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IRRIGATED SAFFLOWER AT DIFFERENT PHENOLOGICAL STAGES OF BRAZILIAN SOUTHEAST DRY SEASON

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1 ABSTRACT

This study was conducted in order to determine the effect of irrigation regime imposed on development stages over safflower growth components (*Carthamus tinctorius* L.) in Engenheiro Coelho, SP, Brazil. The work was conducted in Arenic Hapludult soil. The experimental design was a completely randomized block with eight irrigation regimes and three replications. The irrigation regimes consisted of: water deficit (WD), irrigation at vegetative stage (V), irrigation at flowering stage (F), irrigation at grain formation stage (G), irrigation at vegetative and flowering phases (VF), irrigation in vegetative and grain formation stages (VG), irrigation at flowering and grain formation (FG) and irrigation in vegetative, flowering and grain formation stages (VFG) (control). The results of this study show that safflower is benefited by irrigation in vegetative period; however, irrigation is also effective when applied during flowering period in treatment under water deficit. Water shortage due to irrigation restriction during the vegetative stage reduces morphological components of safflower growth. The grain and oil yield is affected by water restriction in all safflower cultivation stages. Treatment with water availability throughout vegetative and flowering periods produced 895 kg ha^{-1} of grain yield.

Keywords: water deficit, plant growth, *Carthamus tinctorius* L., oilseed.

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CÁRTAMO IRRIGADO EM DIFERENTES ESTÁGIOS FENOLÓGICOS NA ESTAÇÃO SECA DO SUDESTE BRASILEIRO

2 RESUMO

Um estudo foi conduzido com o objetivo de determinar o efeito do regime de irrigação imposto em estágios de desenvolvimento sobre componentes da produção de cártamo (*Carthamus tinctorius* L.) em Engenheiro Coelho, SP, Brasil. O trabalho foi conduzido em um Arenic Hapludult. O delineamento experimental foi em blocos ao acaso, com oito regimes de irrigação e três repetições. Os regimes de irrigação consistiram de: déficit hídrico (DH), irrigação no estádio vegetativo (V), irrigação no estádio de floração (F), irrigação no estádio de formação de grãos (G), irrigação nas fases vegetativa e floração (VF), irrigação na fase vegetativa e formação de grãos (VG), irrigação no florescimento e formação de grãos (FG) e irrigação nas fases vegetativa, floração e formação de grãos (VFG) (controle). Os resultados deste estudo mostram que o cártamo foi beneficiado pela irrigação no período vegetativo, no entanto, a irrigação também é eficaz quando aplicada durante o período de floração em tratamento que estava sob cultivo de sequeiro. A escassez de água devido à restrição da irrigação durante a fase vegetativa reduz os componentes morfológicos do crescimento do cártamo. O tratamento com disponibilidade de água ao longo do período vegetativo e floração produziu 895 kg ha^{-1} de rendimento de grãos.

Palavras-chave: Déficit hídrico, *Carthamus tinctorius* L., oleaginosa.

3 INTRODUCTION

The climate change has caused drastic effects on the regularity of water availability. It leads drought, one of the environmental factors that most limit agricultural production in worldwide by affecting the rate of photosynthesis and transpiration (HEIMANN; REICHSTEIN, 2008).

In order to attenuate these factors, irrigation in agriculture aims to increase agricultural production, however, the water amount required to achieve the desired yield may vary with the crop and its phenological stage. Therefore, drought tolerance evaluation is necessary to quantify the severity of water deficit in each plant development stage. As the water effect is critical to the crops development it will be necessary a better understanding of skills used by plants facing the drought in each development stage (TAIZ; ZEIGER, 2013).

Safflower (*Carthamus tinctorius* L.) is an oilseed that can serve as an alternative for various regions. It is an oilseed crop with great potential for cultivation in dry areas (LOVELLI et al., 2007). In Brazil, this culture is still poorly known, and therefore studies need to be developed aimed at the performance of this species to tropical conditions. Several studies are being conducted in Brazil on water deficit (SANTOS et al., 2018; SANTOS; BASSEGIO; SILVA, 2017), compaction (SARTO et al., 2018) and nutrition of safflower (SAMPAIO et al., 2016).

Irrigation in agriculture aims to increase agricultural production, however, the amount of water required to achieve this production may vary with the culture and phenological stage of crops. In this context, the choice of water restriction periods in irrigated crops during a period of the crop cycle seems to be a necessary and inevitable alternative, as well as at specific stages (SANTOS et al., 2018). Istanbulluoglu (2009) and Istanbulluoglu et al. (2009) found that when irrigation was omitted during the vegetative stage, the grain yield was decreased. Mohammadi et al. (2018) observed that water deficit decreased the yield and oil of safflower.

With the hypothesis that safflower can be a plant little sensitive to water deficit at certain stages in tropical conditions, the aim of this study was to verify the morphometric effect and production in safflower at water restriction in the vegetative, flowering and grain formation stages.

4 MATERIAL AND METHOD

The experiment was conducted at Engenheiro Coelho (22°29'18" S, 47°12'54" W and altitude of 655 m), SP, Brazil, in winter 2014. The predominant soil is classified as Arenic Hapludult (SOIL SURVEY STAFF, 2010), which chemical (RAIJ; QUAGGIO, 1983) and physical (EMBRAPA, 1997) parameters are shown in Table 1.

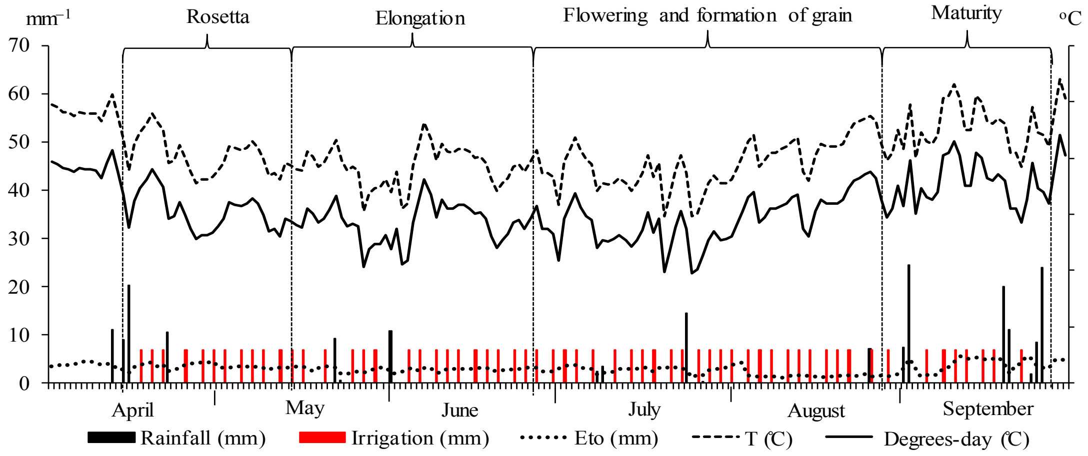
Table 1. Soil physical and chemical attributes of experimental area Engenheiro Coelho, SP before study.

OM	pH	P	K^+	Ca^{2+}	Mg^{2+}	$H^+ + Al^{3+}$	CEC	BS
g dm^{-3}	$CaCl_2$	mg dm^{-3}	mmol$_c$ dm^{-3}					%
17	5.3	13	2.9	25	6	15	49	47
S	B	Cu	Fe	Mn	Zn	Sand	Silt	Clay
mg dm^{-3}						g kg^{-1}		
12	0.21	1.1	27	3.4	1,4	705	123	172

OM = Organic Matter; CEC = Cation Exchange Capacity; BS = Base Saturation.

According to Köppen classification, the region climate is humid, subtropical Cwa, with the warmest month temperatures exceeding 22 °C and the coldest month less than 18 °C. The annual rainfall index in the region is 1328 mm. The daily climate parameters were measured at a weather station located close to the experimental area (Figure 1).

Figure 1. Precipitation, irrigation, temperature (T), degrees-day and reference evapotranspiration (ETo) at different safflower phenological stages in 2014.



Source: Agricultural Experimental Station of Agrocosmo, Engenheiro Coelho, SP.

The experimental design was a randomized block with eight treatments and three replications. The treatments were: water deficit (WD), irrigation at vegetative stage (V), irrigation at flowering stage (F), irrigation in the grain formation stage (G), irrigation in vegetative and flowering stages (VF), irrigation in vegetative and grain formation stages (VG), irrigation in flowering and grain formation stages (FG) and irrigation in vegetative, flowering and grain formation stages (VFG). It was considered the VFG treatment as the control. For the irrigation, treatments selection consisted of three stages of safflower growth: vegetative (V) flowering (F) and grain formation (G). The water application stages were determined according to Doorenbos and Kassam (1979).

The genotype IMA-2232 of was sown on April 14, 2014. The seeding depth was three centimeters. The seeds were treated with Thiram based fungicide. As fertilizers, it was applied 500 kg ha^{-1} of the 4-14-8 formula (N-P_2O_5-K_2O). Each experimental plot was dimensioned with 1.35 m wide × 4.0 m long (3 lines per plot). Line spacing was 0.45 m and plant spacing was 0.10 m. Fertilization, seeding, cultural treatments and harvesting were performed manually.

The safflower experimental plots were harvested in July 27, 2014 for determination of: plant height (PH), stem diameter (SD), stem length (SL), stem fresh mass (FMS), stem dry mass (SDM) and number of stems (NH), number heads (NH), fresh mass of the heads (FMH), dry matter of the heads (DMH), fresh mass of the stem (FMS), dry mass of the stem (DMS), fresh mass (FMR) and dry mass (DMR) of roots. The plant height and stem length measurements were taken from precision ruler and stem diameter by caliper. The fresh mass of the stem, heads, stem and stem dry weight, heads and stem was given from weighing in analytical balance (0.001) and subsequent kiln drying to constant weight at 65 °C. The number of stem and heads was measured from counting of ten plants per plot.

As for the grain production data, the weight of 100 grains (100-Weight), grain yield, oil content and oil yield. The grain yield was obtained by useful track manual area of the plot. For yield and weight of 100 grains the grains were corrected to 120 g kg^{-1}.

The grains oil content was determined from a TD-NMR in SLK-SG-

200 spectrometer (SpinLock Magnetic Resonance Solutions, Malagueño, Córdoba, ARG) at 25 °C, equipped with a permanent magnet of 0.23 T (9 MHz for 1H) and a probe of 13 mm × 30 mm of useful area, using the Condor IDE software with the CPMG pulse sequence with Qdamper, expressed on dry basis. The oil yield was determined by multiplying the grain yield by oil content, thus obtaining oil yield in kg ha^{-1}.

Through the grain yield data, precipitation and water amount applied through irrigation were estimated the overall water yield (WPt) and irrigated water (WPi), as proposed by Pereira, Cordery and Iacovides (2009).

Similar to the water ingress into the system by precipitation, the output by evapotranspiration (ETP) was calculated by Hargreaves and Samani estimating equation (1985). All the experimental plots were irrigated to replace the evaporative demand. The area was irrigated with a local system, using a Naan Dan Jain drip tape with a self-compensating issuer at every 0.2 m, with flow rate of 1.7 L h^{-1}, and service pressure of 90 kPa. Dripper tubes were placed in the central row of each plot at 0.10 m from the planting row.

There was no significant pest attack at this growth stage. In this sense, there was no need to apply pesticides for controlling pests or diseases. The soil was kept free of weeds by hand weeding.

The thermal sum in degrees-day was calculated from the average air temperature subtracted from the base temperature. It was assumed that the plants development was constant between the lower base temperature of 5 °C and the upper base temperature of 32 °C. according to Monteith and Elston (1996).

The experimental design was completely randomized, with three replications. For the statistical analysis, it was considered the variance analysis and the average comparison test by Tukey at 1% probability, using Sisvar version 5.6 for Windows (UFLA, Lavras, MG, Brazil).

5 RESULTS AND DISCUSSION

The seeding was performed in the fall, when the days shorten and the nights extend to the southern hemisphere. With the safflower base temperature at 5 °C, the thermal sum from planting to flowering in these 105 days, was 1595 degrees-day and until the end of the cycle reached 2,522 degrees-day. The average of the temperature period was 20.1 °C and reference evapotranspiration of 2.9 mm day^{-1}. The total rainfall in the experimental period of 167 days was 186 mm. That added to irrigation (420 mm), the total water entering the system was 606 mm (Figure 1).

There was a significant effect of water restriction in phenological stages for plant height, stem diameter, stem length, fresh weight of stem, stem dry weight and number of stems (Table 2). However, for the same variables, there were no significant differences between the fully irrigated treatment (VFG) and the treatment that had irrigation restriction after flowering (VF). Similarly occurred when irrigation was applied only in the grain filling stage (G) compared with water deficit (WD). This shows that the last 30 cycle days as well as the 56 mm of water applied in this period have no effect able to differentiate the variables among treatments. Similar result occurred between VG and V treatments as well as between FG and F for the same variables.

Table 2. Plant height (PH), stem diameter (SD), stem length (SL), fresh mass of the stem (FMS), stem dry mass (SDM) and number of stems (NS) of safflower under water regimes.

Treatments	PH (m)	SD (mm)	SL (cm)	FMS (g)	SDM (g)	NS
VFG	1.13 b	13.3 ab	71 bc	76.1 b	31.5 ab	11.0 ab
VF	1.13 b	13.6 ab	69 c	66.2 bc	27.0 bc	12.0 a
VG	1.33 a	14.5 a	85 a	110.8 a	41.7 a	13.3 a
V	1.34 a	13.1 ab	84 a	92.4 ab	32.0 ab	10.3 ab
FG	1.05 bc	12.5 b	51 d	65.4 bc	23.3 bc	10.5 ab
F	0.97 c	10.2 c	51 d	41.5 cd	15.6 cd	9.3 abc
G	0.76 d	8.0 d	45 de	19.5 d	9.6 d	6.3 bc
WD	0.68 d	6.9 d	23 e	12.3 d	6.1 d	5.3 c
Mean	1.05	11.5	0.6	60.5	23.3	9.7
LSD	0.09	1.7	0.1	29.7	12.2	4.9
CV (%)	3.2	5.4	7.5	17.4	18.6	18.1

Irrigation in vegetative, flowering and grain formation (VFG). Irrigation in vegetative and flowering (VF). Irrigation in vegetative and grain formation flowering (VG). Irrigation at vegetative stage (V). Irrigation in flowering and grain formation (FG). Irrigation at flowering stage (F), irrigation in grain formation stage (G). Water deficit (WD). LSD = Least Significant Difference. CV (%) = Coefficient of Variation. Means followed by different letters, in the column, indicate significant differences at 1% probability by Tukey test.

The morphometric behavior of specific treatments was strictly dependent on the availability of water irrigation due to rainfall distribution during the crop cycle. Indeed, the irrigation application after the beginning to the end of the vegetative stage (FG, F and G) resulted in low increase in the morphometric variables evaluated when compared to treatments that received irrigation until the end of the vegetative period. More pronounced decreases on these variables were observed in treatments with water management where safflower received no irrigation at vegetative stage (V), which resulted in reduction of aerial growth. It is true, since the vegetative stage constitutes a growth phase of vital importance for safflower, if it is severely affected by water stress (HUSSAIN et al., 2015).

The other aerial characteristics, heads number, fresh mass of the heads, dry mass of the heads, fresh mass of the stem and dry weight of the stem (Table 3) were less sensitive in comparison to water deficit in vegetative period. The heads number, dry mass of the heads and dry mass of stem were reduced by the irrigation suspension only at the grain filling stage. Thus, it is evident that safflower growth was not severely affected by the different water management, except in the water deficit treatment. Omid et al. (2012) found that the heads number was more affected than the grain yield when irrigation was interrupted in the early stages, as was also reported by Movahhedy-Dehnavy, Modarres-Sanavy and Mokhtassi-Bidgolet (2009). Shahrokhnia and Sepaskhah (2017) observed that the sensitive growth phase was stem elongation. Similar results were found by Singh et al. (2016a) in the southern plains in New Mexico, USA, where gradual increase of irrigation resulted in an increase in the height of safflower genotypes.

Table 3. Number of heads (NH), fresh mass of the heads (FMH), dry mass of the heads (DMH), fresh mass of the stem (FMS), dry weight of the stem (DMS) of safflower under water regimes.

Treatments	NH	FMH (g)	DMH (g)	FMS (g)	DMS (g)
VFG	31.3 a	153.5 abc	60.1 a	189.4 a	67.8 ab
VF	34.6 a	186.6 ab	77.4 a	184.1 a	70.0 ab
VG	36.6 a	209.7 a	77.7 a	216.1 a	87.2 a
V	30.3 a	155.6 abc	54.8 a	169.5 a	54.1 ab
FG	30.3 a	191.6 ab	76.5 a	183.2 a	67.5 ab
F	30.3 a	163.9 abc	69.2 a	135.2 ab	59.3 ab
G	13.3 b	72.3 bc	24.8 b	41.7 b	17.5 c
WD	8.3 b	48.1 c	17.5 b	27.5 b	10.2 c
Mean	26.7	165.2	57.2	143.3	54.2
LSD	11.3	128.6	28.2	112.9	29.1
CV (%)	15.0	30.8	17.4	27.8	19.0

Irrigation in vegetative, flowering and grain formation (VFG). Irrigation in vegetative and flowering (VF). Irrigation in vegetative and grain formation flowering (VG). Irrigation at vegetative stage (V). Irrigation in flowering and grain formation (FG). Irrigation at flowering stage (F), irrigation in grain formation stage (G). water deficit (WD). LSD = Least Significant Difference. CV (%) = Coefficient of Variation. Means followed by different letters indicate significant differences at 1% probability by Tukey test.

The accumulation of fresh and dry matter of the root system (Table 4) was strongly affected by the irrigation suspension, especially after flowering, with reduction of 169 and 90% of fresh and dry weight, respectively, for irrigation throughout the cycle. Low accumulation of matter observed by the root and shoot is related to absorption of nutrients, especially nitrogen, whose absorption, accumulation, partitioning and translocation rates in safflower plants are affected in water deficit conditions (DORDAS; SIOULAS, 2009). Decrease in the root system and relative growth rate were observed for safflower genotypes in water deficit conditions (HOJATI et al., 2011).

Table 4. Fresh mass (FMR) and dry mass (DMR) roots, yield, 100-Weight, grain yield, oil content and yield oil in safflower under water regimes.

Treatments	FMR (g)	DMR (g)	100-Weight (g)	Yield (kg ha^{-1})	Oil (%)	Oil yield (kg ha^{-1})
VFG	25.2 a	9.5 a	3.5 ab	1313 a	37.9 a	462 a
VF	9.3 bc	5.0 b	3.4 ab	895 b	36.0 ab	300 b
VG	10.3 b	5.3 b	3.1 ab	448 c	32.9 c	137 c
V	5.6 bcd	3.2 bc	2.8 b	312 d	30.2 d	87 d
FG	2.6 cd	1.5 cd	3.8 a	408 c	34.5 bc	130 c
F	2.6 cd	1.4 cd	3.2 ab	306 d	30.0 d	85 d
G	2.0 d	1.1 cd	3.1 ab	68 e	27.3 e	17 e
WD	0.4 d	0.4 d	3.0 ab	48 e	26.3 e	11 e
Mean	7.2	3.4	3.2	470	31.9	154
LSD	6.8	2.3	0.9	9.0	2.5	21.2
CV (%)	32.4	23.3	9.8	6.8	2.8	4.7

Irrigation in vegetative, flowering and grain formation (VFG). Irrigation in vegetative and flowering (VF). Irrigation in vegetative and grain formation flowering (VG). Irrigation at vegetative stage (V). Irrigation in flowering and grain formation (FG). Irrigation at flowering stage (F), irrigation in grain formation stage (G).

Water deficit (WD). LSD = Least Significant Difference. CV (%) = Coefficient of Variation. Means followed by different letters indicate significant differences at 1% probability by Tukey test.

The 100-Weight was little affected by water regimes (Table 4), lining up to the results of Singh et al. (2016b) and Omid et al. (2012). According to Koutroubas, Papakosta and Doitsinis (2004), this is due to the translocation of assimilate stored from vegetative parts to the grains for filling. However, there was a 37% difference between the mass of a thousand safflower grains only irrigated in vegetative period (2.81 g) and the water management with irrigation in flowering and grain filling (3.85 g), highlighting the importance of irrigation for grain filling.

The highest yield was obtained from the VFG treatment with 1313 kg ha^{-1} and 31.78 g, respectively (Table 4). Yield in the treatments with restriction was dependent on the period of restriction, rainfall and its distribution during the cultivation period. When safflower cultivation occurred in the Turkey winter, with irrigation, Istanbulluogh et al. (2009) reported the seeds production with 5220 kg ha^{-1}. Yield was more affected when the irrigation restriction occurred before flowering. Singh et al. (2016b) also observed variation among irrigation treatments and cultivars, with maximum yield of 2300 kg ha^{-1} for the fully irrigated. The yield was more affected when the irrigation restriction occurred before flowering. The yield reduction increases as water shortage occurred earlier in the crop cycle; however, the water amount applied per irrigation was smaller. According to Omid et al. (2012), the reduction in water availability led to a penalty in grain yield of 10 to 38%, as function the growth stage of flower bud formation and early flowering.

Treatment with water availability throughout the vegetative and flowering period produced 895 kg ha^{-1} of grain yield. The V treatment (irrigation only at the vegetative period) presented the lowest yield (312 kg ha^{-1}). The highest productivities occurred when irrigation was before flowering (Table 4). The water deficit (WD) treatment only received rainwater and production reached only 48 kg ha^{-1}. Safflower yield data in different areas of dry farming from 1000 to 3300 kg ha^{-1} were obtained in Potenza in Italy (LOVELLI et al., 2007), and Orissa in India (KAR; KUMAR; MARTHA, 2007). However, water deficit (WD) crop yield obtained in the present study is lower than published in these works, which should be related to the soil fertility and climate conditions of each region. The water amount available for the crop is therefore a key factor in the yield determination.

Regarding the oil content (Table 4), it is verified that the water regime with irrigation only in the vegetative stage and flowering did not reduce the oil content, whose contents in the best conditions are within the 35–45% range. However, in relation to water deficit, there was a 43% reduction in the oil content for safflower irrigated during the whole cycle. Reduction of safflower oil content with increased drought was reported by Santos et al. (2018), despite the oil content does not correlate strongly with the grain yield, which is due to maximum transfer of assimilates for seed development instead of producing more vegetative parts and grains, which is common in the literature. Omid et al. (2012) reported no effect of irrigation regimes in safflower oil content.

Oil yield which constitutes a combination of grain yield and the oil content of grains, has a high influence of grain yield (OMIDI et al., 2012), as observed in the present study, with 54% reduction for irrigation only in the vegetative and flowering in relation to safflower irrigated in vegetative and flowering (Table 4). Koutroubas, Papakosta and Doitsinis (2009), as observed in the present study with 54% reduction for irrigation only in the vegetative and flowering in relation to safflower irrigated in vegetative and flowering. Mohammadi et al. (2018) observed that water deficit decreased the yield of seeds and safflower oil and that safflower cultivars demonstrated different water stress reactions.

Safflower cultivation period in this experiment reached almost six months, which led to a larger sum of water volume to complete the cycle (Table 5). However, it is apparent that the rains on the experimental cultivation period were low and practically 2/3 of the total volume precipitated at the end of the cultivation period. This contributed little to the final production increase.

Table 5. Period of each growth stage, accumulated water (I + $rainfall_t$), rainfall ($rainfall_p$), applied irrigation (irrigation), reference evapotranspiration (ETo), total water yield (WPt) and irrigated water (WPi) in safflower under water regimes.

Treatments	Period (days)	I + $rainfall_t$ (mm)	$Rainfall_p$ (mm)	Irrigation (mm)	ETo (mm)	WPt (kg m$^{-3)}$	WPi (kg m$^{-3)}$
VFG	167	606	186	420	4868	0.33	0.48
VF	137	550	88	364	375	0.29	0.44
VG	135	515	178	329	425	0.20	0.32
V	105	459	81	273	314	0.19	0.33
FG	63	333	104	147	172	0.23	0.54
F	33	277	7	91	61	0.24	0.75
G	30	242	97	56	111	0.19	0.82
WD	167	186	186	0	486	0.14	-

Irrigation in vegetative, flowering and grain formation (VFG). Irrigation in vegetative and flowering (VF). Irrigation in vegetative and grain formation flowering (VG). Irrigation at vegetative stage (V). Irrigation in flowering and grain formation (FG). Irrigation at flowering stage (F), irrigation in grain formation stage (G). water deficit (WD).

The concept of applied water effici ency use concerns the relation between the production of a particular culture and the water amount required to achieve its desired production. Although safflower is one of these cultures with production capacity using smaller water amounts, by the research results, it is possible to verify that there was a reduction in the mass production of grains with the reduction in water volume applied (Table 5).

It is verified that the total precipitation is considered low for the culture development, while the precipitation distribution during the experimental period was irregular. In the period in which the culture most needed water, which is considered the flowering period, it was precisely the period of lower precipitation, respectively 7.6 mm in 33 days. In the following month (September), there was 97 mm in the treatment period (G).

Analyzing the yield and irrigated water, it seems that the VG and the V stages were the ones that least responded to water volume application, because at such stages there were minor increases in grain yield (Table 5), that is, greater decrease of irrigated water yield with the water volume depth applied. In general, grain yield decreases with the reduction in irrigation depth, but the total of both water yield and irrigated decreased with the application of larger water depths.

Therefore, if the safflower production purpose is the maximum yield per area, with no water use limitation, it should be positively affected/reached when irrigation aimed at fully supply the crop water requirement. On the other hand, if the objective is maximum efficiency of water use, then some lack of irrigation should be considered and correspond to the maximum economic efficiency (PEREIRA et al., 2002). When the limitation is not the cultivation area, but the water amount available, lower water in deeper layers along the soil profile should be adopted. Even when the grain yield per area is smaller, it produces higher grains amounts in relation to a determined water amount applied. The results from different conditions of climate and soil, different sowing times and cultivars showed that safflower has seasonal water consumption in a range of 200–1000 mm (DOORENBOS; KASSAM, 1979).

The performance of yield and production components, in general, tended to be greater when irrigation occurred at VG stage. It is noticed that, at this period, the amount of rainfall was only 7.6 mm lower than the irrigated treatment in all stages (VFG). This shows that the 30 days without irrigation in the flowering period was beneficial to the safflower morphometric performance, however, it has not meant higher final grain yield. With irrigation applied separately in F and G treatments, it is possible to verify that the morphometric gain and production was higher when the irrigation occurred at stage (F) compared to G.

6 CONCLUSIONS

Safflower is benefited by irrigation in the vegetative period; however, irrigation is also effective when applied in the flowering period in treatment under water deficit. The water shortage due to the irrigation restriction during the vegetative stage reduces morphological safflower growth components. Safflower oil content does not depend on irrigation in grain filling. The grain and oil yield is affected by water restriction in all safflower cultivation stages.

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