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Hairy Beggarticks (*Bidens pilosa* L. - Asteraceae) Control in Sunflower Fields Using Pre-Emergence Herbicides

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***Abstract*—**One of the most damaging species in sunflower crops in Brazil is the hairy beggarticks (*Bidens pilosa* L.). The large number of seeds, the various vegetative cycles during the year, the staggered germination and the scarcity of selective and effective herbicides to control this weed in sunflower are some of attributes that hinder the effectiveness in controlling hairy beggarticks populations. The experiment was carried out with the objectives of evaluating the control of hairy beggarticks plants in sunflower crops, and to assess sunflower tolerance to residual herbicides. The treatments were as follows: *S*-metolachlor (1,200 and 2,400 g ai ha^{-1}), flumioxazin (60 and 120 g ai ha^{-1}), sulfentrazone (150 and 300 g ai ha^{-1}) and two controls (weedy and weed-free check). Phytotoxicity on sunflower plants, percentage of control and density of hairy beggarticks plants, sunflower stand and plant height, head diameter, oil content and sunflower yield were evaluated. The herbicides flumioxazin and sulfentrazone were the most efficient in hairy beggarticks control. *S*-metolachlor provided acceptable control levels. S-metolachlor (1,200 g ha^{-1}), flumioxazin (60 g ha^{-1}) and sulfentrazone (150 g ha^{-1}) were the most selective doses for sunflower crop.

***Keywords*—**Flumioxazin, *Helianthus annuus*, S-metolachlor, sulfentrazone, weeds.

I. Introduction

BIDENS pilosa L., commonly known as hairy beggarticks, is one of the most prominent species in agricultural regions in South America. In Brazil, it occurs mainly in its Central South region [30].

The species is annual, herbaceous, and it has an erect stem, 40-120 cm high [24]. The inflorescences, also called heads, are formed by yellow flowers that originate seeds (achenes) [5]. Hairy beggarticks can produce 3,000 to 6,000 achenes per plant; therefore, three generations per year are common [4], [19]. Moreover, seed dormancy due to latency allows germination even after five years [19]. The two or three barbed awns at the end of the achenes are essential for spreading the species. It is an effective means of seed dispersal, as awns adhere to fur or clothing and are then transported by animals or humans.

Hairy beggarticks populations were confirmed as resistant to acetolactate synthase (ALS)-inhibiting herbicides [20], as well as to both ALS inhibitors and photosynthesis inhibiting herbicides [34]. Hairy beggarticks populations were also identified as resistant to paraquat [21] and glyphosate [1].

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B. pilosa is considered to be one of the most problematic weed species in Brazilian sunflower fields [9]. The difficulty in controlling this species is also attributed to their similarities to sunflower. Both of them belong to the same family (Asteraceae), having morphological and physiological similarities. Generally, selective herbicides for sunflower do not have effective control of hairy beggarticks. In addition, the scarcity of effective sunflower herbicides to control broadleaf weeds has limited chemical weed management options in sunflower fields [8]. However, herbicides with residual effect are an effective practice in weed control in sunflower [35]. The dynamics of these herbicides in soils are influenced by a number of characteristics, such as type, texture, moisture content, organic matter and pH [17], [15]. Thus, studies of herbicide selectivity as a function of specific conditions are necessary to avoid toxicity on sunflower plants, and to obtain effective control of the main weed species.

The objectives of this study were to evaluate the control of hairy beggarticks plants in sunflower crops, and to assess sunflower tolerance to residual herbicides.

II. Materials and Methods

A. Experimental Site

The experiment was carried in Coronel Pacheco township, Minas Gerais State, Brazil (21°32'55.60"S, 43°15'57.58" W). Soils of the experimental site are classified as Fluvic Cambisol. Chemical and textural profiles are as follows: pH (H_2O) = 5.1, P = 24.5 mg dm^{-3}, K = 168 mg dm^{-3}, Ca^{2+} = 3.7 $cmol_c$ dm^{-3}, Mg^{2+} = 1.4 $cmol_c$ dm^{-3}, $CEC_{(t)}$= 5.7 $cmol_c$ dm^{-3}, CEC ($T_{pH=7.0}$) = 10.3 $cmol_c$ dm^{-3}, V = 54%, organic matter concn. = 2.8 dag kg^{-1}, clay = 56%, silt = 35%, sand = 9%.

B. Experimental Design

A complete randomized block design with four replicates was chosen. The treatments were as follows: two doses of *S*-metolachlor (1,200 and 2,400 g ha^{-1}), two doses of flumioxazin (60 and 120 g ha^{-1}) and two doses of sulfentrazone (150 and 300 g ha^{-1}). Weedy check and weed-free check controls were also performed.

C. Field Experimentation

The experiment was started on May 30, 2016. The soil of the experimental area was plowed and barred and then hairy beggarticks seeds were distributed throughout the experimental area in the amount of 0.5 kg of seeds per 307 m^2.

The sunflower hybrid Paraíso 102 CL® (Clearfield®) was sown (0.8 m row spacing), keeping three seeds spaced 25 cm apart. Plots consisted of four rows, each 3 m long. Watering was performed weekly to a 15-mm water layer. Fertilizer at sowing was applied at 350 kg ha^{-1} NPK (08-28-18). Plant thinning was carried out at ten days after sunflower emergence, keeping a crop stand of ca. 55,000 plants per hectare. Side-dressing was performed 18 days after sunflower emergence with 250 kg ha^{-1} NPK (20-05-20) fertilizer. Boron (B) was applied in mix with the side-dressing fertilizer at 1.2 kg ha^{-1} (boric acid - 17% B). Grass weeds were controlled using fluzifop-p-butyl at 125 g ha^{-1}. Broadleaf weeds, which escaped to the action of the herbicides, were manually eliminated. Herbicide treatments were applied in pre-emergence condition on June 2, 2016. A carbon dioxide (CO_2) backpack sprayer was used, calibrated to deliver a spraying volume equivalent to 160 L ha^{-1}.

D. Statistical Analysis

Phytotoxicity of herbicide treatments on sunflower and hairy beggarticks control were evaluated using a visual scale (0% to 100%) at 30 and 45 days after herbicide application (DAT). Zero values corresponded to no symptoms of phytotoxicity on sunflower plants or no hairy beggarticks control and 100% to complete sunflower death or complete weed control [33]. Density of hairy beggarticks was determined by counting hairy beggarticks plants within a square (0.5 x 0.5 m) at 35 DAT.

Sunflower plant stand was determined by counting the number of plants within the central two rows of each plot and then converted to plants per hectare. Averages of sunflower plant height and head diameter were obtained by measuring five plants from two central rows. The oil content was determined by nuclear magnetic resonance NMR equipment (Oxford, USA). The sunflower yield was obtained by harvesting two 3-m long rows of sunflower within the central area of the plots and subsequent transformation to kg ha^{-1}.

The percentage of phytotoxicity on sunflower plants and the hairy beggarticks control percentages were normalized by square root transformation of (x + 1) to perform analysis of variance [28]. Mean values were compared by Scott-Knott test ($P \leq 0.05$). Statistical analyses were performed using SAEG software [28].

III. Results and Discussion

Treatments with *S*-metolachlor and sulfentrazone did not cause visual symptoms of phytotoxicity to sunflower plants (Table I).

Sulfentrazone was also applied under pre-emergence conditions of sunflower hybrid Morgan M-742 [11]. The applied herbicide dose was tolerated by sunflower, with low values of phytotoxicity at 20 DAT, and plant recovery at 30 DAT. The hybrid Helio 250 was also submitted to the application of sulfentrazone, likewise there were no apparent damages to sunflower growth and development [27].

Flumioxazin was the most phytotoxic herbicide. The percentage of injury reached 1.5% for the lowest dose at 30 DAT. Eventually, the plants recovered and this value declined to zero at 45 DAT. Flumioxazin (30 or 60 g ha^{-1}) was applied on sunflower plants at leaf stages between 2-4 days [23]. The authors considered percentages of phytotoxicity ranging from 17% to 24% as acceptable. This herbicide is highly adsorbed by organic matter and clay [2], and thus poorly leached [14]. Although flumioxazin remains adsorbed to organic matter and clays, it may be readily available in soil solution as a function of water availability [16]. Therefore, heavy rains after application can promote percolation, affecting seed germination. The highest applied dose of flumioxazin killed most (98%) sunflower plants. When flumioxazin was used in pre-emergence, the plant tissues were damaged by contact with the herbicide as seedlings emerge [25]. Post-emergence flumioxazin application also causes similar characteristic symptoms, notably tissue necrosis.

The employed doses of flumioxazin and sulfentrazone yielded the highest percentages of weed control, ranging from 95% to 100% at 45 DAT (Table I). In addition, these two herbicides considerably reduced the density of hairy beggarticks plants. The control of hairy beggarticks as function of flumioxazin applied in pre-sowing desiccation provided residual control of hairy beggarticks already at doses of 50 and 75 g ha^{-1} [26]. In fact, this same herbicide was applied on sugar cane straw at 150 g ha^{-1} in order to achieve satisfactory hairy beggarticks´ control (95% to 100%) [12].

S-metolachlor was not effective for hairy beggarticks control in sunflower crops, especially at the lowest dose. This herbicide is not registered for hairy beggarticks control in Brazil [29]. Despite not being allowed for hairy beggarticks control in Brazil, *S*-metolachlor at doses of 1.5 L ha^{-1} to 7.5 L ha^{-1} of the commercial product showed reductions in weed height [32]. *S*-metolachlor (1,680 g ha^{-1}) applied in pre-emergence of maize also presented acceptable control (71.5%) of hairy beggarticks at 28 days after emergence [13].

The mean values of crop stand, plant height, head diameter, oil content and sunflower yield are described on Table II. The lowest dose of *S*-metolchlor (1,200 g ha^{-1}) did not affect any of the measured variables and, as a result, did not affect sunflower productivity. In fact, *S*-metolachlor (1,440 g ha^{-1}) was applied on sunflower without detectable injuries, making it a potential alternative for weed control in pre-emergence conditions [27].

The highest dose of *S*-metolachlor (2,400 g ha^{-1}) reduced crop yields. This sheds light on the hypothesis that the selectivity of *S*-metolachlor in sunflower might be negatively correlated to herbicide concentration. In contrast, the adsorption of *S*-metolachlor in soils is positively correlated with organic matter and clay content [18], [36]. Thus, when it is applied in pre-emergence conditions, the herbicide concentrates on the soil surface, which accumulates most organic matter [6], [3]. High doses of *S*-metolachlor applied to sandy soils and low organic matter can cause phytotoxicity to sunflower [10]. In addition, the leaching potential of *S*-metolachlor is strictly correlated with rainfall [22]. High doses of *S*-metolachlor associated with irrigation water and rainfall may favor its leaching to deeper soil layers, thereby decreasing crop productivity.

TABLE I
PERCENTAGE OF PHYTOTOXICITY ON SUNFLOWER PLANTS (F%) AND PERCENTAGE OF HAIRY BEGGARTICKS CONTROL (C%) AT 30 AND 45 DAYS AFTER TREATMENT (DAT) AND NUMBER OF HAIRY BEGGARTICKS PLANTS PER 0,25 M^2 (NP) AT 35 DAT. CORONEL PACHECO, MINAS GERAIS STATE, BRAZIL

Treatment	Dose	F (%)		C (%)		NP
	g ai ha^{-1}	30 DAT	45 DAT	30 DAT	45 DAT	
S-metolachlor	1,200	0.0 C[1]	0.0 B	42.7 D	52.0 E	12.2 B
S-metolachlor	2,400	0.0 C	0.0 B	53.0 C	63.0 D	2.0 C
Flumioxazin	60	1.5 B	0.0 B	95.0 B	97.0 B	3.0 C
Flumioxazin	120	93.2 A	98.0 A	99.7 A	100.0 A	1.0 C
Sulfentrazone	150	0.0 C	0.0 B	94.2 B	95.5 C	0.7 C
Sulfentrazone	300	0.0 C	0.0 B	95.0 B	97.0 B	1.7 C
Weedy check	-	0.0 C	0.0 B	0.0 E	0.0 F	44.7 A
Weed-free check	-	0.0 C	0.0 B	100.0 A	100.0 A	0.0 C
Coeficient of Variation (%)	-	3.5	0.6	0.7	0.5	66.6

[1]Mean values followed by different letters are significantly different ($P \leq 0.05$) by the Scott–Knott test.

TABLE II
SUNFLOWER STAND (S) (PLANTS HA^{-1} X 10^4), PLANT HEIGTH (H) (M), HEAD DIAMETER (HD) (CM), OIL CONTENT (O) (%) AND SUNFLOWER YIELD (Y) (KG HA^{-1}). CORONEL PACHECO, MINAS GERAIS STATE, BRAZIL

Treatment	Dose g (ai) ha^{-1}	S	H	HD	O	Y
S-metolachlor	1,200	5,7 A[1]	1.8 A	19.7 A	40.8 A	3,352.0 A
S-metolachlor	2,400	5,5 A	1.9 A	19.7 A	42.5 A	2,629.6 B
Flumioxazin	60	5,0 A	1.9 A	20.5 A	43.1 A	3,657.2 A
Flumioxazin	120	2,0 B	1.5 B	14.5 C	42.2 A	2,984.3 B
Sulfentrazone	150	5,2 A	1.8 A	19.6 A	40.5 A	3,286.4 A
Sulfentrazone	300	5,7 A	1.9 A	20.1 A	40.3 A	3,005.7 B
Weedy check	-	4,7 A	1.6 B	16.3 B	41.1 A	2,866.6 B
Weed-free check	-	5,0 A	1.8 A	20.6 A	40.6 A	3,215.1 A
Coeficient of Variation (%)	-	13.2	9.0	5.1	4.0	7.8

[1]Mean values followed by different letters are significantly different ($P \leq 0.05$) by the Scott–Knott test.

Flumioxazin (60 g ha^{-1}) did not affect sunflower, based on the studied variables (Table II). The selectivity of this herbicide in sunflower crops is also dose-dependent. Thus, doubling the applied herbicide dose decreased all evaluated variables, except oil content. The sunflower stand was the most drastically affected variable, which significantly reflected on sunflower yield losses.

Sulfentrazone at the lowest dose did not affect any of the studied variables, including sunflower yields. Although no visual injuries were observed on sunflower plants at 45 DAT due to the application of the highest dose of sulfentrazone, there was a reduction in crop yields. Sulfentrazone leaching is also dependent on rainfall and soil texture [31]. Increased rainfall arguably drives the herbicide to greater soil depths, causing damage to crop development. Adsorption of sulfentrazone to the soil is also influenced by pH and organic matter content [17]. Poor adsorption of the herbicide in soils containing low levels of organic matter causes increased residual product in soil solution, which probably led sunflower yield losses.

IV. CONCLUSIONS

This research provides alternatives to hairy beggarticks control in sunflower fields. Different herbicide options that are feasible for use in sunflower can facilitate increases in cultivated areas and oil supplies.

The herbicides flumioxazin and sulfentrazone were the most effective in controlling hairy beggarticks in sunflower fields. *S*-metolachlor provided acceptable control levels. *S*-metolachlor (1,200 g ha^{-1}), flumioxazin (60 g ha^{-1}) and sulfentrazone (150 g ha^{-1}) were the most selective herbicides.

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REFERENCES

[1] Alcántara-de la Cruz, R., Fernández-Moreno, P.T., Ozuna, C.V., Rojano-Delgado, A.M., Cruz-Hipolito, H.E., Domínguez-Valenzuela, J.A., Barro, F., De Prado, R. (2016). Target and non-target site mechanisms developed by glyphosate resistant hairy beggarticks (*Bidens pilosa* L.) populations from Mexico. *Frontiers in Plant Science* 7: 1-12.

[2] Alister, C., Rojas, S., Gómez, P., Kogan, M. (2008). Dissipation and movement of flumioxazin in soil at four field sites in Chile. *Pest Management Science* 64: 579-583.

[3] Alletto, L., Benoit, P., Bolognési, B., Couffignal, M., Bergheaud, V., Dumenéry, V., Langueval, C., Barriuso, E. (2013). Sorption and mineralisation of S-metolachlor in soils from fields cultivated with different conservation tillage systems. *Soil Tillage Research* 128: 97-103.

[4] Baio, F.H.R., Pires, L.F., Tomquelski, G. (2013). Mapeamento de picão-preto resistente aos herbicidas inibidores de ALS na região sul mato-grossense. *Bioscience Journal* 29: 59-64.

[5] Bartolome, A.P., Villaseñor, I.M., Yang, W. (2013). *Bidens pilosa* L.

(Asteraceae): botanical properties, traditional uses, phytochemistry, and pharmacology. *Evidence-Based Complementary and Alternative Medicine*, 2013: 1-51,

[6] Bedmar, F., Daniel, P.E., Costa, J.L., Giménez, D. (2011). Sorption of acetochlor, *S*-metolachlor, and atrazine in surface and subsurface soil horizons of Argentina. *Environmental Toxicology Chemistry* 30: 1990-1996.

[7] Bogosavljevic, S.S., Zlatkovic, B.K. (2015). Two aliens species of *Bidens* (Compositae), new to the flora of Serbia. *Phytologia Balcanica* 21: 129-138.

[8] Brighenti, A.M. (2013). Manejo de plantas daninhas. *In*: Oliveira, A.C.B., Rosa, A.P.S.A. *Guia prático do cultivo do girassol*. Embrapa, Brasília, DF, Brasil. p. 37-42.

[9] Brighenti, A.M. (2012). Resistência do girassol a herbicidas inibidores da enzima aceto-alctatosintase. *Pesquisa Agropecuária Tropical* 42: 225-230.

[10] Brighenti, A.M., Castro, C., Gazziero, D.L.P., Voll, E. (2005). Manejo de plantas daninhas no girassol. *In*: Leite, R.M.V.B.C.; Brighenti, A.M., Castro, C. *Girassol no Brasil.* Embrapa Soja, Londrina, Brasil. p. 410-469.

[11] Brighenti, A.M., Fornarolli, D.A., Oliveira Júnior, R.S. Gazziero, D.L.P., Pinto, R.A. (2000). Seletividade de herbicidas aplicados em condições de pré-emergência na cultura do girassol. *Revista Brasileira de Herbicidas* 1: 243-247.

[12] Carbonari, C.A., Gomes, G.L.G.C., Velini, E.D. (2010). Efeitos de períodos sem a ocorrência de chuva na eficácia do flumioxazin aplicado no solo e na palha de cana-de-açúcar. *Revista Brasileira de Herbicidas* 9: 81-88.

[13] Dan, H.A., Barroso, A.L.L., Dan, L.G.M., Finotti, T.R., Feldkircher, C., Santos, V.S. (2010). Controle de plantas daninhas na cultura do milho por meio de herbicidas aplicados em pré-emergência. *Pesquisa Agropecuária Tropical* 40: 388-393.

[14] Deuber, R., Pastre, W., Giusto A.B. (2009). Lixiviação de flazasulfuron e flumioxazin em dois diferentes solos. *Revista Brasileira de Herbicidas* 8: 27-36.

[15] Faustino, L.A., Freitas, M.A.M., Passos, A.B.R.J., Saraiva, D.T., Faria, A.T., Silva, A.A., Ferreira, L.R. (2015). Mobilidade do sulfentrazone em solos com diferentes características físicas e químicas. *Planta Daninha* 33: 795-802.

[16] Ferrell, J.A., Vencill, W.K., Xia, K., Grey, T.L. (2005). Sorption and desorption of flumioxazin to soil, clay minerals and ion-exchange resin. *Pest Management Science* 61: 40-46.

[17] Freitas, M.A.M., Passos, A.B.R.J., Torres, L.G., Moraes, H.M.F., Faustino, L.A., Rocha, P.R.R., Silva, A.A. (2014). Sorção do sulfentrazone em diferentes tipos de solo determinada por bioensaios. *Planta Daninha* 32: 385-392.

[18] Gannon, T.W., Hixson, A.C., Weber, J.B., Shi, W., Yelverton, F.H., Rufty, T.W. (2013). Sorption of simazine and S-metolachlor to soils from a chronosequence of turfgrass systems.Weed Science 61: 508-514.

[19] Gilbert, B., Alves, L.F., Favoreto, R. (2013). *Bidens pilosa* L. Asteraceae (Compositae; subfamília Heliantheae). *Revista Fitos* 8: 1-72.

[20] Guerra, N., Oliveira Júnior, R.S., Constantin, J., Oliveira Neto, A.M., Dan, H.A., Alonso, D.G., Santos, G., Jumes, T.M.C. (2011). Efeito da modalidade de aplicação sobre o controle de *Bidens pilosa* resistente a herbicidas inibidores da enzima ALS. *Global Science and Technology* 4: 61-69.

[21] Heap, I. (2017). International Survey of herbicide resistant weeds. Available:http://www.weedscience.org/Summary/Species.aspx?WeedID=32. (acesso: Junho 2017).

[22] Inoue, M.H., Santana, D.C., Oliveira Júnior, R.S., Clemente, R.A., Dallacort, R., Possamai, A.C.S., Santana, C.T.C., Pereira, K.M. (2010). Potencial de lixiviação de herbicidas utilizados na cultura do algodão em colunas de solo. *Planta Daninha* 28:.825-833.

[23] Jursík, M., Andr, J., Holec, J., Soukup, J. (2011). Efficacy and selectivity of post-emergent application of flumioxazin and oxyfluorfen in sunflower. *Plant Soil Environment* 57: 532-539.

[24] Lorenzi, H. (2014). *Manual de identificação e controle de plantas daninhas: plantio direto e convencional*. Instituto Plantarum, Nova Odessa, Brasil. 379 p.

[25] Oliveira Júnior, R.S. (2011). Mecanismos de ação de herbicidas. *In*: Oliveira Júnior, R.S., Constantin, J., Inoue, M.H. *Biologia e manejo de plantas daninhas.* Omnipax, Curitiba, Brasil. p. 141-191.

[26] Ratier, F.J.P., Guerra, N., Oliveira Neto, A.M. (2015). Efeito de misturas de herbicidas na dessecação pré-semeadura e no desenvolvimento inicial do milho safrinha. *Revista Campo Digit@l: Ver. Ciências Exatas e da Terra e Ciências Agrárias* 10: 63-70.

[27] Reis, R.M., Silva, D.V., Freitas, M.S., Reis, M.R., Ferreira, E.A., Sediyama, T. (2014). Aspectos fisiológicos e crescimento do girassol após aplicação de herbicidas em pré-emergência. *RevistaAgro@ambiente Online* 8: 352-358.

[28] Ribeiro Júnior, J. I. (2001). *Análises estatísticas no SAEG*. Editora UFV, Viçosa, Brasil. 301 p.

[29] Rodrigues, B.N., Almeida, F.S. (2011). *Guia de herbicidas*. Grafmarke, Londrina, Brasil. 697 p.

[30] Santos, J.B., Cury, J.P. (2011). Picão-preto: uma planta daninha especial em solos tropicais. *Planta Daninha* 29: 1159-1171.

[31] Silva Júnior, A.C., Queiroz, J.R.G., Martins, D. (2016). Leaching of sulfentrazone herbicide in soils with different textures. *Científica* 44: 575-583.

[32] Silva, R.A., Oliveira, L.S., Matsumoto, S.N., Oliveira, M.N.; Costa, A.A. (2013). Crescimento de picão-preto em resposta à aplicação de S-metolachlor. *Enciclopédia biosfera*, *Centro Científico Conhecer* 19: 1-7.

[33] (SBCPD). (1995). Sociedade Brasileira da Ciência das Plantas Daninhas. *Procedimentos para instalação e análise de experimentos com herbicidas.* SBCPD, Londrina, Brasil. 42 p.

[34] Takano, H.K., Oliveira Júnior, R.S., Constantin, J., Braz, G.B.P., Franchini, L.H.M., Burgos, N.R. (2016). Multiple resistance to atrazine and imazethapyr in hairy beggarticks (*Bidens pilosa*). *Ciência e Agrotecnologia* 40: 547-554.

[35] Týr, S., Vavrík, D. (2015). Chemical weed control of sunflower stands. *Research Journal of Agricultural Science* 47: 243-251.

[36] Zemolin, C.R., Avila L.A., Cassol, G.V., Massey, J.H., Camargo, E.R. (2014). Environmental fate of S-metolachlor - a review-. *Planta Daninha* 32: 655-664.