

WATER ECONOMIC USE IN DRIP-IRRIGATED MAIZE IN THE REGION OF SERTÃO ALAGOANO

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SUMMARY: The objective of this work was to determine the economic drip irrigation depth for maize in the region of Sertão Alagoano, aiming at a sustainable and economically viable production. For this, the hybrid AG7088 was submitted to five irrigation depths (40, 80, 120, 160 and 200% of ET_c) in an experiment developed at the Federal Institute of Alagoas/Campus Piranhas, with a randomized block design and four replications. Harvesting was carried out 98 days after planting, where grain yield with 12% moisture reached 2.1 and 11.8 Mg ha⁻¹ and water use efficiency of 181.8 and 55.3 mm Mg⁻¹ in treatments with 40 and 160% of ET_c, respectively. The maximum physical productivity estimated by the production function was 11.3 Mg ha⁻¹, obtained with 919 mm of irrigation water. The maximum economic yield was 11.1 Mg ha⁻¹, obtained with depth of 841 mm (160% ET_c).

KEYWORDS: Grain yield, drip irrigation, cost of water for irrigation.

USO ECONÔMICO DA ÁGUA NO CULTIVO DO MILHO IRRIGADO POR GOTEJAMENTO NA REGIÃO DO SERTÃO ALAGOANO

RESUMO: O presente trabalho teve por objetivo determinar a lâmina econômica de irrigação por gotejamento para a cultura do milho na região do Sertão Alagoano, visando uma produção sustentável e economicamente viável. Para isso, o híbrido AG7088 foi submetido a cinco lâminas de irrigação (40, 80, 120, 160 e 200% da ET_c) em experimento desenvolvido no Instituto Federal de Alagoas/Campus Piranhas, com delineamento em blocos casualizados e quatro repetições. A colheita foi realizada aos 98 dias após o plantio, em que a produtividade de grãos com 12% de umidade atingiu 2,1 e 11,8 Mg ha⁻¹ e eficiência no uso da água de 181,8

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e 55,3 mm Mg⁻¹ nos tratamentos com 40 e 160% da ETc, respectivamente. A produtividade máxima física estimada pela função de produção foi de 11,3 Mg ha⁻¹, obtida com 919 mm de água de irrigação. A produtividade máxima econômica foi 11,1 Mg ha⁻¹, obtida com lâmina de 841 mm (160% da ETc).

PALAVRAS-CHAVE: Produtividade de grãos, gotejamento, custo da água para irrigação.

INTRODUCTION

Maize is one of the most consumed cereals in the Northeast region of Brazil, both as an industrialized product and *in natura*, due to its use in food and feed, as well as exercises an important socioeconomic role for the region. According to the National Supply Company - CONAB (2015), the Northeastern States that produced the most maize in the 2015/16 harvest were: Bahia (1.4 million t and 2.3 t ha⁻¹), Maranhão (874 thousand t and 2.4 t ha⁻¹) and Piauí (739 thousand t and 1.5 t ha⁻¹). Alagoas occupies the eighth place, with annual production of 19 thousand tons and average yield of approximately 0.6 t ha⁻¹. This low agricultural yield compared to the other NE States occurs mainly due to the irregular distribution of rainfall.

The maize crop in this region predominates in the rainy season, which occurs from April to August, but in some years occurs periods without rain in the rainy season and the crop is subject to water deficit (Carvalho et al., 2013). Because it is the vehicle of conduction of the nutrients to the root-soil interface and in the xylem, water may interfere with plant physiology, absorption dynamics and nutrient utilization (Ferreira et al., 2008). According to Brito et al. (2013), the occurrence of water deficit during the feeding and the filling of the grains causes losses in the agricultural productivity, because in this phase occurs the synthesis of components of the yield. Thus, the maize water requirement, which is 200 to 400 mm during the production cycle (Bergamaschi et al., 2006), when not fully supplied by rainfall, should be complemented by irrigation.

Irrigation, in this sense, besides supplying this deficiency, may favor the cultivation of other crops during the dry season. However, improper use of water resources in irrigated agriculture, due to the search for higher yields have contributed to the high waste of water, resulting in undesirable consequences for the environment (Bizari et al., 2011). Thus, to use it economically in irrigation projects, it is necessary to know the water consumption by the crop and its response in productivity, the atmospheric demand and the physical-water characteristics of the soil to determine the economic irrigation depth. In addition, it is convenient to make use

of localized irrigation systems, which present better efficiency and uniformity of water application, low energy consumption and keep soil moisture always close to field capacity (Boas et al., 2011). The objective of this work was to determine the drip irrigation depth with the greatest economic efficiency for the maize crop in the Sertão Alagoano region, in order to define the appropriate management and the adoption of sustainable practices with the water use efficient for this culture.

MATERIAL AND METHODS

The experiment was conducted at the Federal Institute of Alagoas/Campus Piranhas, Brazil, during the months of December 2016 to March 2017 in an area of 368 m². The climatic classification of the region, according to Köppen, is of the Bssh type, very hot climate, semi-arid, steppe-type, with a rainy season centered in the months of April, May and June. The average annual rainfall of the region is 483 mm (Souza et al., 2010). The soil of the area is classified as Salic-Sodic Orthic Chromic Luvisol of clay texture (Fernandes et al., 2010). Agroceres AG7088 hybrid was used, with a population of 62,500 plants per hectare, in a randomized block design with four replications. The treatments were five irrigation depths (40, 80, 120, 160 and 200% of ET_c).

The fertilization occurred as a function of an expected yield of 10 t ha⁻¹, (Coelho, 2006), being part in foundation and nitrogen fertilization in cover at 15 days after planting (DAP). The irrigation was done via a drip system with a flow rate of 7.5 L h⁻¹ m⁻¹, nominal pressure of 10 mca and spacing between drippers of 20 cm. In the first 20 DAP all treatments were irrigated with the same depth to meet the germination. From this period, the irrigation depths were differentiated according to the treatments, in which the meteorological data for this estimation were obtained in an automatic data acquisition station belonging to the IFAL/Piranhas and located near the experimental area. The reference evapotranspiration (ET_o) was calculated by the Penman Monteith method (Allen et al., 1998) to make water balance in the soil (with root depth varying from 0.10 to 0.40 m) and to estimate evapotranspiration of culture (ET_c).

At the time of harvesting at the physiological maturation stage, the grains were placed in a drying oven until moisture reached about 12% and the maize yield was determined by the average grain weight. Through grain yield data and ET_c, the water use efficiency (WUE) by the crop in the form of consumption, in mm per Megagrama, was determined based on the methodology cited by Dantas Júnior & Chaves (2014).

The production function of the crop to estimate the maximum physical and economic productivity was obtained according to the methodology developed by Frizzone (1993). For the economic analysis of production, the millimeter price of applied water was calculated based on the costs of farmers who use drip irrigation systems and have these costs monitored (Table 1). The selling prices of maize bag (60 kg) used for the calculation of remuneration were three equidistant values (R\$ 30.00, R\$ 45.00 and R\$ 60.00) due to the variation of the quotation during the harvests, to be used as comparatives in administrative decision making.

Tabela 1. Cost of the water millimeter for drip irrigation in the maize crop.

Descrição	R\$ ha ⁻¹ ciclo ⁻¹	R\$ mm ⁻¹	%
Hydraulic Infrastructure / Buildings (amortized in 20 years – 60 harvests)	46,67	0,12	8,3
Irrigation system (amortized in 10 years – 30 harvests)	166,67	0,42	29,6
Annual operating cost of irrigation	350,00	0,88	62,1
Total cost of irrigation per production cycle	563,33	1,41	100,0
Operation of the irrigation system during 3 production cycles per year			
Average depth irrigation per cycle: 400 mm			

RESULTS AND DISCUSSION

Rainfall during the maize production cycle (2016/12/23 to 2017/03/30 - 98 days) totaled 42.2 mm, and 61% (25.8 mm) of this rainfall occurred only in one day (2017/02/21), characterizing irregular distribution of rainfall during the cultivation period (Figure 1). However, this time of the year does not correspond to the region's rainy season.

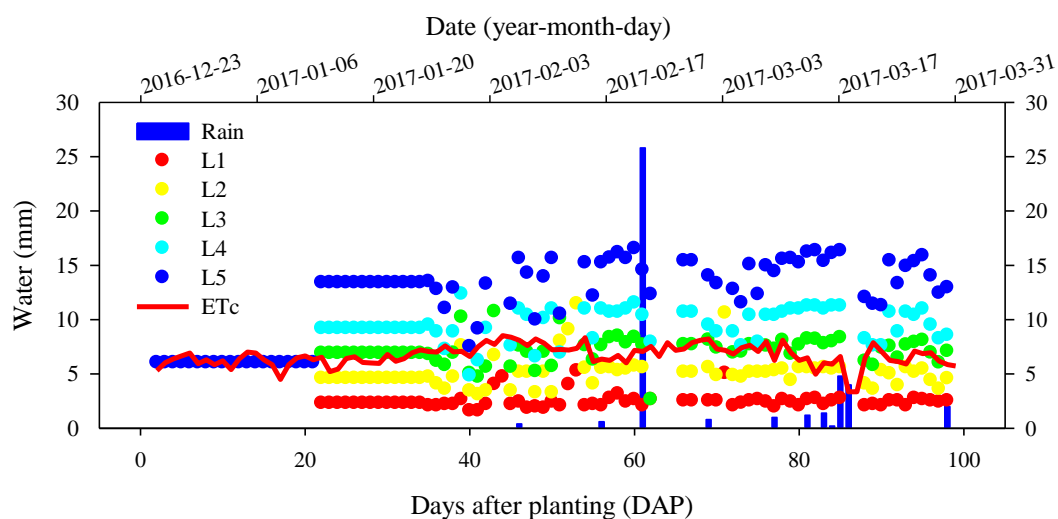


Figure 1. Daily values of rainfall, crop evapotranspiration (ETc) and irrigation depths of the treatments (L1, L2, L3, L4 and L5) during the maize crop cycle, from December 2016 to March 2017 in the region of Piranhas -AL.

Total crop evapotranspiration (ET_c) in the crop cycle was 654 mm, with a minimum of 3.4 mm day⁻¹ (17 and 18 March 2017), maximum 8.5 mm day⁻¹ (February 3, 2017) and a mean of 6.7 mm day⁻¹ (Figure 1). Lower values of ET_c are observed in the period when there is rainfall, when there is high cloudiness and a decrease in the intensity of the solar radiation, the warming of the atmosphere and, consequently, the atmospheric demand.

Irrigation was applied throughout the whole first crop development phase (December 2016) due to the lack of rain during this period to supply the water demand of the plants (Figure 1), in which was applied a depth of 6 mm per day to meet ET_c. The differentiated irrigation depths were applied in the period between the end of the initial phase and the beginning of the crop growth phase (21 DAP), in which from the 34 DAP there was variation of pressure in the catchment system and caused variability in the calculated depths for treatments. The average daily values of the applied depths were 3, 6, 9, 12 and 14.3 mm in L1, L2, L3, L4 and L5, respectively. In this geographic region it is necessary to be aware, because when using the drip system, lateral infiltration of the water with water saturation can occur, since the soils are shallow and there is impediment of drainage by the rock formation.

During the entire initial phase of the crop (0-20 DAP), all treatments had soil water storage equal to the total available soil water (TAW = 20 mm), due to irrigation during this period (Figure 2). From the growth phase the L1 and L2 storage was below the limit of the readily available water (AFD) in most of the days due to the fact of the subirrigation, especially when the crop was in maximum growth, where the water deficit was great intensity. In the treatments L3, L4 and L5 the storage remained close to the TAW throughout the production cycle, since they were irrigated with depths larger than the ET_c. There were some reductions in storage from these treatments due to pressure problems in the system, but not enough to compromise the culture.

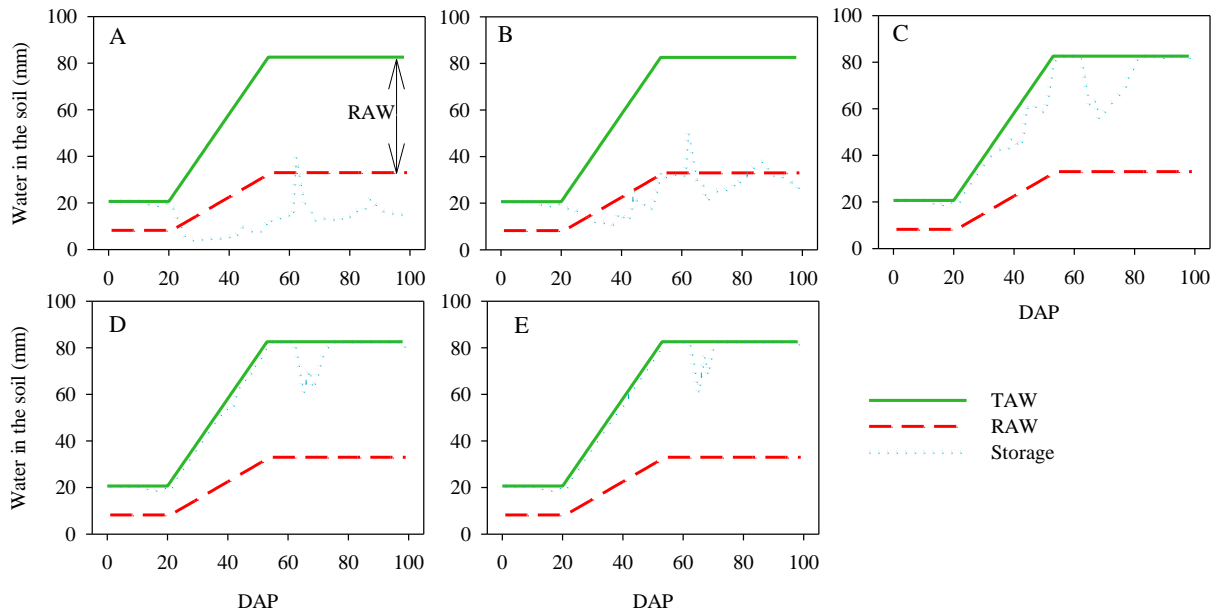


Figure 2. Daily values of the total available soil water in the root zone (TAW), the limit of the readily available water (RAW) and storage of water in the soil (Storage) for treatments with different irrigation depths (A-L1, B-L2, C-L3, D-L4 and E-L5) during the maize crop cycle, from December 2016 to March 2017 in the Piranhas-AL.

Differentiated total irrigation depths ranged from 206 to 1,056 mm and, except for the L1 treatment, all the others exceeded the established ETc percentage (Table 2). Total ETc during the application period of the differentiated depths was 525 mm.

Table 2. Total irrigation values, ETc percentage reached by depths and total crop evapotranspiration (ETc) for treatments with different irrigation depths in maize crop, from December 2016 to March 2017, in the Piranhas-AL.

Treatments	Irrigation Depth (mm)	% of reached ETc	ETc (mm)
L1 (40% ETc)	206	39%	525
L2 (80% ETc)	428	82%	
L3 (120% ETc)	634	121%	
L4 (160% ETc)	849	162%	
L5 (200% ETc)	1.056	201%	

The L4 treatment produced almost five times more than L1, where maize yield as a function of total irrigation depth ranged from 2.1 to 11.8 Mg ha⁻¹ in L1 and L4, respectively (Figure 3). The L5 treatment had lower yield than L4 and this behavior is in accordance with the law of diminishing returns, which corresponds to the analysis of response by the agronomic principle known as “law of the minimum” developed by Carl Sprengel in 1828 and later popularized by von Liebig in 1840. This law says that “the yield of any crop is governed by any change in the quantity and quality of the scarce factor, called the minimum factor. And, to the

extent that the minimum factor is increased, yield also increases in proportion to the supply of that factor until another factor becomes minimal”. In the case of over-supply of the factor, the crop tends to reduce yield by reaching its stress zone by excess.

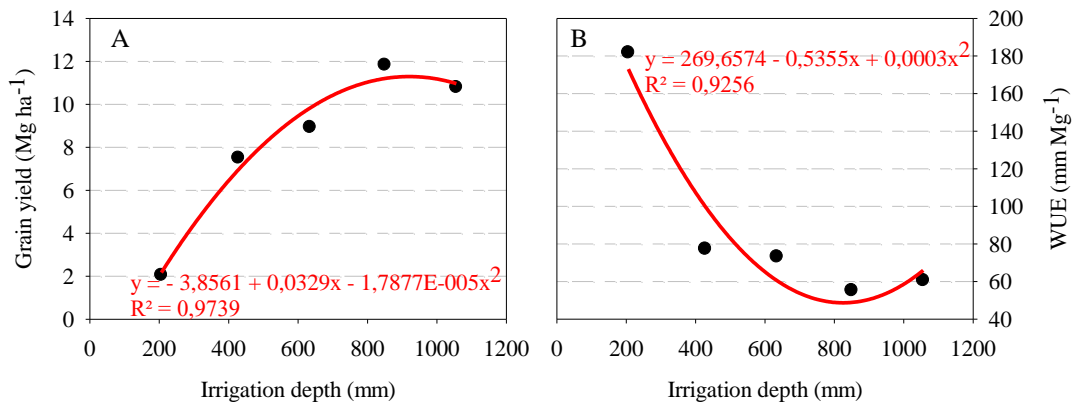


Figure 3. Agricultural productivity (A) and water use efficiency (B) of maize as a function of irrigation depths during cultivation, from December 2016 to March 2017, in Piranhas-AL.

The water use efficiency in the form of consumption decreased from 181.8 to 55.3 mm Mg⁻¹ in the treatments with 40 and 160% of ET_c, respectively, indicating that when irrigation approaches the conditions of crops without water deficiencies a WUE is lower and corroborates with the conclusions of Frizzone (1993). Dantas Júnior & Chaves (2014) cultivated green maize irrigated with depths between 25 and 150% of ET_{pc} and also found that the WUE decreased with the increase of the amount of water applied through irrigation.

The production function presented significant adjustment, in which the coefficient of determination of the equation (R^2) was 97%, since in the observed values there was a maximum point followed by a decrease. According to Silva et al. (2015), the second-degree polynomial is one of the most used mathematical equations as a production function. However, production functions should, in general, be used at convenient intervals, that is, without exceeding economically reasonable input levels.

The maximum physical productivity of the crop, estimated by the production function, was 11.3 Mg ha⁻¹ (Table 3), obtained with a total irrigation depth of 919 mm (175% of ET_c). For productivity above this value, that is, with the crop under optimum soil moisture conditions, other agricultural practices, such as fertilization, pest and disease control, and others must be used. It is observed that there was no significant change in economic productivity as a function of the sale price of maize. In this case, the lowest value of the economical depth (841 mm, 160% of ET_c) is chosen to avoid water waste and higher operating costs. However, the producer must pay attention to the fact that the economic depth depends on the price relation of water (P_x) and

grain (Py) and not on prices properly, that is, when the mm becomes more expensive in relation to kg of grain maize, the economic depth decreases, and vice versa.

Table 3. Depth values and economic productivity for different selling prices of maize grown with irrigation between December 2016 and March 2017, in the region of Piranhas-AL.

Price of bag (R\$)	Economic depth irrigation (mm)	Economic crop yield (Mg ha ⁻¹)
30,00	841	11,16
45,00	867	11,22
60,00	880	11,25
Maximum depth (mm)		Maximum yield (Mg ha⁻¹)
919,0		11,30

The calculation of input costs in agriculture for maximum economic return involves several factors that can not always be controlled, especially when it comes to environmental factors. Therefore, works like this serve to be taken as basis in administrative decisions, provided that the conditions are similar to those of the place where the research was carried out. In addition, economic issues such as input prices and agricultural *commodities* are subject to change on a daily basis, being left to the discretion of the administrator to seek the best solution and to choose the most viable alternative for the use of certain inputs.

CONCLUSIONS

The economic depth of drip irrigation for maize in the Piranhas-AL region with cultivars of genetic potential similar to the one used in this experiment is located around 160% of the ETC, where it is possible to obtain grain yields above 11 Mg ha⁻¹.

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