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DESEMPENHO PRODUTIVO E RETORNO ECONÔMICO DO MILHO IRRIGADO POR ASPERSÃO

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1 RESUMO

A cultura do milho está entre os cereais mais produzidos mundialmente, sendo fundamental na alimentação humana e animal, adaptando-se a diferentes regiões. O uso da tecnologia da irrigação para seu cultivo vem crescendo gradualmente, oferecendo garantia de oferta hídrica para períodos de estiagem e propiciando o cultivo de mais de uma safra anual. Objetivou-se no presente estudo avaliar a produtividade e a lâmina ótima econômica que representa a máxima eficiência econômica da cultura do milho. O experimento foi realizado em área experimental do Instituto Federal Farroupilha - Campus Alegrete, RS, no período de janeiro a junho de 2020. Utilizou-se um delineamento inteiramente casualizado, composto por cinco tratamentos (0, 50, 75, 100 e 125% da ETc) com três repetições. Os resultados obtidos mostraram que tanto o déficit hídrico quanto o excesso de água afetaram diretamente a produção final. A máxima produção de grãos obtida foi de 12.619,66 kg ha^{-1} na lâmina de reposição de 100% da ETc. A lâmina de máxima eficiência econômica foi estimada como sendo cerca de 50% da ETc, sendo lâminas de reposição hídrica acima deste valor não recomendadas para a região de Alegrete, RS.

Palavras-chave: *Zea mays* L., rendimento, lâmina ótima, *sistemas irrigados*.

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PRODUCTIVE PERFORMANCE AND ECONOMIC RETURN OF CORN CROP IRRIGATED BY SPRINKLER SYSTEM

2 ABSTRACT

The corn crop is among the most produced cereals worldwide, being fundamental in human and animal nutrition, adapting to different regions. The use of irrigation technology for cultivation has been growing gradually, offering guaranteed water supply for periods of drought and allowing the cultivation of more than one annual haverst. This study evaluated the productivity

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and optimal economic water depth representing the maximum economic efficiency of the corn crop. The experiment was carried out in an experimental area at the Federal Farroupilha Institute - Campus Alegrete, RS, from January to June 2020. A completely randomized design was used, composed of five treatments (0, 50, 75, 100 and 125% of the ETc) with three replications. The results obtained showed that both the water deficit and the excess of water directly affected the final production. The maximum grain yield obtained was 12,619.66 kg ha^{-1} in the water depth replacement of 100% the ETc. The water depth of maximum economic efficiency was estimated to be about 50% of the ETc, with water depths replacements above this value not recommended for the region of Alegrete, RS.

Keywords: *Zea mays* L., yield, optimal water depths, irrigated systems.

3 INTRODUCTION

Corn is among the most produced cereals worldwide due to its high nutritional value and widespread consumption; it is consumed for both human and animal consumption, in addition to its significant socioeconomic importance, and is cultivated in diverse climate and management conditions.

In Brazil, it is cultivated in rotation, succession and intercropping, owing to the wide plasticity and adaptability of the cultivars available on the market (CONTINI et al., 2019). In the state of Rio Grande do Sul, there is a large annual variation in corn productivity, which is attributed mainly to climatic conditions, causing a reduction in the cultivated area over the last few years, although there is evidence of an evolution in grain production (ROSA; EMYGDIO; BISPO, 2017).

Among the climatic factors that most contribute to crop failure in the state is rainfall. The state has a satisfactory total annual precipitation volume for the production of major grain crops, but it is unevenly distributed. This is demonstrated in the work of Silva et al. (2015), who studied 97 years of data from meteorological stations in the state and reported that it is impossible to determine which months of the year correspond to the dry and rainy seasons, with average precipitation levels of 136.51 mm in winter, 154.17 mm in spring, 126.95 mm in summer, and 125.88 mm in autumn.

Bergamaschi et al. (2004) conducted experiments with irrigated corn in Eldorado do Sul, RS, in the 1998/99 and 2002/03 harvests, comparing the variation between the average productivity of the state and the experiments analyzed, highlighting the importance of variability in the summer rainfall distribution in Rio Grande do Sul for spring–summer crops.

Bergamaschi et al. (2006) analyzed data from the ten-year period from 1993--2003 from field experiments in the municipality of Eldora do Sul, RS. The author demonstrated that, on average, over the ten years, the average rainfall was 497 mm, and the average reference evapotranspiration was 522 mm. Compared with nonirrigated crops, supplemental irrigation favored a 70% increase in corn grain yield. The authors reported that, on average, under such conditions, the farmer assumed the risk of losing two out of every five crops when growing corn without irrigation.

The increase in corn grain production in Rio Grande do Sul with increasing irrigation depth has been addressed by several authors. Ben et al. (2015), in an experiment in the municipality of Alegrete, RS, reported the highest grain productivity of 15,250 kg ha^{-1} in the irrigated treatment, with a replacement depth corresponding to 100% of the ETc, and the lowest productivity of 5,170 kg $^{ha -1}$ was found in the rainfed treatment. Parizi (2010) reported that the use of supplemental irrigation in corn increased grain production by 95.4%, with a water replacement depth of 100% of the ETc, resulting in 12,840 kg ha $^{-1}$ in the region of Santiago, RS.

Corn requires a significant volume of water to reach its productive potential, making it one of the most water-efficient crops and producing a large amount of dry matter per unit of water absorbed. Notably, corn requires 400--600 mm of rainfall throughout the crop cycle (FANCELLI, 2015).

According to Payero et al. (2009), crop performance under irrigation is relatively stable, making it easy to estimate crop yield under rainfed and irrigated systems. However, under deficit irrigation, productivity can vary considerably depending on the irrigation management used.

If the irrigating farmer aims to maximize productivity, irrigation management implies providing the necessary irrigation to fully meet the crops' water needs. However, if the goal is to maximize water use efficiency, it is recommended to adopt controlled deficit irrigation management—that is, deliberately irrigating below the maximum production level, which corresponds to the crop's maximum economic efficiency (PEREIRA; OWEIS; ZAIRI, 2002).

In irrigation systems, it is important to outline management strategies that provide uniform and efficient application of water to ensure correct and economical use, as well as reduce electricity costs through the pumping system, increasing profitability (Mendoza, 2012).

In corn cultivation, sprinkler irrigation systems are generally used, in which, according to Conceição (2016), average water cost values are taken into account, within a range of 0.30 to 1.50 \$ mm $^{-1}$ ha $^{-1}$, considering a variation in relation to the times when the systems are activated, as well as the different locations in the territory.

Calculating profitability allows us to understand that the largest volume of water used in irrigation does not always guarantee the greatest economic return, as it depends on other factors, such as the influence of the amount of water on crop productivity. In other words, it is also important to know how to manage water in such a way that there is a balance to meet the plant's water needs, in line with precipitation, to obtain better economic results and net income (CUNHA et al., 2013).

Currently known as water productivity, this represents a more comprehensive way of evaluating irrigation use, not limited to system management aspects but also considering issues related to the economic return of irrigation, environmental preservation, and rational water use. In terms of production, irrigation water productivity can be assessed by the relationship between the increase in production in weight and the volume of water consumed (TAVARES, 2007).

Irrigating to maximize profit is a substantially more complex and challenging problem than irrigating to maximize physical yield. That is, from an economic perspective, optimal irrigation involves applying lower water depths than does full irrigation, even if there is a consequent reduction in productivity but a significant economic advantage (FIGUEIREDO et al., 2008).

As a result of economic pressures on farmers, such as competition for water use and the control of environmental impacts related to irrigation practices, changes in irrigation practices are observed, motivated by a focus on economic efficiency rather than on crop water demand (FRIZZONE, 2007).

In this sense, studies focused on the economic analysis of irrigated systems are necessary, especially because of the large differences in water level and/or long distances between the catchment and the irrigated area, the use of emitters with high operating pressure, which significantly affects energy costs, or the use of irrigation systems with high implementation costs per unit area. Similarly, analyses of water use efficiency (productivity per unit of applied water depth) should also receive special attention where there is limited water availability for irrigation or in regions where conflicts arise due to multiple water uses (BERNARDO et al., 2019).

Given the above, the objective of this work was to evaluate the influence of different irrigation depths on the productivity of corn crops, aiming to obtain the optimal irrigation depth for maximum economic efficiency of the crop in the region of Alegre, RS.

4 MATERIALS AND METHODS

The experiment was carried out in the field in the experimental area of the Instituto Federal Farroupilha - Campus Alegrete- RS, which is located at the geographic coordinates latitude 29°42'54.50"S and longitude 55°31'23.67"W. The soil comes from a sandy dystrophic Red Argisol (STRECK et al., 2008).

The work was developed in 2019/20, covering the period from January 2020 to June 2020. The data values related to climatological conditions (daily maximum and minimum values of temperature and relative humidity) were obtained with the help of the digital platform of the National Institute of Meteorology (INMET), corresponding to the region of Alegrete, RS.

Sowing occurred in the second week of January 2020 under a no-tillage system. The seeding density consisted of four seeds per linear meter, aiming for a final population of 70,000 plants ha^{-1}. A mechanical seeder-fertilizer was used with 0.45 m row spacing.

Fertilizer application was carried out simultaneously with sowing. Three hundred $kg.ha^{-1}$ of fertilizer with the 24-84-91 formulation was applied. At 15 and 35 days after plant emergence, urea (45% nitrogen) was applied at 400 $kg.ha^{-1}$, corresponding to the V3 and V8 stages, respectively.

When necessary, agricultural pesticides (fungicides, herbicides and insecticides) were applied comprehensively and homogeneously throughout the experimental area.

The experiment consisted of a completely randomized design composed of five irrigation treatments, T1 (0% ETc replacement), T2 (50% ETc replacement), T3 (75% ETc replacement), T4 (100% ETc replacement) and T5 (125% ETc replacement), and three replicates. Table 1 shows the distribution of treatments.

Table 1. Illustrations of the different irrigation treatments to which the corn crop was subjected.

Treatment	Crop systems	Irrigation management (% Etc)
T1	Dryland	0% of ETc
T2	Irrigated	50% of ETc
T3	Irrigated	75% of ETc
T4	Irrigated	100% of ETc
T5	Irrigated	125% of ETc

* ETc - crop evapotranspiration.

Owing to the local climatic conditions, the irrigation management adopted consisted of a fixed irrigation shift of three days between irrigations, that is, when the effective precipitation did not meet the demand of crop evapotranspiration. The water depths were applied according to the ETc determination, as per Equation 1 (DOORENBOS; PRUITT, 1977).

$$Etc = Eto.kc \quad (1)$$

where:
ETc - crop evapotranspiration, mm;
ETo - reference evapotranspiration, mm; and,
Kc - crop coefficient (initial – 0.4, intermediate – 1.2 and final – 0.6)

The reference evapotranspiration was estimated via the indirect method of Benevides and Lopez (1970) according to the availability of meteorological data within the protected environment, as per Equation 2.

$$ETo = 0{,}67.10\,.\left(\frac{7{,}5.T}{T+273{,}5}\right).(1 - 0{,}01.UR) + 0{,}12\,.T - 0{,}38 \quad (2)$$

where:
ETo = reference evapotranspiration, mm;
T= average temperature, °C;
RH= relative humidity, %;

A conventional sprinkler irrigation system was used for irrigation. Sprinklers were connected to secondary lines at 12-meter spacing and 2.0-meter heights above the ground.

To determine the different irrigation depths applied per hour, the system was calibrated via the Christiansen uniformity coefficient (CUC) test.

When the plants reached senescence and a moisture content suitable for harvest, five plants were collected from each replicate and then dried for 14 days under ambient conditions. The total dry matter (TSM) content was subsequently calculated. The yield components evaluated were ear diameter (mm) $^{-1}$, number of rows per ear $^{-1}$, number of grains per ear $^{-1,}$ and average grain weight $^{-1}$ (g), which were obtained by counting five plants per replicate in each treatment.

The estimated productivity in kg.ha $^{-1}$ for each treatment was obtained via Equation 3.

$$PG = \frac{NPL\,.NFE.NGF\,.MCG}{10000} \quad (3)$$

where:
PG= grain productivity, kg ha $^{-1}$;
NPL= NPL – number of plants m $^{-2}$;
NFE = number of rows of grains per ear;
NGF = average number of grains per row;
MCG= mass of one hundred grains, g.

To obtain the production, regression analysis was used between the dependent variable (productivity “Y” in kg ha $^{-1}$) and the independent variable (irrigation depth “w”) via a second-degree polynomial model presented by Oliveira et al. (2012), according to Equation (4).

$$Y = a + bw + cw^2 \quad (4)$$

where:
Y= productivity, kg ha $^{-1}$);
w = irrigation depth (mm);
a, b and c = Adjustment coefficients of the regression equation for grain production.

Considering that the cost of water required for irrigation is entirely composed of the cost of electricity (R$ 153 mm $^{-1}$ ha $^{-1}$), Lima et al. (2012) suggested that the same can be obtained through the specific dissipated energy in the sprinkler irrigation system (kWh mm $^{-1}$ ha $^{-1}$) by the number of hours of operation of the irrigation system and by the average cost of electricity (R$ kWh $^{-1}$).

In this way, the costs of water supply were taken into consideration so that the other factors involved in crop production, such as inputs, fertilizers and machinery, remained fixed at optimal and equal levels for the different treatments.

To obtain the irrigation depth that corresponds to the highest return or economic efficiency (MEE), the model to be minimized is that of net revenue or net profit, represented by Equation 5.

$$W = \frac{\frac{Px-b}{Py}}{2c} \qquad (5)$$

where:
W= Optimal economical blade.

The prices of the applied water depth (Px) used were obtained from the bibliography in Reais (R$) and converted to Dollars ($).

The price of the product (Py) was obtained through the state average of the commercialization value per 60 kg bag for the year 2019. The average values of the cost of water were taken into consideration, within a range of 0.30--1.50 $ mm $^{-1}$ ha $^{-1}$ (CONCEIÇÃO, 2016).

The price of the product (Py) was obtained through the average sales price per 60 kg bag for the state in October 2020, approximately R$ 68.12 (US$ 12.31), obtaining the value for the kilogram of the product of US$ 0.20, paid to the producer in October 2020.

In this case, the price of water varied by $0.30, while the price of the product remained fixed, which led to eleven relationships (Pw/Py), as applied in Equation (5).

To interpret the results, analysis of variance was performed via the Tukey test at a 5% probability of error to interpret the level of significance via the statistical software Sisvar 5.6, and when there was a significant difference between the treatments, regression analysis was performed.

5 RESULTS AND DISCUSSION

Table 2 presents the number of irrigations, average applied depth (mm), total irrigation (mm), rainfall (mm) and total water applied (irrigation and rainfall) (mm) throughout the life cycle of the corn crop for the five irrigation treatments.

Table 2. Illustrations of the number of irrigations during the entire experiment; average hourly water depth applied; irrigation $^{-1}$ mm; total irrigation mm; rainfall mm; total water applied (irrigation+precipitation mm); and throughout the corn crop cycle for the five irrigation strategies.

Treatment (% of ETc)	Number of irrigations	Applied hourly blade irrigation $^{-1}$	Total irrigation (mm)	Rainfall (mm)	Total water applied (mm)
T1 0%	0	0	0	451	451
T2 50%	22	2	75	451	526
T3 75%	22	3.5	113	451	564
T4 100%	22	5	158	451	609
T5 125%	22	6	204.14	451	561.02

* ETc - crop evapotranspiration.

During the experiment, twenty-two irrigations were carried out, except at T1. The rainfall during the corn crop cycle was 451 mm, with an average total amount of water applied (irrigation + rainfall) of 561.02 mm.

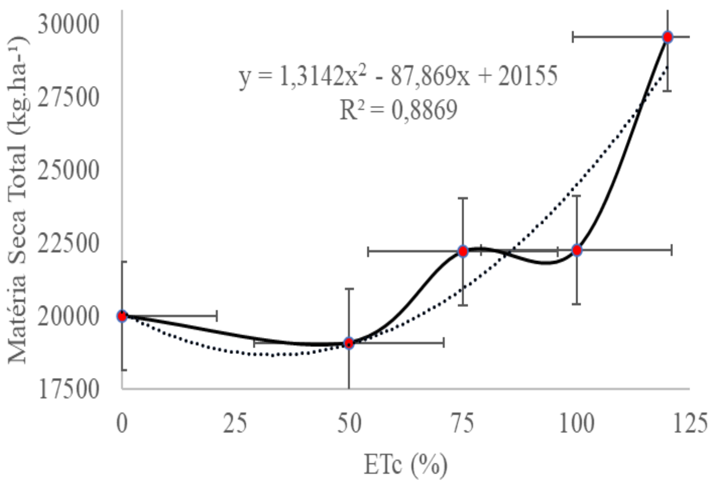
A total rainfall of 451 mm would meet the water needs of the plant. According to Machado (2016), corn requires an average of 400 to 600 mm of water. However, the rainfall distribution was uneven, resulting in a period of up to twenty-four days without rainfall, which led the plants to experience a water deficit. According to Santos et al. (2014), water deficit can affect plants in different ways, resulting in different ecophysiological performances under limited water availability.

In the reproductive phase (128 and 143 days), the highest rainfall amounts of 96.4 mm and 69.6 mm, respectively, were recorded during cultivation.

The total ETo during the crop cycle (158 days) was 735.7 mm, with a daily maximum of 7.9 mm day $^{-1}$ and an average of 4.65 mm day $^{-1}$. The total ETc was 475.2 mm, with an average of 3 mm day $^{-1}$, and when the plants were in the flowering stage, the maximum daily ETc of 7.56 mm day $^{-1}$ occurred. This value is lower than that reported by Suyker and Verma (2009), who determined the total evapotranspiration of corn to be 683 mm in the Mead region of Nebraska. Thus, the application of supplemental irrigation helps replenish water in the crop, avoiding water deficiencies during the vegetative and reproductive periods, which are stages of extreme need for water availability.

The dry matter production performance increased with increasing irrigation depth, with a maximum value of 29,548.67 kg.ha $^{-1}$ for the depth with the highest ETc replacement (125%), and the lowest yield was observed at the lowest ETc replacement depth (25%), with a value of 19,098.67 kg.ha $^{-1}$. Figure 1 shows the influence of the application of supplementary water depth on the dry matter of the crop.

Figure 1. Influence of water applied on the total dry matter of corn.



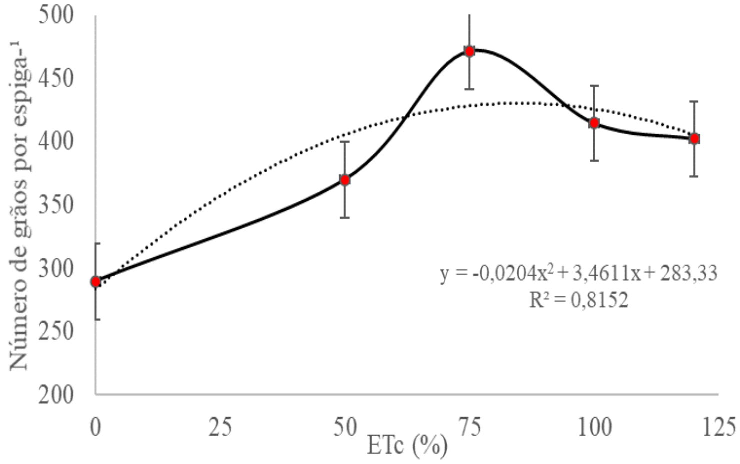
The difference in crop production among the different irrigation depths demonstrated an increasing level of total dry matter (kg.ha $^{-1}$), mainly at the two largest ETc replacement depths (100 and 125%), with production differences of 7,296 kg.ha $^{-1}$ due to the increase in irrigation depth. The treatments with shallower depths (50 and 75% of ETc) resulted in a difference of 31,250.33 kg.ha $^{-1}$. Similar results were obtained by Parizi (2007) in a study with irrigated corn in the municipality of

Santiago, RS, in which maximum productivities of 22,356 and 22,963 kg.ha $^{-1}$ were obtained in water replacements of 80% and 100% of ETc, respectively.

The greater the ETc replacement is, the more significant the increase in dry matter production. Therefore, Albuquerque and Resende (2009) consider corn, known for its high demand, as one of the most efficient crops in terms of water use; that is, it is capable of producing a large amount of dry matter per unit of water absorbed.

Figure 2 shows that there is a reduction in the number of grains per ear (NGE) at the smallest depths with water replacement (0 and 50% of ETc), thus highlighting the reduction in NGE at the smallest irrigation depths due to the lower availability of water for the crop.

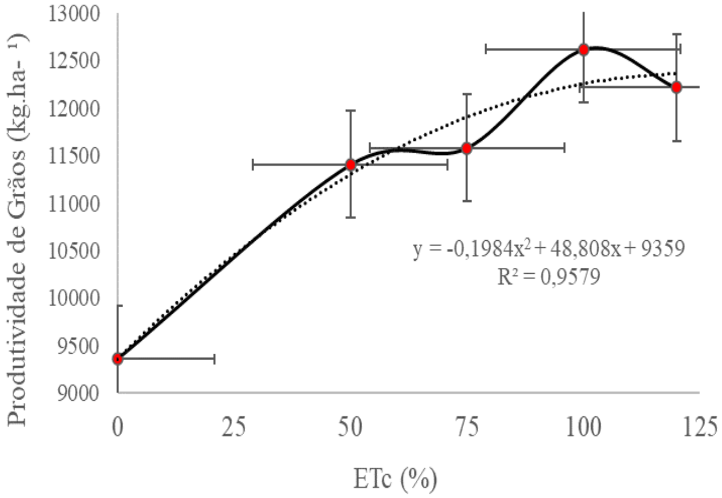
Figure 2. Number of grains per ear of corn in response to irrigation depth.



As the irrigation depth increased, the number of grains per spike (NGE) also increased, reaching an average of 471.6 grains at the irrigation dose of 75% ETc. This value was reduced for treatments related to 100 and 125% of ETc and for values below 75%, that is, 50 and 0% of ETc, for which the corresponding NGE values were found to be 414.53, 402.13, 370, and 289.6 grains per spike $^{-1}$, respectively. According to Bergamaschi et al. (2004), the number of grains per spike is one of the grain production components most affected by water deficit.

Figure 3 shows that the grain productivity of the corn crop gradually increased with increasing blade replacement, resulting in the maximum level of productivity in the blade, which corresponds to 100% replacement of the ETc, with a decrease in productivity occurring for the blade of 125% of the ETc; therefore, a quadratic polynomial function was generated.

Figure 3. Influence of applied water on grain production in corn crops.



The corn grain productivity observed in this study corroborates that reported by Parizi (2010), who, working with irrigated corn in the region of Santiago, RS, obtained higher productivity in the treatment with greater depth replacement (100% of ETo), which was equal to 15,550.90 kg.ha $^{-1,}$ and the lowest productivity in rainfed cultivation, which corresponded to 7,956.97 kg.ha $^{-1}$. Bem (2015) also reported that grain productivity increased with increasing irrigation depth, reaching a maximum productivity level corresponding to 12,390 kg.ha $^{-1}$ at irrigation depths with 100% replacement of ETc, with a decrease in productivity at a depth of 125% of Etc, equivalent to 10,260 kg.ha $^{-1}$. The irrigation depths below these depths resulted in a gradual reduction in productivity for cultivation in the region of Santiago, RS.

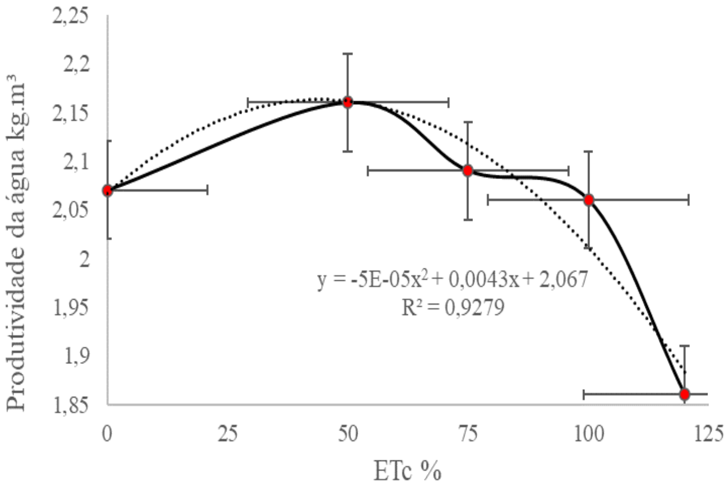
The highest grain yield for corn was achieved at 100% ETc, with a value of 12,619.66 kg.ha $^{-1}$, with a total water application (irrigation + precipitation) of 609 mm throughout the crop cycle. The lowest yields were observed at the lowest replacement water depth (50% of ETc), with a total water application of 526 mm, and in rainfed cultivation, 451 mm, corresponding to 11,405.66 kg.ha $^{-1}$ and 9,359.33 kg.ha $^{-1}$, respectively. The other treatments resulted in production values of 11,852 and 12,214.33 kg.ha $^{-1}$, corresponding to the treatments with water replacement water depths of 75 and 125% of ETc, respectively.

Some researchers, such as Louzada and Jobim (2011), highlight the importance of the need for supplementary irrigation, even in periods when rainfall is more frequent, since there are irregularities in its distribution.

It is also possible to observe that grain production presented the same variable behavior for total dry matter (kg.ha $^{-1}$), increasing with increasing water depth, which highlights the relationship of this variable with the final productivity of the corn crop.

According to Figure 4, water productivity presented a decreasing linear behavior, which generated a quadratic polynomial function according to the increase in irrigation depth; that is, the highest value of 2.16 kg m $^{-3}$ was obtained in the treatment with the lowest irrigation depth (50% of ETc). Notably, this treatment presented the lowest grain production in this study (11,405.66 kg.ha $^{-1}$), with the highest grain production (12,619.66 kg.ha $^{-1}$) achieved in the treatment with a depth replacement of 100% of ETc (Figure 3).

Figure 4. Water productivity performance under the influence of irrigation depth for corn crops.



Therefore, irrigation depths above this level, when aiming for maximum grain production, should be economically recommended only when water is not a limiting factor or results in low costs in agricultural production.

An analysis of the results revealed that the water productivity response was greater in the treatments with lower water depth replacements (50 and 75% of the ETc), which presented water productivity values equivalent to 2.16 and 2.09 kg m $^{-3}$, respectively, than in the rainfed treatment (0% of the ETc), which presented 2.07 kg m $^{-3}$ of water productivity. In the treatments with greater water depth replacement (100 and 125% of ETc), there was a reduction in water productivity, with values of 2.06 and 1.86 kg m $^{-3}$, respectively.

The results obtained in this study corroborate those of Martins et al. (2016), who reported that corn presented greater water productivity in treatments with the application of higher water deficits, 2.87 kg m $^{-3}$ and 2.47 kg m $^{-3}$, which corresponded to treatments with water depth replacements of 30 and 40% of ETc, respectively. Greater water depths represented a decrease in water productivity, with a value of 1.99 kg m $^{-3}$ in the treatment with a water depth replacement of 100% of the ETc.

In a study by Andrade et al. (2004), the water productivity ranged from 1.74 to 1.22 kg m $^{-3}$, with the highest value associated with the application of water depths lower than those required by the crop. Pereira, Oweis and Zairi (2002) emphasized that if a farmer's objective is to maximize water use efficiency, controlled deficit irrigation can be adopted. Lima et al. (2012) reported that well-planned deficit irrigation can increase water productivity for several crops without causing drastic reductions in yield.

In this study, the greatest efficiency in terms of water use was obtained by plants subjected to deficit irrigation, which resulted in a greater grain yield per m³ of water applied.

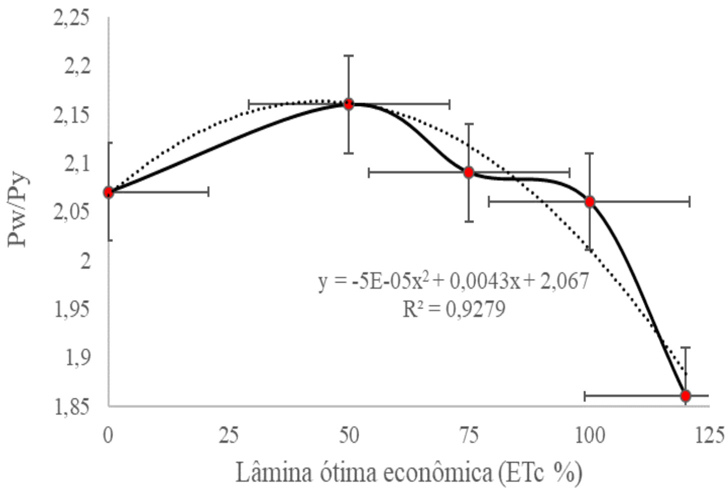
Table 3 presents the irrigation depth (mm), total water applied (irrigation and precipitation) (mm), total dry matter (kg.ha $^{-1}$), grain production (kg.ha $^{-1}$), water productivity (kg.m $^{-3}$) and net revenue (R$), obtained at the end of the crop cycle, throughout the life cycle of corn for the five treatments.

Table 3. Irrigation depth (mm), total water applied (irrigation and precipitation) – TAA (mm), total dry matter – MST (kg.ha $^{-1}$), grain production – PG (kg.ha $^{-1}$), water productivity (kg.m $^{-3}$) and net revenue (R$), obtained at the end of the crop cycle, throughout the life cycle of corn for the five treatments.

Treatment (% of ETc)	Irrigation blade (mm)	TAA (mm)	MST kg.ha $^{-1}$	PG kg.ha $^{-1}$	Water productivity kg m $^{-3}$	Net revenue (R$)
T1 0%	0	451	20021.33	9359.33	2.07	0
T2 50%	75	562	19098.67	11405.66	2.16	12790.90
T3 75%	113	564	22224	11582	2.09	13245.86
T4 100%	158	609	22282.67	12619.66	2.06	14054.82
T5 125%	204.14	655.14	29578.67	12214.33	1.86	13536.99

The optimal irrigation depth for obtaining maximum economic efficiency in corn crops is shown in Figure 5. According to the equation expressed in Figure 5, when the Pw/Py ratio is zero, the optimal depth that provides the maximum economic efficiency of the crop is 49.60% of ETc, with the application of depths greater than this value being considered economically inappropriate.

Figure 5. Optimal economic depth as a function of the cost of applying the irrigation depth (Pw) (R$ mm ha $^{-1}$) and the selling price of the product (R$ kg $^{-1}$).



Thus, as Pw/Py increases (increasing water costs), different water management strategies that involve deficit depths are economically viable, thus achieving maximum economic efficiency.

The cost of electricity per applied water depth of R$1.30 was considered. When supplemental irrigation was used, the net income per hectare was greater than that in the nonirrigated treatment, making irrigation management of the corn crop economically profitable. However, the higher grain production did not translate into higher net revenue, as the energy cost increased significantly to replace the 125% ETc depth, which corresponded to 204.14 mm. The highest economic return, corresponding to a net revenue of R$12,790.90, was found for the depth with 50% ETc replacement.

Martins et al. (2012), studying the efficiency and productivity of water in the irrigation of corn silage, with treatments in full irrigation and deficit irrigation, obtained gross revenues of R$ 4,522.5, R$ 4,287.5 and R$ 4,212.5 for irrigation depths of 245 mm, 174 mm and 65 mm, respectively. The results of Pegorare et al. (2009) are lower than the electricity costs, R$ 26.25 for the 140 mm depth, R$ 43.75 for the 190 mm depth, R$ 78.75 for the 290 mm depth and R$ 113.05 for the 388 mm depth, which are due to the value of the annual tariff charged for energy use in the states, since adjustments have been made in the amounts charged in the last eleven years.

In view of the above findings, as the amount of water applied increased, there were positive increases in the productivity of the corn crop until it reached a maximum value. Subsequently, the productivity yield decreased with increasing total amount of water applied.

6 CONCLUSION

Compared with supplementary irrigation, treatments with deficit irrigation resulted in lower productivity; however, treatments with lower ETc depth replacement (%) presented greater water productivity and economic efficiency for irrigated corn crops.

Under the conditions of this study, the optimal economic depth determined was 50% of ETc. Supplemental irrigation proved to be economically viable; however, the higher grain yield did not result in the highest economic return for the corn crop.

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