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A comparative study of the conventional drip system and by pulses in pepper yield

Um estudo comparativo do sistema de gotejamento contínuo e por pulsos na produtivdade do pimentão

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ABSTRACT
Fractionating the irrigation blade over the course of a day can improve water efficiency, extending the time of water availability in the soil and obtaining better use by the plants. This work evaluates the effects of the pulsed drip irrigation system on pepper yield compared to the continuous drip system. The agronomic characteristics of the fruits, productivity and water use efficiency were measured in the context of drip irrigation in an experimental test in randomized blocks. Analysis of variance and averages test were assigned for data validation, principal component analysis and dendrogram graph were used to analyze the trend and similarity of the data, generated by the RStudio ® software. The fractionated irrigation blade in 4 applications performed better than the other fractionations, in terms of productivity and water use efficiency. In pulse 4, the diameter, height and thickness of the fruit wall obtained results that did not differ from the effects of pulse 5. Plants irrigated by pulse 4 produced more fruit, characterizing higher yield. It was demonstrated that the fractionation of the irrigation blade in 4 applications significantly increased the productivity and the efficiency of water use in the pepper culture.

Keywords: *Capsicum annum* L., Evapotranspiration, Percolation, Water efficiency.

RESUMO
Fracionar a lâmina de irrigação ao longo de um dia pode melhorar a eficiência da água, ampliando o tempo de disponibilidade da água no solo e obtendo melhor aproveitamento pelas plantas. Este trabalho avalia os efeitos do sistema de irrigação por gotejamento pulsado na produtividade do pimentão em comparação com o sistema de gotejamento contínuo. As características agronômicas dos frutos, produtividade e eficiência do uso da água foram mensuradas no contexto de uma irrigação por gotejamento em um ensaio experimental em blocos casualizados. Foram atribuídas análises de variância e teste de médias para validação dos dados, análise de componentes principais e gráfico dendrograma foram utilizados para analisar a tendência e similaridade dos dados, gerados pelo software RStudio®. A lâmina de irrigação fracionada em 4 aplicações apresentou desempenho superior aos demais fracionamentos, em termos de produtividade e eficiência do uso da água. No pulso 4 o diâmetro, altura e espessura da parede do fruto obtiveram resultados que não diferenciaram dos efeitos do pulso 5. As plantas irrigadas pelo pulso 4 produziram mais frutos, caracterizando maior rendimento. Foi demonstrado que o fracionamento da lâmina de irrigação em 4 aplicações aumentou significativamente a produtividade e a eficiência do uso da água na cultura do pimentão.

Palavras-chave: *Capsicum annum* L., Evapotranspiração, Percolação. Eficiência da água.

1 INTRODUCTION

Pulse irrigation or intermittent irrigation is an irrigation technique that performs the application of water by small fractions, which are applied to plants during the day and according to their water needs (Almeida *et al*. 2015), this technique allows keep water and soluble nutrients close to the root zone of the crop (Zamora *et al.* 2019).

The application of pulses in irrigation can be carried out for any irrigated crop, whether in the drip system or not (Zin El-Abedin 2006). Vegetables are the main crops subjected to this irrigation technique due to their high economic value (Zamora *et al.* 2019). Among these cultures, peppers stand out among the 10 most economically important in Brazil (Albuquerque *et al.* (2011).

The drip irrigation method is very adaptable to the pepper culture, besides obtaining a better efficiency in the application of water, it also contributes to the cultural treatments avoiding the spread of invasive plants. This type of irrigation system, due to its application characteristics, small flows and high frequencies, allow a better use of the applied water (Testezlaf 2017).

There is a need to determine the water consumption of the crop to optimize the use of irrigation, the determination occurs through direct or indirect methods, one of the direct methods is the use of drainage lysimeters. Once the water consumption of the crop is determined, irrigation management is carried out consciously, making the amount of water available to the crop corresponding to its need in such a way as to favor water absorption throughout the day.

Pepper is a crop that requires a regular supply of water throughout the cycle. However, the accumulation of water in the soil must be avoided in order not to favor the emergence of diseases that can cause decay of the fall and roots, as well as abortion and fall of flowers (Carvalho *et al.* 2011).

The following research is based on the hypothesis that the use of the pulse technique in irrigation ensures greater yield in the pepper culture, objective was to analyze the effects of the pulsed drip irrigation system on the pepper yield compared to the continuous drip system.

2 MATERIAL AND METHODS

2.1 CHARACTERIZATION OF THE AREA AND EXPERIMENTAL DESIGN

The experimental was conducted in the Agreste region of the State of Alagoas (latitude 9º41’56.8” N; longitude 36º41’ 12.83” W; Altitude average 310 m). This region has a tropical 'As' climate with a dry summer season, according to the Köppen classification criterion (1948), with an average rainfall of 854 mm.year^{-1}, initially distributed in the month of May extending to the month of August (Xavier and Dornellas 2010). The soil was classified as dystrophic Red Yellow Latosol (Araújo Filho *et al.* 2012).

The area where the research was conducted has no productive history, imposing the determination of the physical-chemical characteristics of the soil for subsequent correction and recommendation of nutrients for the crop (Table 1), in this area the Kolima hybrid of the pepper culture was implanted. For this study, the experimental trial consisted of an arrangement by randomized blocks, adopting 7 blocks and 5 treatments. With a driving period from January to March 2019, the evaluations were carried out in the first crop production cycle.

The treatments consisted of 5 irrigation pulses, equivalent to: Pulse 1 (Pulse continuous), the irrigation blade was available in a single application on the day; Pulse 2, the irrigation blade was divided into two daily applications; Pulse 3, fractionation of the irrigation blade in three daily applications; Pulse 4, fractionation of the irrigation blade in four daily applications and Pulse 5, fractionation of the irrigation blade in five daily applications.

2.2 DETERMINATION OF CULTURE EVAPOTRANSPIRATION

The water requirement of the culture was obtained through the evapotranspiration of the culture (ETc), determined by drainage lysimeter. Five sets of drainage lysimeters were used, each set consisting of five lysimeters, referring to an irrigation pulse, totaling twenty-five drainage lysimeters in the experimental area, the spacing used to implant the lysimeters obeyed the culture spacing, 0.4 x 1.0 meters between plants and rows, respectively.

After the lysimeters reached their field capacity, the whole process of determining the water requirement of the crop began. A water slide of known volume was applied daily and 24 hours after this application, the volume of drained water was collected. This monitoring made it possible to obtain the necessary data to determine the ETc. During the period of conduction of the experiment, the data of daily precipitation were collected from a meteorological station, located 50 m from the place of the experiment. The pluviometry data are shown in Figure 1, beginning the collection after transplanting the seedlings.

For the management of irrigation it was necessary to use the pluviometry data and the application and water drainage data of the lysimetric sets, thus determining the ETc (Equation 1).

$$\mathrm{ETc} = \frac{(W_A - W_D + P)}{A} \tag{1}$$

Where: ETc = Crop evapotranspiration (mm); W_A = Water slide applied to the lysimeter (l); W_D = Slide of water drained from the lysimeter (l); P = Precipitation (mm); A = Lysimeter area (m^2).

2.3 IRRIGATION SYSTEM AND APPLICATION AUTOMATION

The irrigation method used was the localized, with the drip system, for this experimental test drip tapes with a flow rate of 2,1 l/h with a spacing between drippers of 0.20 m were used. For pumping water to the irrigation system, a peripheral motor pump of 0.5 cv was used. The water for irrigation came from a local supply unit, with an electrical conductivity of 0,14 $d\cdot Sm^{-1}$. The working pressure of the irrigation system used was 0.8 bar, this pressure was calculated based on the uniformity coefficient (UC).

The entire water slide application system was automated, requiring only a daily schedule. For this, it was necessary to use timers and solenoid valves, the valves functioned according to the programming of the timers. In the timers, the start time of the irrigation (9: 00H) and the end time were inserted, which varied according to the ETc. For the treatments that consisted of the fractionation of the irrigation blades, it was necessary to program the interval between applications, which was determined a period of one hour, thus, when the first fraction of the irrigation blade was applied, after one hour the second fraction of the irrigation blade started. The irrigation time was given through Equation 2.

$$\text{Irrigation time} = \frac{\text{ETc}}{A} \cdot (\text{Q} \cdot 2)^{-1} \qquad (2)$$

Where: Crop evapotranspiration (mm); A = Lysimeter area (m²); Q = Dripper flow (l/h).

Note that in Equation 2 the flow (Q) is multiplied by two, this is due to the relationship between the spacing of the plants and the drippers, thus making two drippers available per plant.

2.4 ANALYZED VARIABLES AND VALIDATION PARAMETERS

To validate the effect of the pulses on the drip irrigation system in the pepper culture, eight parameters were used as an evaluation criterion, among them four biometric components: fruit diameter (FD) (cm), fruit height (FH) (cm), fruit wall thickness (FWT) (mm), number of fruits per plant (NFP) (unit); two productive components: fruit weight to determine productivity (PP) ($t\cdot ha^{-1}$) and water use efficiency (WUE) ($kg\cdot ha^{-1}\cdot mm^{-1}$), for this it was necessary to use the productivity data and the water consumption of the crop. The remaining two parameters used the interactions between the variables FD*FH e EWT*NFP.

The harvest was carried out at 60 days after transplantation, considering all the fruits present in the plants useful for the analysis. The data obtained were subjected to analysis of variance and the average test by the Tukey method ($p < 0.05$), graphs of principal component analysis and dendrogram were generated by the software RStudio®.

3 RESULTS AND DISCUSSION

According to the analyzes carried out, it can be seen that the evaluation parameters showed significant results in relation to the irrigation pulses, validating the effect of the pulses on the yield of the pepper culture (Table 2), except for the parameters of interaction between the variables.

It is noted in Table 2 that the values of the variables fruit diameter, fruit height, thickness of the fruit wall showed lower values when subjected to a fractionation of the water blade in a maximum of 3 daily applications, providing greater yield in the irrigation pulses 4 and 5, which did not differ statistically. The productive increase that these variables obtained with the fractionation of irrigation in pulses 4 and 5, kept them with values of approximately 7.2 cm in diameter, 6.3 cm in height of the fruit and 5.2 mm in wall thickness.

Water availability is the main factor responsible for fruit growth, in the case of pulses 1, 2 and 3, what can be attributed is a poor availability of the water blade for plants, causing water deficit, which in turn directly affects the physiological processes of the crop, such as cell elongation, which promotes tissue expansion and fruit growth (Taiz *et al.* 2017).

Despite the positive effect of the pulses for the variables, interactions between diameter and height of the fruit were not found for any of the treatments evaluated, making it possible to state that the irrigation pulses are not an impacting factor for this relationship. The genetic composition of the fruit can be considered the main responsible for this interaction. Charlo *et al.* (2009) highlight that the diameter and height of the fruit is a factor related to the shape of the fruit, and that for square shaped fruits the ratio of the variables will be closer to 1, a result similar to that found in the present work using the hybrid Kolima which has a square shape (Table 2).

Rocha *et al.* (2018) analyzed the pepper production under different irrigation strategies with and without soil mulch, and observed that the fruit height did not show significant results for the treatments used, however, due to the productive cycles the height of the fruit was higher in the first cycle.

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There was a greater development in the thickness of the fruit wall in pulses 4 and 5, not differing for the other pulses analyzed, this means that a fractionation of the irrigation blade in 4 and 5 applications enabled greater efficiency in water absorption by plants, promoting greater physiological functionality.

The plants corresponding to the treatments of pulses 1, 2 and 3 at noon had already received their respective water slide in full, thus, the results may have been affected by a relationship between the time of application of the water slide and the temperature , since, at the hottest times of the day, the water available in the soil will be at the peak of evaporation, giving them less water available for absorption by the plants, possibly providing some level of water stress.

The thickness of the pepper wall is one of the main aspects that determines the choice of the fruit by the consumer, thicker walls provide greater resistance to the fruit, in addition to providing longer shelf life and greater mass yield (Charlo *et al.* 2009). In the case of fruits harvested in the first productive cycle, the greatest thickness of the fruit wall found was 5.2 mm, similar results were obtained by Frizzone *et al*. (2001), finding 5.4 mm in a yellow subgroup.

The highest number of fruits per plant was found in the plots that received treatment with pulse 4, plus a variable that corresponded increasingly to the effects of this treatment. The number of fruits per plant depends directly on the water flow in the soil, a good response of this factor corresponds to an efficient translocation of nutrients to the root zone, facilitating its absorption by the plants. A good flow of water in the soil can not only refer to the required amount of water applied, but also how this application was carried out and the impact it can have on the availability of water for plants.

Santana *et al.* (2004) evaluating the behavior of water stresses in the soil in the yield of some variables, including the number of fruits, highlighted calcium as possible responsible for the yield of this variable, also reporting that sufficient calcium application may not be the only parameter to be used considered, since this nutrient comes into contact with the roots by mass flow, that is, depending entirely on an adequate soil moisture.

Starting from a hypothesis in which the thickness of the fruit wall is influenced by the number of fruits per plant and, following the context that the more fruits per plant the greater the water and nutritional requirements, it is therefore necessary to, given the growing conditions , with regard to the availability of water and nutrients, this hypothesis can be accepted, however the irrigation pulses were not able to express a correlation between these variables, a possible relationship may occur with the variation in nutrient doses, which may alter the metabolism of plants and their development as a whole.

Pepper productivity showed better response to the effects of pulse 4, with a yield of approximately 18.3 $t{\cdot}ha^{-1}$, the other pulses did not differ statistically from each other (Table 2). Frizzone *et al*. (2001) when they analyzed the pepper yield in the first productive cycle, according to the irrigation level defined by the soil's water potential, they obtained a productivity of approximately 13 $t{\cdot}ha^{-1}$, a value similar to that found in the present work when the irrigation blade corresponded to the application by single pulse (14.53 $t{\cdot}ha^{-1}$), thus establishing the importance of fractioning the irrigation blade so that better use of water by plants occurs.

Pepper productivity was obtained from the total weight of fruits per treatment and the number of fruits per plant. By making a relationship with crop spacing, it was possible to estimate this yield per hectare. Considering that all variables interfere in productivity and that the best treatment for all variables, in general, was pulse 4, we have that the highest productivity is obtained in a fractionation of the irrigation blade in 4 applications.

For the efficiency of water use, pulse 4 also behaved as the best treatment, obtaining a value of approximately 60.3 $kg{\cdot}ha^{-1}{\cdot}mm^{-1}$, thus characterizing that the best form of water availability for the pepper culture occurs when there is a correct fractionation of the applied water blade. Considering that water is the limiting factor for the production of peppers, this variable is the key point to characterize the yield of peppers for each millimeter of water supplied to the crop.

It can be seen with the results that the amount of water applied was not the factor that defined the highest productivity, therefore, the factor that presented the best result regarding the mentioned statement was the way in which the water was made available, that is, in the fractionation of water irrigation in four daily applications.

Abdelraouf *et al.* (2012) observed a greater efficiency in the application of the irrigation blade through the pulsed drip system with 4 pulses, it was noted that when restoring 100% da ETc, of the ETc, the irrigation pulses promoted a water application efficiency of 94%, while for continuous irrigation efficiency was 89%.

The drip by pulses provided a higher level of humidity and better uniformity of the moisture distribution pattern, with a significant increase in the efficiency of water use, corresponding to 13.55%, through the use of drip pulses in the corn crop (Zin El-Abedin 2006).

With a greater volume of wet soil in the root zone, there was a greater volume of water stored in the root zone (Abdelraouf *et al*. 2012).

A lower performance of pulse 5 may be conditioned by the constant evaporative rate of water in the soil in detriment to the low volume of water applied, which favors the loss of water in the soil through vaporization, making it difficult to infiltrate a satisfactory hydraulic load to the root region of the pepper culture.

Pulses 1, 2 and 3 showed the lowest yield for the analyzed variables, in general. The high volume of water applied in these treatments promoted a possible percolation of the applied water layer, causing water deficit due to the inefficient availability of water for the plant throughout the day.

The performance of each irrigation pulse can be observed in a list of main components, a clear difference in the positioning of the points in relation to each analyzed variable is observed (Figure 2). Pulses 1, 2 and 3 show low yield behavior, both had midpoints opposite the growth levels for the variables, and are not associated with any elements, this fact means that the values obtained from the variables collected and analyzed in the pulses of irrigation are not significantly representing yield as pulses 4 and 5.

It can still be considered a caveat for pulse 1, where it presented a relevant increase for WUE, presenting a point of this treatment in the follow-up of growth close to the line of the mentioned variable. This fact can be explained by the productivity obtained due to the low water consumption, despite the amount of water applied being the same, part of it was lost through percolation, characterizing less consumption. Figure 1 shows the similar behavior of ETc in the irrigation pulses.

Pulse 5 obtained an average representation of the points in favor of growth levels for the variables FD, FH and FWT, variables that showed significance for that pulse together with pulse 4. Pulse 4 was associated with all the variables analyzed, observed this treatment follows the mutual growth axis for both variables, characterizing its high yield ratio.

It is still possible to analyze the degree of similarity between the variables and treatments (Figure 2). The closer to 1.5 on the Z-Score scale, greater the positive effect of the pulses on the variables, on the other hand, the closer to -1.5 the lower this effect, the similarity scale is performed based on the standardization of the variable values. Thus, in pulse 4, the best results were presented for all variables, noting that for variables FWT, FD and FH, pulse 5 stands out with high similarity with pulse 4, which implies a significant similarity results obtained.

Analyzing the degree of similarity between pulses 1, 2 and 3, a similar behavior is observed for the variables, not differing statistically, as shown in Table 2.

4 CONCLUSION

This experiment demonstrated that irrigation fractionation in 4 applications had a higher productivity and water use efficiency when producing 18.26 $t{\cdot}ha^{-1}$ and 60.26 $kg{\cdot}ha^{-1}{\cdot}mm^{-1}$, respectively, in comparison to the other pulses evaluated for the pepper culture.

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TABLE 1 - Physico-chemical attributes of soil analysis in the experimental area and fertilization recommendation for the pepper culture according to the manual of the 5th approach to Minas Gerais.

Physical Characteristics					
Coarse Sand	Thin Sand	Total Sand	Silte	Clay	Textural Class
g·kg⁻¹					
296	303	599	217	184	*Sandy Franco*

Chemical Characteristics											
pH (H_2O)	M.O.	PST	V	Na	P	K	Ca	Mg	Al	H+Al	CTC $_{(pH\ 7)}$
	%			*mg·dm⁻³*			*Cmolc·dm⁻³*				
6.20	2.30	1.60	59.70	17	17	96	1.50	1.00	0.00	1.90	4.72

Fertilization Recommendation			
	Nitrogen Source (Urea)	Phosphorus source (Triple Superphosphate)	Potassium source (KCl)
		g·plant⁻¹	
Planting	2.67	4.88	1.10
1° Roof	1.33	—	1.33
2° Roof	1.33	—	1.33
3° Roof	1.99	—	1.99
4° Roof	1.99	—	1.99
5° Roof	2.67	—	2.67
6° Roof	1.33	—	1.33

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TABLE 2 - Synthesis of the values of the analysis of variance and average test by the Tukey method for each analyzed variable.

FACTOR	DF	MS							
		FD	FH	FD*FH	FWT	NFP	FWT*NFP	PP	WUE
Pulses	4	0.268361 ***	0.0895 ***	0.0024 NS	0.37435 ***	2.45638 ***	0.0274 NS	27.6371 ***	196.13 ***
Block	6	0.01304 NS	0.0207 *	0.0026 NS	0.01087 NS	0.53398 NS	0.0303 NS	4.9463 NS	56.349 NS
Residuals	24	0.014966	0.0077	0.0013	0.01626	0.21617	0.0099	2.4171	27.609
C.V. (%)		1.76	1.42	3.20	2.57	7.65	8.19	10.29	10.19
Pulse 1		6.887 b	6.143 b	1.1 NS	4.849 b	6.043 b	1.2 NS	14.530 b	51.481 b
Pulse 2		6.693 c	6.104 b	1.1 NS	4.764 b	5.700 b	1.2 NS	13.841 b	48.968 b
Pulse 3		6.873 bc	6.132 b	1.1 NS	4.745 b	5.464 b	1.2 NS	13.219 b	46.133 b
Pulse 4		7.138 a	6.379 a	1.1 NS	5.205 a	7.014 a	1.3 NS	18.266 a	60.259 a
Pulse 5		7.156 a	6.242 ab	1.1 NS	5.199 a	6.157 b	1.2 NS	15.667 b	51.085 b

NS: not significant ($p > 0.05$); *: significant ($p < 0.05$); ***: significant ($p < 0.001$); C.V.: coefficient of variation.

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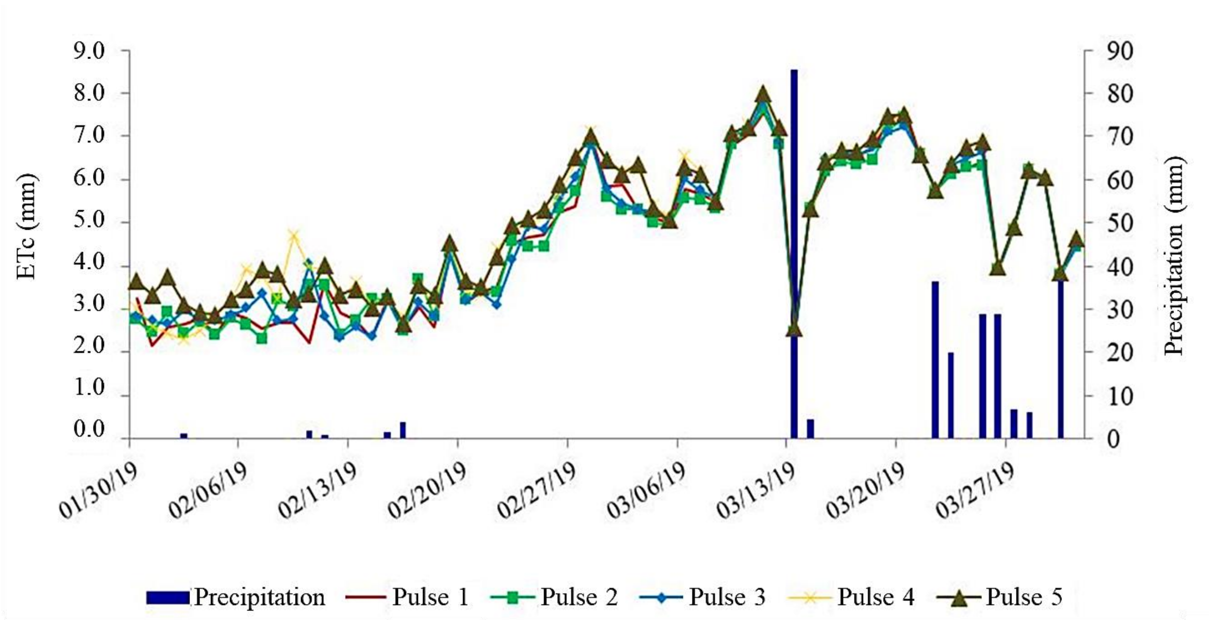
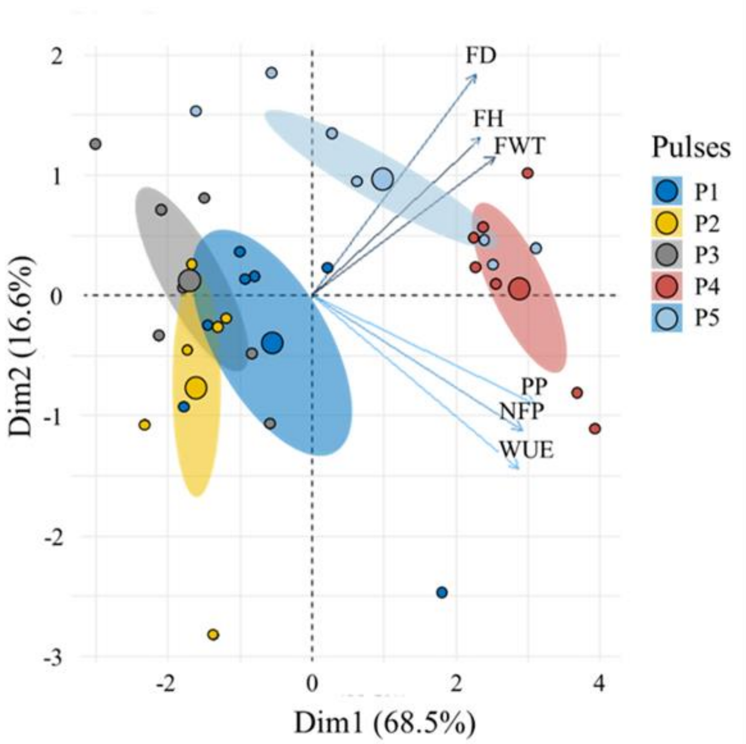
FIGURE 1 - Precipitation and evapotranspiration rate of the crop during the period of conducting the experiment with the pepper culture in the experimental area, Arapiraca - AL.



Author (2020).

FIGURE 2 - Principal component analysis for variables significant to the effects of irrigation pulses.



Author (2020).

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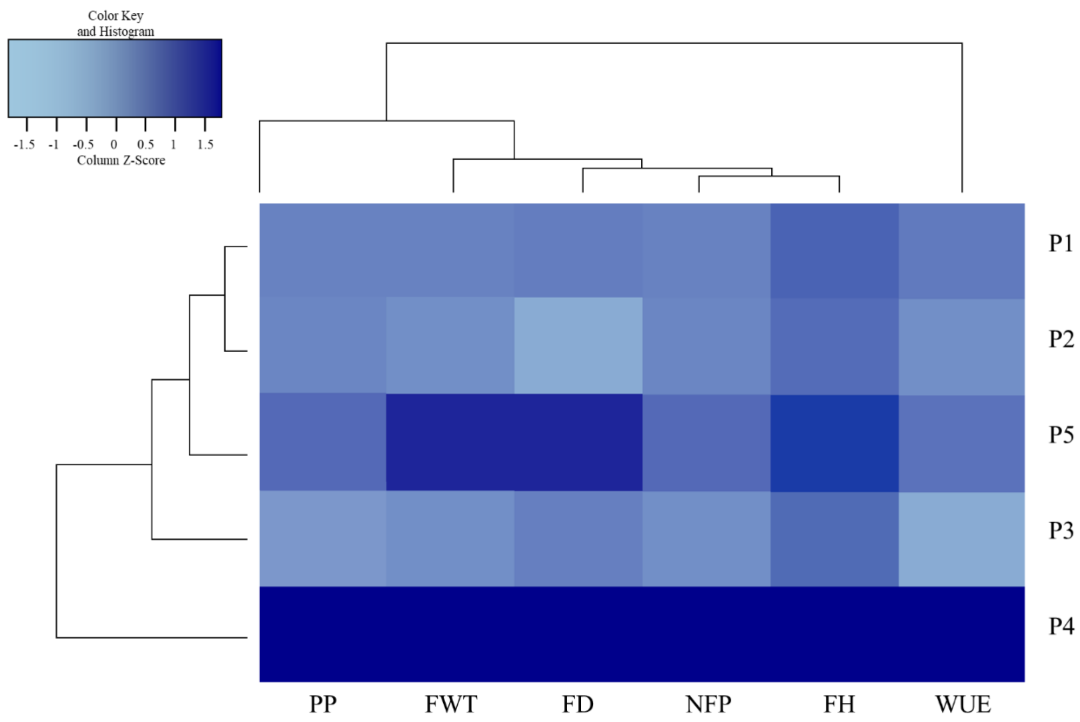
FIGURE 3 - Dendrogram similarity graph between significant variables and irrigation pulses.



Author (2020).