¹, the percentage of material retained in the filter also increased. For these three tests, after one hour of operation, no increase in pressure was observed through the pressure gauge installed at the filtration system inlet.

The comparison of means via the t test revealed that 0.6 mm sand is more efficient than 1.2 mm sand, with confidence intervals ranging from 68% to 80% and 51% to 71%, respectively. This difference is attributed to the greater porosity of the 1.2 mm sand (Table 1), which allows the average passage of suspended solids (approximately 40% of the pumped water). However, for both treatments, the solids not removed were clay-like and were smaller than 0.002 mm in diameter. In this case, it is recommended to install flush valves at the end of the lateral irrigation lines and to clean the system more frequently, thus reducing the risk of emitter clogging.

Considering the results obtained (Figures 7 and 8), the highest suspended

solids removal values were obtained for ABC, with an average particle diameter of 0.6 mm, retaining 81% of the material after 1 hour of filtration system operation. An increase in the filtration rate, associated with a decrease in the sand particle size, increases the removal efficiency but accentuates pressure loss over time, which reduces the removal of smaller particles throughout the filtration cycles (DEUS; TESTEZLAF; MESQUITA, 2015).

However, either of the two ABC sand filter sizes (0.6 mm or 1.2 mm) can be used for microirrigation systems. Notably, no pressure increase occurred in any of the tests as a function of the filtration flow rate and time studied, indicating that the filter element can be backwashed after a longer period of operation.

6 CONCLUSIONS

Campinarana white sand with an average particle diameter of 0.6 mm or 1.2 mm can be used as a filter element in sand filters in microirrigation systems. However, Campinarana white sand particles with an average diameter of 0.6 mm retained up to 11% ~~more suspended solids than~~ particles with an average diameter of 1.2 mm.

7 ACKNOWLEDGMENTS

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