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Article

Estimating Yield Losses in Soybean Due to Sourgrass Interference

Estimativas de Perdas de Rendimento na Soja Devido à Interferência do Capim-Amargoso

GAZZIERO, D.L.P.[1]
ADEGAS, F.S.[1]
SILVA, A.F.[2]*
CONCENÇO, G.[3]

ABSTRACT - Efficient management of sourgrass is one of the main challenges faced by Brazilian soybean farmers. Biological and ecological characteristics of this weed, as well as wide distribution of glyphosate-resistant biotypes, make it difficult to control this species. The objective of this work was to estimate interference of sourgrass in soybean yield. Seven experiments were conducted during three consecutive years (2012/2013, 2013/2014 and 2015/2016 cropping seasons); six of them were on-farm trials where sourgrass infestation was mainly originated from clump regrowth, while infestation originated from seeds in one trial. Data from all sites and experiments were submitted to a combined analysis, according to the study factors and variables, to determine the greatest number of information points for the variable under each circumstance. To each data set, a 1st degree polynomial regression was fit, with a 95% confidence interval. The degree of sourgrass interference varies according to plant origin (seed or clump regrowth) but, in both cases, yield losses are directly correlated with sourgrass densities, aboveground dry mass accumulation and soil coverage. Plants coming from clumps tend to cause higher yield losses than those originated from seeds. These data highlight the importance of performing proper management of sourgrass, especially in its initial stages of development, in view of the high level of losses that perennial plants can cause to crops.

Keywords: *Digitaria insularis*, perennial, glyphosate-resistant weed, *Glycine max*.

RESUMO - O manejo do capim-amargoso se destaca como um dos principais desafios enfrentados pelos sojicultores brasileiros. Características relacionadas a sua biologia e ecologia, associado à ampla distribuição de biótipos resistentes ao glyphosate, tornam essa planta daninha uma espécie de difícil controle. Objetivou-se com este trabalho avaliar a interferência do capim-amargoso na fase inicial de desenvolvimento e dos rebrotes de plantas entouceiradas na cultura da soja. Sete experimentos foram conduzidos nas safras 2012/2013, 2013/2014 e 2015/2016. Seis experimentos avaliaram a interferência de diferentes densidades de rebrotes de capim-amargoso na produtividade da soja, e um ensaio avaliou a interferência de plantas emergidas junto com a cultura. Os dados de todas as propriedades e anos/experimentos foram analisados de forma combinada, conforme os fatores e as variáveis em questão, de modo que fosse obtido o maior número de pontos de informação para a variável em função do fator em estudo. A cada conjunto de dados foi ajustada uma equação polinomial linear, com o respectivo intervalo de confiança da média a 95%. O grau de interferência do capim-amargoso varia em função da origem da planta (semente ou touceira). Plantas oriundas de touceiras tendem a ocasionar maiores níveis de perda de produtividade, comparadas àquelas

*** Corresponding author:**
<alexandre.ferreira@embrapa.br>

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[1] Embrapa Soja, Distrito de Warta, Londrina-PR, Brasil; [2] Embrapa Milho e Sorgo, Sete Lagoas-MG, Brasil; [3] Embrapa Clima Temperado, Pelotas-RS, Brasil.

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oriundas de sementes. Esses dados reforçam a importância de se realizar o adequado manejo do capim-amargoso sobretudo em sua fase inicial de desenvolvimento, tendo em vista o alto nível de perdas que plantas perenizadas podem ocasionar nas lavouras.

Palavras-chave: *Digitaria insularis*, planta perene, planta daninha resistente ao glyphosate, *Glycine max*.

INTRODUCTION

Brazil is the second largest soybean producer in the world, with an estimated area of 33.91 million hectares in the 2016/2017 cropping season, and a net production volume of 115 million tons (Conab, 2017).

Weed interference in soybean can account for as much as 90% of losses in grain yield if no effective control method is used (Silva et al., 2009a). Among the weeds with increasing importance in soybean production systems, sourgrass (*Digitaria insularis*) is one of the main challenges currently faced by South American farmers (Lopez Ovejero et al., 2017). This weed is considered to be a hard-to-control species, because of its ability to reproduce both by seeds and rhizomes, adaptability to germinate and grow in a wide range of light and temperature conditions, and the widespread selection of glyphosate-resistant biotypes (Machado et al., 2006; Mondo et al., 2010; Carvalho et al., 2011; Mendonça et al., 2014; Gilo et al., 2016). As a result of its perennial growth habit, plants growing during the period between harvest and sowing of subsequent crops usually form large clumps.

The first record of a glyphosate-resistant sourgrass biotype was reported in 2008 by Adegas and Gazziero (Adegas and Gazziero, 2014), in a soybean field from Guaíra, in the Northwest region of Paraná, Brazil (Heap, 2017). Since then, new reports of glyphosate-resistant biotypes have spread throughout the central region of Brazil, mainly in grain-producing areas, most likely because of farm machinery movement, wind-mediated dispersal (Lopez Ovejero et al., 2017) and local selections (Takano et al., 2018).

The increasing number of fields with glyphosate-resistant biotypes and the usual delayed applications of this herbicide in perennialized plants have led to an increase in control failure reports and crop production costs (Gazola et al., 2016). Poor control in pre-planting burndown applications usually results in regrowth of sourgrass during early crop development and, consequently, in grain yield losses (Timossi, 2009). The interference potential of sourgrass in annual crops is still not well-documented and there are only a few reports addressing the subject.

Studies that evaluate the interference of sourgrass established either from seeds concomitantly with crop emergence or from clump regrowth, are of great importance to quantify its impact on soybean. Our hypothesis is that sourgrass causes significant crop yield losses. Quantifying these losses will help farmers decide on suitable management strategies. Therefore, the objective of this work was to evaluate the interference of sourgrass in soybeans when these species are under competition, on the basis of weed origin - growing from seeds or from re-sprouting of old perennialized clumps.

MATERIALS AND METHODS

Seven experiments were conducted in the 2012/13, 2013/14 and 2015/16 cropping seasons; six of them on farmer's fields (on farm) and one in an experimental area (experimental area), with a view to assessing the interference of sourgrass on soybean productivity. In the on-farm experiments, sourgrass plants came from the preceding cropping season, or alternatively emerged in the fallow period; they were well-established and had formed clumps by the time of experiment setup. In all on-farm sites, there was a history of glyphosate-resistant sourgrass problems and a successional soybean/corn system cropped within the same year. In the experimental area, weed seeds were sown manually; in this case, the weeds emerged and developed concomitantly with the crop plants.

Experimental station trial

The experiment was carried out between October 2015 and February 2016 in the experimental area of Embrapa Soja, in Londrina (PR), Brazil. Treatments consisted on the coexistence of soybean and seven sourgrass densities (0, 1, 2, 3, 4, 5 and 6 plants m^{-2}), arranged in a randomized block design with four replications.

Sourgrass densities were obtained by sowing approximately 40 seeds m^{-2}, with subsequent mild harrowing for seed incorporation, 20 days prior to soybean sowing. Plot size was 2 x 8 m, with 0.5 m between soybean rows, and the effective area consisted of a central area of 9 m^2 in each plot. Soybean cv. BRS 360 was sown at 4 cm depth on October 22, 2015, at a seeding rate of 267,000 seeds ha^{-1}. Before soybean emergence, sourgrass was thinned to densities according to the proposed treatments. At soybean emergence, sourgrass plants were still in an early stage of development, with an average of 1.2 tillers per plant.

The experiment was conducted with the necessary cultural practices, aiming at high yields, based on the official recommendations for soybean crops recurrently published by Embrapa. Weed control of weed species other than sourgrass was made by manual weekly weeding, until crop canopy formation; afterwards, plots were surveyed fortnightly.

Soybean yield was evaluated by manual harvest of four 1.0 m row samples, within the central area of each plot. To determine soybean grain yield, all plants in plots were manually harvested, threshed, and the grains were later separated from impurities and weighed. Samples for moisture determination were taken from each plot and grain moisture was corrected to 13%. All sourgrass aerial parts were collected in the plots for posterior determination of the respective dry mass content after drying at 70 °C for 72 hours.

On-farm trials

Six on-farm experiments were conducted in 2013, 2014 and 2016 during soybean harvest periods, in commercial areas surrounding Londrina (PR), Brazil. Track records of all areas indicate a history of problems with glyphosate-resistant sourgrass. All decisions about crop management were made exclusively by farmers on each site. At the end of each crop cycle, plots were established one day before harvest, and sourgrass densities were determined in each plot.

At each combination of location and year, sampling plots of 4 m^2 (comprising four 2 m long soybean rows) were used to estimate crop yield (as determined above) and sourgrass densities and aboveground mass accumulation.

At the first farm trial (2012/2013, in Sertanópolis, PR, Brazil), 32 plots with sourgrass densities ranging from 0 to 7.8 plants m^{-2} were established. In the 2013/2014 cropping season, three farm trials were conducted: two of them in Ipê (SP), Brazil, with 34 plots with sourgrass densities ranging from 0 to 6.7 plants m^{-2} and one in Londrina (PR), Brazil, with 49 plots and sourgrass densities ranging from 0 to 4.4 plants m^{-2}. In 2015/2016 cropping season, another trial was carried out in Londrina (PR), with 172 plots with sourgrass densities ranging from 0 to 10.3 plants m^{-2}.

In addition to evaluations of the impact of sourgrass densities on soybean grain yield, sourgrass aboveground dry mass accumulation at the end of crop cycle was also recorded at the 2013/2014 and 2015/2016 trials. Immediately after manual crop harvest of experimental plots, all biomass of sourgrass from each plot was collected and stored into paper bags. After that, biomass samples were dried at 70 °C for 72 hours and dry mass was determined with a precision scale.

In the 2015/2016 season, two other variables were evaluated: soil coverage by sourgrass plants (visual scale, 0 - 100%), and 1000 grain weight for soybean grains. Moreover, in the 2015/2016 season, another trial with 20 plots was carried out in Londrina (PR). For this specific trial, a fixed density of 1 clump m^{-2} was established to evaluate the interference of sourgrass in soybean yield components. A sample was taken from each plot and number of pods per plant, plant height, 1000 grain weight and soybean yield were recorded. In all on-farm areas, sourgrass plants were predominantly originated from clumps.

Statistical analysis

Data from all farms and years/experiments were combined previously to analysis, according to the factors and variables in question, to obtain the greatest number of information points for the matching factors/variables. For each data set, a linear polynomial equation was adjusted, using the respective 95% confidence interval (Brabanter et al., 2016). Analysis of variance (ANOVA) for regression preceded each analysis, to verify whether there was significance in the data set as function of the increase in sourgrass densities. ANOVA was performed at $p \leq 0.05$. Outliers in the data sets were identified through the graphical method of residuals by using functions at the "base" package of the statistical environment "R"; when present, outliers were disregarded in the regression analysis, but all points are shown in the graphs.

Levels of the factor were considered as detrimental/with an effect, when the expected maximum estimated response (upper limit of the confidence interval) was below the minimum expected value (lower limit of the confidence interval) for the respective control treatment. This limit was indicated by a horizontal red line, reflected on the X axis by a vertical red line. Levels of the factor higher than this indication are prone to cause reduction in the variable in question, under similar edaphoclimatic and management conditions found in the experiment (95% confidence intervals).

For the trial at the experimental station, continuously clean plots (control plots) were compared to plots whose infestation level by sourgrass was 1 plant m^{-2}. Data were presented in bar graphs, with the respective 95% confidence interval for each treatment. When the confidence intervals for both treatments did not overlap, under similar edaphoclimatic and management conditions, the treatments can be considered as distinct in extrapolations to real production fields.

All data were processed into the statistical environment "R", by applying functions available in the "base" package and the additional package "ggplot2". The sample size (n) used in each data set is indicated in the caption of each figure.

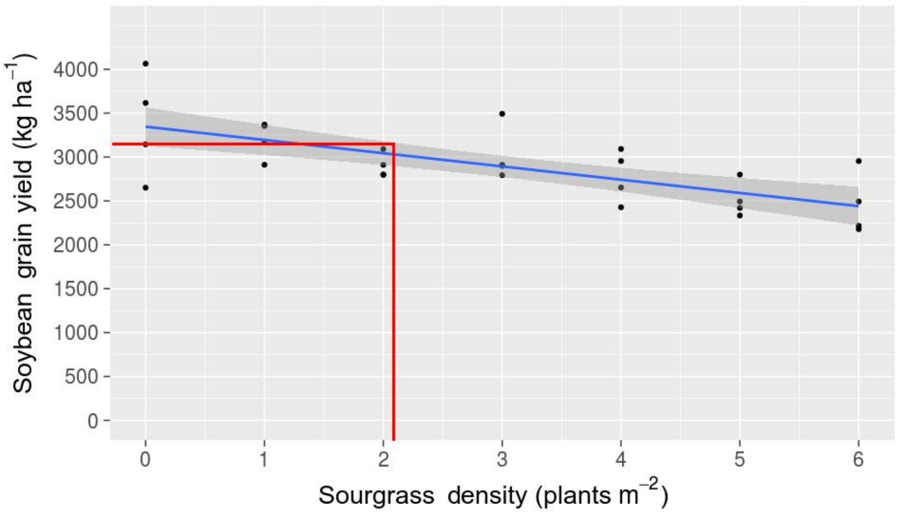
RESULTS AND DISCUSSION

Experimental station site

The increase in sourgrass density caused proportional crop grain yield losses (Figure 1). Grain yield losses caused by young plants of sourgrass were inversely proportional to sourgrass densities and, based on the confidence interval, were found to be more consistent from the density of 2.1 plants m^{-2} onwards; at this level of infestation, losses ranged from 0 to 375 kg ha^{-1} (Figure 1). Densities of 6.0 plants m^{-2} of sourgrass, for example, resulted in soybean yield losses between 600 and 1,300 kg ha^{-1}.

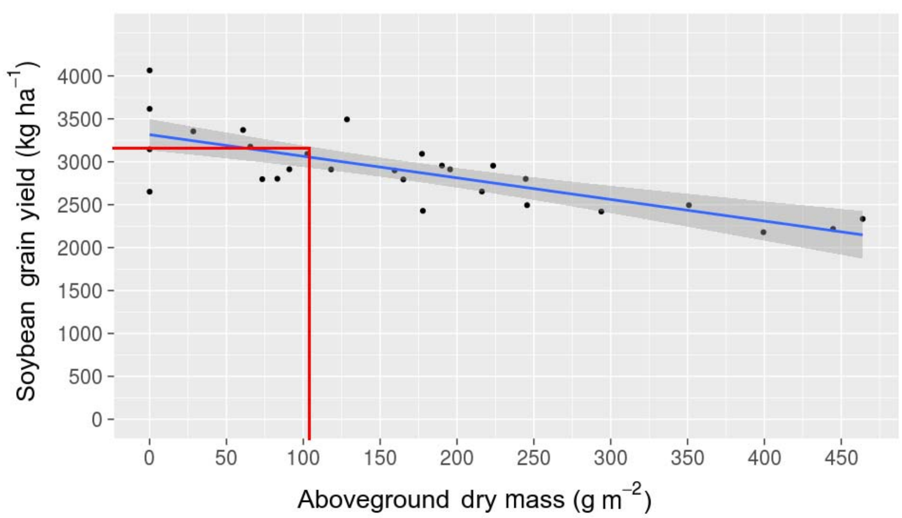
Previous studies have shown that soybean plants may exhibit superior competitiveness over Poaceae and broad leaves (Bastiani et al., 2016). Sourgrass presents slow initial growth on the first 45 days after its emergence, but from that period until flowering, growth rate is relatively high (Machado et al., 2006), which may favor sourgrass suppression by soybean, since the crop forms its canopy early in the cycle, before sourgrass increases its growth rate. Soybean, however, presented low competitive ability in avoiding yield losses even under competition with lower sourgrass densities.

Another reference that could be used to estimate yield losses caused by sourgrass is aboveground mass accumulation. Substantial soybean grain yield losses in competition with sourgrass originated from seeds were found, starting at 104 g m^{-2} of sourgrass dry mass at the end of the crop cycle, which decreased yield from 0 to 333 kg ha^{-1} (Figure 2). However, increases in sourgrass dry mass result in a linear decrease of soybean yield. Accumulation of 200 g m^{-2} of sourgrass dry mass resulted in losses between 223 and 722 kg ha^{-1} in soybean grain yield. Because of carbon metabolism through the C_4 cycle, sourgrass requires greater light intensities to express its full competitive potential, and its growth rate may be strongly affected by shading. This result indicates that although sourgrass may have a slow initial growth rate, soybean is not able to efficiently suppress its growth even at low densities. Apparently, due to the erect growth of this weed, some tillers can overcome the soybean canopy and, thus, promote a more efficient radiation capture.



The line indicates the point from where grain yield losses may occur in fields grown under similar edapho-climatic and management conditions to those fields which were monitored (95% confidence intervals). Sample size: n = 28.

Figure 1 - Soybean grain yield as a function of sourgrass (*Digitaria insularis*) densities.



The line indicates the point from where grain yield losses may occur in fields grown under similar edapho-climatic and management conditions to those fields which were monitored (95% confidence intervals). Sample size: n = 28.

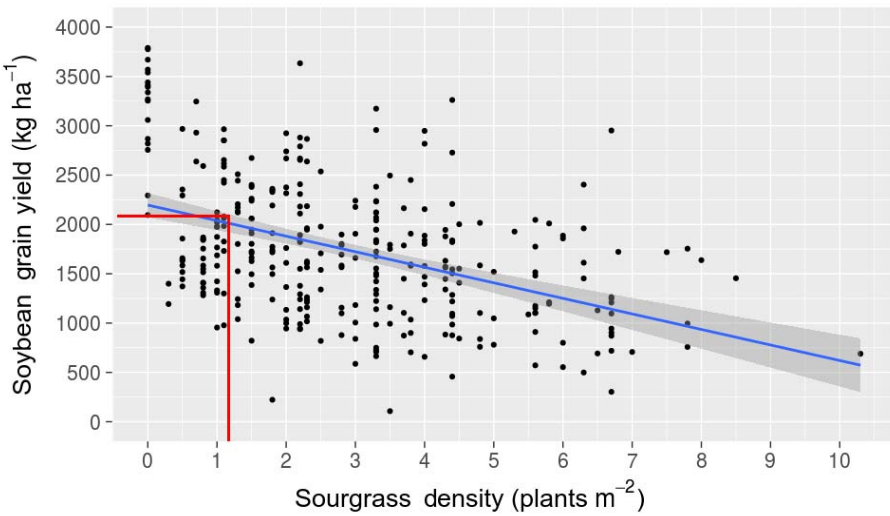
Figure 2 - Soybean grain yield as a function of sourgrass (*Digitaria insularis*) aboveground dry mass accumulation.

This metabolic characteristic of sourgrass shows that soybean plays an important cultural role in its suppression. Increasing densities of soybean associated with the use of cover crops during fallow are important cultural measures to reduce weed interference in soybean (Ryan et al., 2011; Wells et al., 2014). Petter et al. (2015) concluded that 4 t ha^{-1} of dry mass of *Urochloa brizantha* cv. Piatã, mucuna bean (*Mucuna pruriens*) or pigeon pea (*Cajanus cajan*), promote a significant reduction of emerged plants, germination rate, and shoot and root dry mass accumulation of sourgrass. Complete suppression, however, was found only with at least 8 t ha^{-1} of dry mass of the cover crops.

Another factor to be considered in the cultural suppression of sourgrass by soybeans is growth architecture of soybean varieties. Older soybean varieties used by Brazilian farmers were predominantly of determinate growth habit (Vaz Bisneta, 2015), and were usually characterized as more competitive against weeds, because of more effective shading resulting from early cover of inter-rows. However, the currently preferred soybean varieties are of semi-determinate or indeterminate growth types, which take longer to cover inter-rows (Souza et al., 2013). This characteristic contributes to sourgrass growth in the initial stages in which it was supposed to present slow initial growth.

On-farm sites

Data on sourgrass densities show that soybean productivity is affected from 1.2 clumps m^{-2} onwards, with losses of up to 350 kg ha^{-1} (Figure 3). Five and ten clumps m^{2} of sourgrass decreased soybean yield, respectively, between 600-1,100 and 750-2,000 kg ha^{-1}. This fact demonstrates the great competitive capacity of sourgrass clumps against soybean. The higher degree of interference may be due to the fact that plants originated from re-sprouting clumps already have an established root system, which leads to fast shoot development and early competition. Sourgrass is characterized by high requirements of nutrients such as K and N, which are also required in great amounts by most crops with agronomic importance (Carvalho et al., 2013).



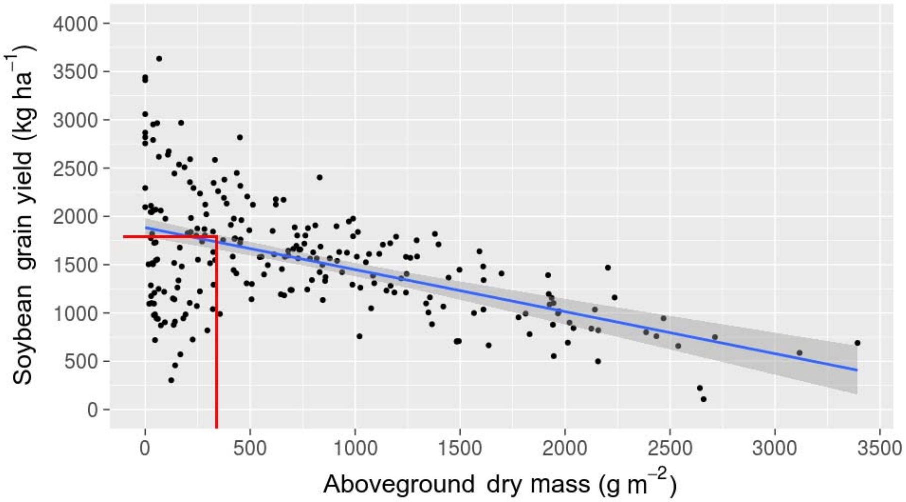
The line indicates the point from where grain yield losses may occur in fields grown under similar edapho-climatic and management conditions to those fields which were monitored (95% confidence intervals). Sample size: n = 321.

Figure 3 **-** Soybean grain yield as a function of density of sourgrass (*Digitaria insularis*) clumps.

There was effect on soybean yield starting at 320 g m^{-2} of sourgrass dry mass, with reductions ranging from 0-250 kg ha^{-1} (Figure 4). Increasing sourgrass mass resulted in proportional yield losses. For instance, accumulation of 1,000 and 2,000 g m^{-2} caused grain yield losses ranging from 250-650 and 300-1,100 kg ha^{-1}, respectively. The large dry mass accumulation may be due to the fact that plants originated from rhizomes have leaves with higher stomatal index and thicker leaf blade as compared to those coming from seeds (Machado et al., 2008). Such anatomical differences may contribute to higher photosynthetic rates and more efficient light use by plants originated from clumps (Taiz and Zeiger, 2013), and may also be an adaptive attribute to crop canopy shading.

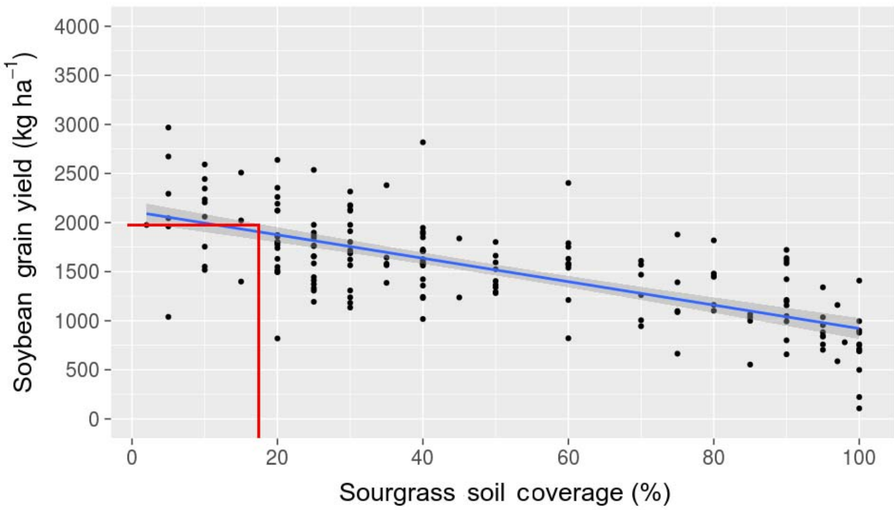
Tillering ability of sourgrass can result in substantial soil cover, suppressing proper soybean development as a result of reduced radiation incidence. Yield losses (0-700 kg ha^{-1}) were found when sourgrass covered at least 18% of soil surface (Figure 5). Soil coverage of 50% by sourgrass caused grain yield losses ranging from 350 to 750 kg ha^{-1}. The capacity of sourgrass to provide soil coverage shows the aggressiveness of the sprouts in quickly occupying the area and becoming the dominant weed.

Thousand-grain weight was not affected by density, aboveground dry mass accumulation or soil coverage by sourgrass (Figure 6). Although this yield component may be affected by biotic and abiotic factors, grain weight is usually considered to be much more dependent on the genetics of the variety (Silva et al., 2009b).



The line indicates the point from where grain yield losses may occur in fields grown under similar edapho-climatic and management conditions to those fields which were monitored (95% confidence intervals). Sample size: n = 321.

Figure 4 **-** Soybean grain yield as a function of dry mass accumulation of sourgrass (*Digitaria insularis*) clumps.

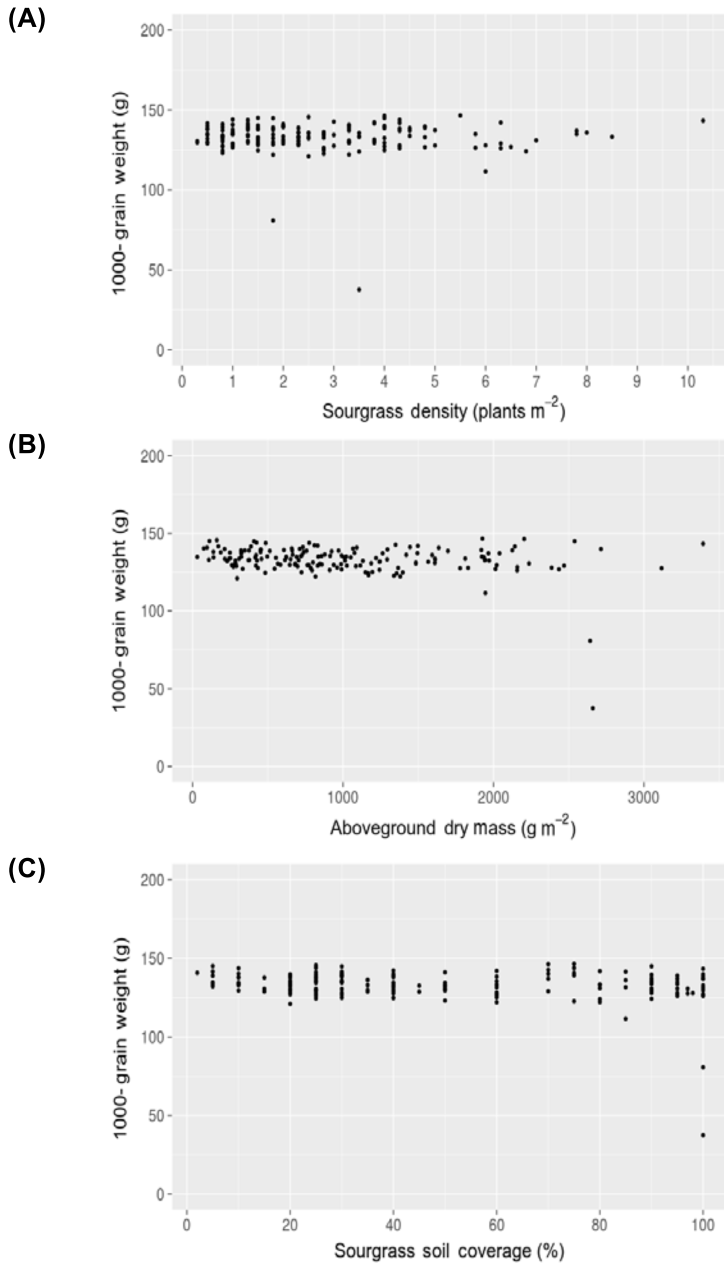


The line indicates the point from where grain yield losses may occur in fields grown under similar edapho-climatic and management conditions to those fields which were monitored (95% confidence intervals). Sample size: n = 172.

Figure 5 **-** Soybean grain yield as a function of soil coverage (%) by sourgrass (*Digitaria insularis*) clumps.

Perennialized plants are much more difficult to control as compared to plants in earlier stages of development. After rhizome formation, efficiency of systemic herbicides tends to decrease (Tuffi Santos et al., 2004). Underground storage mass of sourgrass provides a buffering effect, since large amounts of starch present in rhizomes can serve as a barrier to herbicide translocation, promoting the rapid regrowth of treated plants (Machado et al., 2006). To achieve efficient control of glyphosate-resistant perennialized sourgrass biotypes in pre-planting burndown, most systems will include the associated applications of glyphosate and ACCase inhibitors, followed by a sequential application of a contact herbicide (Gemelli et al., 2013). After soybean emergence, sourgrass is usually controlled by the sequential application of two ACCase inhibitors from different chemical groups (Gilo et al., 2016).

When analyzing the effect of a single sourgrass clump per m^{-2} on some yield components of soybean, 1,000 grain weight, plant height and number of pods per plant were not affected. However, there was a reduction in soybean grain yield of about 500-1,400 kg ha^{-1} when sourgrass occurs at a density of 1 plant m^{-2} (Figure 7). Therefore, other components of crop yield may have been

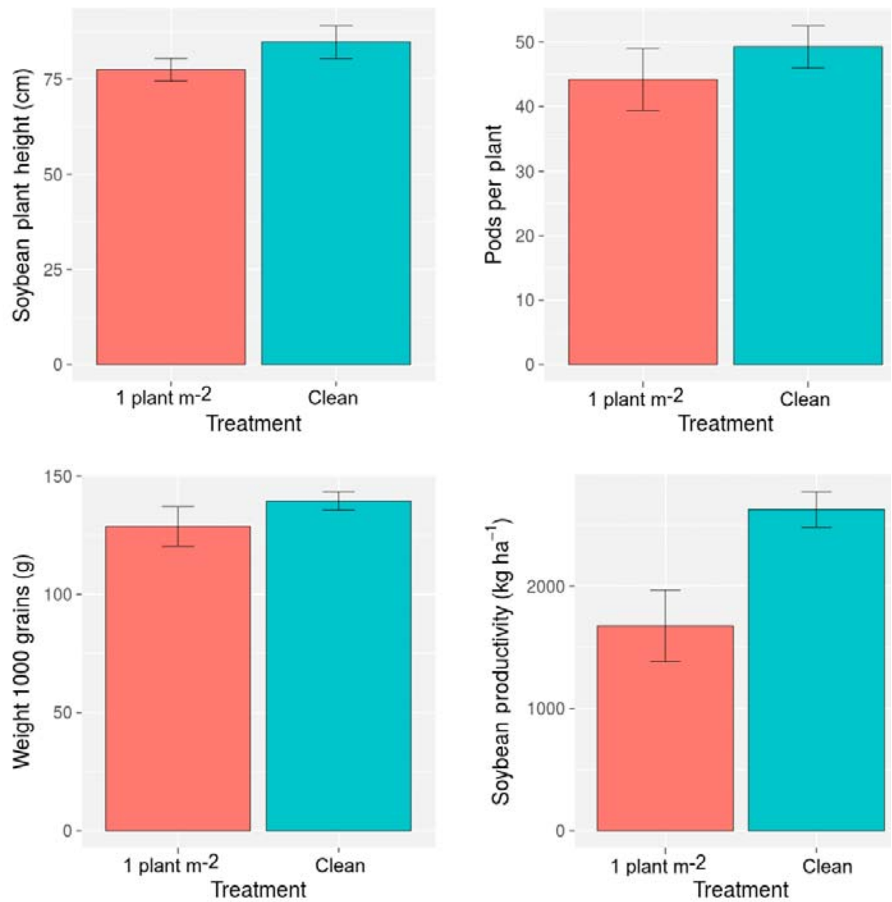


Sample size: n = 172.

Figure 6 - 1,000 grain weight of soybean as a function of density of sourgrass (*Digitaria insularis*) plants, aboveground dry mass accumulation and soil coverage by clumps.

affected. For example, yield loss could be due to a reduction in soybean plant stand, or by other yield components such as number of seeds per pod and branching intensity. Clumps of developed sourgrass plants may cause death or growth suppression of surrounding soybean plants because of increased competition for resources (water, light and nutrients).

In short, sourgrass plants originated either from seeds or clump regrowth, cause severe grain yield losses in soybean. Plants originated from seeds emerge concomitantly with soybeans and tend to cause yield losses only at higher densities as compared to plants originated from clump regrowth, and they also accumulate less dry mass as compared to sprouts. The levels of losses caused by sourgrass sprouts tend to be higher than those caused by plants originated from seeds. Soil coverage by sourgrass can be used to estimate reduction in soybean yield as a result of competition. The yield components of soybeans evaluated in the present study were not affected



Sample size: n = 12 for "clean", and n = 8 for 1 plant m^{-2}.

Figure 7 **-** Plant height, number of pods per plant, 1,000 grain weight and soybean grain yield free from sourgrass competition (■) or under competition with 1 sourgrass clump per square meter (■). 95% confidence intervals are supplied.

by sourgrass interference. These data highlight the importance of performing proper management of sourgrass, especially in its initial stages of development, to avoid the high level of losses that perennial plants can cause to crops.

REFERENCES

Adegas FS, Gazziero DLP. Resistência de *Digitaria insularis* aos herbicidas inibidores da EPSPS. In: Agostineto D, Vargas L., editores. Resistência de plantas daninhas a herbicidas no Brasil. Pelotas: UFPel, 2014. p.304-13.

Bastiani MO, Lamego FP, Agostinetto D, Langaro AC, Silva DC. Competitividade relativa de cultivares de soja com capim-arroz. Bragantia. 2016;75(4):435-45.

Brabanter K, Liu Y, Lua C. Convergence rates for uniform confidence intervals based on local polynomial regression estimators. J Nonparam Stat. 2016;28:31-48.

Carvalho LB, Bianco MS, Bianco S. Accumulation of dry mass and macronutrients by sourgrass plants. Planta Daninha. 2013;31(4):785-92.

Carvalho LB, Cruz-Hipolito H, González-Torralva F, Alves PLCA, Christoffoleti PJ, et al. Detection of sourgrass (*Digitaria insularis*) biotypes resistant to glyphosate in Brazil. Weed Sci. 2011;59(2):171-6.

Companhia Nacional de Abastecimento – Conab. Acompanhamento de safra brasileira: grãos, décimo-segundo levantamento, safra 2016/17, setembro 2017. Brasília: Conab; 2016. v.4.

Gazola T, Belapart D, Castro EB, Cipola Filho ML, Dias MF. Características biológicas de *Digitaria insularis* que conferem sua resistência a herbicidas e opções de manejo. Científica. 2016;44(4):557-67.

Gemelli A, Oliveira Jr RS, Constantin J, Braz GBP, Jumes TMC, Gheno EAA, et al. Estratégias para o controle de capim-amargoso (*Digitaria insularis*) resistente ao glyphosate na cultura do milho safrinha. Rev Bras Herb. 2013;12:162-70.

Gilo EG, Mendonça CG, Espírito Santo TL, Teodoro PE. Alternatives for chemical management of sourgrass. Biosci J. 2016;32(4):881-9.

Heap I. The international survey of herbicide resistance weeds. [acesso em: 15 de jan de 2017]. Disponível em http://www.weedscience.com

Machado AFL, Meira RMS, Ferreira LR, Ferreira FA, Tuffi Santos LD, Fialho CMT, et al. Caracterização anatômica de folha, colmo e rizoma de Digitaria insularis. Planta Daninha. 2008;26(1):1-8.

Machado AFL, Ferreira LR, Ferreira FA, Fialho CMT, Tuffi Santos LD, Machado MS. Análise de crescimento de *Digitaria insularis* (L.) Fedde. Planta Daninha. 2006;24(4):641-7.

Mendonça GSD, Martins CC, Martins D, Costa NV. Ecophysiology of seed germination in *Digitaria insularis* (L.) Fedde). Rev Cienc Agron. 2014;45:823-32.

Mondo VHV, Carvalho SJP, Dias ACR, Marcos Filho J. Efeitos da luz e temperatura na germinação de sementes de quatro espécies de plantas daninhas do gênero Digitaria. Rev Bras Sem. 2010;32(1):131-7.

Lopez Ovejero RF, Takano HK, Nicolai M, Ferreira A, Melo MSC, Cavenaghi AL, et al. Frequency and dispersal of glyphosate-resistant sourgrass (*Digitaria insularis*) populations across Brazilian agricultural production areas. Weed Sci. 2017;65(2):285-94.

Petter FA, Sulzbacher AM, Silva AF, Fiorini IVA, Morais LA, Pacheco LP. Use of cover crops as a tool in the management strategy of sourgrass. Rev Bras Herb. 2015;14(3):200-9.

Ryan MR, Mirsky SB, Mortensen DA, Teasdale JR. Potential synergistic effects of cereal rye biomass and soybean planting density on weed suppression. Weed Sci. 2011;59(2):238-46.

Silva AF, Concenço G, Aspiazú I, Ferreira EA, Galon L, Freitas MAM, et al. Período anterior à interferência na cultura da soja-RR em condições de baixa, média e alta infestação. Planta Daninha. 2009a;27(2):57-66.

Silva AF, Galon L, Reis MR, Rocha PRR, Ferreira EA, Tironi SP, Aspiazu I, Silva AA. Período anterior a interferência e componentes de rendimento de produtividade da soja transgênica em função do método de semeadura. Sci Agr. 2009b;10(6):489-98.

Souza CA, Figueiredo BP, Coelho CMM, Casa RT, Sangoi L, et al. Plant architecture and productivity of soybean affected by plant growth retardants. Biosci J. 2013;29(3):634-43.

Taiz L, Zeiger E. Fisiologia vegetal. 5ª.ed. Porto Alegre: Artmed; 2013.

Takano HK, Oliveira Jr RS, Constantin J, Mangolim CA, Machado MFPS, Bevilaqua MRR. Spread of glyphosate-resistant sourgrass (*Digitaria insularis*): independent selections or merely propagule dissemination? Weed Biol Manag. 2018;18(1):50-9.

Timossi PC. Manejo de rebrotes de *Digitaria insularis* no plantio direto de milho. Planta Daninha. 2009;27(1):175-9.

Tuffi Santos LD, Meira RMSA, Santos IC, Ferreira FA. Efeito do glyphosate sobre a morfoanatomia das folhas e do caule de *Commelina diffusa* e *Commelina benghalensis*. Planta Daninha. 2004;22(1):101-8.

Vaz Bisneta M. Influência do tipo de crescimento em caracteres morfoagronômicos de cultivares de soja [dissertação]. Goiânia: Universidade Federal de Goiás; 2015.

Wells MS, Reberg-Horton SC, Mirsky SB. Cultural strategies for managing weeds and soil moisture in cover crop based no-till soyeban production. Weed Sci. 2014;62:501-11.