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ECONOMIC EVALUATION AND EFFECTIVENESS OF HERBICIDES APPLIED IN PRE-EMERGENCY IN THE SESAME[1]

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ABSTRACT - The sesame crop has great economic potential due to the various possibilities of exploitation, however, there is a lack of information about the chemical control of weeds in the crop, mainly about the application of herbicides in pre-emergence. Therefore, the objective of this study was to evaluate the economic viability and efficacy of herbicides applied in pre-emergence for the control of weeds in the sesame crop. The experimental design was in randomized blocks, with four replications. The treatments consisted of seven herbicides (diuron, flumioxazin, oxadiazon, oxyfluorfen, metribuzin, linuron, and S-metolachlor) and a mixture (metribuzin + oxyfluorfen) applied in pre-emergence. The two control treatments were weeded and non-weeded plots. The variables evaluated were percentage of control of the weed community, grain yield, gross and net income, rate of return, and profitability index. The highest productivity value was for weeding, followed by the herbicides diuron and flumioxazin, with 2,000.44 kg ha^{-1}, 1,957.35 kg $ha^{-1,}$ and 1,933.13 kg ha^{-1}, respectively. The herbicides diuron and flumioxazin obtained the highest net income, in the amounts of R$ 7,831.26 and R$ 7,762.85, respectively. The diuron and flumioxazin applied in pre-emergence showed more than 80% in the control of weeds in the sesame crop, showing efficiency in the control. The use of herbicides applied in pre-emergence to control weeds, mainly diuron and flumioxazin, is as efficient as mechanical control, demonstrating the potential for use and economic viability in relation to mechanical control, which presents a high cost/benefit ratio.

Keywords: *Sesamum indicum* L.. Chemical control. Production cost. Productivity. Profitability.

AVALIAÇÃO ECONÔMICA E EFICÁCIA DE HERBICIDAS APLICADOS EM PRÉ-EMERGÊNCIA NO GERGELIM

RESUMO - A cultura do gergelim apresenta grande potencial econômico por conta das diversas possibilidades de exploração, contudo há carências de informações a respeito do controle químico de plantas daninhas na cultura, principalmente sobre a aplicação de herbicidas em pré-emergência. Sendo assim, o objetivo deste estudo foi avaliar a viabilidade econômica e a eficácia de herbicidas aplicados em pré-emergência para o controle de plantas daninhas na cultura do gergelim. O delineamento experimental foi em blocos casualizados, com quatro repetições. Os tratamentos foram constituídos de sete herbicidas (diuron, flumioxazin, oxadiazon, oxyfluorfen, metribuzin, linuron e S-metolachor) e uma mistura (metribuzin + oxyfluorfen) aplicados em pré-emergência. Os dois tratamentos testemunhas foram as parcelas capinadas e não capinadas. As variáveis avaliadas foram porcentagem de controle da comunidade infestante, produtividade de grãos, rendas bruta e líquida, taxa de retorno e índice lucratividade. O maior valor de produtividade foi para o tratamento capinado, seguido dos herbicidas diuron e flumioxazin, com 2.000,44 kg ha^{-1}, 1.957,35 kg ha^{-1} e 1.933,13 kg ha^{-1}, respectivamente. Os herbicidas diuron e flumiozaxin obtiveram as maiores rendas líquidas, nos montantes de R$ 7.831,26 e R$ 7.762,85, respectivamente. O diuron e flumioxazin aplicados em pré-emergência apresentaram mais de 80% no controle de plantas daninhas na cultura do gergelim, demostrando eficiência no controle. O uso de herbicidas aplicados em pré-emergência para o controle de plantas daninhas, principalmente o diuron e flumioxazin, é tão eficiente quanto o controle mecânico, demonstrando potencial de uso e viabilidade econômica em relação ao controle mecânico que apresenta custo/benefício elevado.

Palavras-chave: *Sesamum indicum* L.. Controle químico. Custo de produção. Produtividade. Lucratividade.

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INTRODUCTION

Sesame (*Sesamum indicum* L.) is an oilseed that has great potential for economic exploitation, both through the consumption of seeds, highly rich in proteins and carbohydrates, as well as through the use of oil and other products derived from this plant species (RIBEIRO et al., 2018; LIMA et al., 2020). Despite this, the low production of sesame makes Brazil not competitive on the world market, and this is motivated by the high cost of labor, low technological level, and inputs used in the production environments in the country (SANTOS et al., 2018). In addition, national consumption is superior to the product's offer, making it necessary to import sesame to supply market demand (FAO, 2018).

The weed control method, through manual weeding, is the one most commonly used by small and medium producers in semi-arid regions of Brazil. This method is not only labor-intensive, expensive, and tiring, but it can also cause mechanical damage to the growing branches and roots of the plants. In addition to the high cost, the availability of labor is uncertain, leading to a greater risk of loss of crop yield (DHAKA et al., 2013).

The coexistence of weeds with the crop can negatively interfere in the growth of sesame, with direct effects on productivity, also affecting profitability (REGINALDO et al., 2021). When weed management measures are not adopted, especially in the initial periods, sesame productivity can be reduced by 50 to 75% (LINS et al., 2019). Thus, when weed control periods are defined for the crop, the choice of management methods that will be adopted is a fundamental step for the successful elimination/suppression of the weed community.

In relation to production in extensive areas, the chemical control method is the most used due to its high efficiency and low cost of execution (NOGUEIRA et al., 2019). In pre-emergence applications, the residual effect of the herbicide on the soil can control weeds during the initial periods, reducing the number of post-emergence applications (SANTIAGO et al., 2018). However, the use of this method in sesame crops is limited due to the scarcity of information on the selectivity and efficiency of herbicides in this modality of application for the crop.

Studies have already demonstrated the activity of some herbicides applied in pre-emergence, isolated only or with manual weeding complementation, to obtain efficient control of weeds in the sesame crop (GRICHAR et al., 2018; GRICHAR; DOTRAY; LANGHAM, 2009; GRICHAR; DOTRAY; LANGHAM, 2012; LINS et al., 2020). In addition, the use of herbicides has been reported to be more profitable than manual weeding in sesame production (BELTRÃO et al., 1991).

In the selection of herbicides or other weed control measures, there is also a need to consider the economic analysis of weed control methods. In some situations, a weed control treatment can produce the highest yield, but decrease the net return, possibly due to an increase in production cost and a reduction in profit (SURIA et al., 2011).

However, this information is not available to small and medium producers for the use of herbicides in pre-emergence in the sesame crop in Brazil, since the sesame crop is still underdeveloped and emerging in the country.

Therefore, the objective of this work was to evaluate the economic viability and efficacy of herbicides applied in pre-emergence for the control of weeds in the sesame crop.

MATERIAL AND METHODS

The experiment was conducted at the experimental farm belonging to the Universidade Federal Rural do Semi-Árido, Mossoró, RN. Which is located in the following geographical coordinates: latitude 5°03’37” S and longitude 37°23’50” W Gr with an approximate altitude of 72 m.

According to Köppen, the climate is BSwh’, dry and very hot, characterizing the region as semiarid (ALVARES et al., 2013). The average meteorological data for the period of the experiment were collected from the INMET Automatic Meteorological Station and are shown in Figure 1.

The soil in the experimental area is classified as Dystrophic Argisolic Red Latosol (RÊGO et al., 2016). The physical and chemical characteristics of the soil were as follows: pH (water) = 5.3; EC = 0.07 ds m^{-1}; OM = 3.31 g kg^{-1}; P, K, and Na = 3.3; 64.1; and 5.7 mg dm^{-3}; Ca, Mg, Al, H + Al, and CTC effective = 0.80; 0.90; 0; 0; and 14.73 $cmol_c$ dm^{-3}; sand; silt; and clay = 0.57; 0.10; and 0.33 kg kg^{-1}; frank sand texture. The soil preparation was carried out by plowing and harrowing. Fertilization was carried out according to the needs of the crop, based on soil analysis (CAVALCANTI, 2008). Fertilization before planting was carried out with 80 kg of P_2O_5 in the form of monoammonium phosphate. Two cover fertilizations of 25 kg of N in the form of urea and one with 60 kg of K_2O in the form of potassium chloride, both fertilizations were applied via fertigation, with the aid of a bypass tank.

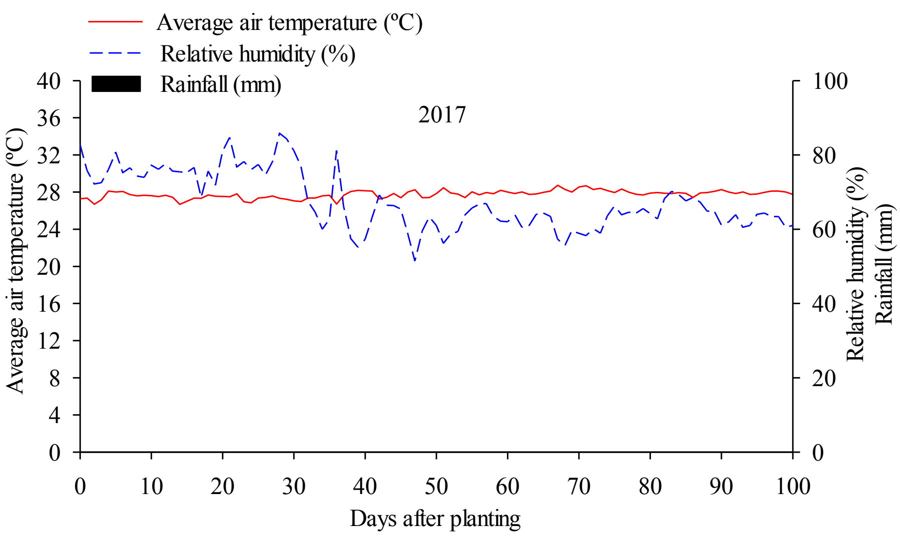

Figure 1. Average values of air temperature (°C), relative humidity (%), and rainfall (mm). Evaluation period of the experiment: August 15 to November 25, 2017.

The experimental design used was randomized blocks, with four replications. The treatments consisted of different herbicides applied in pre-emergence in isolation, in addition to an association between herbicides and two other treatments that comprised the controls, one of which was weeded, free from weed interference and the other not weeded, with the coexistence between crop and weeds. The complete list of treatments, as well as the doses applied, are listed in Table 1.

Table 1. List of herbicides and doses applied pre-emergence on sesame.

Common name *	Commercial name	Dose (g a.i. ha^{-1})
Diuron	Diox 500 SC	1750
Flumioxazin	Flumizyn 500 WP	60000
Oxadiazon	Ronstar 250 BR EC	750
Oxyfluorfen	Goal BR 240 EC	480
Linuron	Afalon 450 SC	720
Metribuzin + Oxyfluorfen	Sencor 480 SC + Goal BR 240 EC	480 + 480
Metribuzin	Sencor 480 SC	480
S-metolachlor	Dual Gold 960 EC	1680

*Herbicide application one day after planting (DAP).

The total area of the experiment was 288 m^2 and each experimental plot consisted of four rows of plants, totaling an area of 7.2 m^2 (3.0 x 2.4 m). The spacing used was 0.60 m x 0.30 m, with two plants per pit, totaling 32 plants in the useful area (2.88 m^2) and a population of 111,111 plants ha^{-1}.

Phytosanitary control of *Pulgão* (*Aphis* sp.) and Whitefly (*Bemisia argentifolii*) was carried out using systemic insecticides based on the active ingredient diflubenzuron (benzoiluréia) according to the technical recommendations and needs of the crop and accounted for in the production costs of the economic analysis.

Planting took place on August 15, 2017. The sesame cultivar used in the field study was the “BRS Seda”. Direct sowing was carried out at 0.02 m in depth, sowing 8 to 10 seeds per hole. After ten days of the emergency, thinning occurred, leaving two plants per hole.

The drip system used was drip irrigation, with emitters spaced every 0.30 m. Irrigations were performed daily, based on the ETc of the crop corresponding to a total applied liquid layer of 506.35 mm (AMARAL; SILVA, 2008).

The treatments were applied one day after planting (DAP), where a pressurized CO_2 sprayer was used, equipped with a bar with four XR 110 02 nozzles, spaced 0.50 m apart, kept at the height of 0.50 m from the target, at a pressure of 0.25 MPa and a displacement speed of 3.6 km h^{-1}, which provided a flow rate of 150 L ha^{-1} of spray solution. During application, neighboring plots were laterally protected with polyethylene plates to prevent drift. The environmental conditions at the time of application of the treatments were collected and described below: air temperature (°C) = 22.4, relative air humidity (%) = 80, wind speed (km h^{-1}) = 2.8.

The weeded control was kept clean throughout the cycle by means of five manual weedings and the other non-weeded control remained in contact with the weeds present in the area.

The harvest was carried out 100 days after planting. The evaluated characteristics were the effectiveness of the herbicides in the control of weeds, grain yield, and economic indicators to evaluate the efficiency of the treatments. The effectiveness of weed control was carried out at 99 days after the emergence of the plants in the entire useful area of each plot, with grades being given visually from 0 to 100, where 0 indicates no control and 100, total control of the plants. harmful in relation to treatment without herbicides and weeding (SBCPD, 1995). The productivity was realized by weighing the grains of the plants in the useful area and their values were expressed in kg ha^{-1} (GRILO JÚNIOR; AZEVEDO, 2013).

Variable costs for sesame cultivation included spending on labor, seeds, fertilizers, agrochemicals, administrative expenses, technical assistance, land tax, financial expenses (financing interest), fixed costs (depreciation and periodic maintenance of facilities), and revenue factors (expected return on fixed capital and leasing). Expenses were calculated according to the methodology adapted from Conab (2010).

The production cost (PC) was estimated for one hectare of sesame, calculated, and analyzed at the end of the harvest. Gross income (GI) [GI = productivity kg ha^{-1} of sesame x amount paid for grain, actual data per hectare] was measured by the value of grain production per hectare in November 2017 (R$ 7.00) in the municipality from Mossoró, RN. The net income (NI) was calculated by the difference between the gross income and the production cost involved in obtaining the seeds [NI = GI - PC, actual data per hectare]. The rate of return (RR) was determined from the ratio between gross income and production costs [RR = GI/PC], corresponding to the capital obtained for each real applied to the sesame crop. The profitability index (PI) consisted of the relationship between net income and gross income (PI = NI/GI x 100) and expressed as a percentage.

Analysis of variance was performed for all evaluated characteristics, using the software SISVAR 5.6® (FERREIRA, 2011). In case of significance, the data were compared using the Scott Knott test, at 5% probability. The SigmaPlot 12.0® software was used to make the graphics.

RESULTS AND DISCUSSION

The treatments studied varied significantly for effectiveness in weed control since the application of diuron and flumioxazin showed the highest efficiency in weed control (95%) (Figure 2). The main species of weeds found in the study area were: *Mimosa pudica* L., *Mollugo verticillata* L., *Waltheria indica* L., *Blainvillea lanceolata*, *Soliva pterosperma*, *Richardia brasiliensis*, *Pavonia cancellata* L., *Stenandrium dulce*, *Portulaca oleracea*, *Sida spinosa* L., *Aeschynomene rudis*, *Cyperus rotundus*, *Cenchrus echinatus*, *Senna alata* L., *Ipomoea triloba*, *Macroptilium atropurpureum, Cynodon dactylon,* and *Commelina benghalensis* L.

The herbicides diuron and flumioxazin were able to control most of the species present in the study area, showing efficacy both on monocots and on dicots. The ability to control weeds in pre-emergence can reduce the number of applications during the crop cycle, reducing expenses linked to the application, such as products, labor, and hourly/ machine costs. Sesame has a medium cycle, and these herbicides, by promoting greater control until the end of the cycle, showed the best performance for use in pre-emergence (GRICHAR; DOTRAY, 2007; GRICHAR; DOTRAY; LANGHAM, 2009; LINS et al., 2020).

The method of mechanical control, with the use of manual weeding, had the greatest efficiency, requiring five weeds to control weeds until the canopy closes in the sesame crop in drip irrigation system. According to Beltrão et al. (1991), the chemical control method, represented mainly by the herbicide diuron, applied in pre-emergence in the sesame crop for the control of weeds, was as efficient as the mechanical method with the use of a hoe.

The application of oxyfluorfen and the mixture of metribuzin + oxyfluorfen showed efficiency in the control of weeds of 60%, at the end of the sesame cycle compared to the non-weeding treatment (Figure 2). Despite the mixture of the herbicides metribuzin + oxyfluorfen, the effectiveness of weed control was insufficient in this treatment. The application of the herbicides metribuzin + oxyfluorfen and the isolated treatment oxyfluorfen did not reduce the majority of weed species observed in the area. Herbicide blending is intended to increase the control spectrum (MAHAJAN; TIMSINA, 2011), however, the mixture metribuzin + oxyfluorfen did not promote greater efficacy in weed control than treatment with isolated applications of oxyfluorfen. This fact can be proven when evaluating the efficiency in the control of weeds in the plots with isolated applications of metribuzin, which was only 30% (Figure 2). In this treatment, good weed control was not observed. The addition of metribuzin to the mixture only promoted the control of some weed species that were sensitive to this herbicide, such as *Aeschynomene rudis*, *Cenchrus echinatus*, *Senna alata* L., *Macroptilium atropurpureum,* and *Commelina benghalensis* L. (VAFAEI; RAZMJOO; KARIMMOJENI, 2013).

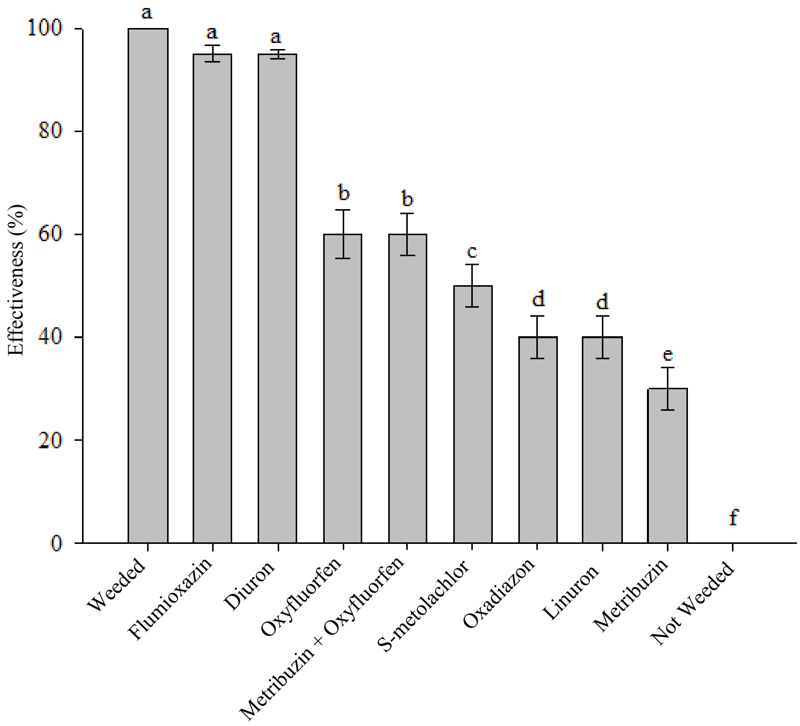

Figure 2. Efficacy in controlling weeds in the sesame crop with herbicides applied in pre-emergence. The averages followed by the same letter in the column do not differ by the Scott-Knott test, at 5% probability. Error bars indicate the standard error of the sample.

The treatment with the application of the herbicide S-metolachlor promoted a 50% efficacy in the control of the weed community compared to the non-weed treatment (Figure 2). According to the scale of scores for evaluating the effectiveness of weed control by SBCPD (1995), the efficiency of the herbicide S-metolachlor was regular (50%) in this study, not showing a good performance in weed control. Thus, S-metolachlor did not present a desirable efficiency in the control of weeds when applied pre-emergence in the sesame crop. However, this herbicide was superior to the other 3 herbicides in terms of control effectiveness, but showing lower productivity than them. Possibly, this treatment may have caused some type of inhibition in the initial growth in the sesame crop, an alternative would be to study this treatment in post-emergence applications in order to obtain better results (GRICHAR; DOTRAY; LANGHAM, 2009).

Oxadiazon and linuron are 40% effective in controlling weeds, respectively, compared to non-weed treatment (Figure 2). These herbicides did not control most of the weed species present in the area. The low efficiency of these herbicides in controlling species at the end of the sesame crop cycle makes oxadiazon and linuron herbicides ineffective for preemergence management in isolated applications. An alternative is to increase the spectrum of action through mixtures with other herbicides capable of controlling species not sensitive to oxadiazon and linuron (BHADAURIA; ARORA; YADAV, 2012). The effectiveness of any production system is ultimately assessed on the basis of its economy.

Table 2 shows grain yield in kilograms per hectare, gross income per hectare, net income per hectare, rate of return, and profitability index of the sesame produced by different herbicides applied in pre-emergence together with a weeded witness and another witness not weeding. Regarding economic indicators, there was a significant difference between all treatments. The highest yield was 2,000.44 kg ha^{-1} (weed control), followed by 1,957.35 kg ha^{-1} (diuron), 1,933.13 kg ha^{-1} (flumioxazin), 1,654.54 kg ha^{-1} (oxadiazon), 1,556.75 kg ha^{-1} (oxyfluorfen), 1,506.77 kg ha^{-1} (linuron), 1,395.55 kg ha^{-1} (metribuzin + oxyfluorfen), 1,045.75 kg ha^{-1} (metribuzin), 1,037.30 kg ha^{-1} (non-weeded control) while the lowest productivity was 1,001.71 kg ha^{-1} (S-metolachlor).

Table 2. Economic evaluation of the use of different herbicides applied in the pre-emergence in the production of sesame.

Treatment	Productivity (kg ha^{-1})	Gross income (R$ ha^{-1})	Net income (R$ ha^{-1})	Return rate	Profitability index (%)
Weeded*	2,000.44 a	14,003.12 a	8,091.07 a	2.37 a	57.70 a
Diuron	1,957.35 a	13,701.47 a	7,831.26 a	2.34 a	57.00 a
Flumioxazin	1,933.13 a	13,531.94 a	7,762.85 a	2.33 a	55.43 a
Oxadiazon	1,654.54 b	11,581.77 b	5,224.61 b	1.82 b	42.51 b
Oxyfluorfen	1,556.75 b	10,897.26 b	4,978.79 b	1.84 b	44.59 b
Linuron	1,506.77 b	10,547.41 b	4,523.82 b	1.75 b	40.40 b
Metribuzin + Oxyfluorfen	1,395.55 c	9,768.85 c	3,775.29 b	1.63 b	38.33 b
Metribuzin	1,045.75 d	7,320.25 d	1,547.64 c	1.26 c	21.01 c
Not Weeded*	1,037.30 d	7,261.15 d	1,992.66 c	1.38 c	27.37 c
S-metolachlor	1,001.71 d	7,011.99 d	1,213.11 c	1.21 c	17.30 c
CV (%)	15.06	15.06	28.88	14.72	18.91

The means followed by the same letter do not differ by the Scott-Knott test, at 5% probability. CV: Coefficient of variation. *Witnesses.

The highest gross income, net income, rate of return, and profitability index were observed for weed treatment and for treatments with diuron and flumioxazin application. The herbicides diuron and flumioxazin stood out due to the higher productivity observed in these treatments, which compared to the weeded control did not differ significantly. The above results may be due to the efficiency of the herbicides diuron and flumioxazin in controlling most of the weeds present in the area (Figure 2), which minimized the competition of weeds with the crop leading to better use of growth resources (mineral nutrients, water, and light) and better crop development in relation to other treatments.

Diuron and flumioxazin showed high selectivity in the sesame crop since the productivity did not differ statistically from the weeded control, being potentially recommended for pre-emergence application in the sesame crop. The herbicides diuron and flumioxazin were applied pre-emergence in two seasons of the year in southern Texas and were selective for the sesame crop (GRITHAR; DOTRAY; LANGHAM, 2009; GRITHAR; DOTRAY; LANGHAM, 2012).

The herbicides oxadiazon, oxyfluorfen, linuron, metribuzin + oxyfluorfen, metribuzin, and S -metolachlor showed good performance in productivity. However, the efficiencies of these herbicides were less than 80% of weed control, showing no cost and benefit potential in the sesame crop applied in pre-emergence, making them unfeasible. The results mentioned above may be due to the phytotoxic effects of these herbicides and their ineffectiveness to control the weeds present in the area (IMOLOAME; JOSHUA; GWORGWOR, 2010).

Gross income showed the same behavior of productivity, differing statistically between all treatments. Manual weeding (R$ 14,003.12 ha^{-1}), diuron (R$ 13,701.47 ha^{-1}), and flumioxazin (R$ 13,531.94 ha^{-1}) provided the highest gross income due to the higher productivity obtained in these treatments. The other treatments presented gross income below the weeded control, being oxadiazon (R$ 11,581.77 ha^{-1}), oxyfluorfen (R$ 10,897.26 ha^{-1}), linuron (R$ 10,547.41 ha^{-1}), metribuzin + oxyfluorfen (R$ 9,768.85 ha^{-1}), metribuzin (R$ 7,320.25 ha^{-1}), non-weeded control (R$ 7,261.15 ha^{-1}), and S-metolachlor (R$ 7,011.99 ha^{-1}) (Table 2). The results above show the advantage of effective weed control by manual weeding and the use of herbicides applied in pre-emergence diuron and flumioxazin. Although manual weeding resulted in the highest yield and increase in all economic variables analyzed, manual weeding registered a higher production cost compared to the use of diuron and flumioxazin (Table 3).

Table 3 shows the components of total costs in the production of one hectare of sesame according to the application of different herbicides applied in pre-emergence and two control treatments (weed and non-weed).

These results show the advantage of using herbicides in pre-emergence to control weeds, such as S-metolachlor, metribuzin, and mainly diuron and flumioxazin, which were selective to the crop, over manual weeding in reducing the production cost in the Sesame. This study agrees with Imoloame, Joshua and Gworgwor (2010), that the gain in cost-benefit was much more profitable and advantageous due to the application of diuron in sesame than the gain in yield in plots with weeds at the cost of using manual weeding.

Table 3. Average values of total costs in the production of one hectare of sesame according to different herbicides applied in pre-emergence.

I - COST OF FARMING EXPENSES	Unit	Quantity	Total (R$)
1 - Machinery rental			
Tractor with harrow, tractor with limestone distributor	h	2.50	275.00
2 – Manpower			
Mounting the irrigation system	daily rate	3.00	120.00
Manual seeding	daily rate	3.00	120.00
Thinning	daily rate	3.00	120.00
Irrigation and fertigation	h	72.00	360.00
Weeded	daily rate	3.00	600.00
Not Weeded	daily rate	0.00	0.00
Spraying (Insecticide)	h	15.00	600.00
Harvest	daily rate	10.00	400.00
Grain processing	daily rate	6.00	240.00
3 – Seeds			
Sesame	kg	3.00	24.00
4 – Fertilizers			
Urea (45% N)	kg	77.78	124.45
Potassium chloride (60% K_2O)	kg	100.00	152.00
Monoamonic phosphate (61% P_2O_5 and 12% N)	kg	131.15	524.60
5 - Defensive agricultural			
Herbicide – Diuron	L	3.50	161.00
Herbicide - Oxadiazon	L	3.00	615.00
Herbicide – Linuron	L	1.60	304.00
Herbicide - Metribuzin + Oxyfluorfen	L + L	1.00 + 2.00	276.00
Herbicide - Oxyfluorfen	L	2.00	206.00
Herbicide - S-metolachlor	L	1.75	94.50
Herbicide - Metribuzin	L	1.00	70.00
Herbicide – Flumioxazin	g	120	66.72
Insecticide	L	3.25	240.40
6 – Others			
Electric power for irrigation	kWh	368.65	140.09
Soil analysis	Unit	1.00	30.00
Individual protection equipment	Unit	1.00	30.00
TOTAL COST OF EXPENSES FARMING (A)			4,061.54
II - OTHER EXPENSES			
7 - Administrative expenses (3% of crop costs)			121.85
8 - Technical assistance (2% of crop costs)			81.23
9 - Rural land tax (R$ 10.00 $year^{-1}$)			3.01
TOTAL OTHER EXPENDITURE (B)			206.09
III - FINANCIAL EXPENSES			
10 - Financing interest (7.49% $year^{-1}$)			91.77
TOTAL FINANCIAL EXPENSES (C)			91.77
VARIABLE COST (A + B + C = D)			4,359.39
IV – DEPRECIATIONS			
11 - Depreciation of improvements/facilities*			899.73
TOTAL DEPRECIATIONS (E)			899.73
V - OTHER FIXED COSTS			
12 - Periodic maintenance of improvements/installations (1% $year^{-1}$)			35.63
TOTAL OTHER FIXED COSTS (F)			35.63
FIXED COST (E + F = G)			935.37
OPERATIONAL COST (D + G = H)			5,294.76
VI - INCOME OF FACTORS			
13 - Expected remuneration on fixed capital (6% $year^{-1}$)			213.81
14 - Tenancy (R$ 1,200.00 ha^{-1} $year^{-1}$)			361.64
TOTAL INCOME OF FACTORS (I)			575.45
TOTAL COST (H + I = J)			
Diuron			5,870.21
Oxadiazon			6,357.17
Linuron			6,023.59
Metribuzin + Oxyfluorfen			5,993.56
Oxyfluorfen			5,918.48
Weeded			5,912.04
S-metolachlor			5,798.88
Metribuzin			5,772.60
Flumioxazin			5,769.09
Not weeded			5,268.49

*16,667 m of low-density polyethylene hose, with emitters spaced at 0.30 m, and nominal diameter of 16 mm (useful life of 2 years; value of the new good R $ 0.34 m^{-1}); PVC pipes and fittings (useful life of 16 years; very new value R$ 1,423.25); motor pump 7.5 hp (useful life of 16 years; value of the new good R$ 4,735.00).

The average values of treatments in variable, fixed costs, and factor income for the production of one hectare of sesame had the following values: R$ 4,357.59 ha^{-1}; R$ 935.37 ha^{-1}; and R$ 575.45 ha^{-1}, respectively. It can be seen that, according to Table 3, the most relevant expenses for the cost of sesame crop were related to labor, which corresponded on average to 57% of costs, and to inputs (seeds, fertilizers, pesticides), which represented an average of 31% of this component of production costs, demonstrating the low competitiveness and low technological level that Brazil has in relation to sesame crop (QUEIROGA et al., 2011).

The expenses with the rental of machines were less onerous to the farmer, since this cost had, on average, a 5% share of the total costs (Table 3). In the cultivation of sesame, a lot of labor is used, as it is carried out using traditional technologies and simple management in the semiarid region of Brazil, which implies a high dependence on labor in the stages of sowing, thinning, harvesting, and processing (BELTRÃO et al., 2013).

Net income corresponds to the value of gross income subtracted from production costs, so there is a profit from the investment. There was a significant difference in net income in the evaluated treatments. Higher net income was obtained for manual weeding (R$ 8,091.07 ha^{-1}), diuron (R$ 7,831.26 ha^{-1}), and flumioxazin (R$ 7,762.85 ha^{-1}) (Table 2). This increase is due to the higher productivity of these treatments, which is directly reflected in greater profitability. Higher productivity due to better weed control. The lowest net income was observed in the treatment with the application of the herbicide S-metolachlor (R$ 1,213.11 ha^{-1}) (Table 2). This low value is the result of the lower productivity of this treatment, due to the phytointoxication caused by this herbicide to crop and the low efficiency in the control of weeds.

The results show that the use of herbicides showed the same net yield as manual weeding. However, the cost of labor for manual weeding is much more expensive than the cost of purchasing herbicides for weed control. In addition, the time spent on control and the difficulty in finding specialized labor for manual weeding make chemical control more profitable in the production of sesame than manual weeding. These data are similar to those found by Beltrão et al. (1991), Mane et al. (2017), Rahman et al. (2017), and Imoloame, Joshua and Gworgwor (2010) reported satisfactory net returns obtained with herbicide application compared to other weed control methods.

The rate of return that corresponds to the capital obtained for each real invested had a significant difference between all treatments. The average values obtained were proportional to the net income, being that the weeded control (2.37), diuron (2.34), and flumioxazin (2.33) presented the highest rates of return, followed by oxadiazon (1.82), oxyfluorfen (1.84), linuron (1.75), metribuzin + oxyfluorfen (1.63), metribuzin (1.26), non-weeded control (1.38), and S-metolachlor (1.21) (Table 2).

The lower cost/benefit recorded by the application of herbicides in this study means that the use of herbicides is more economically viable than manual weeding in the production of sesame in the Brazilian Semiarid. Beltrão et al. (1991) report the optimal cost/benefit ratio with herbicide application compared to other weed control methods (manual weeding with hoe use) in the semiarid region of Brazil.

The profitability index consists of the relationship between net income and gross income and there was a significant difference between all treatments analyzed. The average values obtained in the profitability index achieved were 57.70% (weeded control), 57% (diuron), 55.43% (flumioxazin), 42.51% (oxadiazon), 44.59% (oxyfluorfen), 40.40% (linuron), 38.33% average (metribuzin + oxyfluorfen), 21.01% (metribuzin) 27.37% (non-weeded control), and 17.30% (S-metolachlor) (Table 2).

The herbicides diuron and flumioxazin provided higher profitability rates compared to other treatments with herbicide application in pre-emergence, this was due to the lower cost of production that provided more economic return in this cultivation system in the sesame crop. In summary, pre-emergent herbicides can control most annual grasses, Cyperaceae, and broadleaf weed species due to their residual activity in the soil (GRICHAR; DOTRAY, 2007). In this regard, diuron and flumioxazin applied in preemergence should be used once sesame seeds have been soaked in water, but before germination of sesame and weeds.

The economic analysis revealed that when weeds were not controlled, farmers had to face a loss of R$ 6,099.98 ha^{-1} and the benefit-cost ratio was low. Taking into account that the rate of return and the profitability index consists in relation to production costs, gross income, and net income, factors that can assist the farmer in decision making regarding the need to apply capital for investment, as well as allowing it to notice the occurrence of economic return. The success and acceptance of any technique depend on the economic feasibility and costs involved (SHAH et al., 2013).

In summary, the use of herbicides is an efficient and low-cost method for controlling weeds in sesame crops in the semiarid region of Brazil. Manual weeding can be adopted in areas where labor is easily available and inexpensive. When herbicide selection is correct, treatments that comprise herbicides require less cost producing greater net benefits than manual weeding.

CONCLUSIONS

Diuron and flumioxazin applied in pre-emergence are effective in controlling weeds in the sesame crop, presenting a performance similar to that obtained with the use of manual weeding.

The pre-emergence application of diuron and flumioxazin provided higher net income, of R$ 7,831.26 and R$ 7,762.85, respectively.

Chemical control with the use of herbicides applied in pre-emergence is economically feasible in relation to mechanical control.

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