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Analysis of Energy and Economic Efficiency of Irrigated Canola Production in Brazilian Central-West Region

Eder P. Gomes[1], Carolina Bilibio[2], Oliver Hensel[2], Arthur C. Sanches[1], Cesar José da Silva[3], Dhiones Dias[1]

[1]Federal University of Grande Dourados, Dept. of Agricultural Engineering, Brazil
[2]University of Kassel, Dept. of Agricultural Engineering, Germany;
[3]Brazilian Enterprise for Agricultural Research , Embrapa Agropecuária Oeste, Brazil

Introduction

Energy efficiency, defined as the ratio between energy produced and energy consumed, is a major tool to assess sustainability of agricultural activities (Alluvione et al., 2011). Energy consumption in Brazilian agriculture increased especially after the Green Revolution, when new technologies such as mineral fertilizers, which tripled in this period, were introduced to production systems (Woods et al., 2010).

Determination of the energy balance in agriculture can be a first step to identify more efficient production processes (Alluvione et al., 2011). Several studies have been done to evaluate the energy efficiency of crops.

Banaeian & Zangeneh (2011) examined energy efficiency of a maize crop in Iran. The authors found that the average efficiency of energy use was 2.59. Pishgar Komleh et al. (2011) found that direct energy accounted for 25% of power consumption in corn silage production and 75% of indirect energy, respectively. Asgharipour et al. (2012) found that 57% of the total energy input in sugar beet production in Iran was direct energy, while the remaining 43% was indirect.

Although studies on energy efficiency in agriculture provide important tools for energy consumption, this study does not cover all aspects of sustainable agriculture. Thus, other areas such as economy and water use (Alluvione et al., 2011) should be included.

Considering the aspects described, a two-year experiment with irrigated canola was conducted at the Federal University of Grande Dourados to assess the economic and energy efficiency of cropping.

Material and methods

The experiment was conducted at the Experimental Station of Irrigation, Faculty of Agricultural Sciences at the Federal University of Grande Dourados from May to September 2012 and repeated from May to September 2013.

We used a randomized block split plot design with three irrigation frequencies, without irrigation - SI, weekly irrigation - IS, irrigation three times a week - I3S, and four repetitions totaling 12 experimental plots. The plots were 3m long x 1.8m wide ($5.4 m^2$) with four plantation lines, 0.45 m between rows and 0.17 m between plants.

The plots were irrigated by drip tapes installed between plant rows. Irrigation management was conducted by reading the water tension in soil tensiometers installed at a depth of 0.20 m.

At the end of each experimental cycle we evaluated the grain yield (kg ha^{-1}) of the Canola. The components were subjected to an analysis of variance at 5% probability. In cases of significant differences we applied the Tukey test.

The economic analysis was based on production operating cost (COT) and effective operating cost (COE), using the market quotes. In the composition of COE we included input costs, agricultural operations, labour, taxes and administrative expenses. COT was obtained by summing the COE and the capital depreciation (Martin et al., 1994).

COT = COE + DC. Where: COT - production operating cost, R$ ha^{-1}; COE - effective operating cost, R$ ha^{-1}; DC - capital depreciation, R$ ha^{-1}

Total operating profit (LOT), which represents long-term economic viability, was calculated by the difference between gross revenue (RB) and total operating cost (COT): LOT = RB – COT. Where: LOT - total operating profit, R$ ha^{-1}

Analysis of energy efficiency was performed through the evaluation of energy inputs, corresponding to energy used, and energy outputs, equivalent to the energy extracted from the agricultural production system: EF = EE/EU. Where: EF - energy efficiency, dimensionless; EE - energy extracted, MJ ha-^{1} ; EU - energy used, MJ ha^{-1}

Results and discussion

There was significant difference between irrigation frequencies by F test at 5% probability for grain yield. The highest yield was obtained with irrigation performed three times a week proportional to 2,982.86 kg ha^{-1}, taking the average of two years.

Effective operating cost, R$ 829.97 ha^{-1} and total operating cost, R$ 1,083.57 ha^{-1}, were obtained from inputs in the experimental area. Effective operating cost and total operating costs increase as irrigation frequency increases (Table 1), which is due to energy expenses and depreciation of the irrigation system. Similar results were found by Gomes et al. (2013), when assessing economic results of bean crop under different irrigation depths in the state of Paraná.

Table 1. Cost and operating profit of canola under different irrigation frequencies in 2012, 2013 and a two year-average

Treatment	Yield (kg ha^{-1})	RB	COE	COT	LOE	LOT
		(R$ ha^{-1})				
			2012			
I3S	3,425.72	2,535.03a	1,162.85	1,581.53	1,372.19	953.51
IS	2,553.51	1,889.60a	1,120.29	1,497.20	769.31	392.40
SI	1,384.03	1,024.18b	829.97	1,083.57	194.21	-59.39
			2013			
I3S	2,540.00	1,879.60a	1,051.46	1,360.80	828.14	518.80
IS	2,049.47	1,516.61a	1,076.22	1,409.88	440.38	106.73
SI	35.82	26.51b	829.97	1,083.57	-803.46	-1,057.06
			Two year-average			
I3S	2,982.86	2,207.31a	1,107.15	1,471.17	1,100.16	736.15
IS	2,301.48	1,703.09b	1,098.26	1,453.54	604.84	249.56
SI	709.93	525.34c	829.97	1,083.57	-304.62	-558.22

LI – irrigation depth; PROD - productivity; RB – gross profit; COE - actual operating cost; COT - total operating cost; LOE - actual operating profit; LOT - total operating profit. Values followed by the same lowercase letter in each row do not differ significantly at 5% probability by Tukey test. *1 US$ = 2.40 R$ in 2014

Energy used (EU) for the non-irrigated canola crop (LI = 0) was 8,695.14 MJ ha^{-1} (Table 2) with 266.6 MJ ha^{-1} consumed in the form of energy depreciation, 8,421.0 consumed as energy demanded by inputs and 7.54 MJ ha^{-1} in the form of energy used in labour.

Due to energy expenses and energy depreciation of irrigated treatments, energy used (EU) was higher in irrigated systems, totalling 14,096.92 MJ ha^{-1} for systems irrigated once a week and 14,560.83 MJ ha^{-1} for systems irrigated 3 times a week, representing use of 62.12% and 67.46% more energy than the non-irrigated treatment, respectively.

Conversely, the energy extracted (EE) corresponding to energy of grain yield was also higher in irrigated systems due to higher yields achieved in these treatments, which ultimately caused a positive net energy gain (GL) (Table 2).

Table 2. Energy used (EU), energy extracted (EE), net energy gain (GL), energy efficiency (EF), specific energy (ES) and EI / EU ratio of canola under irrigation depths (LI) in 2012, 2013 and for a two year-average

LI (mm)	EU (MJ ha^{-1})	EE (MJ ha^{-1})	GL (MJ ha^{-1})	EF	ES	EI / EU
			Two year-average			
I3S	14,560.83	71,588.64a	57,027.81	4.92a	4.88b	0.58
IS	14,096.92	55,235.52b	41,138.60	3.92a	6.13b	0.60
SI	8,695.17	17,038.32c	8,343.15	1.96b	12.25a	0.97

Values followed by the same lowercase letter in each row do not differ significantly at 5% probability by Tukey test.

Energy demanded by inputs (EI) was responsible for 97% of energy used (EU) in non-irrigated treatments, followed by 60% in treatments irrigated weekly and 58% in treatments irrigated three times a week, showing that inputs account for the largest amount of energy used in all treatments (EI / EU > 0.5).

Conclusions

1. Economically, the absence of irrigation prevents offseason canola cultivation in the Central-West region of Brazil. 2. Irrigation promotes energy and economic viability with positive increases depending on the irrigation depths. 3. Irrigation performed more frequently, three times a week, promotes the best energy and economic results.

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