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RETORNO ECONÔMICO-FINANCEIRO DA PRODUÇÃO DE ÓLEO VEGETAL DE CULTIVARES DE SOJA IRRIGADA*

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1 RESUMO

O objetivo deste trabalho foi avaliar o retorno econômico-financeiro da produção de óleo de soja em vários cenários, com diferentes cultivares, lâminas de irrigação e valores de comercialização. Foram conduzidos dois experimentos nos anos de 2017/2018 e 2018/2019, em área experimental do Colégio Politécnico da UFSM. O delineamento experimental foi um bifatorial em blocos ao acaso, com o primeiro fator de 5 lâminas de irrigação mais a testemunha e o segundo fator três cultivares de soja. Para a irrigação, utilizou-se um sistema do tipo aspersão convencional fixo, com turno de rega de 7 dias. Foi realizado o levantamento dos custos de todo sistema produtivo. O retorno econômico-financeiro foi determinado pelos indicadores de investimento, valor presente líquido, taxa interna de retorno, razão benefício/custo e payback. Considerando quatro preços de comercialização do óleo bruto, totalizando 72 cenários. As lâminas de irrigação de 0% e 100% da ETo apresentaram os maiores retornos econômicos, para todos os indicadores. O preço de comercialização do óleo a R$ 2,50 kg^{-1} não foi economicamente viável, nas diferentes lâminas de irrigação e cultivares. Nos preços de R$ 6,50 e R$ 8,50 kg^{-1}, o retorno econômico foi satisfatório para todas as condições testadas.

Palavras-chave: *Glycine max L.*, manejo de irrigação, preço de produto, indicadores econômicos.

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ECONOMIC AND FINANCIAL RETURN ON VEGETABLE OIL PRODUCTION FROM IRRIGATED SOYBEAN CULTIVARS

2 ABSTRACT

This work aimed to evaluate the economic-financial return of soybean oil production in several scenarios, with different cultivars, irrigation depths and commercialization values. Two experiments were conducted in the years 2017/2018 and 2018/2019, in an experimental area of the Polytechnic College of UFSM. The experimental design was a two-factor randomized block design, with the first factor of 5 irrigation depths plus the control and the second factor of three

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soybean cultivars. Irrigation, a fixed conventional sprinkler system with a 7-day irrigation shift was used. A survey of the costs of the entire production system was carried out. The economic-financial return was determined by the investment indicators, net present value, internal rate of return, benefit/cost ratio and payback. Considering four crude oil marketing prices, totalizing 72 scenarios. The irrigation depths of 0% and 100% of ETo presented the highest economics returns, for all indicators. The oil commercialization price at R$ 2.50 kg^{-1} was not economically viable, in the different irrigation depths and cultivars. At the prices of R$ 6.50 and R$ 8.50 kg^{-1}, the economic return was satisfactory for all conditions tested.

Keywords: *Glycine max L.*, irrigation management, product price, economics indicators.

3 INTRODUCTION

Soybean cultivation is one of the main products in terms of cultivated area, production, and export, driving Brazil's development (CATTELAN; DALL'AGNOL, 2018). Soybeans are used in the production of edible oil and raw materials for biodiesel, generating other coproducts from their bran (POTRICH et al., 2020).

Owing to its geographic distribution in the country, understanding the interference of environmental factors in the production and composition of soybeans is essential to achieve higher productivity and quality (MERTZ-HENNING et al., 2018). The oil content of soybeans is approximately 20% of their weight (CAO et al., 2017) and may vary due to the influence of biotic factors such as the environment (ASSEFA et al., 2018), temperature, sowing time (MOURTZINIS et al., 2017), and water availability (MERTZ-HENNING et al., 2018).

Precipitation, on most farms, remains the only source of water available for crops. However, in locations where water demand is not met, grain yield and quality are affected (GAJIĆ et al., 2018). Thus, irrigation plays a role in grain productivity, and its influence on oil content varies according to the literature (AYDINSAKIR, 2018).

Mertz-Henning et al. (2018) and Morsy et al. (2018) reported that water deficit during the reproductive period of soybean crops reduced the oil content of the grains. On the other hand, Wijewardana, Reddy and Bellaloui (2019), Basal and Szabó (2020) and Aydinsakir et al. (2021) reported that lower water availability increased the oil content of grains.

The processes conventionally used in oil extraction include mechanical and solvent processes (CHENG; ROSENTRATER, 2017a). The most commonly used approach is hexane solvent extraction (CHENG et al., 2019), which results in greater oil extraction capacity from the grain, a lower cost, and solvent reuse. The technologies used in industry are essential for determining production costs, but the productivity and oil concentration in grains can directly influence these costs (CHENG et al., 2018).

The implementation of irrigation systems is a technology with a high initial cost, but it increases productivity and consequently dilutes production costs per hectare (CAVALCANTE et al., 2021), considering the necessary investment and benefits of the system (CARRÊLO et al., 2020).

For the planning, dimensioning and construction of these projects, the analysis of economic parameters is essential and requires indicators that assist in decision-making, facilitating the choice of scenarios with greater financial returns (SALES et al., 2017).

Given the above, the objective of this study was to evaluate the economic-financial return of soybean oil production in various scenarios with different cultivars, irrigation depths and marketing values.

4 MATERIALS AND METHODS

To obtain soybean productivity data, two experiments were conducted in 2017/2018 (harvest 1) and 2018/2019 (harvest 2) in an experimental area belonging to the Polytechnic College of UFSM, located in Santa Maria, RS. The coordinates of the experimental area are 29° 42'55.7 "S, 53° 44'21.4"W and an altitude of 120 m. According to the Köppen–Geiger classification, the climate of the region is type Cfa (humid subtropical climate), with well-defined seasons (ALVARES et al., 2013). According to INMET, the average annual precipitation in the region is 1450 to 1650 mm, with an average air temperature of 18–20°C.

Sowings for harvests 1 and 2 were carried out on 12/14/2017 and 11/23/2018, respectively. The experimental design consisted of a bifactorial randomized block design, with the first factor consisting of 5 irrigation depths plus the control (0, 25, 50, 75, 100, and 125% of the reference evapotranspiration). The second factor consisted of 3 soybean cultivars (*Glycine max L.*), NS 6909 PRO RR, BRASMAX Ponta IPRO 7166 RSF and BRASMAX Valente RR 6968 RSF.

A conventional fixed sprinkler system was used for irrigation. The water distribution uniformity and irrigation application rate calibration (mm h^{-1}) were determined via the Christiansen uniformity test (CUC). The irrigation application uniformity was 82%, and the system application rate was 11.5 mm h^{-1}.

Irrigation timing was carried out with a fixed irrigation shift of 7 days between irrigations when there was no precipitation to meet the crop's water demand. Irrigation management was based on reference evapotranspiration (ETo), which was calculated via the Penman–Monteith–FAO equation (ALLEN et al., 1998).

Meteorological data were obtained from the automatic station of the National Institute of Meteorology, located at the Federal University of Santa Maria. The data collected daily included the following data: rainfall (mm), maximum and minimum air temperatures (°C), relative humidity (%), wind speed (ms $^{-1}$) and solar radiation (kJ m $^{-2}$).

The irrigation requirements were determined according to Eq. 1:

$$NI = ET_o - P_{ef} \quad (1)$$

where NI is the irrigation requirement (mm), ETo is the reference evapotranspiration for the seven-day period (mm) and P_{ef} is the effective precipitation (mm).

The effective precipitation was determined according to Millar (1978), which considers the parameters of the soil textural class, area slope (%) and vegetation cover. The fraction of rainfall lost through surface runoff was considered 30% of the total precipitation.

The irrigation depths were applied according to the irrigation time, according to Eq. 2:

$$Ti = \frac{Ln}{Lr\,.Ua}.100 \quad (2)$$

where TI is the irrigation time (h), L_n is the required depth (mm), L_R is the reference depth (mm h^{-1}) and U_a is the application uniformity (%).

At the end of the crop cycle, plants were collected from a useful area of 4.5 m² and subsequently threshed, impurities were removed and weighed, and moisture correction was performed to 13%. Oil extraction was subsequently performed from the soybeans in the laboratory with petroleum ether solvent in a Soxhlet extractor according to the procedure described in the Analytical Standards of the Adolfo Lutz Institute (1985). The oil productivity (kg ha $^{-1}$) was calculated from the product between the oil content of the grain and the grain productivity.

A survey of the costs of the entire production system was carried out and divided into fixed costs not related to irrigation, fixed costs related to irrigation and variable costs related to irrigation (CONAB, 2010).

Fixed costs not related to irrigation were the values referring to fertilizer, seeds, labor, machine hours, and the acquisition and application of pesticides, among other materials necessary for production; all these costs were adjusted to R$ ha $^{-1}$.

Fixed costs related to irrigation were determined on the basis of a standard irrigation system adapted from Torres et al. (2019) to obtain the acquisition, installation, and maintenance costs. The acquisition cost of the system was spread over its useful life, maintaining value regardless of whether the system was activated. In this project, an effective spray depth of 60% of the sprinkler head radius was considered.

The calculation of fixed costs related to irrigation was performed according to Eq. 3:

$$C_{FRI} = C_D + C_j + C_s \quad (3)$$

where C_{FRI} is the fixed cost related to irrigation (R$ ha $^{-1}$), C_D is the cost of depreciation of the system components (R$ ha $^{-1}$), C_J is the cost of interest on invested capital (R$ ha $^{-1}$) and C_S is the cost of insurance of the irrigation system components (R$ ha $^{-1}$).

The system depreciation cost was calculated according to Eq. (4), considering the residual value of 20% of the new asset (CONAB, 2010).

$$C_D = \left[\frac{VN - VR}{VU_H}\right] . H_s T_R \quad (4)$$

where C_D is the depreciation of the system component (R$), VN is the acquisition value of the new component (R$), VR is the residual value of the component (R$), VU_H is the useful life of the component (h) and $H_S T_R$ is the total hours worked per hectare.

To calculate the cost of interest on invested capital (Eq. 5), an interest rate on invested capital of 2.8% was adopted.

$$C_J = T_{AJ} . VN \quad (5)$$

where C_J is the interest in invested capital (R$), T_{AJ} is the annual interest rate (%), and V_{AE} is the acquisition value of the new component (R$).

The insurance cost was determined to be 0.35% of the average investment value (CONAB, 2010), according to Eq. 6.

$$S = \frac{VN}{2} . 0{,}0035 \quad (6)$$

where S is the insurance cost (R$) and VN is the acquisition value of the new component (R$).

The variable costs related to irrigation were determined according to Eq. 7:

$$C_{VRI} = C_{VE} + C_{VMO} + C_{VMan} \quad (7)$$

where C_{VRI} is the variable cost related to irrigation (R$), C_{VE} is the variable cost of electricity (R$), C_{VMO} is the cost of labor employed in irrigation (R$), and C_{VMan} is the cost of equipment maintenance (R$).

To calculate the variable cost of electricity, the power of the motor pump set and the time to apply the irrigation depth were considered, as per Eq. 8. The cost of electricity was obtained according to the energy price charged by the region's concessionaire, considering the green tariff (21 hours of operation per day).

$$C_{VE} = P_W \,.\, E_e \,.\, T \,.\, L \quad (8)$$

where C_{VE} is the variable cost of electricity (R$), Pw is the power of the motor pump set (kW h $^{-1}$), Ee is the price of electricity (R$ kW h $^{-1}$), T is the time to apply one millimeter of water (h mm $^{-1}$), and L is the irrigation depth (mm).

The labor cost was determined using the hourly value equivalent to the rural minimum wage (CONAB, 2010) and calculated according to Eq. 9.

$$C_{VMO} = N_i \,.\, N_S \,.\, 0{,}5 \,.\, \frac{V_{SMin}}{220} \quad (9)$$

where C_{VMO} is the cost of labor employed in irrigation (R$), N_i is the number of irrigations, N_s is the number of sectors in the irrigation system and V_{SMin} is the value of the rural minimum wage (R$).

Maintenance costs were calculated according to Eq. 10, considering values relative to 1% of the acquisition cost of the irrigation system and 10% of the amount spent on energy.

$$C_{VMan} = VN \,.\, 0{,}01 \,.\, \frac{C_{VE}}{10} \quad (10)$$

where C_{VMan} is the cost of equipment maintenance (R$), VN is the acquisition value of the new component (R$ ha $^{-1}$), and C_{VE} is the variable cost of electricity.

The economic-financial return was determined by the investment indicators, net present value (NPV), internal rate of return (IRR), benefit/cost ratio (B/C) and payback (PB).

The NPV was calculated according to Eq. 11:

$$VPL = \sum_{t=0}^{N} \frac{F_t}{(1+j)^t} \quad (11)$$

where NPV is the net present value (R$ ha $^{-1}$), j is the minimum attraction rate (MAR), N is the project horizon (years), t is the project period (years) and Ft is the net cash flow in each year (R$ ha $^{-1}$).

The IRR was calculated according to Eq. (12).

$$TIR = \sum_{j=0}^{N} \frac{F_t}{(1+TIR)^t} \quad (12)$$

where IRR is the internal rate of return, in decimals, and j is the minimum attraction rate (MAR), in decimals.

AB/C was determined according to Eq. (13).

$$\frac{B}{C} = \frac{\sum_{t=0}^{N} B_k \,(1+j)^{-t}}{\sum_{t=0}^{N} C_k \,(1+j)^{-t}} \quad (13)$$

where B/C is the benefit/cost ratio, B is the revenue (R$ ha $^{-1}$) and C is the expenses (R$ ha $^{-1}$).

The PB calculation was performed according to the ratio of the initial investment to the average cash flow for the period (20 years). For the analysis of economic and financial viability, 72 scenarios were developed, considering three soybean cultivars, five irrigation depths plus the control, and four crude oil marketing values (R$2.50, R$4.50, R$6.50, and R$8.50 kg $^{-1}$), taking into account that the average value over the last five years was approximately R$4.00 kg $^{-1}$. The production cost per ton of processed soybean was set at R$31.36 ton $^{-1}$ (POTRICH et al., 2020), considering a dollar exchange rate of R$5.38.

5 RESULTS AND DISCUSSION

The CFNRI was R$ 2,403.38 ha $^{-1,}$ and the CFRI was R$ 1,378.70 ha $^{-1}$ for the three cultivars in the two years of the experiment. The CVRIs for the first harvest were R$ 124.04 (25% of ETo), R$ 142.28 (50% of ETo), R$ 160.51 (75% of ETo), R$ 162.37 (100% of ETo) and R$ 196.99 ha $^{-1}$ (125% of ETo), and for the second harvest, they were R$ 120.26, R$ 138.44, R$ 156.61, and R$ 158.45 R$ 192.95 ha $^{-1}$ at the respective irrigation depths. Dalchiavon et al. (2019) reported a production cost for soybean crops of R$ 3,063.00 ha $^{-1}$ without the use of irrigation; this value is 27% higher than the CFNRI of this study.

In the first harvest, the average oil production costs between the irrigation depths varied from R$ 156.15 ha $^{-1}$ (0% of ETo) and R$ 208.96 ha $^{-1}$ (100% of ETo); these results represent a difference of 25.27%.

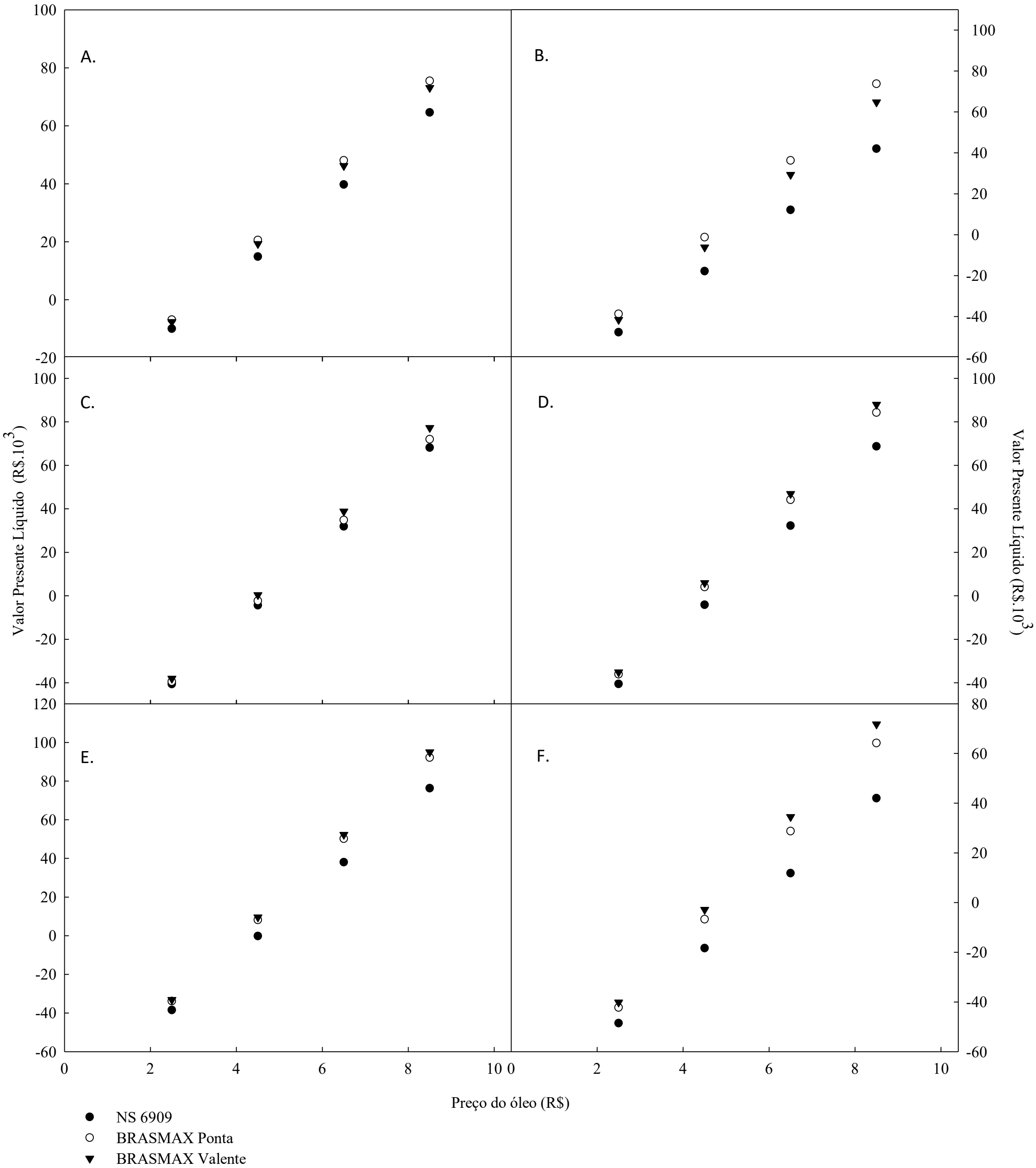
In the control, there was a variation between cultivars of 11.62% in cost, with the lowest value for NS 6909 (R$ 144.95 ha $^{-1}$) and the highest for BRASMAX Ponta (R$ 164.01 ha $^{-1}$). The cultivar NS 6909 had a value of R$ 203.67 ha $^{-1}$ and a value of R$ 217.58 ha $^{-1\ at\ 100\%}$ ETo blade, varying by 6.39% in terms of the cost of oil production.

The average oil production costs between irrigation depths during the second harvest varied from R$ 153.81 ha $^{-1}$ (0% of ETo) to R$ 198.37 ha $^{-1}$ (100% of ETo), representing a 22.46% difference. The NS 6909 cultivar presented a cost of R$ 150.02 ha $^{-1}$, which is 5.47% lower than the oil cost for BRASMAX Valente, which presented a value of R$ 158.71 ha $^{-1}$. At the 100% ETo depth, the lowest value was R$ 191.13 ha $^{-1}$ for NS 6909, and the highest value was R$ 204.92 ha $^{-1}$ for BRASMAX Valente, which represented a 6.73% variation.

The production costs for the two years of the experiment were lower for the control and cultivar NS 6909, with values of R$ 2,548.34 and R$ 2,553.40, and the highest values were for cultivar Valente at the 125% ETo level, at R$ 4,170.05 and R$ 4,174.12, respectively. For harvest 1, the difference between the costs of the nonirrigated treatment and the 125% ETo level was 41.04%, and for harvest 2, this value was 38.83%.

Figure 1 presents the net present value (NPV) data as a function of irrigation depth.

Figure 1. NPV values in the 0% (A.) and 25% (B.) treatments.), 50% (C.), 75% (D.), 100% (E.) and 125% of ETo (F.) as a function of different oil sales prices.



The highest values were obtained for the 100% ETo blade, with an oil price of R$ 8.50 kg $^{-1}$ and NPVs of R$ 76,264.04 (NS 6909), R$ 92,153.16 (BRASMAX Ponta) and R$ 95,025.44 (BRASMAX Valente). In the scenario of a sales price of R$ 2.50 kg $^{-1}$, the NPV did not demonstrate viability in any of the blades or cultivars studied.

Corroborating the results of this study, in which the investment became viable for values higher than the average marketing price, Kenkel et al. (2006), when analyzing the economic-financial viability of canola oil production with four marketing prices, reported a negative NPV for the two lowest prices and a positive NPV only from the average sales price.

For the price of R$ 4.50 kg $^{-1,}$ some scenarios presented negative NPVs, and only the nonirrigated treatment returned positive values for all cultivars, with R$ 14,866.50 for NS 6909, R$ 20,559.68 for BRASMAX Ponta and R$ 19,288.46 for BRASMAX Valente.

With increasing irrigation depth, the NPV increased, with 75.5%, 22.1% and 30% differences between the nonirrigated treatment and the 100% ETo treatment, respectively, in the scenario of R$ 8.50 kg $^{-1}$ for the NS 6909, BRASMAX Ponta and BRASMAX Valente cultivars, respectively. An increase in the NPV, in the comparison between the two highest selling prices, was observed by Kenkel et al. (2006). In the present study, the increase was 72.76% for the cultivar BRASMAX Ponta in the nonirrigated treatment and 89.90% for the cultivar BRASMAX Valente at the 100% ETo depth, compared with the prices of R$ 4.50 and R$ 8.50 kg $^{-1}$.

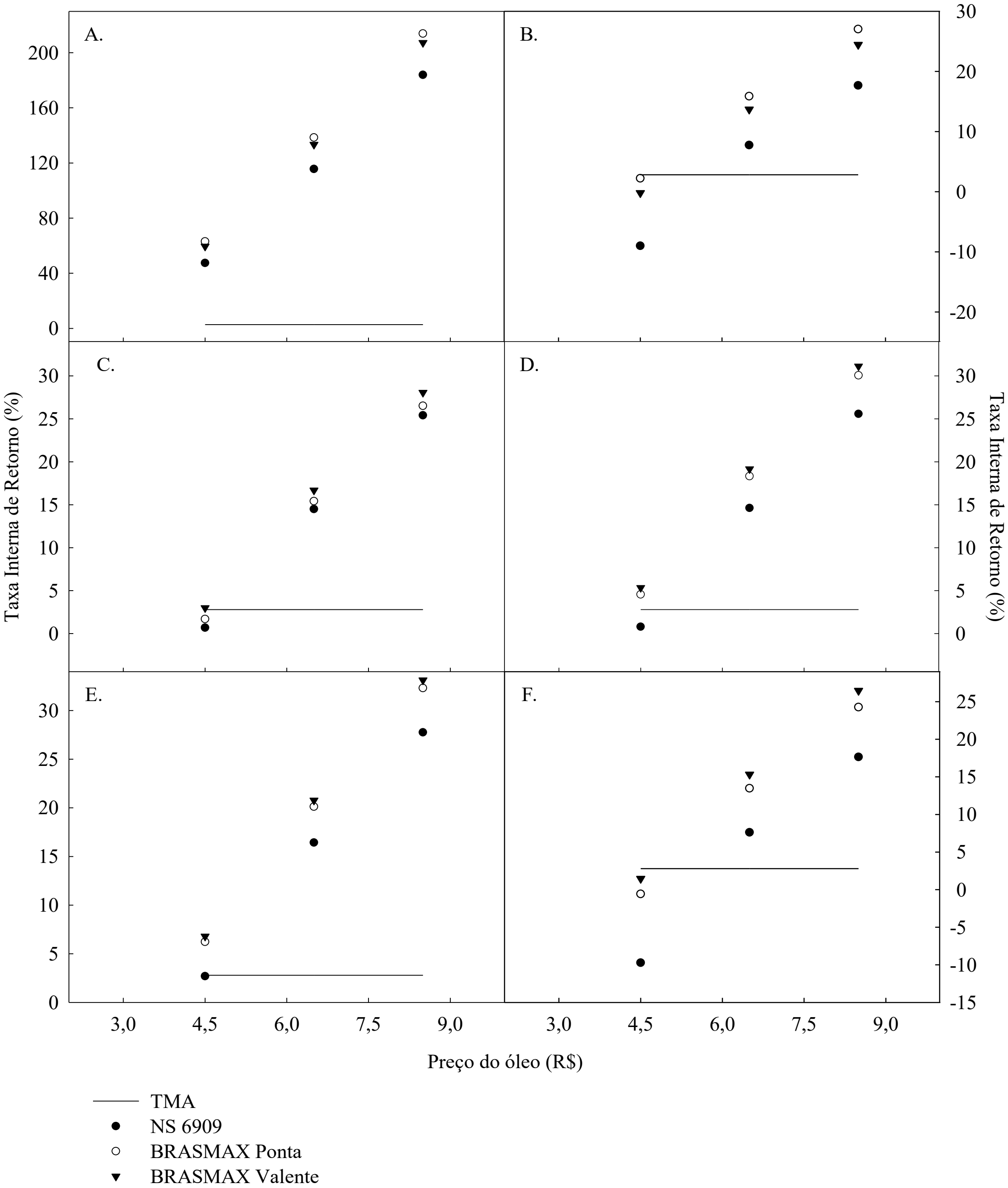
When three crops (soybean, canola, and sunflower) were compared, Belarmino, and Padula (2017) reported that the oil production of soybean was profitable. According to the authors, this is due to the higher grain yield of soybeans, since the oil content is lower than that of the other two crops. On the other hand, Mupondwa et al. (2016), when working with camelina oil production at different grain yields, oil contents, IRRs, oil prices, and production plant capacities, reported that at low grain yields, the NPV returns are negative in any of the scenarios.

In the present study, the highest net profits were directly associated with the treatment with better grain productivity (100% of ETo), with values of R$ 1,938.77 ha $^{-1}$, R$ 4,643.18 ha $^{-1}$, R$ 7,347.59 ha $^{-1}$, for marketing prices of R$ 4.50, R$ 6.50 and R$ 8.50 kg $^{-1}$, respectively.

Regardless of grain yield, soybeans can yield lower returns than can crops with higher oil contents. Adhikari et al. (2017) reported 31.83% greater returns for sunflowers than for soybeans when evaluating the economic and financial viability of oil production from these crops.

The internal rate of return (IRR) results for the oil sales price of R$2.50 kg $^{-1}$ did not return values in any of the scenarios. Therefore, Figure 2 shows only the IRR data for the prices of R$4.50, R$6.50 and R$8.50 kg $^{-1}$.

Figure 2. IRR values in the 0% (A.) and 25% (B.) treatments.), 50% (C.), 75% (D.), 100% (E.) and 125% of ETo (F.) as a function of different oil sales prices.



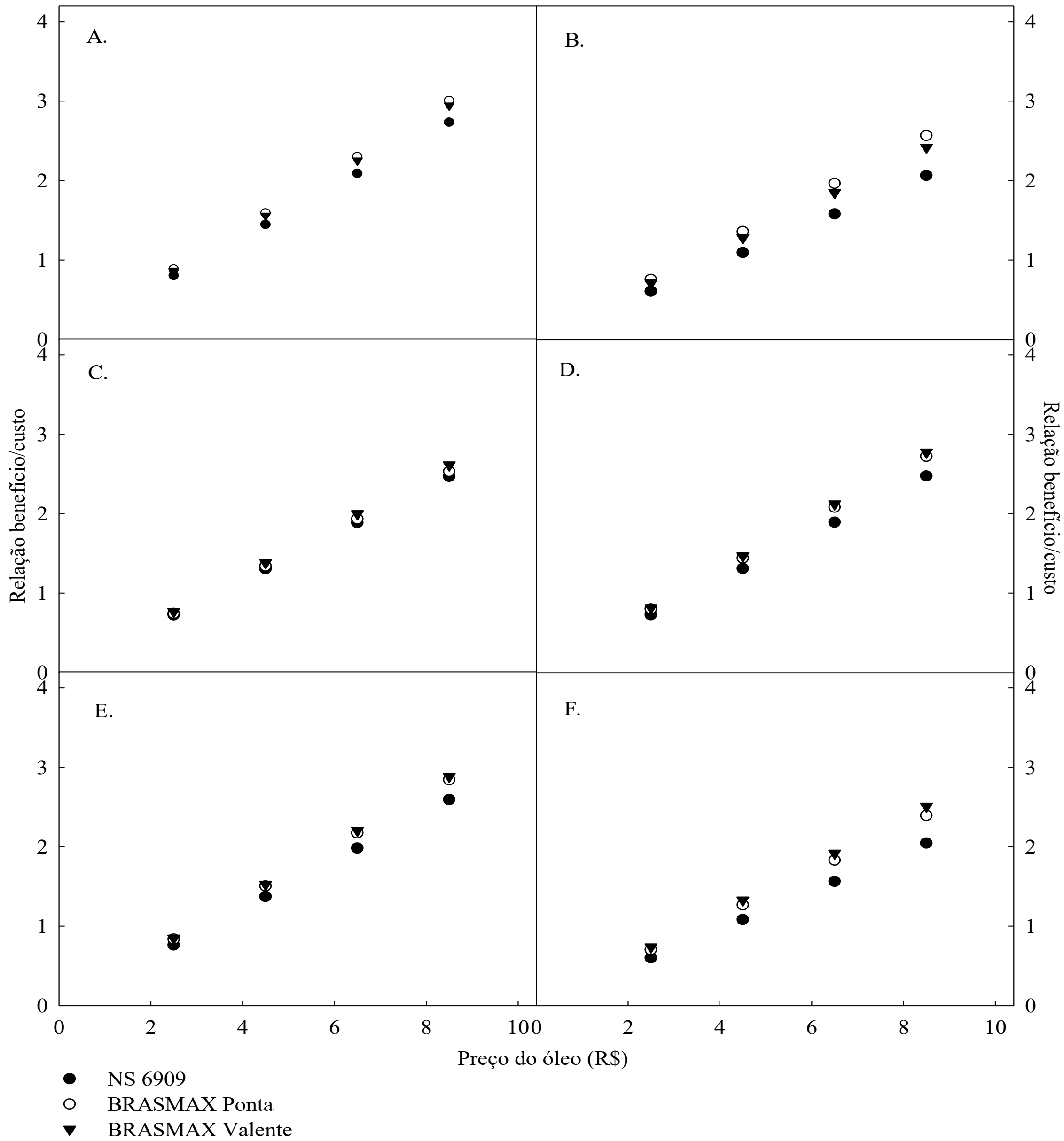
The treatment without irrigation was profitable in all the studied scenarios, with oil selling prices starting at R$ 4.50 kg $^{-1}$. Among the irrigated treatments, the best return was observed at the 100% ETo depth, at selling prices of R$ 6.50 and R$ 8.50 kg $^{-1}$, with values of 16%, 20% and 21%, and 28%, 32% and 33% for the cultivars NS 6909, BRASMAX Ponta and BRASMAX Valente, respectively. At the 25% and 125% ETo depths with a price of R$ 4.50 kg $^{-1}$, the IRR values were lower than the MRTs for all the cultivars.

Kenkel and Holcomb (2008), when studying biodiesel production from canola, sunflower, and soybeans, reported that at low marketing prices, compared with other crops, soybeans are not economically viable due to their oil content. The authors also highlight that production only became viable with IRR values above the average market price for canola.

Kenkel et al. (2006), when working with canola oil production, did not obtain IRR values for the lowest marketing price, corroborating the results found for the price of R$ 2.50 kg $^{-1}$. The same authors also observed that as sales prices increased, there was an increase in the IRR, which is in agreement with the findings of this study.

The B/C ratio was lower than 1.00 for all blades and cultivars at the oil sales price of R$ 2.50 kg $^{-1}$, which demonstrates that these scenarios are not favorable for investment (Figure 3).

Figure 3. B/C values in the 0% (A.), 25% (B.), 50% (C.), 75% (D.), 100% (E.) and 125% of ETo (F.) as a function of different oil sales prices.



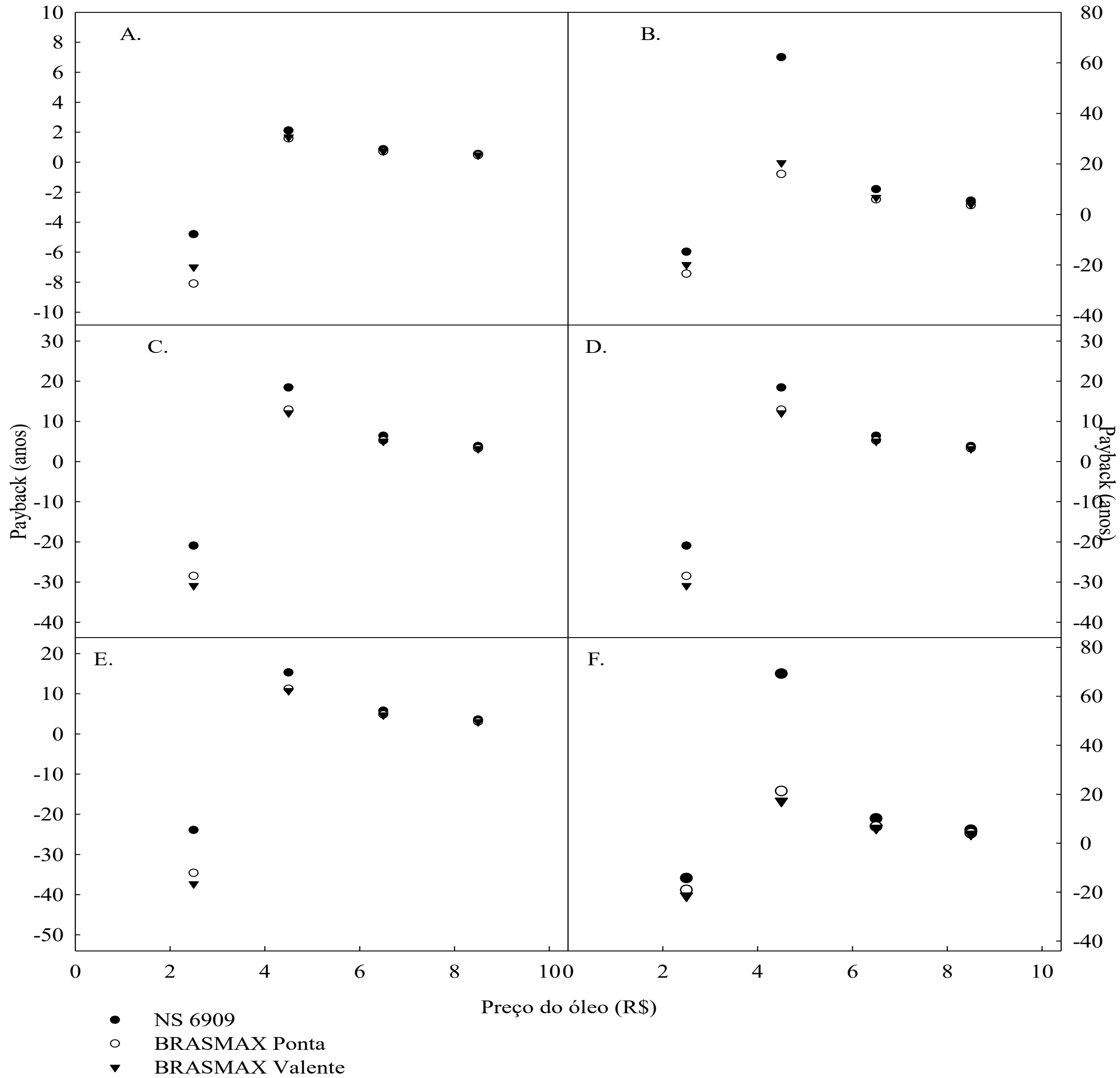
All the scenarios presented results above 1.00 at R$ 4.50 kg $^{-1}$; however, the highest values were observed at the 0% and 100% ETo depths for all the cultivars.

Supplemental irrigation proves to be economically viable because, although the treatment without irrigation presents higher B/C values, the results are close to the values of the 100% ETo depth, with differences of 5.1% for NS 6909, 5.6% for BRASMAX Ponta and 2% for BRASMAX Valente.

Kenkel et al. (2006) reported a B/C ratio of less than 1 for two lower marketing prices of canola oil; however, the relationship became attractive as remuneration increased. This behavior is similar to that found in this study, as the B/C ratio was less than 1 for all conditions tested, with a selling price of R$2.50 kg $^{-1,}$ and became profitable as the marketing value of the product increased, which was above the average price.

Figure 4 shows the PB values in the different irrigation treatments according to the four oil sales price scenarios.

Figure 4. CP values in the 0% (A.) and 25% (B.) treatments.), 50% (C.), 75% (D.), 100% (E.) and 125% of ETo (F.) as a function of different oil sales prices.



The CP results at a price of R$ 2.50 kg $^{-1}$ were not viable for any of the irrigation treatments or cultivars. The sale of the oil at R$ 4.50 kg $^{-1}$ demonstrated a CP with high amplitude, ranging from 2 years (0% of ETo) for all cultivars to 69 years (125% of ETo) for NS 6909. For the prices of R$ 6.50 kg $^{-1}$ and R$ 8.50 kg $^{-1}$, the values remained below 10 years. Mupondwa et al. (2016) reported that for high grain yield, the CP was lower than that in the analysis period, ranging from 0.72--17 years, for any sale price of camelina oil.

In the treatment without irrigation, the lowest PB results were observed, with six months of return for all cultivars, at a price of R$ 8.50 kg $^{-1}$. Among the irrigated treatments, water replacements of 75% and 100% ETo presented an average value of 3 years, representing a faster economic return than the other layers did.

Higher sales prices and lower production costs presented shorter payback times, as reported by Kenkel et al. (2006), who, when working with four canola oil sales prices, obtained BPs only for the two remunerations above the average marketing price of 5 and 4 years, respectively. The BP results are in agreement with those of this study and are similar to the values of the treatment without irrigation, with prices starting at R$ 4.50 kg $^{-1}$.

The results demonstrate that higher profitability was achieved through lower production costs, high oil production, and higher selling prices. The cost of soybeans and the selling price of soybean oil are critical factors in the oil extraction process, so lower soybean prices and higher oil selling prices are desirable (CHENG; ROSENTRATER, 2017b).

6 CONCLUSION

The nonirrigated treatment and the NS 6909 cultivar presented the lowest production costs. The 125% ETo depth resulted in a greater cost with the BRASMAX Valente cultivar, representing an average increase of 39.94% compared with the nonirrigated treatment.

The irrigation depths that presented the highest economic and financial returns were 0% and 100% of the ETo for all the indicators. The irrigation treatments that presented the lowest economic and financial viability, according to the indicators analyzed, were 25% and 125% ETo.

BRASMAX Valente was the cultivar that performed best across the different scenarios for the indicators analyzed. The cultivar that presented the lowest economic and financial viability was NS 6909.

The oil marketing price of R$2.50 kg $^{-1}$ was not economically viable for the different irrigation depths and cultivars. At prices of R$6.50 and R$8.50 kg $^{-1}$, the economic and financial returns were satisfactory for all the conditions tested.

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