



MAIZE SECOND SEASON IRRIGATED BY CENTER PIVOT IN SANDY SOIL

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ABSTRACT

The aim of this study was to evaluate the development of a corn (*Zea mays*) crop grown in Brazil on a sandy soil, in a Savannah climate, and under center pivot irrigation. A randomized complete block design with four replicates of three irrigation treatments including a rainfed control treatment (I_0), a 100% replacement (I_1), and a 200% replacement (I_2) of crop evapotranspiration (ET_c). The grain yield (GY) and the plant characteristics including plant height (PH), corn cob insertion height (CIH), stem diameter (SD), and 100 grain mass (M100) were measured. The grain yield results were (I_2) 9,634 kg ha⁻¹, (I_1) 7,680 kg ha⁻¹, and (I_0) 4,229 kg ha⁻¹. All of the plant characteristic variables had higher values for irrigated treatments than for the rainfed treatment. For all except M100, the I_2 treatment increased plant characteristic values the most. The I_1 just treatment had the highest values for M100. The sandy soil has good drainage and a high soil infiltration rate, so the higher irrigation depth for I_2 did not cause water logging and poor aeration in the soil. Maintaining a higher moisture content increased grain yield, but a cost-benefit analysis is needed to assess cost effectiveness from applying more water.

Keywords: grain yield, soil texture, *Zea mays*.

MILHO SEGUNDA SAFRA IRRIGADO VIA PIVO CENTRAL EM SOLO ARENOSO

RESUMO

O objetivo desse estudo foi avaliar o desenvolvimento da cultura do milho, (*Zea mays*), em solo arenoso na região do Cerrado Brasileiro, sob irrigação via sistema de Pivô Central. Utilizou-se delineamento experimental em blocos casualizados em área de Pivô Central, com quatro repetições de três tratamentos, sendo o sequeiro a Testemunha (I_0), e as lâminas de 100% de

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reposição (I₁) e 200% da reposição (I₂) da Evapotranspiração da Cultura (ET_c). Foram avaliadas as características morfológicas e de produtividade. A maior produtividade foi obtida no tratamento I₂, atingindo 9.633,52 kg ha⁻¹, seguido do I₁ com 7.679,99 kg ha⁻¹ e, o I₀ com 4.229,21 kg ha⁻¹. Todas as variáveis analisadas superaram seus resultados nas condições irrigadas em relação ao sequeiro. Para todas as variáveis analisadas, exceto para M100, a lâmina de irrigação I₂ apresentou melhor desenvolvimento e expressou seu potencial produtivo. Já para M100 os maiores valores foram obtidos com a lâmina I₁. Os altos índices de umidade em solo arenoso podem contribuir para incrementos de produtividade, porém é necessário o estudo de viabilidade econômica para checar o custo benefício bem como a disponibilidade de recursos hídricos para se fazer isso.

Palavras-chave: produtividade, solo arenoso, *zea mays*.

INTRODUCTION

The corn crop (*Zea mays*) presents significant importance in the world (FERREIRA et al., 2011), this is the result for the fact that it is destined to feed the human, animal and still serve as raw material for the industries. The use for animal feed is higher, it's between 60% and 80% of the country's production and it varies from year to year (EMBRAPA, 2017). Hybrids of this crop are adapted for cultivation both to first and second seasons, usually as a succession of soybean cultivation.

In the agricultural year 2015/16, according to CONAB (2017), the total area of maize cultivation in Brazil reached 9,550,600 ha, which 64% were in the Midwest region and 16.9% in the state of Mato Grosso do Sul. South region, which in turn presents its largest area under savannah conditions with, generally, sandy soils, low natural nutrition and high acidity, the rainfall season is defined from September to April, and the other months are predominant dry.

In these regions crop cultivation occurs in a rainfed system, and the main water supply comes from the rains that occur during its cycle. In the second season maize, it's common occurring drought periods, causing water stress and damaging the development of the plant, however, Silva et al. (2010), verified that under these conditions, when irrigation is used, increases the grain yield potential. According to Bergamaschi et al. (2006), the occurrence of water shortage from the pre-flowering period

to the beginning of the grain filling, results in a reduction of grain yield.

Thus, an alternative to avoid water stress and low grain yield, is the supply of water to the crop at a time when rainfall is not sufficient to supply the water demand during its development and mainly in the reproductive stage, then it does not reduce grain yield. Benjamin et al. (2014), emphasize that the rational use of irrigation guarantees sustainability and maximizes crop productivity.

Therefore, the aim of this study is to evaluate the effect of different water depths in the maize in sandy soil in the Savannah region of Mato Grosso do Sul.

MATERIAL AND METHODS

The present research was carried out at Santo Antônio Farm, in the city of Paraíso das Águas - MS, with latitude 18°59'04" South and longitude 52°54'60" West, and altitude of 664 meters.

The climate of the region is defined as tropical with dry season, according to a classification of Köppen, with average annual temperature of 25°C and average annual precipitation between 1600 and 1800 mm. The soil of the area is classified as Red Latosol (EMBRAPA, 2013).

The sowing of corn occurred on March 22, 2016, on soil with residues of the previous soybeans, under center pivot system area. The hybrid used was the 2B810 PW.

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A randomized block design with three irrigation levels (0, 100, 200% ETC) and four replications was set up in an area with two center pivots, where both were

managed with 100% ETC replacement. However, in the area of overlap of these pivots, double water application was verified (Figure 1).

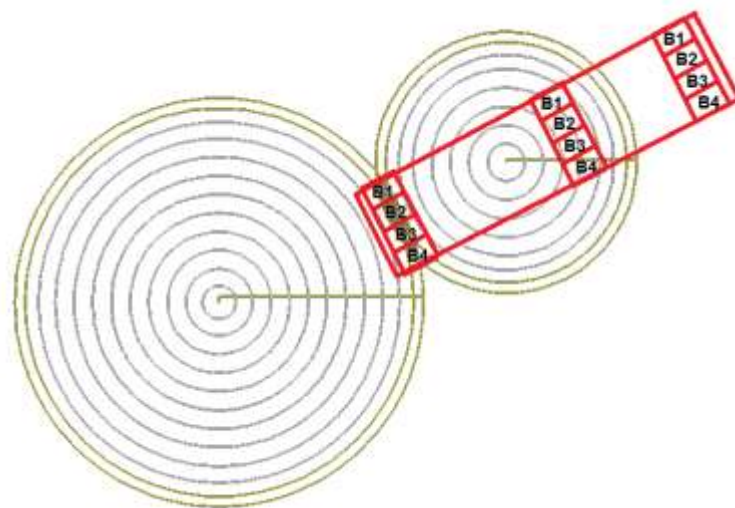


Figure 1. Overlap in the pivots with double water application and three conditions of water level.

The experimental units consisted of 11 planting rows spaced at 0.45 m. In order to carry out the evaluation, 3 center lines with 4 m of length, totaling 5.4 m², were classified as useful part.

The methodology for the management of irrigation was using meteorological data, through an automatic station of the National Institute of Meteorology (INMET), installed near the experimental area where the research was carried out. Estimates of ETo were obtained by the Penman Monteith-FAO

method, according to Allen et al. (1998). The crop evapotranspiration (ETc) was obtained by the product of Reference Evapotranspiration (ETo) and the Crop Coefficient (Kc).

In order to monitor the water balance, the crop coefficients and depth of the root system of each subperiod (Table 1) were defined according to the recommendations of DETOMINI *et al.* (2009), where the gradual variation of the passage from one subperiod to the other was performed days after emergence.

Tabela 1 - Crop coefficients (Kc)

Stage (days after emergency)	Kc (adm.)
Up to 4 leaves visible (0-18)	0,32
4 to 8 leaves visible and still attached to the stem (19-37)	1,07
8 to 12 leaves visible and still attached to the stem (37-50)	1,50
Tasseling, flowering and pollination (51-64)	1,43
Pollination ending to Dough (64-77)	1,25
Dough to Dent (78-89)	1,01
Dent to mid-dent (90-99)	0,39
Mid-dent to maturity (100-110)	0,23

Table 2 - Physical-water soil analysis.

Layer (cm)	θ_{FC} ($\text{cm}^3 \text{cm}^{-3}$)	θ_{PMP} ($\text{cm}^3 \text{cm}^{-3}$)	WCA (mm cm^{-1})	SD (g cm^{-3})	TP (%)	Fractions Granulometric			Textural Class
						Sand	Silt (%)	Clay	
0 – 10	0,185	0,048	3,15	2,3	16	87,5	2,5	10,0	paleudalf
10 – 20	0,197	0,050	3,38	2,3	14	88,0	2,5	9,5	
20 - 30	0,204	0,061	3,15	2,2	16	88,5	2,0	9,5	

θ_{FC} - Moisture in the field capacity at the matric potential (ψ_m) of 0.3 atm;
 θ_{PMP} - Permanent wilting point in ψ_m of 15 atm; WCA - Water capacity available; SD - Soil Density; TP - Total soil porosity.

The soil texture was classified as sandy (Table 2). Irrigations were performed only when the availability of soil water approached the lower

limit of the readily available water (RAW), calculated by Equation 1.

$$RAW = (\theta_{FC} - \theta_{PMP}) * d * Z_r * p \quad (\text{Equation 1})$$

Where: RAW – Readily available water, mm;
 θ_{FC} – Water content at field capacity, $\text{m}^3 \text{m}^{-3}$;
 θ_{PMP} – Field Capacity, $\text{m}^3 \text{m}^{-3}$; d – Soil Density, kg m^{-3} ;
 Z_r – Effective Depth of Root System, m and p – Depletion Fraction, adm.

Harvesting was carried out on August 03, 2015. The variables total plant height (PH), ear insertion height (EIH), stem diameter (SD), mass of one hundred grains (M100) and grain yield (GY) were analyzed by the Tukey test at 5% probability.

RESULTS AND DISCUSSION

Table 3 shows the relationship between the water depths applied in the treatments and the response of the culture to the variables evaluated. The low volume of rainfall during the crop cycle, directly affected the development of the crop in the rainfed treatment. Figure 2 shows the water balance of the period.

Table 3 - Average values of plant height, ear insertion height, stem diameter, one hundred grain mass and grain yield in function of water depths.

Variable	Water Depths (% ETc)		
	0	100	200
Plant Height (cm)	173,00b	220,74a	238,00a
Ear Insertion Height (cm)	58,12c	83,25b	92,18a
Stem Diameter (mm)	15,15c	19,07b	25,46a
One Hundred Grain Mass (g)	29,12b	37,81a	29,81b
Grain Yield (kg ha^{-1})	4229,21c	7679,99b	9633,52a

Means followed by lower case distinct letters in the line differ among themselves by the Tukey test ($p < 0.05$).

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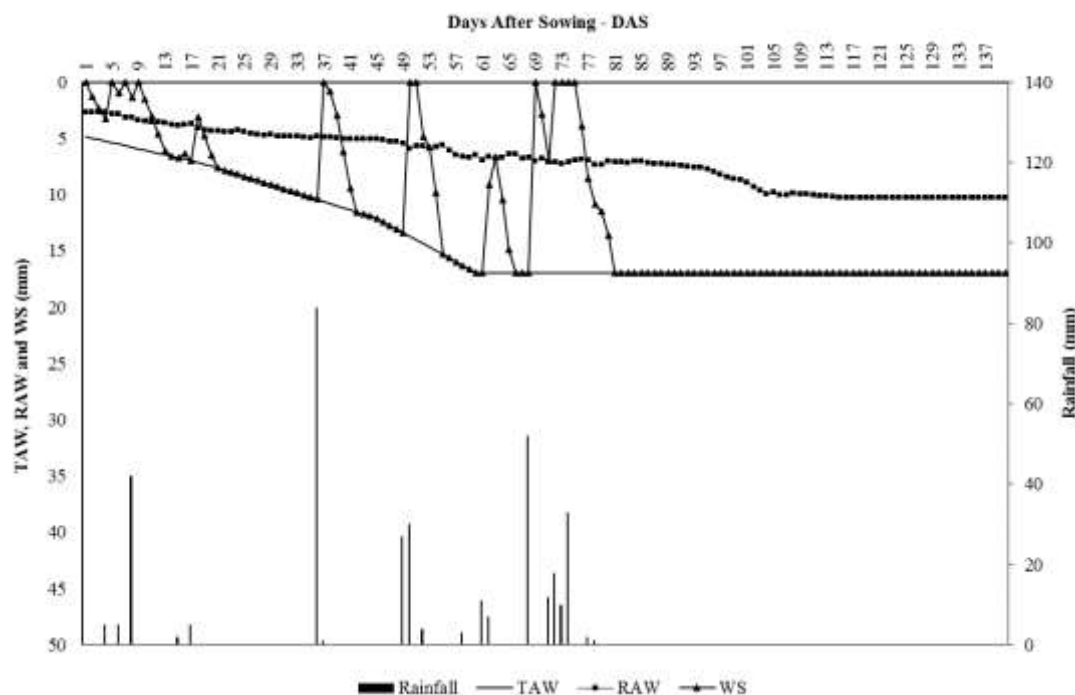


Figure 2. Water balance with average values of rainfall, total available water (TAW), readily available water (RAW) and soil water storage (WS), according to the days after sowing (DAS) in rainfed.

In general, the best results came from the treatment with water depth of 200% ETC replacement, the plants developed very well, presenting higher plant height, stem insertion, stem diameter and productivity, this behavior can be explained by the high drainage in this kind of soil, it had the favorable conditions, thus being able to express the maximum of its potential. The responses obtained with the 100% treatment of ETC replacement were intermediate to the other treatments, and the rainfed presented the lowest results.

Parizi et al. (2016), working with evaluation of maize productivity in different water depths, found a linear increase until a larger water depth was tested, finding the highest values with 600 millimeters of total application.

The mass of 100 grains presented the best result in the water depth of 100% ETC replacement, the rainfed and 200% ETC replacement treatments showed no significant difference between them. This result is totally the same found per Ben et al. 2016, working in sandy soil and with maize second season. They tested 0, 50, 75, 100 e 125% of ETC and the

best results to mass of 100 grains was in a 100% of ETC.

The highest grain yield, 9,633.52 kg ha⁻¹, was obtained in the water depth of 200% ETC replacement. Since the soil is sandy, it has a high drainage capacity and a basic infiltration velocity of the soil, so that the crop was able to take advantage of the available water more efficiently and for a longer period. IBRAHIM et al. (2016), in a study with corn in sandy soil, also verified that the ideal replacement was a water depth above 100% of ETC, a result obtained in two consecutive harvests. The water depth of 100% ETC replacement had an intermediate productivity to the other treatments, 7,679.99 kg ha⁻¹, but was also very high. It is now necessary to carry out an economic feasibility study and to check which is more profitable.

On the other hand, rainfed grain yield was the smallest of all, as expected, due to the water deficit suffered during important stages of crop development.

According to Gava et al. (2016), reports that in very sandy soils, water depths above 100% of ETC result in higher yields. Working with soybean, they found a maximum yield in

the ETc 150% and a tendency to increase beyond this value, which was the maximum value he tested in the work here cited.

In the same way Santos et al. (2017) concluded that in situations where the Maize suffer defoliation, independent of the level of defoliation, water depths over than 100% ETc were better to crop in your gas exchange.

The same behaviors are found for other crops in sandy soils, where higher rates of application result in higher yields.

For the bean culture, cultivated in paleudalf soil, Conceição et al. (2017) verified that grain yield was directly influenced by irrigation, presenting a positive linear behavior according to the increment of the water depth.

In the tomato crop, in RED-YELLOW ARGISSOLO of sandy-loam texture, the irrigation high frequency promotes better productive performance (NETO et al., 2017).

Also in the cotton Zonta et al. (2017) concluded that in soils with texture sandy-clayey, with 49% sand, 45% clay, and 6% silt water deficit causes greater losses in cotton yield mainly during the First Bloom and Peak Bloom phenological stages, because of the high water demand in these phases.

CONCLUSIONS

The treatment with water depth of 200% ETc replacement showed the highest grain yield.

Irrigation in very sandy soils with water depths above 100% of ETc resulted in higher yields.

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