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ECONOMIC AND ENERGY VIABILITY OF SUNFLOWER IRRIGATED CROP

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KEYWORDS

Helianthus annuus L., operating cost of production, energy depreciation, central pivot.

ABSTRACT

This study was carried out with the objective of assessing grain yield, economic analysis and energy balance of three sunflower genotypes with and without irrigation. The experiment was installed in the Experimental Farm of the Faculty of Agrarian Sciences of the Federal University of Grande Dourados in the 2011/2012 and 2012/2013 harvests in Dourados-MS, Brazil. The experimental design used was a random complete block design with subdivisions, with and without irrigation (plots), with three genotypes (subplots) and four replications, constituting 24 plots. There were no differences in productivity among the genotypes. The irrigation increased the operational cost of the sunflower crop production, but it did not economically obstruct the activity, due to the increase of productivity of 74.5% and 30% in the harvests of 2011/2012 and 2012/2013. The energy ratios of the sunflower crop were not altered by irrigation, equal to 5.7 and 8.7 in the harvests of 2011/2012 and 2012/2013, respectively.

INTRODUCTION

Among the several technologies developed for the sunflower production, the appropriate choice of genotype with high grain yield comprises the main component of the crop production system (Porto et al., 2007). Despite the tolerance to water deficit when compared to other annual crops, sunflower is sensitive to the availability of water in the soil, increasing grain yield under irrigation (Gomes et al., 2012).

The sunflower culture shows national average productivity of 1500 kg ha^{-1} (AGRIANUAL, 2012). However, if adequately managed, the productivity may increase to 1500 to 2200 kg ha^{-1} (Dos Santos et al., 2016; Oliveira et al., 2014; Porto et al., 2007). Under irrigation, grain yield is generally in the range of 2200 to 3000 kg ha^{-1} (Biscaro et al., 2008; Gomes et al., 2010; Guedes Filho et al., 2015; Schwerz et al., 2015), and can reach more than 4000 kg ha^{-1} in favorable soil and climatic conditions (Gomes et al., 2010; De Aquino et al., 2013), being able to reach 4.000 kg ha^{-1} in favorable edaphoclimatic conditions (Karam et al., 2007; Anastasi et al., 2010; Gomes et al., 2012).

Since the adoption of the National Program for the Production and Use of Biodiesel, introduced in 2005, it has been growing the oilseed production in the country, especially in family agriculture (there are incentives to the overwhelming power plants that buy from this sector); however, different from the expectation of diversification, soybean cultivation continues to predominate (Silva, 2013). With technical assistance and structured production chain, sunflower cultivation could become an interesting alternative in the summer harvest, with higher oil productivity (Jasper et al., 2010) and lower production costs in relation to soybean (AGRIANUAL, 2012).

In addition to economic viability, studies of the energy ratio in different production systems can provide subsidies for the Brazilian agriculture to become increasingly sustainable (Capellesso & Cazella, 2013). The energetic ratio can be obtained by the energy value of the productivity on all the energy expenditures coming from the implantation of the culture, being an important instrument of technological choice (Assenheimer et al., 2009), avoiding and replacing the genotypes and productive systems with relation less than one (Albuquerque et al., 2007).

Irrigation is among the technologies that most contributes to the increase of productivity (Lira et al., 2015; Pereira et al., 2015); however, it also increases the input (consumption) of energy in the agricultural system. In this sense, some studies have been carried out over the last years aiming to analyze the energetic ratio of irrigated crops (Gomes et al., 2013, Jordan et al., 2012a; Jordan et al., 2012b).

This experiment was developed with the objective of performing economic analysis and energetic ratio of

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sunflower genotypes for two years, with and without irrigation, in the region of Dourados, Mato Grosso do Sul, Brazil.

MATERIAL AND METHODS

The experiment was carried out at the Experimental Farm of the Faculty of Agricultural Sciences - FCA, Federal University of Grande Dourados - UFGD, in Dourados, Mato Grosso do Sul, located at the geographical coordinates 22°12' south latitude, 54°56' west longitude and average altitude of 452 m.

The climate of the region is classified by Köppen as Cwa (humid mesothermic with rainy summer). The soil of the experimental area is classified as Red Latosol Distroferric (EMBRAPA, 2006). The values of the chemical analysis of the soil referring to the depth of 0 - 0.20 m are found in Table 1.

TABLE 1. Chemical analysis of the soil in the 0 – 0.20 m layer of the experiment with irrigated and non-irrigated sunflower in the years 2011/2012 and 2012/2013.

	pH ($CaCl_2$)	P	V	$H^+ + Al^{3+}$	Al^{3+}	Ca^{2+}	Mg^{2+}	K^+
Experiment		mg dm^{-3}	%	-------------- $cmol_c\ dm^{-3}$				-------------
2011/2012	5.00	15.20	62.0	5.76	0.08	6.66	2.21	0.53
2012/2013	5.00	11.20	64.5	4.90	0.05	6.59	2.25	0.37

For two years, the experimental area was prepared with plowing and harrowing, 30 days before sowing, incorporating 1500 kg ha^{-1} and 1000 kg ha^{-1} of dolomitic limestone PRNT 80%, respectively, aiming to raise the base saturation by 70% (V). Afterwards, the irrigation system and the tensiometers were installed. In the sowings carried out on October 22nd, 2011 and October 31st, 2012, 150 kg ha^{-1} of the 8-20-20 formulation and 1 kg ha^{-1} of boron in the form of borax were also applied. In the cover fertilization, 40 days after sowing (DAS), 50 kg ha^{-1} of nitrogen in the form of urea was also applied.

The same experimental design was utilized in both years: random blocks, in schemes of subdivided plots, with and without irrigation (plots), with three genotypes (subplots) and four repetitions, comprising 24 plots. The plots were implanted with an area of 36 m^2, (15 m x 2.4 m), with four plant rows spaced in 0.60 m and with spacing between plants of 0.2 m. The subplots were implanted with 12 m^2 (5 m x 2.4 m). It was utilized genotypes from EMBRAPA: BRS 321, EMBRAPA 122 V2000 and BRS 323.

The irrigation system was assembled using three lines of dripping tapes between the plant rows, with spacing between the emitters of 0.40 m and drain of 3.65 L h^{-1} m^{-1}, to 100 kPa of service pressure, obtaining an application intensity of 6.1 mm h^{-1}. The service pressure was maintained by means of a drawer register installed next to a pressure gauge with a resolution of 5 kPa.

Irrigation management was done from tensiometers installed at 0.2 m depth. The irrigation depth (ID) was determined by the difference between volumetric moisture in the field capacity (θ_{cc}) and the current volumetric humidity (θ_a), multiplied by the effective depth of the root, equal to 400 mm. The volumetric humidity was estimated by means of the soil water retention curve ($\theta a = 0.4394\ \gamma^{-0.077}$; $R^2 = 0.981$). It was considered as soil water stress in the field capacity (γ_{cc}) the value of 6 kpa. Irrigation was suspended at 90 DAS (R8 stage - back of the yellowish chapter and green bracts).

Table 2 shows the values of temperature, relative humidity, rainfall and irrigation in the experimental periods. Irrigated treatments received 270.9 mm and 290.5 mm of water depth in the first and second year, respectively.

TABLE 2. Temperature (T), relative humidity (RH), precipitation (P) and irrigation (I) during experimental cycles of sunflower cultivation *.

Period DAS	$T_{11/12}$ (°C)	$T_{12/13}$ (°C)	$UR_{11/12}$ (%)	$UR_{12/13}$ (%)		$P_{11/12}$ (mm)	$P_{12/13}$ (mm)	$I_{11/12}$ (mm)	$I_{12/13}$ (mm)
0-20	24.2	25.5	65.6	69.7		87.8 (5)	50.0 (4)	0	39.7
21-40	24.4	26.9	66.3	72.6		139.6 (5)	112.6 (4)	59.8	75
41-60	25.1	26.5	61.1	75.2		33.8 (2)	48.6 (4)	97.5	76.8
61-90	26.4	25.1	66.9	73.8		110.8 (3)	76.6 (4)	113.6	99.0
91-110	25.8	25.7	73.1	76.1		104.4 (3)	141.1 (5)	0	0
Average:	25.2	25.9	66.6	73.5	Total:	476.4	428.9	270.9	290.5

At the end of the cycles, on February 10th, 2012 and February 18th, 2013, 06 plants were removed per subplot with the objective of evaluating productivity, correcting seed moisture to 13%. The productivity data were submitted to analysis of variance and Tukey test at 5% of probability.

The economic analysis was made based on the total production operating cost (TPO) and the effective operating cost (EOC), using market quotations. In the composition of the EOC it was considered the expenses with inputs, labor, electric energy in the case of irrigation, tax and revenue expenses. TPO was obtained by adding EOC plus capital depreciation (Martin et al., 1994).

$$EOC = CI + MC + TOR + EOR + LC + CE \quad (1)$$

where,

EOC - effective operating cost, R\$ ha^{-1};

CI - cost of inputs, R\$ ha^{-1};

MC - maintenance cost, R\$ ha^{-1};

TOR - tax on revenue, R\$ ha^{-1};

EOR - expenditure on revenue, R\$ ha^{-1};

LC - labor cost, R\$ ha^{-1},

CE - cost of electricity, R\$ ha^{-1}

$$TPO = EOC + CD \quad (2)$$

where,

TPO - total production operational cost, R\$ ha^{-1};

EOC - effective operational cost, R\$ ha^{-1},

CD - capital depreciation, R\$ ha^{-1}

Because it is a self-propelled system (central pivot simulation), it was not considered a labor increase due to irrigation. In the region there is still no charge for the use of water.

From the applied irrigation depth, the simulation was based on the power, mechanical efficiency and power factor of the electric motor of a central pivot water pump for 100 ha with flat topography, with electrical power required for pumping the order of 1.472 kW ha^{-1}, which is considered in the calculation of the energy cost. It was also considered an application intensity of 0.43 mm h^{-1} and maintenance cost (MC) for central pivot estimated at 1.5% per year (Frizzone et al., 2005). The electric power was taxed according to the green horticultural price, adopting the energy prices (EP) established by CERGRAND (Cooperative of Energizing and Rural Development of Grande Dourados) equal to R\$ 0.2103 kWh^{-1} in the off-peak period with a discount of 80% from 9:30pm to 6:00am (R\$ 0.0421 kWh^{-1}). The monthly contracted demand rate (CDR), equal to R\$ 13.96 kW^{-1}, was converted to R\$ 20.55 ha^{-1} $month^{-1}$. It was considered a variable watering time for water depth equal to 9 mm, with irrigation time of 21 hours, avoiding peak time (5:30pm to 8:30pm) and obtaining, by weighted average, EP equal to R\$ 0.1424 kWh^{-1}. The energy cost was estimated as follows:

$$CE = (1.472 \times EP \times IT) + CDR \quad (3)$$

where,

EP - energy price, R\$ kW h^{-1};

IT - Irrigation time per production cycle, h,

CDR - contracted demand rate (R\$ ha^{-1})

The effective operating profit (EOP), which represents the economic viability in the short term, was obtained by the difference between the revenue (REV) and the effective operating cost (EOC):

$$EOP = REV - EOC \quad (4)$$

where,

EOP - effective operational profit, R\$ ha^{-1},

REV - revenue, R\$ ha^{-1}

Total operating profit (TOP), which represents long-term economic viability, was obtained by the difference between gross revenue (GR) and total production operating cost (TPO):

$$TOP = REV - TPO \quad (5)$$

where,

TOP - Total operational profit R\$ ha^{-1}

Capital depreciation (CD) was calculated using the capital recovery factor method (Tokairin et al., 2014), disregarding the residual value. In the case of irrigated plots, the irrigation system of the Central- Pivot type was considered (being the most used in irrigation of crops in the region), admitting a value of R\$ 5500.00 ha^{-1}, according to average practiced price in 2011, using an interest rate (R) of 7.5% per year. For the Central-Pivot, it was used a 20-year life span (n) and use capacity equal to 2000 h $year^{-1}$ (Frizzone et al., 2005). For the other machines and equipment, life values were adopted according to Pacheco (2000).

$$CD = \left[\frac{C \times R(R+1)^n}{(1+R)^n - 1}\right] \times F \quad (6)$$

where,

CD - capital depreciation, R\$ ha^{-1};

C - capital cost acquisition, R\$ ha^{-1};

R- annual interest rate, decimal;

n - life span, years,

F - ratio between hours of use per cycle and hours per year, decimal

The energy viability analysis was performed using energy relations using the process analysis methodology (Hülsbergen et al., 2001):

$$ER = \frac{EE}{UE} \quad (7)$$

where,

ER – energetic relationship, dimensionless;

EE - extracted energy, MJ ha^{-1},

UE - utilized energy, MJ ha^{-1}

The UE was estimated as follows:

$$UE = ED + EI + EML + EEL \quad (8)$$

where,

ED - Energy depreciation of equipment, MJ ha^{-1};
EI - Energy demand for the use of inputs, MJ ha^{-1};
EMO - energy employed in manual labor, MJ ha^{-1},
EEL - energy consumed in the form of electricity, MJ ha^{-1}

The energy required for the use of inputs was adopted according to values recommended by Hülsbergen et al. (2001) and Melo et al. (2007). Energy depreciation

(ED) was estimated as recommended by Assenheimer et al. (2009), in the case of non-propelled equipment (implements):

$$ED_{NPE} = \frac{57.2M}{n} H \quad (9)$$

In the case of the propelled equipment (tractor and center pivot) the ED was calculated as follows:

$$ED_{PE} = \frac{69.8M}{n} H \quad (10)$$

where,

ED_{NPE} - energy depreciation of non-propelled equipment, MJ ha^{-1};

ED_{PE} - energy depreciation of propelled equipment, MJ ha^{-1};

M - mass of machinery and equipment, kg,

n - life span, h

H – usage time per cycle, h

The mass of machines and equipment was adopted as recommended by Assenheimer et al. (2009) and the life span according to Chechetto et al. (2010). The mass of the central pivot irrigation system, equal to 57.2 kg m^{-1}, was obtained according to information from Valmont Industry and Commerce Ltd.

RESULTS AND DISCUSSIONS

Productivity was affected by irrigation and harvests (P <0.05) independent of the cultivated genotype (P> 0.05). The highest yields were obtained in the 2012/2013 crop (Table 3), probably due to more favorable edaphoclimatic conditions (Tables 1 and 2), such as elevation of base saturation (V), higher temperature and better distribution of rainfall, mainly from 41 to 60 DAS (stage R4 - opening of the inflorescence).

The yields of sunflower obtained under irrigation are above the values found by Guedes Filho et al. (2015) and Biscaro et al. (2008), both in second crop cultivation (small harest). In the 2012/2013 harvest, productivity under irrigation approached the mark of 4.000 kg ha^{-1}, surpassed in other surveys conducted in the first harvest (Anastasi et al., 2010, Gomes et al., 2012).

TABLE 3. Productivity of sunflower genotypes* in the 2011/2012 and 2012/2013 harvests with and without irrigation.

Systems / crops	BRS 323	BRS 321	E122 V2000	Averages**
	………………………………………(Kg ha^{-1})	………	………	………
With irrigation	3046 a	2955 a	3253 a	3085 a
Without irrigation	2238 b	1489 b	1576 b	1768 b
Crop 2011/2012	2642 A	2222 A	2415 A	2426 A
With irrigation	3328 a	4375 a	3867 a	3857 a
Without irrigation	2872 b	2879 b	3144 b	2965 b
Crop 2012/2013	3100 B	3627 B	3501 B	3411 B

* There weren't significant differences in yield between genotypes.
** Meaningful differences between systems (small letters) and between crops (capital letters).

Considering the irrigation depths applied in the two years of experiment equal to 270.9 mm in 2011/2012 and 290.5 mm in 2012/2013 (Table 2), adopting application intensity of 0.43 mm h^{-1}, it was obtained in their respective years the irrigation time (IT) equal to 630 and 676 hours. Applying the equation 03, considering the energy price (EP) of R$ 0.1424 kWh^{-1} and the contracted demand cost (CDC) equal to R$ 20.55 ha^{-1} month^{-1}, during the harvests 2011/2012 and 2012/2013 the energy costs (EC) for irrigation was equal to R$ 234.81 ha^{-1} and R$ 244.45 ha^{-1}, respectively.

Table 4 shows the prices of the inputs used in sunflower cultivation in the two years of experiment, equal to R$ 619.19 in 2011 and R$ 599.30 in 2012. Table 5 shows the capital depreciation of the machinery and implements, equal to R$ 62.10 per year. The used time of the plow and grid was measured at the site. In the treatments that received irrigation, it was also considered the depreciation of the Central- Pivot type system, equals to R$ 169.83 in 2011/2012 and R$ 181.16 in 2012/2013.

TABLE 4. Prices of Input used in the sunflower crops*.

	Unit ha^{-1}	Unit price 2011 (R$)	Total price 2011 (R$ ha^{-1})	Unit price 2012 (R$)	Total price 2012 (R$ ha^{-1})
Formulated 8-20-20 (kg)	150	1.149	172.35	0.996	149.40
Dolomitic limestone (kg)	1500 (1000)*	0.083	124.50	0.130	130.00
Urea (kg)	111	1.136	126.10	1.100	122.10
Bórax (kg)	1	4.000	4.00	4.000	4.00
Diesel (L)	60	2.180	130.80	2.180	130.80
Seeds (kg)	4.6	7.500	34.50	7.500	34.50
Desiccant (L)	3	7.100	21.30	7.000	21.00
Inseticide (L)	0.1	56.400	5.64	75.000	7.50
			619.19		599.30

TABLE 5. Capital depreciation and maintenance cost of machines, implements and irrigation system.

Machines and Implementation	Usage of Time (h ha^{-1})	Cost (R$)	Life Span	CD (R$ ha^{-1})	MC** (R$ ha^{-1})
Scrubber	0.33	18000	10 years (200 h year^{-1})	2.91	1.49
Plow	2.00	6250	5 years (400 h year^{-1})	3.07	3.13
Grid	0.50	15500	5 years (400 h year^{-1})	1.90	1.94
Seed Drill	0.42	24000	5 years (240 h year^{-1})	4.12	4.20
Pulverizer (Spray)	0.40	9300	5 years (240 h year^{-1})	1.52	1.55
Tractor 75 cv	4.19	85000	10 years (1000 h year^{-1})	32.18	16.41
Harvester 140 cv	0.44	380500	10 years (1000 h year^{-1})	16.42	8.37
Irrigation (Central Pivot)	630(672*)	5500***	20 years (2000 h year^{-1})	169.83 (181.16*)	25.99 (27.72*)
Total with irrigation				62.10	37.09
Total without irrigation				231.93 (243.26*)	63.08
			(64.81*)		

(*) related to the crop 2012/2013; **[(50% acquisition cost (R$) x usage of time (h ha^{-1}) / life span (h)]; *** cost per hectare

The table 6 shows the average values of productivity (PROD), revenue (REV), tax (TAX) and expenditure on revenue (EOR) for sunflower genotypes, with and without irrigation. The REV was obtained from the prices practiced in the months of February 2012 and 2013, when the sunflower sacks were sold at R$ 47.32 and R$ 55.47, respectively.

TABLE 6. Productivity, income, tax and expenses of sunflower cultivation with and without irrigation in the harvests of 2011/2012 and 2012/2013.

Sunflower Genotypes	$PROD_{11/12}$ (kg ha^{-1})	$PROD_{12/13}$ (kg ha^{-1})	$REV_{11/12}$ (R$ ha^{-1})	$REV_{12/13}$ (R$ ha^{-1})	$TAX_{11/12}$ (R$ ha^{-1})	$TAX_{12/13}$ (R$ ha^{-1})	$EOR_{11/12}$ (R$ ha^{-1})	$EOR_{12/13}$ (R$ ha^{-1})
With irrigation	3085(51.4)	3857(64.3)	2432.25	3566.72	55.94	82.03	121.61	178.34
Without irrigation	1768(29.5)	2965(49.4)	1395.94	2740.22	32.11	63.03	69.78	137.01

For the composition of the effective operational cost - EOC (Table 07), the labor expense was considered from the work of two employees in the agricultural operations (4.63 hours each, equal to the time used of the tractor plus harvester - Table 05), considering the work hour of each equal to R$ 9.38 (R$ 1500.00 month^{-1}), obtaining R$ 86.81 ha^{-1}. The revenue tax (TAX) and revenue on expenses (EOR) were obtained by applying percentages of 2.3% and 5% of revenues (REC), respectively (equation 01).

TABLE 7. Costs and operating profits from sunflower cultivation in the harvests of 2011/2012 and 2012/2013.

Sunflower Genotypes	$EOC_{2011/12}$ (R$ ha^{-1})	$EOC_{2012/13}$ (R$ ha^{-1})	$TPO_{2011/12}$ (R$ ha^{-1})	$TPO_{2012/13}$ (R$ ha^{-1})	$EOP_{2011/12}$ (R$ ha^{-1})	$EOP_{2012/13}$ (R$ ha^{-1})	$TOP_{2011/12}$ (R$ ha^{-1})	$TOP_{2012/13}$ (R$ ha^{-1})
With irrigation	1181.44	1255.74	1413.37	1499.00	1250.81	2310.98	1018.88	2067.72
Without irrigation	844.98	923.24	907.08	985.34	550.96	1816.98	488.86	1754.88

The irrigation increased the effective operating cost (EOC) of production by 41% and 36% in the 2011/2012 and 2012/2013 harvests, respectively. The increase in total production operational cost (TPO) with irrigation was 56% and 52% in the 2011/2012 and 2012/2013 harvest seasons, respectively. These costs were offset by increased productivity under irrigation, with increases of 127% and 27% for effective operational profit (EOP) in the harvests of 2011/2012 and 2012/2013, respectively (equation 04). The total operating profit (TOP) under irrigation obtained an increase of 108% and 18% in the harvests of 2011/2012 and 2012/2013, respectively (equation 05).

These results make feasible the irrigation technique in short (EOP) and long term (TOP). Guedes Filho et al. (2015), conducting the sunflower experiment under irrigation with the genotype EMBRAPA 122/V-2000, reached an average productivity of 2494 kg ha^{-1} with 100 kg ha^{-1} de N, and observed viability only in the short term. At the time the value of the bag was R$ 31.80.

At the current conjuncture, it seems unlikely the long term economic inviability for irrigated sunflower cultivation, since only the activity would become impracticable at a price lower than R$ 27.50 a bag, or else (if the price of the bag remains at R$ 50.00) with the productivity less than 30 bags ha^{-1} (1800 kg ha^{-1}).

The energy used in sunflower cultivation through inputs was 8564.76 and 7964.76 MJ ha^{-1} (average value as 8265 MJ ha^{-1}), in the harvests of 2011/2012 and 2012/2013, respectively (Table 8), that is, 98.8% of the average energy used (EU) without irrigation (Table 11). Jordan et al. (2012a) also found that inputs were responsible for more than 90% of the energy demand in sunflower cultivation without irrigation. In general, inputs are mainly responsible for energy demand in conventional agriculture (Checheto et al., 2010; Gomes et al., 2013).

TABLE 8. Energy demanded for the use of inputs (EI) used in sunflower cultivation.

Input	Unit	Energy Unit (MJ)	Quantity (unit ha^{-1})	EI (MJ ha^{-1})
Nitrogen (N)	kg	50.3	62	3118.6
Phosphorum (P_2O_5)	kg	12.6	30	378
Potassium (K_2O)	kg	6.8	30	204
Boron	kg	15.35	1	15.35
Dolomitic Limestone	kg	1.2	1500 (1000*)	1800
Diesel	L	35.5	47.7	1693.35
Treated seeds	kg	25.1	4.6	115.46
Inseticide	L	400	0.1	40
Desiccant	L	400	3	1200
Total				8564.76 (7964.76**)

(*) Quantity used in the 2012/2013 harvest; (**) energy by the use of inputs employed in the 2012/2013 harvest.

The average energy used (EU) to produce the sunflower crop without irrigation was 8365 MJ ha^{-1} (Table 10), with 100.03 MJ consumed in the form of energy depreciation (Table 9), 9 MJ of energy of hand of (EHO). In the estimation of EHO it was considered a daily requirement (8 hours) of 2000 kcal (8.38 MJ), with 4.3 hours of work (the same as machine hours), employing two employees in agricultural operations.

TABLE 9. Energy depreciation (ED) as a function of the time using machines and equipment used in the cultivation of sunflower in a conventional system.

Machines - implements	Mass (kg)	Life span (h)	Usage of time (h)	ED (MJ ha¹)
Pulverizer (Spray)	110	1200	0.4	2.10
Plow	402	2000	2	22.99
Grid	1422	2000	0.5	20.33
Seed Drill	899	1200	0.42	20.02
Cultivator	493	2000	0.54	7.61
Tractor 75 cv	899	10000	3.86	24.22
Harvester 140 cv	899	10000	0.44	2.76
Total				100.03

Table 10 shows the energy consumed by irrigation in the form of electric energy (EEL) and energy depreciation (ED), adding an average energy demand of 3827 MJ ha^{-1}, that is, an increase in consumption Energy consumption of 45.8% due to irrigation, mainly because of electricity.

TABLE 10. Energy spend in the form of electricity (EEL) and energy depreciation (ED) in the irrigation system

Year	Irrigation (mm)	Time used (h)	EEL (kWh ha¹)	EEL (MJ ha¹)	ED (MJ ha¹)
2011/2012	270.9	630	927.36	3338.50	354.78
2012/2013	290.5	676	994.46	3580.06	380.69

The highest energy ratio was obtained in the 2012/2013 harvest ($p < 0.05$); however, without effect under irrigation ($p > 0.05$) (Table 11). Contrary behavior was verified by Jordan et al. (2012a), in a study conducted with the sunflower crop, where the energy ratio was lower with irrigation.

TABLE 11. Used energy (UE), extracted energy (EE), energy ratio (ER) with and without irrigation in the sunflower crop.

Genotype	$UE_{11/12}$ (MJ ha¹)	$EE_{11/12}$ (MJ ha¹)	$ER_{11/12}$	$UE_{12/13}$ (MJ ha¹)	$EE_{12/13}$ (MJ ha¹)	$ER_{12/13}$
With irrigation	12358	77434	6.27 Aa	12026	96811	8.05 Ab
Without irrigation	8665	44377	5.12 Aa	8065	74422	9.23 Ab

Capital letter: among systems; small letter: among crops.

CONCLUSIONS

1. The sunflower genotypes showed similar yields in both years;
2. The cultivation of the irrigated sunflower crop is economically viable in a short and long term;
3. The irrigation does not alter the energy ratio of the sunflower crop;
4. The highest economic return and higher energy ratio occurs in the 2012/2013 crop due to higher yield.

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