SULFENTRAZONE FOR VOLUNTEER SOYBEAN CONTROL AND SELECTIVITY IN SUNFLOWER CROP

Alexandre Magno Brighenti

SUMMARY

*The control of volunteer soybean (*Glycine max*) plants between crop seasons is mandatory due to the increasing incidence of diseases, mainly Asian soybean rust (*Phakopsora pachyrhizi*). Moreover, competition from volunteer soybean plants can cause yield losses in other crops. The objectives of this study were to evaluate the control of volunteer soybean plants by sulfentrazone doses and selectivity in sunflower crop (*Helianthus annuus*). Two experiments were carried out under field conditions in the municipality of Rio Verde, Goiás State, Brazil. The experimental design was randomized complete blocks with four replications. Treatments applied in Experiment 1 were sulfentrazone 0, 25, 50, 100 and 150g·ha^{-1} and hoed check. The same treatments were applied in Experiment 2 plus sulfentrazone 200 and 250g·ha^{-1}. Polynomial regression models were fitted to the data of percentage of sunflower phytotoxicity, percentage of soybean control, sunflower plant height, head diameter, sunflower grain yield and dry biomass of volunteer soybean plants. Doses ranging from 114.1 to 158.8g·ha^{-1} provided the highest sunflower yield, preventing the competition of volunteer soybean plants with the crop. Sulfentrazone did not completely eliminate the volunteer soybean plants, but there was a temporary stoppage of soybean growth that enabled the initial startup of the sunflower plants.*

Introduction

There are many questions about the presence of volunteer soybean plants in cultures established in succession. These plants germinate from seeds that fall on the ground by the natural thrashing of pods (Bond and Walker, 2009) or through losses in the crop harvest (Toledo *et al*., 2008; Loureiro Júnior *et al*., 2014). The control of these plants is mandatory and regulated by law in several Brazilian states due to the requirement of a host-free period (Seixas and Godoy, 2007). Except for the time traditionally used for the sowing of the crop, the law defines the period of the year for the absence of live soybean plants. This practice is regarded as one of the main strategies for the management of soybean rust, preventing the survival and spread of the fungus.

The emergence of transgenic soybean varieties resistant to glyphosate led to changes in the management of voluntary soybeans because this herbicide is no longer an effective means of control (Dan *et al*., 2011). This situation may be further aggravated if transgenic soybean plants emerge in other glyphosate resistant crops such as cotton (Braz *et al*., 2013) or corn (Dan *et al*., 2009). Additionally, yield losses in subsequent crops occur due to competition from high densities of volunteer plants. For example, corn yield loss at low volunteer soybean densities was similar to losses reported for low densities of velvetleaf and redroot pigweed, with 10% yield loss estimated to occur at 3 to 4 volunteer soybean plants/m^2 (Alms *et al*., 2016). A negative aspect of volunteer soybean was also observed in cotton (Lee *et al*., 2009); results demonstrate the sensitivity of cotton yield to soybean interference, indicating that soybean can be considered a problematic weed in cotton

KEY WORDS / *Glycine max* / *Helianthus annuus* / Spontaneous Soybean / Sulfentrazone / Weeds /
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SULFENTRAZONE EN CONTROL DE PLANTAS DE SOJA VOLUNTARIA Y SELECTIVIDAD EN EL CULTIVO DE GIRASOL

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RESUMEN

*El control de la soja voluntaria (*Glycine max*) se requere entre temporadas debido a la incidencia creciente de enfermedades, principalmente la roya de la soja (*Phakopsora pachyrhizi*). Por otra parte, la competencia de las plantas de soja puede causar pérdidas de rendimiento en otros cultivos. Los objetivos de este estudio fueron evaluar el control de plantas voluntarias de soja por la aplicación de dosis de sulfentrazone y la selectividad en el cultivo de girasol (*Helianthus annuus*). Dos experimentos fueron conducidos en condiciones de campo en el municipio de Rio Verde, Goiás, Brasil. El diseño experimental fue de bloques completos al azar con cuatro repeticiones. Los tratamientos en el Experimento 1 fueron sulfentrazone 0, 25, 50, 100 y 150g·ha^{-1} y testigo desmalezado con azada. En el Experimento 2 se aplicaron los mismos tratamientos más sulfentrazone 200 y 250g·ha^{-1}. Se ajustaron modelos de regresión polinomial a los datos de porcentaje de fitotoxicidad en girassol, porcentaje de control de plantas voluntarias de soja, altura de la planta de girasol, diámetro del capítulo, rendimiento de grano y la biomasa seca de las plantas de soja. Las dosis que van desde 114,1 hasta 158,8g·ha^{-1} proporcionaron los mayores rendimientos de girasol, evitando la competencia de las plantas de soja con el girasol. El sulfentrazone no leminó por completo las plantas de soja, pero hubo una interrupción temporal del crecimiento de soja que permitió el crecimiento inicial de las plantas de girasol.*

SULFENTRAZONE NO CONTROLE DE PLANTAS VOLUNTÁRIAS DE SOJA E SELETIVIDADE EM CULTIVOS DE GIRASSOL

Alexandre Magno Brighenti

RESUMO

*O controle de plantas voluntárias de soja (*Glycine max*) em cultivos de entressafra é obrigatório devido ao aumento crescente da incidência de doenças, principalmente a ferrugem asiática (*Phakopsora pachyrhizi*). Além disso, a interferência de plantas voluntárias de soja pode causar perdas de rendimento de cultivos implantados em sucessão. Os objetivos deste estudo foram avaliar o controle de plantas voluntárias de soja pela aplicação de doses de sulfentrazone e a seletividade em girassol (*Helianthus annuus*). Dois experimentos foram conduzidos em condições de campo no município de Rio Verde, Estado de Goiás, Brasil. O delineamento experimental foi em blocos casualizados, com quatro repetições. Os tratamentos aplicados no Experimento 1 foram sulfentrazone nas doses 0, 25, 50, 100 e 150g·ha^{-1} e a testemunha capinada. No Experimento 2, foram aplicados os mesmos tratamentos e acrescentadas as doses de 200 e 250g·ha^{-1} de sulfentrazone. Modelos de regressão polinomial foram ajustados aos dados de porcentagem de fitotoxicidade em plantas de girassol, porcentagem de controle de plantas voluntárias de soja, altura das plantas de girassol, diâmetro de capítulos, rendimentos de grãos e massa de matéria seca de plantas voluntárias de soja. Doses variando 114,1 a 158,8g·ha^{-1} proporcionaram os maiores rendimentos de girassol, evitando a interferência das plantas voluntárias de soja com a cultura do girassol. O sulfentrazone não matou completamente as plantas voluntárias de soja mas, houve uma paralisação temporária do crescimento, que permitiu o arranque inicial da cultura de girassol.*

necessitating early management. Season-long interference with a soybean density of 1 plant/m of row would be expected to reduce cotton yield 14%.

Considering sunflower crops, weed surveys were conducted in the Brazilian savannas (Brighenti *et al*., 2003; Adegas *et al*., 2010). The presence of volunteer soybean plants was observed in all sampled counties, with a frequency of 0.24, density of 1.48 plants/m^2 and a 13.5% index of relative importance (Brighenti *et al*., 2003).

The control of these plants becomes even more complex because of the scarcity of effective and selective herbicides to control broadleaf weeds in sunflower (Santos *et al*., 2012). Although the most effective and widely used method is chemical control, there is no herbicide registered to control volunteer soybean plants in cultivated sunflowers. The herbicides registered for the sunflower crop in Brazil are few and none of them are efficient in controlling volunteer soybean plants (Brighenti, 2015). Contact herbicides applied at the beginning of the sunflower cycle were likely to suppress volunteer soybean plants and allow the recovery of the sunflower crop (Brighenti, 2015).

The objectives of this study were to evaluate the control of volunteer soybean plants by using sulfentrazone doses and the selectivity in sunflower crop.

Material and Methods

Two experiments were conducted under field conditions in the municipality of Rio Verde, Goiás State, Brazil (17º46'06.36"S, 51º02'04.20"W). The soil is classified as Yellow Haplustox in the locations of both experiments. The monthly rainfall and air temperature during the conduction of the experiments are shown in Table I.

TABLE I
MEAN MONTHLY RAINFALL PRECIPITATION AND AIR TEMPERATURE DURING THE EXPERIMENTS. RIO VERDE, GOIÁS STATE, BRAZIL*

	Month				
	Feb	Mar	Apr	May	Jun
Rainfall (mm)	143.80	271.81	108.61	11.00	5.8
Air temperature (ºC)	23.57	23.12	23.21	21.38	21.38

* Provided by the Weather Station of the Centro Tecnológico Comigo, Rio Verde, Goiás State, Brazil, 2014.

The experimental design was a randomized complete block with four replications. Treatments applied in Experiment 1 were sulfentrazone 0, 25, 50, 100 and 150g·ha^{-1} and hoed control. The same treatments were applied in Experiment 2 plus sulfentrazone 200 and 250g·ha^{-1}. The herbicide was FMC Química do Brasil LTDS, Campinas, SP, Brazil. The two added doses were applied to verify sunflower tolerance at higher doses and soybean control at more advanced phenological stages.

The experiments were sown on February 27, 2014, in succession to a soybean (cultivar BRS 7980) crop. Soybean seeds that fell by natural threshing or through losses in the crop harvest emerged after planting the sunflower. The sunflower genotype used was the hybrid BRS 323, with row spacing of 0.5m, for a density of 45,000 plants/ha. Each plot consisted of five 5m long rows. The net area of the plots was 6m^2 (1.5×4.0m). The sowing fertilization was 400kg·ha^{-1} of NPK (08-20-18). Side dressing was performed with 50kg nitrogen/ha and boron (1.2kg·ha^{-1}) at 25 days after sunflower sowing (DAS). The herbicides were applied at the growth stages of the sunflower and soybean V_2 and V_1 (Experiment 1) and V_3 and V_2 (Experiment 2), respectively. The sprayer (Herbicat Ltda, Catanduva, São Paulo, Brazil) was pressurized by compressed CO_2 (296kPa) and equipped with a 1.5m wide boom. Four plane jet spraying nozzles (110 01 BD) were maintained 0.5m apart and delivered a spraying volume equivalent to 80L·ha^{-1}.

The phytotoxicity percentages on sunflower plants and the percentage of volunteer soybean control were evaluated at 7, 14 and 21 DAA (days after application), with zero corresponding to no visual injury symptom on sunflower or no soybean control and 100% corresponding to plant death of both sunflower and soybean. Plant height and head diameter of the sunflower were evaluated in Experiment 2 at 60 DAS by using a graduated tape. The production of dry biomass of the volunteer soybean was determined by collecting plants in the central area of the plots using a square of 0.5×0.5m (0.25m^2) at 21 DAA for both experiments. The plants were placed in an oven with forced air ventilation at 55ºC for 72h. Crop yield was obtained within the net area of the plots. The data were subsequently converted to kg·ha^{-1}, considering 11% moisture content in the achenes.

Statistical analyses were performed according to Ribeiro Júnior (2013). Polynomial regression models were fitted to the data of percentage of sunflower phytotoxicity, percentage of soybean control, sunflower plant height, head diameter, sunflower grain yield and dry biomass of volunteer soybean plants.

Results and Discussion

Percentages of phytotoxicity to sunflower plants as a function of the doses of sulfentrazone are shown in Figures 1a and b. Lower doses (25 and 50g·ha^{-1}) caused slight symptoms of phytotoxicity. However, intermediate doses of 100 and 150g·ha^{-1} caused tissue necrosis of the leaf blade of the sunflower plants. This occurs because sulfentrazone inhibits the action of the enzyme protoporphyrinogen oxidase (Rodrigues and Almeida, 2011). The formation of singlet oxygen causes lipid peroxidation of the plasma membrane, leading to cell death.

An intensification of the symptoms was detected in the evaluation at 14 DAA. However, plant recovery was observed at 21 DAA.

The two highest doses showed a similar behavior but with higher intensities of injury (Figure 1b). The apical bud of the sunflower plants did not suffer major damage. Plant recovery was observed even with the two highest doses. The percentage of phytotoxicity decreased to values ranging from 11 to 14% in the final evaluation for doses of 200 and 250g·ha^{-1}, respectively (Figure 1b).

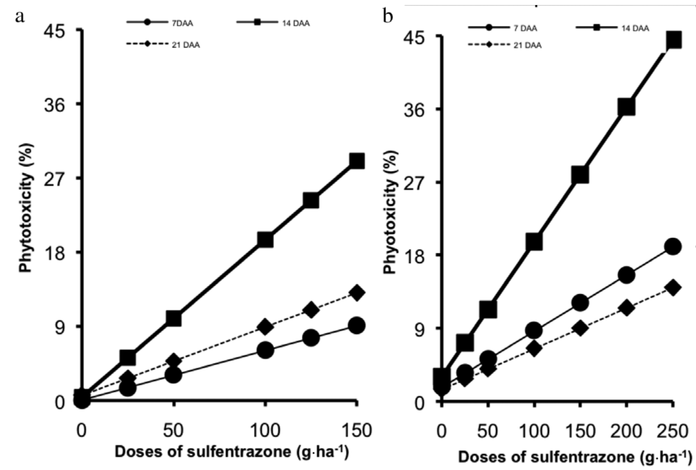

Figure 1. Percentage of phytotoxicity to sunflower plants as a function of the doses of sulfentrazone. Rio Verde, Goiás State, Brazil, 2014. a: Experiment 1- 7DAA, $Y=0.077+0.060X$, $R^2=0.97$; 14 DAA, $Y=0.413+0.191X$, $R^2=0.86$; 21 DAA, $Y=0.624+0.083X$, $R^2=0.80$) and b: Experiment 2- 7DAA, $Y=1.773+0.069X$, $R^2=0.95$; 14 DAA, $Y=3.034+0.166X$, $R^2=0.93$; 21 DAA, $Y=1.505+0.050X$, $R^2=0.83$.

The total death of volunteer soybean plants was not achieved even at highest doses. However, intermediate doses provided satisfactory control. First derivatives were calculated to determine the maximum control values of the quadratic functions at 21 DAA, which reached 119.7 and 212.6g·ha^{-1} for the Experiment 1 and 2, respectively (Figures 2a and b).

The phenological stage of the target plants at application time is crucial for the efficacy of sulfentrazone (Rodrigues and Almeida, 2011). Under the conditions of the experiments, the volunteer soybean plants were at stages V_1 (Experiment 1) and V_2 (Experiment 2). The lethal dose capable of killing 50% of soybean plants (LD50) was calculated using the model adjusted to 21 DAA. LD50 was lower in Experiment 1 (64.0g·ha^{-1}) when compared with Experiment 2 (76.0g·ha^{-1}).

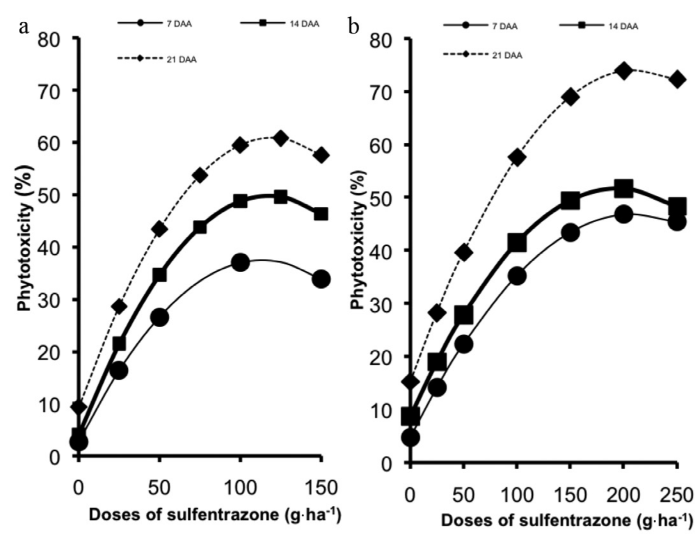

Figure 2. Percentage of control of volunteer soybean plants as a function of the doses of sulfentrazone. Rio Verde, Goiás State, Brazil, 2014. a: Experiment 1- 7 DAA, $Y=2.743+0.612X-0.0027X^2$, $R^2=0.95$; 14 DAA, $Y=4.012+0.777X-0.0033X^2$, $R^2=0.93$; 21 DAA, $Y=9.270+0.862X-0.0036X^2$, $R^2=0.80$) and b: Experiment 2- 7 DAA, $Y=4.794+0.400X-0.00095X^2$, $R^2=0.96$; 14 DAA, $Y=8.702+0.441X-0.00113X^2$, $R^2=0.89$; 21 DAA, $Y=15.315+0.553X-0.0013X^2$, $R^2=0.82$.

This fact support that the effectiveness of sulfentrazone is higher when applications are carried out in the early soybean cycle.

Sulfentrazone causes limited translocations in plants (Rodrigues and Almeida, 2011) and the symptoms observed in soybean were characterized by necrotic spots and curling of the leaf blades, leading to slowed growth. Herbicides able to completely eliminate volunteer soybean plants after the emergence of the sunflower crop probably also eliminate the sunflower plants. However, the temporary stoppage of growth of the volunteer soybean plants allows sunflower establishment, reducing the effects of competition. Braz *et al.* (2013) observed that the suppression imposed by the herbicide pyrithiobac-sodium on volunteer soybean plants reduces competition with cotton.

First derivatives were calculated to determine the maximum points of the quadratic functions for plant height, head diameter and sunflower yield. Intermediate doses provide the highest values of plant height and head diameter, which reached 192.87and 19.68cm at 133.22 and 132.76g·ha^{-1}, respectively (Figures 3a and b).

The behavior observed in plant height and head diameter was similar to that of the achene productivity, where intermediate doses also provided the greatest sunflower yields. A dose of 114.16g·ha^{-1} provided 2,754.69kg·ha^{-1} in Experiment 1 (Figure 4a), and 158.80g·ha^{-1} yielded 2,448.25kg·ha^{-1} in Experiment 2 (Figure 4b). Sulfentrazone was applied to the sunflower at doses of 75, 100 and 250g·ha^{-1} and caused injury to sunflower immediately after application; however, plant recovery was observed, with no yield losses (Brighenti, 2015).

Sulfentrazone is registered for soybean crop in pre-emergence conditions (MAPA, 2018). However, this herbicide causes damage to the aerial parts of the soybean even when applied in pre-emergence conditions (Taylor-Lovell *et al.,* 2001).

The dry biomass of the volunteer soybean plants decreased with the increasing dose of sulfentrazone (Figures 5a and b). Considering the doses that caused the highest grain yield of the sunflower crop, the dry biomass of soybean decreased from 30g/0.25m^2 to 7.8g/0.25m^2 at a dose of 114.16g·ha^{-1} (Figure 5a) and from 35g/0.25m^2 to 14.5g/0.25m^2 with the application of 158.80g·ha^{-1} (Figura 5b).

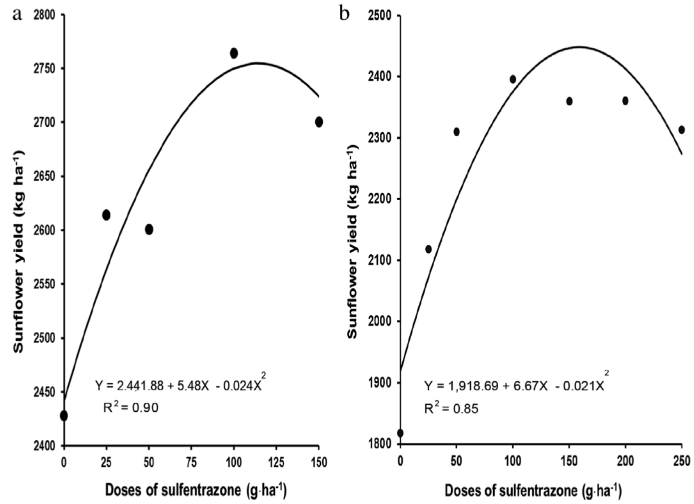

Figure 4. Sunflower yield as a function of dose of sulfentrazone. a: Experiment 1 and b: Experiment 2. Hoed check= 2,751.2kg·ha^{-1} (Experiment 1) and 2,345.5kg·ha^{-1} (Experiment 2). Rio Verde, Goiás State, Brazil, 2014.

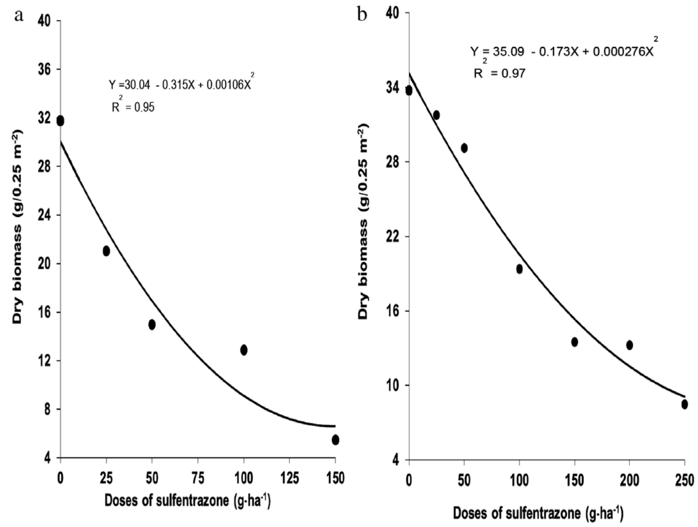

Figure 5. Dry biomass of volunteer soybean plants as a function of dose of sulfentrazone. a: Experiment 1 and b: Experiment 2. Rio Verde, Goiás State, Brazil, 2014.

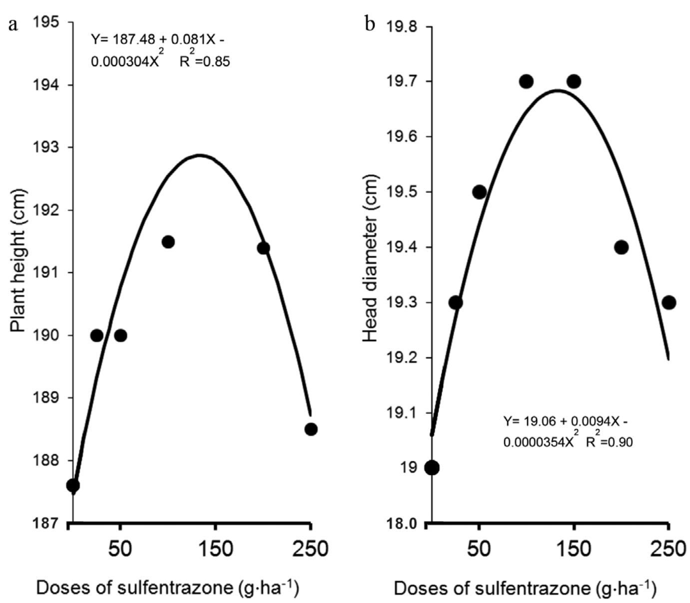

Figure 3. Plant height (a) and head diameter (b) as a function of the dose of sulfentrazone (Experiment 2). Hoed check=190.4cm plant height and 20.7m head diameter. Rio Verde, Goiás State, Brazil, 2014.

This research provides an alternative of using sulfentrazone in post emergence of sunflower to control volunteer soybean plants, avoiding competition between soybean and sunflower.

Conclusions

Doses ranging from 114.1 to 158.8g·ha^{-1} cause phytotoxicity to sunflower promptly after application, but recovery of injured plants ensues thereafter.

Doses ranging from 114.1 to 158.8g·ha^{-1} provide the highest sunflower yield, preventing competition from volunteer soybean plants.

Sulfentrazone is unable to completely kill the volunteer soybean plants, but the temporary stoppage of soybean growth is favorable to the initial emergence of the sunflower plants.

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