Effectivity and selectivity of herbicides applied in pre-emergence in the sesame (*Sesamum indicum* L.) crop

Eficacia y selectividad de herbicidas aplicados en pre-emergencia en el cultivo del sésamo (*Sesamum indicum* L.)

Hamurábi Anizio Lins, Aurélio Paes Barros Júnior*, Daniel Valadão Silva,
Matheus de Freitas Souza, Márcio Alexandre Moreira de Freitas,
Enielson Bezerra Soares, Maria Alice Formiga Porto, Hélida Campos de Mesquita,
Fernando Sarmento de Oliveira

Originales: *Recepción:* 07/07/2018 - *Aceptación:* 12/03/2020

Abstract

Weed control in the sesame crop (*Sesamum indicum* L.) is a fundamental practice that ensures high grain yield. Choosing adequate control methods is a crucial step to reduce costs and reach success in weed management. Among these methods, application of chemicals shows high efficiency and low cost for farmers. However, the use of this method in sesame crops is limited because there is a restricted number of herbicides registered for pre- and post-emergence applications. Considering the importance of chemical methods for weed management, the objective of this research was to select herbicides to be applied in pre-emergence that could be used to control weeds in the sesame crop. Two experiments were carried out, one to determine the efficiency and another to determine the selectivity of herbicides applied in pre-emergence. The experiments were performed in a randomized complete block design (CBD) with four replicates. The treatments consisted of seven herbicides, a mixture of herbicides applied in pre-emergence, and two control treatments, one weed-free and one with weeds. Diuron and flumioxazin were found to be selective for pre-emergence. Metribuzin exhibited high toxicity to sesame, but it was effective to control several weed species, and metolachlor did not provoke high phytotoxicity in sesame, but reduced yield.

Keywords
Sesamum indicum L. • Chemical ontrol • weed control • oilseeds

Universidade Federal Rural do Semi-Árido. Department of Agronomic and Forest Sciences. Av. Francisco Mota. 572. Costa e Silva.
Caixa-postal: 137. CEP: 59625-900. Mossoró. RN. Brazil. * aurelio.barros@ufersa.edu.br

Resumen

El control de malezas en el cultivo del sésamo (*Sesamum indicum* L.) es una práctica fundamental para asegurar la alta productividad de esta oleaginosa. La elección de los métodos de control que serán adoptados son fundamentales para el éxito del manejo de malezas. Entre los métodos que se pueden aplicar, el químico es el más utilizado debido a su eficiencia y bajo costo. Sin embargo, el uso de este método en cultivos de sésamo es limitado debido a la escasez de información sobre la selectividad y eficiencia de herbicidas aplicados en pre-emergencia para este cultivo. El objetivo de este trabajo fue seleccionar herbicidas aplicados en pre-emergencia que pueden ser utilizados para el control de malezas en el cultivo de sésamo. En el año 2017, se realizaron dos experimentos, uno para determinar la eficiencia y otro para determinar la selectividad de herbicidas aplicados en pre-emergencia. Los experimentos fueron conducidos en un diseño estadístico de bloques (DBC) con cuatro repeticiones. Los tratamientos estuvieron constituidos por diez tratamientos (por siete herbicidas y una mezcla de herbicidas aplicados en pre-emergencia) y otros dos tratamientos, desmalezado (libre de malezas) y sin desmalezar (con malezas). Los herbicidas diuron y flumioxazin fueron selectivos para el cultivo de sésamo en pre-emergencia. El herbicida metribuzin causó alta toxicidad a las plantas de sésamo y no controló las malas hierbas. Metalachor no provocó intoxicación del sésamo, pero redujo la productividad del cultivo.

Palabras clave

Sesamum indicum L. • Control químico • control de malezas • oleaginosas

Introduction

Sesame (*Sesamum indicum* L.) has its origin in Africa and is cultivated in countries such as Iran, Egypt, India, and China (2). Several small producers in arid and semiarid regions opt for this species because of its adaptability to conditions of low water availability and high temperatures. Sesame seed has high nutritional value (50% oil and 20% protein), and its filter cake is widely used by the food, chemical, and pharmaceutical industries (10, 30).

The sesame crop is sensitive to competition with weeds. The low competitiveness of this crop is directly linked to its slow initial growth, especially when compared to C4 plants (24, 31). Therefore, when weed management measures are not adopted, especially in the initial periods, the yield of sesame may be reduced between 50 and 75% (5, 22).

Once the control periods are defined, the choice of control methods that will be adopted is a crucial step to ensure the efficiency of weed management. Among the methods, the chemical is the most used because of its efficiency and low cost (27). The herbicides can be applied in pre- or post-emergence of the crop. 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 (15, 16).

However, pre-emergence application in sesame is limited due to the scarcity of information about herbicide selectivity and efficiency for this crop. In addition, few herbicides are registered for sesame pre-emergence applications (18).

The registration process of an herbicide involves several studies, including its environmental and human health impact, as well as its selectivity and efficacy for the crop. Studies have shown that some herbicides are selective for sesame, but this selectivity has varied according to the used dosage and soil proprieties where the herbicide is applied (3, 7, 11, 17, 18, 21, 25).

The divergence between results for herbicides for use in sesame suggests that further evaluations should be carried out in the field. Thus, it was hypothesized that some herbicides applied in pre-emergence can be selective and efficient to control weeds in the sesame crop. Therefore, the objective of this work was to determine the herbicides selectivity and efficacy applied in pre-emergence to control weeds in the sesame crop.

Materials and Methods

Site description

Experiments were carried out at the experimental farm (5°03'37" S and 37°23'50" W Gr), altitude approximately 72 m, and the climate according to Thornthwaite is classified as DdAa' (6). The average precipitation is 750 mm per year, with annual evaporation of 2000 mm. The average meteorological data were collected during the period of the experiments (figure 1).

The soil is classified as Abrupt Eutrophic Red-Yellow Latosol, with sandy texture (12). The soil tillage with a moldboard plow and disking was performed in all the test area. Fertilization was carried out according to crop needs and on the basis of soil analysis (table 1, page 328) (8).

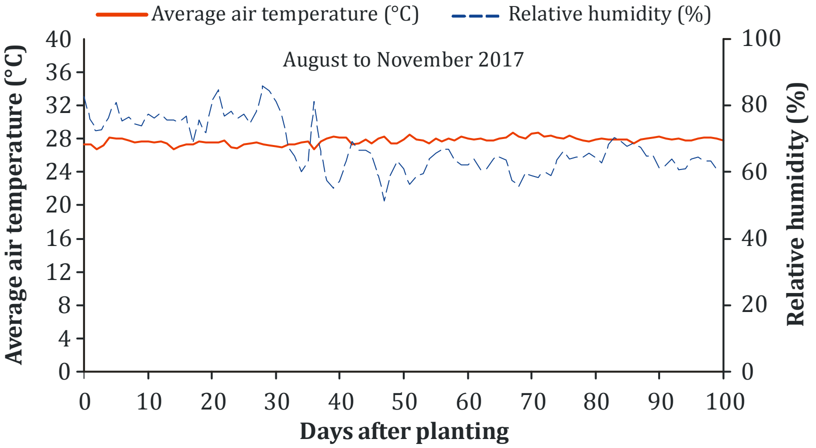


Figure 1. Mean values of maximum and minimum temperature (°C) and relative air humidity (%) in the season. Source: INMET Automatic Weather Station and rain gauge installed at the experimental farm.

Figura 1. Valores medios de temperatura máxima y mínima (°C) y humedad relativa del aire (%) en la temporada. Fuente: estación meteorológica automática INMET y pluviómetro instalados en la granja experimental.

Table 1. Soil chemical characterization of the sesame crop area.

Tabla 1. Caracterización química del suelo del área de cultivo de sésamo.

Year	N	OM	K	P	Na	Ca	Mg	pH	EC
	g kg^{-1}	g kg^{-1}	--------mg dm^{-3}--------			---cmol$_c$ dm^{-3}---			ds m^{-1}
2017	0.42	7.31	64.1	3.3	5.7	0.80	0.90	7.40	0.07

N = nitrogen; MO = organic matter; K = potassium; P = phosphorus; Na = sodium; Ca = calcium; Mg = magnesium; pH = ionic hydrogen potential; EC = electrical conductivity.

The fertilization before planting was carried out with 80 kg of P_2O_5 ha^{-1}, supplied as monoammonium phosphate. Two applications of 25 kg of N ha^{-1} and 60 kg of K_2O ha^{-1}, supplied as urea and potassium chloride, respectively, were performed after crop emergence via irrigation, with the aid of a bypass tank. Phytosanitary control of pests and diseases was carried out according to the technical recommendations and crop needs.

Treatments and experimental design

Two experiments were conducted, one to determine the efficiency and another to determine the selectivity of the herbicides applied in pre-emergence. The sesame cultivar used in the field studies was "BRS Seda". The experiments were conducted in a randomized complete block design with four replicates. The treatments consisted of seven herbicides applied isolated, a mixture of herbicides, and two control treatments (weed-free and with weeds) (table 2).

Pre-emergence herbicide application was performed one day after planting (DAP), using a costal sprayer equipped with a bar with four XR 110 02 nozzles, spaced 50 cm apart, at the height of 50 cm from the soil. The sprayer pump pressure of 0.25 MPa and velocity of 3.6 km h^{-1} allowed an application volume of 160 L ha^{-1} of syrup.

Table 2. Relationship of the treatments evaluated for the selectivity and efficiency in the sesame crop and in the control of weeds.

Tabla 2. Relación de los tratamientos evaluados para la selectividad y eficiencia en el cultivo de sésamo y en el control de malezas.

Common name	Commercial name	Trade mark	Dosage (g a.i. ha^{-1})
Weeded* / Not weeded*			
Diuron	Diox	Ouro Fino®	1750
Flumioxazin	Flumizin	Sumitomo Chemical®	60000
Linuron	Afalon	Adama®	720
Metalachor	Dual	Syngenta®	1680
Metribuzin	Sencor	Bayer®	480
Metribuzin + Oxyfluorfen	Sencor + Goal	Bayer® + Dow AgroSciences®	480 + 480
Oxadiazon	Ronstar	Bayer®	750
Oxyfluorfen	Goal	Dow AgroSciences®	480

Application 1 day after planting (DAP); *Witnesses. / Aplicación 1 día después de la siembra (DAP); *Testigos.

During the application, the neighboring plots were protected laterally with polyethylene plates to avoid drift of herbicides. In the weed-free control, the weeds were controlled during the entire crop cycle by hand weeding. In controls with weeds, no control method was applied during the crop cycle. The environmental conditions at the moment of herbicide application were: air temperature 22.4°C; air relative humidity 80%; wind speed 2.8 km h^{-1}.

Seeding and division of plots

The sesame seeds were planted in August 2017. The planting was performed directly at 2 cm depth, placing 8 to 10 seeds per hole. Ten days after emergence, only two plants remained in each hole. The experimental plot was 3 m in length with four crop rows, totaling an area of 7.2 m^2 (3.0 x 2.4 m). The plant spacing used was 0.30 x 0.60 m.

Irrigation of experiments

The irrigation was achieved by a drip irrigation system. The drip tapes were spaced 0.60 m apart, with 0.30 m between drippers. Irrigations were performed daily according to the estimated ETc of the crop (ETc = ETo x Kc). The values of Kc correspond to the stages of sesame development (1, 26).

Data collection

The variable dry matter weight of weeds was used to determine the herbicide efficacy. The weeds were collected in sample areas of 0.25 m^2 in each treatment at sesame harvest. After this procedure, the weeds of each plot were counted, identified, packed in paper bags and dried in a forced-air circulation oven for 72 hours at 65°C and weighed to determine its dry matter weight. The dry matter of the weed community was extrapolated to g m^{-2}.

The variables phytotoxicity (%), plant height (cm), leaf area (cm^2), stem diameter (mm), dry matter weight (g per plant) and yield of sesame were used to evaluate the herbicide selectivity. Phytotoxicity determinations were carried out at 7, 14, 21, 28 and 35 days after application (DAA), using a scale of grades varying from 0 to 100%, where 0% corresponded to the absence of symptoms, and 100% corresponded to the death of plants (29).

The weed species that occurred in the study areas 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.

Plant height, leaf area, stem diameter and dry matter weight of sesame were measured 100 days after emergence. The leaf area was estimated using the formula AF = C x L x f, where C = leaf length (cm), L = leaf width (cm), and f = correction factor (0.7) (26, 32). The sesame harvest was performed 100 days after the emergence, with the capsules presenting a basal yellow coloration. The plants in the useful area (1.5 m in length, 2 middle rows) of each plot were collected to estimate the dry matter and yield of sesame. The plants were dried in full sun for 30 days. Posteriorly, the capsules were collected, and the yield estimated in kg ha^{-1}, with humidity corrected to 6% (20).

Statistical analysis

Weed dry matter data were shown in figures and compared descriptively. The other measured variables were subjected to analysis of variance by the F test and, when significance was indicated, the data were compared by Scott-Knott test, at 5% probability.

SigmaPlot 12.0® software was used to construct the selectivity and efficiency graphs.

Results and Discussion

Herbicides efficiency

The applications of metribuzin, oxyfluorfen, metribuzin + oxyfluorfen, and in the treatment without weed control, the number of weed species observed varied between 11 and 13 (figure 2).

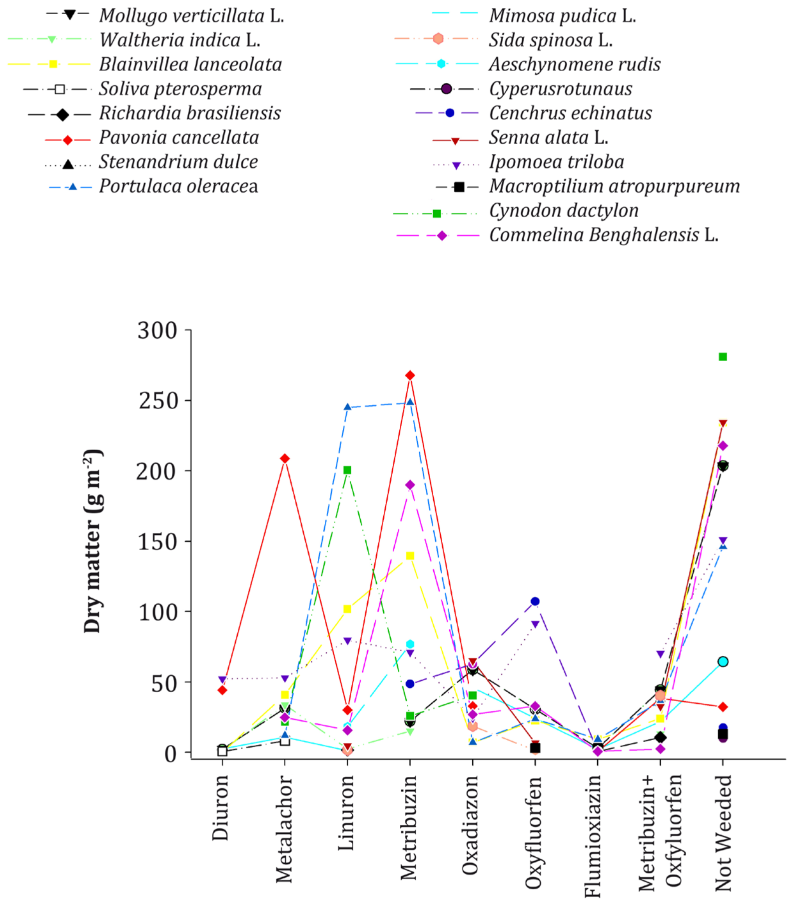


Figure 2. Dry matter of weeds after application of different treatments in the sesame crop.

Figura 2. Materia seca de malezas después de la aplicación de diferentes tratamientos en el cultivo de sésamo.

Although the difference among these treatments for the number of species was small, the application of metribuzin + oxyfluorfen and oxyfluorfen alone reduced the dry matter of most of the species observed in the area. Only the species *Ipomoea triloba* showed higher tolerance for the mixed applications of metribuzin + oxyfluorfen and isolated for oxyfluorfen.

The herbicide mixture aims to increase the control spectrum (23). However, the mixture between metribuzin and oxyfluorfen did not promote a greater reduction in the dry matter of weeds than the treatment with isolated applications of oxyfluorfen. This fact can be verified when evaluating the accumulation of dry matter of weeds in plots with isolated applications of metribuzin. In this treatment, a reduction was not observed in the dry matter of weeds. The addition of metribuzin in the mixture only promoted the control of the species *Aeschynomene rudis*, since this weed has not been shown to be sensitive to the oxyfluorfen applied in isolation.

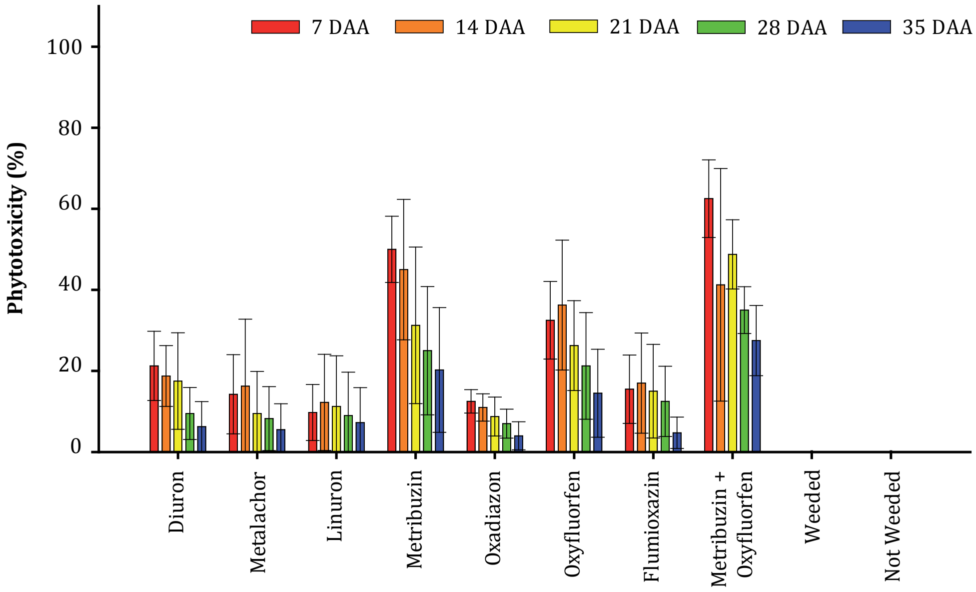
The herbicides metolachlor and oxadiazon promoted the highest dry matter reduction of the weed community (figure 2, page 330). The number of species observed in the plots with the metolachlor and oxadiazon application was 11 and 12, respectively, values close to that observed in the treatment without weed control. However, the species showed high sensitivity to these herbicides, accumulating on average 65% less dry matter than in this control treatment.

Flumioxazin and diuron reduced dry matter of weeds by 95%, compared to treatment without weed control, and reduced the number of species present in the area (figure 2, page 330). These herbicides were able to control most of the species, both monocotyledonous and dicotyledonous. The ability to control pre-emergence plants can reduce the number of applications during the crop cycle, reducing application costs (product, labor and time and machine costs), mainly in crops with a long cycle, as sesame. The flumioxazin and diuron showed the highest potential for use in pre-emergence due to efficient control promoted until the end of the cycle.

Linuron reduced the dry matter of weeds, except for the species *Soliva pterosperma*, *Pavonia cancellta*, *Portulaca oleracea* and *Ipomea triloba* (figure 2, page 330). The low efficiency for these species at the end of the sesame cycle makes linuron an herbicide with low potential in isolated applications. However, an alternative is to use another herbicide able to control species that are nonsensitive to the linuron.

Herbicides selectivity

The treatments diuron, metolachlor, linuron, oxadiazon, and flumioxazin promoted a similar phytotoxicity (20%) in sesame at 7, 14, 21, 28, and 35 DAA (figure 3, page 332). Poisonings in sesame, when these herbicides were applied, were not detected after 35 DAA (figure 3, page 332). The herbicides diuron, metolachlor, and linuron were used in two growing seasons in south Texas and were selective for sesame when applied in pre-emergence (17). In post-emergence applications, only flumioxazin was not selective for sesame (18). Oxadiazon, a protoporphyrinogen oxidase inhibitor herbicide, is recommended for pre-emergence applications in garlic due to its high selectivity for this crop (9). In sesame, this herbicide also was selective, demonstrating a potential for use in pre-emergence.



(DDA = Days after application). / (DAA = Días después de la aplicación).

Figure 3. Phytotoxicity of sesame plants in different evaluations carried out after application of treatments containing herbicides.

Figura 3. Toxicidad de plantas de sésamo en diferentes evaluaciones llevadas a cabo después de la aplicación de tratamientos que contienen herbicidas.

Treatments with metribuzin, oxyfluorfen, and metribuzin + oxyfluorfen caused the highest sesame phytotoxicity at 7 DAA (figure 3). The effects of poisoning reduced to 35 DAA for all treatments (figure 3). Unlike the other herbicides inhibiting protoporphyrinogen oxidase and photosystem II used in this study, the sesame did not show the same tolerance to metribuzin and oxyfluorfen. Although the herbicides diuron, linuron, and metribuzin have the same mode of action, the chemical group of these herbicides is different.

The group of ureas (diuron and linuron) caused less poisoning to the sesame than the triazine group. The differentiated selectivity of chemical groups has already been evidenced in other studies (14). The same behavior was observed for the chemical groups phthalimides and diphenylethers, inhibitors of protoporphyrinogen oxidase, evaluated in this work.

The sesame yields when submitted to oxadiazon, oxyfluorfen, linuron, and metribuzin + oxyfluorfen applications were similar to, but lower than, those of the weed-free treatments (figure 4, page 333).

The treatments with oxyfluorfen and metribuzin + oxyfluorfen caused high initial phytotoxicity in sesame compared to those with oxadiazon and linuron; however, the yields under these treatments were similar. This fact demonstrates the ability of sesame to recover from the harmful effects caused at 7 DAA by oxyfluorfen and metribuzin + oxyfluorfen applications.

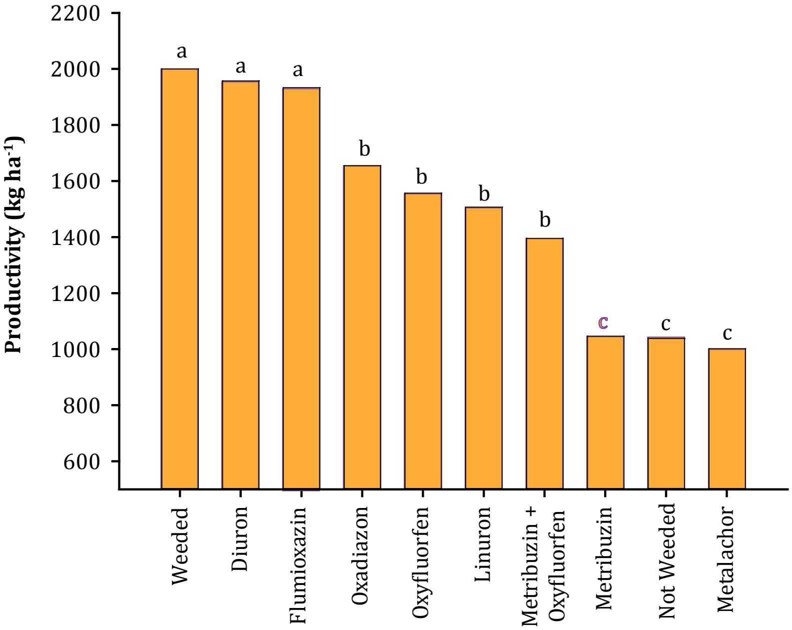


Figure 4. Productivity of sesame submitted to herbicide applications in pre-emergence.
Figura 4. Productividad del sésamo sometido a aplicaciones de herbicidas en preemergencia.

The lowest yield was observed in treatments with the metolachlor and metribuzin application, equaling those in nonweeded plots (figure 4). Despite the fact that the poisoning caused by these herbicides at 35 DAA was similar to that caused by the other herbicides applied, the yield in plots with metolachlor or metribuzin was lowest. Although not evident, the toxic effect of these herbicides may have resulted in increased metabolic stress, affecting yield in these treatments. In addition, sesame is a plant capable of masking phytotoxicity caused by herbicides in vegetative (19). Therefore, the yield assessment proves to be a more reliable parameter for selectivity trials.

The highest yield was observed in plots with the diuron and flumioxazin application, not differing from the yield of the weed-free treatment (figure 4). This higher productivity in the plots with these herbicides may be a response to the small stress caused in the initial periods of application. Sesame showed a good capacity to recover from phytotoxicity symptoms.

The lower phytotoxicity provoked by herbicide photoinitiators of FSII belonging to the chemical group of ureas also was reflected in a higher yield. Differently, flumioxazin and diuron may not have caused hidden damage capable of reducing the sesame yield as did the herbicides metribuzin and metolachlor (4).

All herbicides reduced plant height and stem diameter compared to weed-free treatment (table 3, page 334).

Table 3. Leaf area, plant height, stem diameter and sesame dry matter weight of plants submitted to pre-emergence herbicide applications.

Tabla 3. Área de la hoja, altura de la planta, diámetro del tallo y materia seca de sésamo sometida a aplicaciones de herbicidas de preemergencia.

Treatments	Leaf area (cm^2)	Plants height (cm)	Stem diameter (mm)	Dry matter (g $planta^{-1}$)
Witness (weeding)	123.3850 a	198.3333 a	20.7516 a	0.1277 a
Metribuzin	138.9033 a	143.8333 b	9.8450 b	0.1109 a
Oxadiazon	135.5666 a	164.3750 b	14.4000 b	0.0878 b
Flumioxazin	111.8133 a	160.1666 b	13.9983 b	0.1231 a
Diuron	77.7933 b	155.0000 b	12.7033 b	0.0691 b
Linuron	74.0133 b	156.8333 b	16.0716 b	0.1218 a
Metalachor	70.9566 b	137.3333 b	11.5700 b	0.0773 b
Metribuzin + Oxyfluorfen	70.3150 b	153.1666 b	14.4000 b	0.0593 b
Oxyfluorfen	69.6033 b	156.6666 b	12.5587 b	0.1222 a
Witness (not weeded)	42.6825 b	157.0000 b	12.9087 b	0.0973 b
CV (%)*	20.42	8.42	15.55	22.88

* Coefficient of variation. / * Coeficiente de variación.

The leaf area of the sesame plants was lower when the diuron, linuron, metolachlor, oxyfluorfen and metribuzin + oxyfluorfen were applied, equaling that of the non-weed control treatments (table 3).

The herbicides metribuzin, oxyfluorfen, linuron, and flumioxazin did not reduce sesame dry matter weight compared to that in the weed-free control (table 3).

Although some herbicides reduced plant height, stem diameter, leaf area, and dry matter, the sesame yield was not affected. For example, the diuron reduced these variables, but a high productivity was observed in the plots with the application of this herbicide. This phenomenon has been demonstrated in others crops for herbicide inhibitors of protoporphyrinogen oxidase. It has been reported (13) that fomesafen applications provoked high phytotoxicity and reduced the plant height of cowpea, but this treatment did not affect the grain yield. This fact may be related to low stress caused by the herbicide that shortens the vegetative stage, stimulating and reallocating the photo-assimilates for the reproductive development.

Conclusions

The herbicides diuron and flumioxazin are selective for pre-emergence sesame crop. The herbicide metribuzin caused high toxicity to sesame plants and did not control weed species. Metolachlor did not cause high phytotoxicity in sesame plants. However, this herbicide reduces crop productivity.

References

1. Amaral, J. A. B.; Silva, M. T. 2008. Evapotranspiração e coeficiente de cultivo do gergelim por manejo de irrigação. Revista Brasileira de Oleaginosa e Fibrosa. 12(1): 25-33.
2. Arriel, N. H. C.; Beltrão, N. E. M.; Firmino, P. T. 2009. Gergelim: o produtor pergunta, a Embrapa responde. Embrapa Informação Tecnológica. Brasília. Brasil. 209 p.
3. Beltrão, N. E. M.; Vieira, D. J.; Nóbrega, L. B.; Santos, J. W. 1991. Adubação, cultivar e controle de plantas daninhas na cultura do gergelim. Pesquisa Agropecuária Brasileira. 26(5): 605-611.
4. Belz, R. G.; Duke, E. O. 2017. Herbicide-mediated hormesis. In: Pesticide Dose: Effects on the Environment and Target and Non-Target Organisms. American Chemical Society. 135-148.
5. Bhadauria, N.; Arora, A.; Yadav, K. S. 2012. Effect of weed management practices on seed yield and nutrient uptake in sesame. Indian Journal of Weed Science. 44(2): 129-131.
6. Carmo Filho, F.; Espínola Sobrinho, J.; Maia Neto, J. M. 1991. Dados climatológicos de Mossoró: um município semi-árido nordestino. ESAM. Mossoró-RN. Brasil. 121 p.
7. Caur, B. L.; Tomar, D. S. 1978. Chemical weed control in sesame. Indian Journal of Agronomy. 23(1): 71.
8. Cavalcanti, F. J. A. 2008. 2° ed. Recomendações de adubação para o estado de Pernambuco: 2ª aproximação. IPA. Recife-PE. Brasil. 212 p.
9. Deuber, R.; Fornasier, J. B.; Lisbao, R. S. 1983. Efeito de diferentes herbicidas nas culturas de alho e cebola. Bragantia. 42(1): 119-129.
10. Dhaka, M. S.; Yadav, S. S.; Shivran, A. C.; Choudhary, G. L.; Prajapat, K. 2013. Effect of weed management on performance of sesame (*Sesamum indicum* L.) under varying levels of nitrogen. Annals of Agricultural Research New Series. 34(2): 179-184.
11. Dungarwal, H. S.; Chaplot, P. C.; Nagda, B. L. 2003. Integrated weed management in sesame (*Sesamum indicum* L.). Indian Journal of Weed Science. 35: 236-238.
12. Embrapa. 2018. Sistema brasileiro de classificação de solos. 5ª ed. Embrapa Solos: Brasília. Brasil. 567 p.
13. Fontes, J. R. A; Oliveira, I. J.; Gonçalves, J. R. P. 2013. Seletividade e eficácia de herbicidas para cultura do feijão-caupi. Revista Brasileira de Herbicidas. 12(1): 47-55.
14. Green, J. M.; Owen, M. D. K. 2010. Herbicide-resistant crops: utilities and limitations for herbicide-resistant weed management. Journal of agricultural and food chemistry. 59(11): 5819-5829.
15. Grichar, W. J.; Sestak, D. C.; Brewer, K. D.; Besler, B. A.; Stichler, C. R.; Smith, D. T. 2001. Sesame (*Sesamum indicum* L.) tolerance and weed control with soil-applied herbicides. Crop Protect. 20(5): 389-394.
16. Grichar, W. J.; Dotray, P. A. 2007. Weed control and sesame (*Sesamum indicum* L.) response to preplant incorporated herbicides and method of incorporation. Crop Protect. 26(12): 1826-1830.
17. Grichar, W. J.; Dotray, P. A.; Langham, D. R. 2009. Sesame (*Sesamum indicum* L.) response to preemergence herbicides. Crop Protect. 28(11): 928-933.
18. Grichar, W. J.; Dotray, P. A.; Langham, D. R. 2012. Sesame (*Sesamum indicum* L.) growth and yield as influenced by preemergence herbicides. International Journal of Agronomy. 2012: 1-7.
19. Grichar, W. J.; Dotray, P. A.; Langham, D. R. 2015. Sesame (*Sesamum indicum* L.) Response to Postemergence-directed Herbicide Applications. Herbicides, Agronomic Crops and Weed Biology. 2: 31-50.
20. Grilo Jr, J. A. S.; Azevedo, P. V. 2013. Crescimento, desenvolvimento e produtividade do gergelim BRS seda na agrovila de Canudos, em Ceará Mirim-RN. HOLOS. 2(29): 19-33.
21. Ibrahim, A. F.; El-Wekjl, H. R.; Yehia, Z. R.; Shaban, S. A. 2008. Effect of some weed control treatments on sesame (*Sesamum indicum* L.) and associated weeds. Journal of Agronomy and Crop Science. 160(5): 319-324.

22. Lins, H. A.; Souza, M. F.; Albuquerque, J. R. T.; Santos, M. G.; Barros Júnior, A. P.; Silva, D. V. 2019. Weed interference periods in sesame crop. Ciência e Agrotecnologia. 43:e000819.
23. Mahajan, G., Timsina, J. 2011. Effect of nitrogen rates and weed control methods on weeds abundance and yield of direct-seeded rice. Archives of Agronomy and Soil Science. 57(3): 239-250.
24. Mane, S. V.; Kanade, V. M.; Shendage, G. B.; Sarawale, P. P.; Shetye, V. N. 2017. Weed Management in Sesamum (*Sesamum indicum* L.) Grown under Coastal Region of Maharashtra. Journal of the Indian Society of Coastal Agricultural Research. 35(1): 31-33.
25. Mazzani, B. 1983. Cultivo y mejoramiento de plantas oleaginosas. FONAIAP. Caracas. Venezuela. 169-226 p.
26. Noguera-Talavera, Á.; Salmerón, F.; Reyes-Sánchez, N. 2019. Bases teórico-metodológicas para el diseño de sistemas agroecológicos. Revista de la Facultad de Ciencias Agrarias. Universidad Nacional de Cuyo. Mendoza. Argentina. 51(1): 273-293.
27. Silva, A. A.; Silva, J. F. 2013. 1° ed. Tópicos em manejo de plantas daninhas. Editora UFV. Viçosa-MG. Brasil. 367 p.
28. Silva, L. C.; Santos, J. W.; Vieira, D. J.; Beltrão, N. E. M.; Alves, I.; Jerônimo, J. F. 2002. Um método simples para se estimar área foliar de plantas de gergelim (*Sesamum indicum* L.). Revista Brasileira de Oleaginosas e Fibrosas. 6(1): 491-495.
29. Sociedade Brasileira da Ciência das Plantas Daninhas. 1995. Procedimentos para instalação, avaliação e análise de experimentos com herbicidas. SBCPD. Londrina-PR. Brasil. 42 p.
30. Soto-Landeros, F.; Alcaraz-Meléndez, L.; Angulo-Escalante, M. A.; Reynoso-Granados, T.; Pérez-Rubio, V. 2019. Seed oil content and composition of *Jatropha curcas* (L.) and grafted *Jatropha curcas* (L.) on *Jatropha cinerea* (Ortega) Muell. Arg. rootstock. Revista de la Facultad de Ciencias Agrarias. Universidad Nacional de Cuyo. Mendoza. Argentina. 51(2): 68-77.
31. Souza, M. F.; Silva, T. S.; Santos, J. B.; Carneiro, G. D. O. P.; Reginaldo, L. T. R. T.; Bandeira, J. N.; Santos, M. S.; Pavão, Q. S.; Negreiros, M. Z.; Silva, D. V. 2020. Soil water availability alter the weed community and its interference on onion crops. Scientia Horticulturae. 272: 109573.
32. Tittonell, P. 2019. Las transiciones agroecológicas: múltiples escalas, niveles y desafíos. Revista de la Facultad de Ciencias Agrarias. Universidad Nacional de Cuyo. Mendoza. Argentina. 51(1): 231-246.

Acknowledgements

To "Aperfeiçoamento de Pessoal de Nível Superior - Brazil (CAPES) - Finance Code 001" for financial support.