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Sustainable Techniques in Water Resource Conservation in Agriculture in Brazil

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ABSTRACT

The scarcity of water for irrigation, drinking water, and other uses is increasing. It is also known that water distribution and availability are irregular and can vary throughout the year and from region to region. Therefore, one of the sustainable and strategic practices for the conservation of this water resource is to establish criteria for appropriate uses in agricultural activity. The experiment was conducted under protected environment conditions, on the premises of the Universidade Federal Rural de Pernambuco (UFRPE), Recife campus in Pernambuco - Brazil, from information and studies that may contribute to the conservation and optimization of natural resources. The irrigation technique proposed in this paper considered the balance between agricultural productivity, preservation of water availability and improvement of application efficiency. The experimental design adopted was a 2x5 factorial scheme, with three repetitions, totaling 10 treatments. Two types of water application were tested (continuous and pulse drip) and five fertigation sheets at the following percentages (40, 60, 80, 100 and 120% of crop evapotranspiration (ETC)). The application by pulses consisted of dividing the irrigation blade in six pulses with intervals of sixty minutes resting time. The ETc was determined from the water balance in drainage lysimeters. The adoption of pulse irrigation positively influenced both the rate of emitter clogging, providing lower results in emitter clogging, and the Uniformity of Water Distribution (CUD), obtaining higher values of uniformity coefficients in the distribution, depending on the blade of water replacement. Adopting the strategy of legume application it is possible to obtain an economy of up to approximately 40% of water in commercial production in the vegetative phase of the cilantro crop.

INTRODUCTION

One of the most relevant processes for the development of agricultural production, irrigation has been gaining significant ground in Brazilian agriculture. It is known that water is one of the main constituents of plant tissue, responsible for ensuring the effectiveness of processes such as translocation of solutes and opening and closing of stomata, and its unavailability can cause damage to the metabolism of the plant, in Brazil the availability of water for irrigation, at present has become increasingly smaller, both in quantity and in quality, due to increasing competition between users of urban, rural and industrial areas. (Phogat *et al.,* 2013).

Brazil has a territorial surface of 851 million hectares, according to the IBGE survey (2015). Although it is in a privileged position in relation to most countries, with 8% of freshwater available worldwide, according to Rebouças (1997), the water crisis in the country is basically a result of the lack of resource management, stimulating urbanization and industrialization in areas where water is already scarce. Reducing the volume of water applied is beneficial both to preserve its consumption and to reduce production costs and minimize leaching of nutrients and pesticides into the groundwater (Puiupol et al., 1996).

One technique that can be used to favor water distribution uniformity is pulse irrigation. Pulsed irrigation consists of applying the actual irrigation required (IRN) fractionally throughout the day, where the cycle repeats until the entire blade is applied, being an alternative, which has a positive effect on Water Use Efficiency (WUE) and on the total and commercial productivity of crops. Pulse irrigation allows the reduction of the irrigation blade without reducing the productivity of the crop (ALMEIDA, 2012).

This irrigation technique has been studied by several countries in the world (Zin El-Abedin, 2006; Abdelraouf et al., 2012; Abdelghany, 2009). According to ABIMAQ/CSEI (2015), the area irrigated by this technique has been growing by an average of 36 thousand ha per year. An important characteristic of the pulse irrigation technique is that the amount of water and the total time of application are the same as in a continuous irrigation system, but divided into phases or cycles, defined at the time of operation (GarcíaPrats & Guillem-Picó, 2016).

Among the various types of irrigation systems, the drip system is the one that presents the best application and when well managed has good results in water and fertilizer efficiency. In addition, the drip system when in pulses, has significant effects on increased productivity, improved product quality, savings in water use, and reduced energy consumption (Almeida et al., 2015; Zamora, 2018). According to García-Prats & Guillem-Picó (2016), by applying pulse irrigation in irrigated perimeters that operate on demand, they observed savings in power, energy consumption, and electricity costs. They concluded that adopting techniques that combine low discharge rates, longer irrigation times, high frequencies, and pulse irrigation provide potential energy savings, especially in irrigated perimeters that operate on demand. Phogat et al. (2013), observed that by subjecting the crop to constant water deficit conditions, the pulse irrigation technique is an option that improves irrigation efficiency while maintaining production and profit.

Zamora (2018) cites that the fractioning of the irrigation blade enabled an increase in plant height for the same fertigation blade. Freire (2008) also observed significant results with the application of pulse irrigation. He observed greater yields in papaya with irrigation three times a day.

Bernardo et al. (2006) mention that the uniformity of distribution or application of water in the irrigated plot can be expressed by indexes or coefficients, such as the distribution uniformity coefficient (CUD) and the statistical uniformity coefficient (CUE). The first (CUD) represents the uniformity of application of the flow in relation to the average of 25% of the lowest flow values observed in the irrigated plot. The CUE, in turn, represents the uniformity of application in relation to the standard deviation of the average flow rate of the emitters in the plot.

According to ASAE (1994) water distribution uniformity can be classified as excellent (94 to 100% for CUD and 95 to 100% for CUE), good (81 to 87% for CUD and 85 to 90% for CUE), reasonable (68 to 75% for CUD and 75 to 80% for CUE), poor (56 to 62% for CUD and 65 to 70% for CUE), and unacceptable (< 50% for CUD and < 60% for CUE).

Batista et al. (2010) calls attention to the clogging of drippers supplied with low quality water, in which the distribution uniformity was evaluated in different times of system operation, with a significant decrease in the flow rate of the emitters and in the CUC and CUD coefficients.

According to Silva et al. (2012) when studying the performance of the Katif model dripper, it was found that domestic sewage treated by means of a digester decanter associated with a digester filter was more efficient in reducing the flow variation.

Water application efficiency can be very high in a drip irrigation system provided control of the sources of losses (leaching, surface runoff, evaporation and wind drift) is achieved, according to Barro et al. (2008). Water distribution efficiency depends on the rate of emitter clogging, i.e. the lower the rate of clogging the greater the potential for improvement in water distribution uniformity, allowing high yields and water savings to be obtained (Cun et al., 2011).

Abdelraouf et al. (2012), working with drip irrigation for organic potato production, observed that the rate of clogging of the drippers decreased with the increase in the number of pulses adopted. Regarding the uniformity of water distribution, the authors observed that the highest values of uniformity were obtained in the plots irrigated by pulses, and the higher the number of pulses the higher the coefficient of uniformity of water distribution.

Thus, the objective of this article is to contribute to the discussion about drip irrigation agriculture with fractional blade application, based on the evaluation of the water distribution uniformity coefficient of the irrigation system with and without the adoption of pulses and the influence on the quantification of the clogging index of emitters under pulse irrigation and continuous irrigation.

MATERIALS AND METHODS

The experiment was installed in the UFRPE premises, Recife Campus, Pernambuco, with geographical coordinates 8º 01' 05" south latitude and 34º 5 56' 42" west longitude and altitude 6.4m. According to Koppen's classification, the study area has climate type As', called tropical hot and humid, with autumn-winter rainfall, presenting a dry or dry season, which lasts from September to February, and a rainy season from March to August (Jales et al., 2012). "Climate is the most dominant variable in determining plant growth." (PURBA et al, 2016, p100).

The experimental plots were installed in a protected environment, a chapel-type greenhouse with a plastic cover of 162m². Each plot had 1.02 m² (5.10 x 0.20m) and a depth of 0.20m. Each experimental unit was waterproofed with polyethylene plastic and provided with a drainage pipe with the function of leaching excess water and nutrients. Each experimental plot consisted of two rows of plants spaced 0.10 m between rows and 0.15 m between plants, with a useful sampling area of 0.12 m².

For the execution of the experiment was chosen the green coriander crop, Coriandrum Sativum L. The soil used in the experiment was characterized with sandy texture, containing 904g/kg of sand, 32 g/kg of silt and 64 g/kg of clay. The soil and particle densities were 1.5 and 2.5 kg.dm^{-3}. The soil water storage limits of the experimental area are 0.10 m^3. m^{-3} (field capacity) and 0.09 m^3. m^{-3} (permanent wilting point).

Table 1. chemical analysis of the soil used in the experiment

PH	Ca	Mg	AL	Na	K	P	H+AL
1:2,5	**cmolc■dm^{-3}**					**mg.dm^{-3}**	**cmolc■dm^{-3}**
5,1	2	1,5	0,20	0,01	0,01	2,00	4,68

Because of the acidic condition of the soil, it was necessary to correct its acidity by applying agricultural lime. The experimental design adopted was randomized blocks in a 2x5 factorial scheme. The treatments consisted of two types of water application (pulse and continuous irrigation) and five ETc replacement plates (120, 100, 80, 60, and 40%), with three repetitions, totaling ten treatments, and 30 experimental plots. Six irrigation pulses were defined with a 60-minute rest interval between two successive irrigations. The determination of crop evapotranspiration (ETc) was performed by water balance in percolation lysimeters installed in 5.0 liter vases inside the greenhouse.

The ETc was taken as the average of four observations. Irrigation of the plots was by drip tape (DN 16 mm) with integrated drippers spaced at 0.30 m with 0.60 L h-1 nominal flow rate. The pressure during system operation was regulated to 10 meters per water column (mca). The experimental design adopted was randomized blocks in a 2x5 factorial scheme. The treatments consisted of two types of water application (pulse and continuous irrigation) and five ETc replenishment sheets (120, 100, 80, 60 and 40%), with three repetitions, totaling ten treatments and 30 experimental plots.

Six pulses of irrigation were defined with a 60 minute rest interval between two successive irrigations. The determination of crop evapotranspiration (ETc) was performed by water balance in percolation lysimeters installed in 5.0 liter vases inside the greenhouse. The ETc was taken as the average of four observations. Irrigation of the plots was by drip tape (DN 16 mm) with integrated drippers spaced at 0.30 m with 0.60 L h-1 nominal flow rate. The pressure during system operation was set at 10 mca. For the proper operation of the irrigation system were used registers, solenoid valves, pressure regulator, filter, microcontroller and a pumping system with installed power of 0.5 horsepower (CV).

The irrigation time was determined considering the gross irrigation blade to be applied in each treatment. The gross irrigation blade was obtained by the simple relation between ETc and the average application efficiency of the irrigation system. The differentiation of treatments began on the tenth day after sowing. Until this day, all plots received daily irrigations applying 100% of ETc continuously.

The plotting of the gross irrigation blade and the calculation of application times, according to each treatment, was done automatically by means of an electronic control circuit in ARDUINO. The daily irrigations started at nine in the morning. Fertilization was based on soil analysis and considering the nutritional demand of the cilantro crop, according to the Fertilization Recommendation for the State of Pernambuco (IPA, 2008).

The application of phosphorus (simple superphosphate) was done in the foundation, the rest of the nutrients were applied daily via fertigation, taking as reference the recommendation of Furnali (1998) for leafy vegetables. To study the effect of pulse irrigation the Coefficient of Uniformity of water distribution was determined, as well as the clogging index of the emitters at the end of the experiment. The CUD was calculated and as a criterion for the evaluation of emitter clogging the relative emitter flow rate (qR) and the percentage of average discharge reduction (qRED) were determined according to the methodology described by Liu & Wang (2009). Where the average emitter flow rate for each measurement represents the average flow rate ($L.h^{-1}$) of the 60 new emitters operating at rated pressure. The methodology established by

Wu et al. (2008) employed by Zhou et al. (2015) was used to evaluate and classify the effect of pulse irrigation on emitter clogging. The data obtained were submitted to the analysis of variance and when significant by the F test the means were compared by the Scott Knott test at 5% probability in order to verify any significant difference between the treatments.

RESULTS AND DISCUSSION

The average flow rate of the new drippers was (0.560 ± 0.003) L/h. The Distribution Uniformity Coefficient (DUC) for new drippers was (98.71 ± 0.14) %.

For this CUD value the uniformity is classified as "excellent", as recommended by ASAE (1994). The values of the dripper clogging index determined at the end of the cycle are shown in Figure 1.

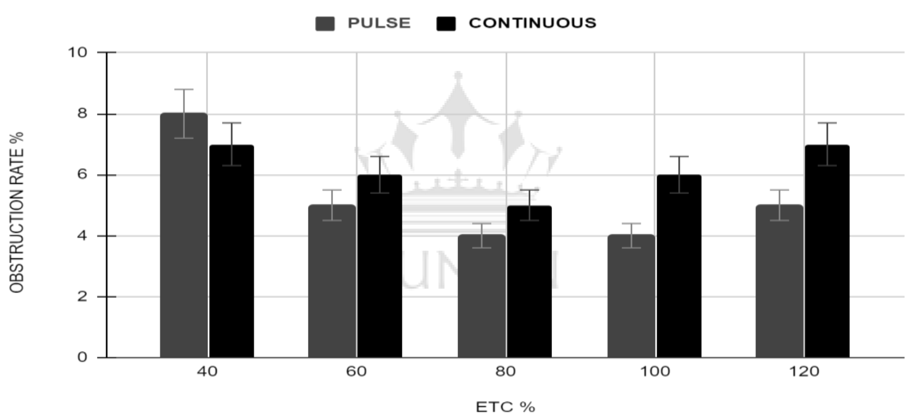

Figure 1. Fouling index of the drippers at the end of the experiment: The vertical bars represent the standard error of the means.

It was observed with the use of pulse irrigation that the rate of emitter plugging was lower for all the percentages of ETc applied except for 40 and 120% of ETc. This result is similar to that obtained by Abdelraoulf (2009). According to this author, the pulse irrigation technique attenuates the effect of emitter clogging due to the successive on and off cycles in each irrigation event.

The Coefficients of Uniformity of water distribution (CUD) determined at the end of the experiment are shown in Figure 2.

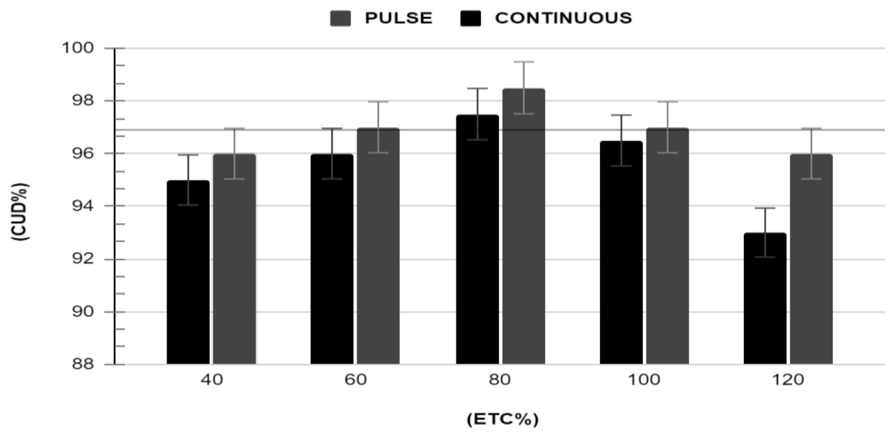

Figure 2 - Coefficients of Uniformity of Water Delivery (CUD) as a function of water application and ETc replacement slopes: The vertical bars represent the standard error of the means.

Figure 2 shows the superiority of the CUDs for the plots submitted to pulse irrigation. Thus, it was possible to verify, for the conditions of the experiment, the benefit of using the pulse irrigation technique regarding the uniformity of water distribution. Abdelraoulf (2009) also found similar results in his experiment when evaluating a drip irrigation system subjected to pulse irrigation. As water distribution efficiency depends directly on the rate of emitter clogging, therefore decreasing the rate of clogging would increase the potential to improve water distribution uniformity, thus allowing water savings.

CONCLUSION

Pulse irrigation provided lower rates of emitter clogging and higher values of water distribution uniformity coefficients, and consequently can be used as a strategy to save water application in the vegetative stages of the crop. The pulse irrigation technique allowed a lower rate of emitter clogging due to the successive interval cycles between on and off in each irrigation event, and consequently there was an improvement in water distribution. This paper sought to present quantitatively the optimization of water resources, the efficiency of distribution uniformity and the effect of significant improvement in the rate of dripper clogging under pulse irrigation, from statistics, experimental and comparative studies.

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