PLANTA DANINHA

SOCIEDADE BRASILEIRA DA CIÊNCIA DAS PLANTAS DANINHAS

<http://www.sbcpd.org>

ISSN 0100-8358 (print)
1806-9681 (online)

Article

Urochloa ruziziensis Desiccation, Straw Quantity and Position on Nodulation and Production of Soybean 'M-SOY 7908 RR'

*Época de Dessecação de **Urochloa ruziziensis**, Quantidade e Posicionamento da Palha na Nodulação e Produtividade da Soja 'M-SOY 7908 RR'*

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ABSTRACT - This study aimed to evaluate the effects of the quantity and soil position of *Urochloa ruziziensis* straw desiccated with glyphosate for different periods of time on 'M-SOY 7908 RR' soybean nodulation, growth and production characteristics. Three experiments were conducted under semi-controlled conditions. In the first, three quantities of *U. ruziziensis* straw (2.5, 5.0 and 10 ton ha^{-1}) previously desiccated with glyphosate were incorporated into the soil (10 cm deep) or deposited on the soil surface, and in the second experiment, the treatments consisted of three *U. ruziziensis* desiccation periods, 0, 7 and 12 days before soybean sowing, and one treatment without *U. ruziziensis.* In the third treatment, desiccation was performed at 0, 5 and 10 days before soybean sowing, and the desiccated plant shoots were removed or left in place before soybean sowing. For each of the experiments, a completely randomized experimental design was adopted, and the masses of the shoot and root dry matter, the degree of nodulation and soybean production were evaluated. The deposition of *U. ruziziensis* straw on the soil surface promoted the nodulation and growth of 'M-SOY 7908 RR' soybean plant shoots, while its incorporation into the soil, even at 2.5 ton ha^{-1}, caused deleterious effects. Desiccation of *U. ruziziensis* from 0 to 7 days before sowing was also detrimental to the nodulation and growth of M-SOY 7908 RR soybean, reducing its productivity.

Keywords: *Glycine max*, ground cover, no-till farming, glyphosate.

*RESUMO - Objetivou-se neste estudo avaliar o efeito da quantidade e do posicionamento de palha de **U. ruziziensis**, dessecada com glyphosate em diferentes épocas, sobre a nodulação, o desenvolvimento e as características produtivas da soja M-SOY 7908 RR. Para isso, foram conduzidos três experimentos sob condições semicontroladas. No primeiro, os tratamentos constituíram-se da incorporação (a 10 cm de profundidade) ou deposição na superfície do solo de três quantidades de palha de **U. ruziziensis** (2,5, 5,0 e 10 t ha^{-1}), previamente dessecada com glyphosate. No segundo experimento, os tratamentos constaram de três épocas de dessecação de **U. ruziziensis**: 0, 7 e 12 dias antecedendo a semeadura da soja, e um tratamento sem **U. ruziziensis**. Para o terceiro, realizou-se a dessecação aos 0, 5 e 10 dias antecedendo a semeadura da soja, retirando-se ou não a parte aérea da planta dessecada, antes da semeadura da soja. Foram avaliadas a massa de matéria seca da parte aérea e raízes, a nodulação e a produção da soja. Em todos os ensaios, o delineamento experimental adotado foi o inteiramente casualizado. A deposição da palha de **U. ruziziensis** na superfície do solo favoreceu a nodulação e o crescimento da parte aérea das plantas de soja M-SOY 7908 RR, enquanto a incorporação, já a partir de 2,5 t ha^{-1}, causou efeitos deletérios. A dessecação de*

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Received: July 13, 2016
Approved: November 21, 2017

Planta Daninha 2019; v37:e019166586

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Doi: 10.1590/S0100-83582019370100071

U. ruziziensis *dos 0 aos 7 dias antecedendo a semeadura da soja M-SOY 7908 RR foi prejudicial à nodulação e ao desenvolvimento da cultura, reduzindo sua produtividade.*

Palavras-chave: *Glycine max*, cobertura vegetal, plantio direto, glyphosate.

INTRODUCTION

The no-till farming system (NTS) has shown to be efficient in erosion control, through the maintenance of plant residues on the soil surface, also providing increased availability of nutrients (Nunes et al., 2006), besides being related to the suppression of weeds (Pitelli and Pitelli, 2004). However, NTS implies knowing and defining the ground cover species, which should have a proper biomass production and be sufficiently persistent, for the physical protection of the soil and provision of nutrients (Nunes et al., 2006).

In the search for adequate species for ground cover, those from the *Urochloa* genus seem to be feasible alternatives of excellent quality and have become important allies for the formation of ground cover (straw) for NTS (Silva et al., 2004; Barbosa et al., 2008). However, several farmers report reduced growth, yellowing and decrease in soybean production when the plant residues of *Urochloa* are incorporated into the soil (Maciel et al., 2003; Nepomuceno et al., 2012). Souza et al. (2003) state that, in field observations, brachiaria (*U. decumbens*) proved to be harmful when incorporated into the soil, in the areas where eucalyptus seedlings were planted. Souza et al. (2006) evaluated the incorporation of brachiaria (*U. decumbens*) to the growth of seven cultivated plants, including soybeans, and found a drastic reduction in nitrate levels in the soil. However, some authors indicated *U. brizantha* as a good species in nutrient cycling when used for ground cover (Silva et al., 2009; Ferreira et al., 2010).

Another species also used for ground cover is *Brachiaria ruziziensis* R.Germ. & C.M.Evrard (synonymized binomial in *Urochloa ruziziensis*). Native to Africa, it grows in several types of soil, from sandy to clayey ones. It is a perennial, erect, clumping, dense-pubescent plant, whose height reaches 0.9-1.3 m; it usually presents a yellowish-green color, with the wide or winged racemes of inflorescences with 3.0-5.0 cm in width (Kissmann, 1997).

Machado et al. (2010) evaluated the straw and forage production by annual and perennial species, including *U. ruziziensis*, in succession to soybeans and concluded that, because they keep on growing throughout the dry season and are easy to desiccate, the forage species *U. ruziziensis* and *U. decumbens* may be better used for ground cover purposes. In addition, *U. ruziziensis* proved to be a good option as a ground cover plant for the Northwestern region of the State of São Paulo (Borges et al., 2015).

The expansion of no-till farming areas, combined with biotechnological advances that have allowed the commercialization of cultivars of genetically modified plants tolerant to glyphosate, has promoted an increase in the use of this herbicide in agrosystems. The widespread use of glyphosate may impact the biotic components of the ecosystem, especially the soil microbiota and root symbiont microorganisms, such as atmospheric nitrogen fixing bacteria and arbuscular mycorrhizal fungi (AMF), which occur invariably associated with soybean roots, having a major influence on the nutrition and health of this crop (Siqueira et al., 2004).

Glyphosate-resistant soybean cultivars contain the EPSP enzyme, which is insensitive to the herbicide. However, N_2 fixing bacteria (*Bradyrhizobium* genus), which are associated with the root system of soybeans, do not present such enzymatic insensitivity, and glyphosate may interfere in the symbiotic interaction, affecting the development of the crop (Santos et al., 2004).

In the pasture reformation system, in which *Urochloa* is used as a plant cover for no-till farming, the desiccation prior to soybean sowing is performed with herbicides, especially glyphosate. Thus, the time of use of the herbicide for the desiccation of the cover species may, according to some authors, interfere with the productivity of the crop. According to Santos et al. (2007), the interval between the chemical management of the plant cover and the sowing of soybeans must be of at least seven days, since the chemical management and sowing on the same day affects the development of the crop, and it can also affect the activity of the soil microorganisms.

Silva et al. (2013) evaluated the efficacy of glyphosate in the desiccation of three *Urochloa* species and verified that *U. ruziziensis* was controlled more quickly than the others, which is highly desirable, since it allows the anticipation of the crop sowing, after desiccation.

In view of what was reported, the objective was to evaluate the effect of the quantity and positioning of *U. ruziziensis* straw, desiccated with glyphosate at different times, on the nodulation, development and production characteristics of the M-SOY 7908 RR soybean.

MATERIAL AND METHODS

Three experiments were installed using the M-SOY 7908 RR soybean cultivar, whose seeds were previously treated with fungicides (thiabendazole, at a dose of 150 g c.p. 100 kg^{1} of seeds, and thiram, at a dose of 280 mL c.p. 100 kg^{-1} of seeds). The seeds were then inoculated with *Bradyrizobium japonicum* at a dose of 2 g c.p. 100 kg^{-1} of seeds. For the three experiments, soil from a typical Eutrophic Red Latosol with a clay texture was used as substrate (Andrioli and Centurion, 1999), with the following chemical characteristics: pH (CaCl2) of 6.0 g; MO of 39.00 mg dm^{-3}; 40.0 mg dm^{-3} of P (resin); and 5.5; 49.0; 31.0; 22; 85.5 and 107.0 $mmol_c$ dm^{-3} of K, Ca, Mg, H+Al, SB and T, respectively; and V of 80%. For soybeans, fertilization consisted of the application of 270 kg ha^{-1} of the 02-20-20 (N-P-K) formulation in the seeding groove.

The desiccation of *U. ruziziensis*, used in the experiments, was performed with 1,440 g a.e. ha^{-1} of glyphosate using a pressurized back sprayer equipped with a bar with six flat spray tips (TT 110.02), at a distance of 0.5 m from each other, with spray consumption equivalent to 200 L ha^{-1}, at constant pressure of 2.24 kgf cm^{-2}.

The experiments were carried out under semi-controlled conditions (without water restriction) and all preventive and curative measures were taken in order to ensure the proper health of the plants.

All data obtained were submitted to analysis of variance according to the F test and the means were compared according to Tukey's test at 5% probability.

Experiment 1

The shoot of the *U. ruziziensis* plants was collected in a stabilized pasture area, 30 days after the pasture desiccation. After having dried completely naturally, the straw was manually fractioned into parts of approximately 3 cm in length.

Plastic vases (25 x 30 cm) with capacity for 10 L, filled with the sieved substrate, were used as experimental plot. The treatments consisted of incorporating three amounts of *U. ruziziensis* straw into the soil surface at a depth of 10 cm or depositing it on the soil surface: 2.5, 5.0 and 10 ton ha^{-1}.

Six M-SOY 7908 RR soybean seeds were deposited by vase at a depth of 3 cm, with thinning seven days after emergence, leaving three seedlings per vase. When the soybean plants were in the phenological stage V6, they were cut close to the ground and left to dry in a forced air ventilation greenhouse at 70 ^{o}C to determine the mass of dry matter. The soil and roots of each vase were washed in running water with the help of a sieve to separate and clean the roots. Then, the rhizobic nodules present in the roots were separated and counted. The roots and nodules were stored separately in paper bags and dried until they reached constant mass.

The experimental design used was completely randomized, with the six treatments in four replications, totaling 24 plots.

Experiment 2

The second experiment was conducted using soil collected from a *U. ruziziensis* pasture area. The desiccation of *U. ruziziensis* was conducted in three periods: 0, 7 and 12 days prior to the sowing of soybean (DAS), constituting the evaluated treatments. The soil collected together with the *U. ruziziensis* plants (previously desiccated in the three periods) was stored in vases (25 x 30 cm) with capacity for 10 liters.

The sowing of the M-SOY 7908 RR soybean was performed manually, simulating a no-till sowing of soybeans in the desiccated cover, depositing eight seeds per vase, at a depth of 3 cm, with thinning seven days after emergence (DAE), leaving four seedlings per vase (corresponding to 24 seeds per meter).

At 46 DAE, when the soybean plants were in the phenological stage V5, they were cut close to the ground, collected and properly stored in plastic bags. Subsequently, the procedures and characteristics analyzed were the same as those described in experiment 1, also analyzing the height and leaf area of soybean plants.

The experimental design used was completely randomized, with the three treatments (desiccation periods) in addition to one control without *U. ruziziensis* in six replications, totaling 24 experimental plots.

Experiment 3

For the third experiment, cement frames were used directly on the soil (typical eutrophic Red Latosol with clay texture), corresponding to squares with an area of 1.33 square meters, which constituted the experimental plots. In each plot, approximately 200 seeds of *U. ruziziensis* were sown by broadcast seeding, for the formation of the plant cover.

The desiccation of *Urochloa* was conducted in three periods: 0, 5 and 10 days prior to the sowing of soybeans. The M-SOY 7908 RR soybeans were manually sown, in two rows per plot, with 0.45 m between the rows, at a depth of 5 cm. Twenty-three seeds were distributed per meter.

This experiment consisted of five treatments: T1 - desiccation at 5 days before sowing of soybeans (DAS); T2 - desiccation at 5 DAS, with removal of the shoot of *Urochloa* (maintaining the roots) when sowing; T3 - desiccation at 10 DAS; T4 - desiccation at 10 DAS, with removal of the shoot of *Urochloa* when sowing; and T5 - desiccation at 0 DAS. The experimental design used was completely randomized, with the five treatments in five replications, totaling experimental 25 plots.

The harvest of all soybean plants in the plots was manually conducted, at 130 DAE, in which the total number of pods and the weight of 100 grains were determined, and the productivity was calculated (with humidity corrected to 13%).

All data obtained were submitted to analysis of variance according to the F test and the means were compared according to Tukey's test at 5% probability.

RESULTS AND DISCUSSION

Experiment 1

In Figure 1A, for the three amounts of *U. ruziziensis* coverage, there is a 40% increase in the dry matter of the shoot of soybean plants in the treatments in which the straw was arranged on the soil surface, when compared to the treatments with the incorporation of the plant material.

These beneficial results from the use of surface plant cover are associated with conservation practices adopted in the no-till farming system, which have shown to be efficient in increasing the availability of nutrients (Alvarenga, 1996), in supplying N by decomposing organic matter and increasing the amount of water available in the soil (Stone and Moreira, 2000; Fageria and Stone, 2004), providing better crop development.

Maciel et al. (2003) used 6.0 ton ha^{-1} of *U. decumbens* straw in soybeans and in *Euphorbia heterophylla* (wild peanut), arranged on the soil surface or incorporated at a depth of 10 cm, and did not observe significant differences in treatments for leaf area, dry matter mass and leaf area ratio, 20 days after the emergence of soybean.

However, Souza et al. (2006), when evaluating the allelopathic effect of *U. decumbens* on the initial growth of seven species of cultivated plants, including soybeans, concluded that the

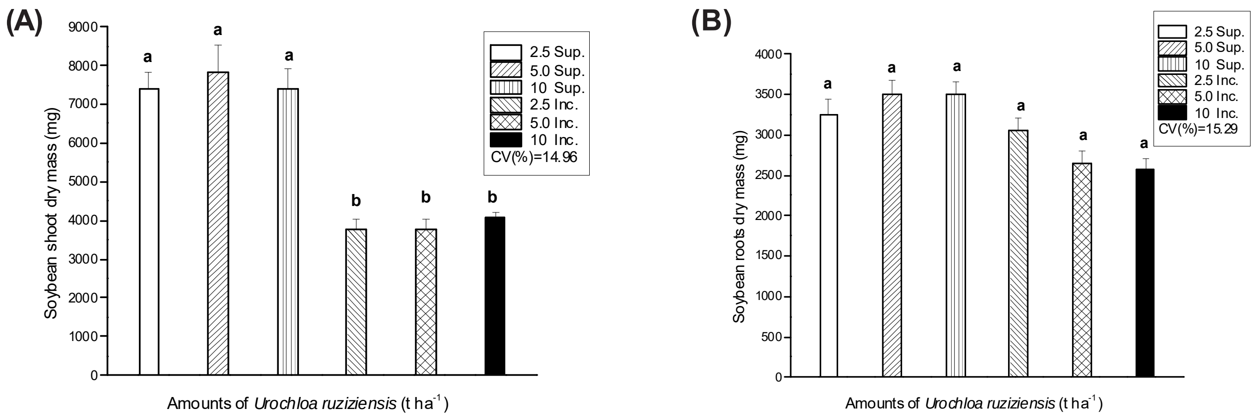

Figure 1 - Dry matter mass of the shoot (A) and roots (B) of soybean plants, M-SOY 7908 RR cultivar, in response to the different amounts of plant cover of *Urochloa ruziziensis* on the surface or incorporated into the soil. Jaboticabal, SP.

grinding/incorporation of the shoot of *U. decumbens* affected the initial growth of all studied plants, in addition to reducing the nitrate (NO_3) levels in the soil. The same authors mention this change in nitrate availability as a cause of plant development restriction, but do not rule out the possibility of releasing toxic agents (allelochemicals) into the soil during the decomposition of *U. decumbens*.

Regarding the results of the dry matter mass of the roots of soybean plants, although there was no significant difference among the treatments, there was an average increase of 21% in the dry matter mass of the roots in the treatments with straw deposited on the soil, in relation to the treatments with *Urochloa* straw incorporated into the soil (Figure 1B).

Figure 2A shows that the treatment with 2.5 ton ha^{-1} of *U. ruziziensis* on the soil surface (T1) presented a lower number of accumulated nodules (172) than the other treatments, which, on average, reached 327 nodules. However, this reduction in the number of nodules was compensated by the size and mass of the nodules (Figure 2B), since in T1 they were larger and had a greater mass than those in the other treatments.

The dry matter mass of the nodules, in the treatments in which the *U. ruziziensis* plant cover was maintained on the soil surface, was, on average, 37% higher when compared to the results of the treatments with incorporation of straw in the soil. Regardless of the amount of straw used, the dry matter mass of soybean nodules in the treatments with surface straw was, on average, 0.240 g per plant, while for treatments with incorporated straw, it was 0.150 g per plant.

These values found for the dry matter mass of the nodules per plant are lower than those reported by Fontaneli et al. (2000), that obtained 0.361 g per plant, which is considered a high dry

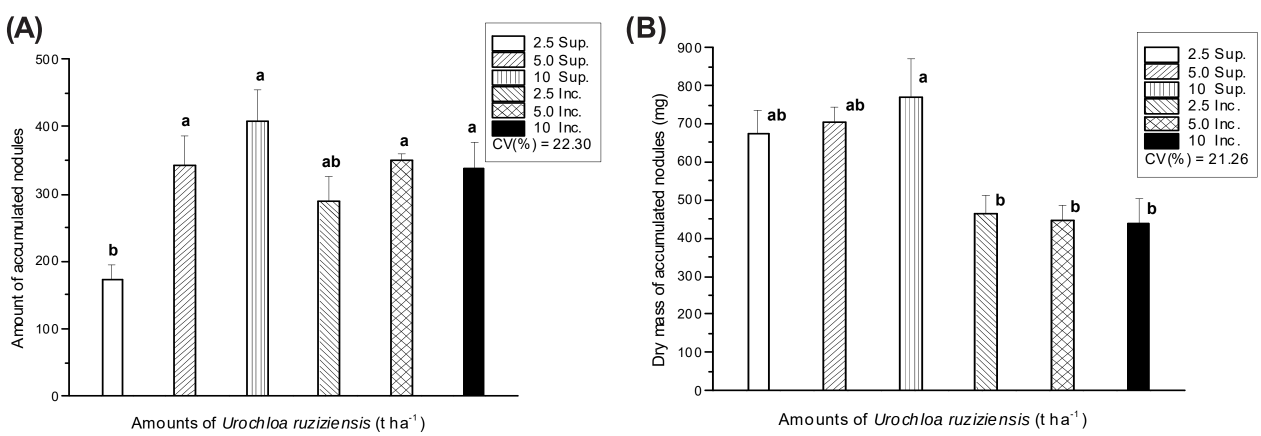

Figure 2 - Number of accumulated nodules (A) and dry matter mass of accumulated nodules (B) in soybean roots, M-SOY 7908 RR cultivar, in response to the amounts of the *Urochloa ruziziensis* straw on the surface or incorporated into the soil. Jaboticabal, SP.

matter mass for nodules. The authors state that for a good biological nitrogen fixation (BNF) it is not enough to have a large quantity of nodules; it is necessary for them to be formed by efficient strains of *Bradyrhizobium* spp. Brandelero et al. (2009) evaluated the nodulation of different soybean cultivars and its effects on grain yield and verified that the nodulation is closely related to the final grain yield among the studied cultivars.

The results of the productive characteristics of soybeans, mainly the dry matter mass of the shoot and of the nodules, were lower in the treatments in which *U. ruziziensis* was incorporated into the soil. This deleterious effect on the soybean crop is probably related to allelopathic products in the *U. ruziziensis* plant cover, which are soluble in water and which, when incorporated into the soil, are available in the soil solution, initially at high concentrations.

It has already been observed that the *Urochloa* genus has inhibitory allelopathic activity in seed germination and in the development of plants of different species (Souza Filho et al., 1997a; Martins et al., 2006; Souza et al., 2006), including soybeans (Nepomuceno et al., 2017).

More recent studies with *Brachiaria* species (syn. *Urochloa*) confirmed the presence of the steroidal saponin protodioscin in the leaves of *B. decumbens* and *B. brizantha* (Ferreira et al., 2009; Brum et al., 2009; Castro et al., 2009; Ferreira et al., 2011). In addition, saponins may be related to allelopathic effects, since studies conducted with alcoholic and aqueous extracts of *B. decumbens* revealed this effect (Melo et al., 2008), which was also observed with *B. ruziziensi* (Nepomuceno et al., 2017).

Experiment 2

The plant height and leaf area were negatively influenced by the desiccation periods, with a pronounced reduction in leaf area (on average 33.8%) in treatments in which soybeans were desiccated and sown on the same day ("apply and plant") and with seeding seven days after desiccation (DAS) (Figure 3A).

The dry matter mass of the leaves, stems and roots of soybeans sown immediately after desiccation and at 7 DAS was lower than those sown at 12 DAS, with reductions reaching 25, 31 and 20%, respectively, for the dry matter mass of leaves, stems and roots.

The number of nodules was not affected by the different desiccation periods (Figure 4). However, the dry matter mass (DM) of the accumulated nodules, in treatments with desiccation at 12 DAS and without plant cover in the soil, exceeded by 28 and 43%, respectively, the treatments with desiccation at 0 and 7 DAS. It is reasonable to infer that the shorter time interval between the desiccation and seeding of soybeans is providing greater translocation of glyphosate from the

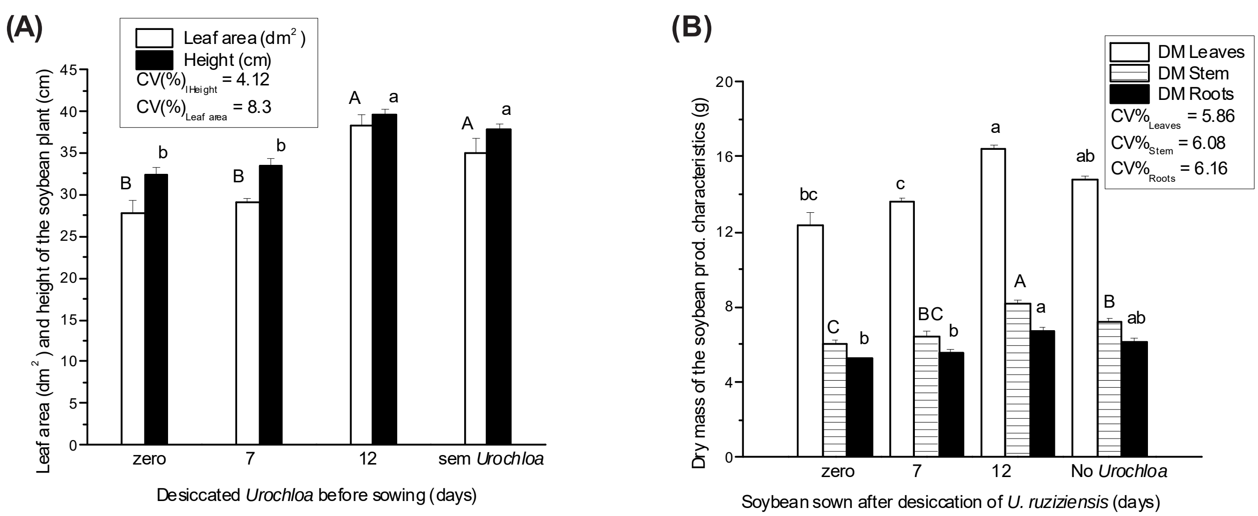

Figure 3 **-** Leaf area (dm^2) and height of the plants (cm) (A) and dry matter mass of the leaves, stems and roots (B) of soybean, M-SOY 7908 RR cultivar, in response to the desiccation periods of *Urochloa ruziziensis* with glyphosate. Jaboticabal, SP, 2011.

desiccated plant to the emerging soybean seedlings, thus affecting the development of the root system, BNF, as well as mycorrhizae. King et al. (2001) reported that the application of glyphosate increased the number and decreased the mass of rhizobium nodules in soybeans.

Nepomuceno et al. (2012) stated that the recommended period for the chemical management of *U. ruziziensis* with glyphosate is between 10 and 20 DAS for soybeans, and the period of desiccation of *U. ruziziensis* is related to the productivity of the crop. Lucio et al. (2007) evaluated the influence of desiccation period of different plant coverings on the formation of soybean nodules, with glyphosate, and observed that the increase in the interval between desiccations provided a greater number of nodules, greater height of the plant and greater dry matter mass of the roots, in relation to the "apply and plant" system.

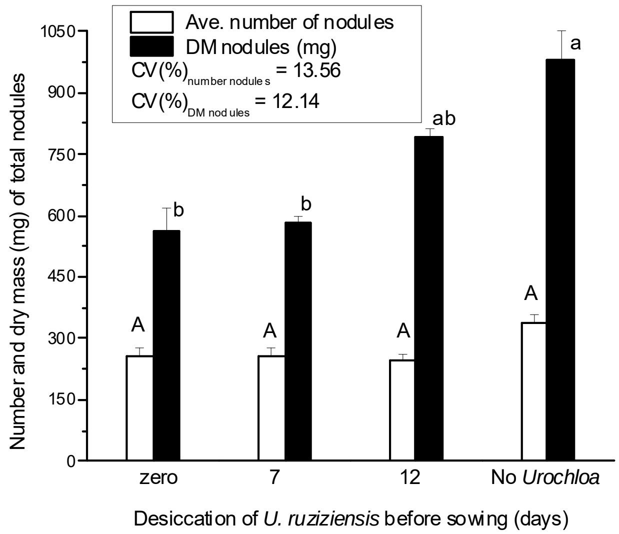

Figure 4 **-** Number and dry matter mass of rhizobium nodules in soybean, M-SOY 7908 RR cultivar, in response to desiccation periods of *Urochloa ruziziensis* with glyphosate. Jaboticabal, SP, 2011.

Studying the effect of glyphosate applied to soil, Malty et al. (2006) concluded that increasing doses of glyphosate equivalent to 0.45; 0.90; 1.8; 2.7; and 3.6 kg ha^{-1}, applied ten days before the conventional soybean sowing, did not influence the nodulation, mycorrhizal colonization and dry matter mass of the shoot of the plants at 17, 31 and 45 DAS.

In short, it was possible to observe a better development of the soybean plants sown at 12 days after the desiccation of *U. ruziziensis*. This may be associated with the leaching of possible allelopathic substances from the straw, since the rainfalls that preceded the sowing may have caused an inert *Urochloa ruziziensis* straw, providing several benefits to soybean crop.

Experiment 3

The desiccation of *Urochloa* 0 and 5 days prior to the soybean sowing provided a reduction in the number of pods per plant (NPP), in the mass of 100 grains (M100G) and, consequently, in grain productivity (GP); in the treatment in which the shoot of *Urochloa* desiccated at 5 DAS was removed, there was no reduction in these evaluated characteristics (Table 1). This result shows that the inhibitory substances are probably mainly found in the shoot of the *Urochloa* plants or that the concentrations of deleterious substances for the soybean crop in the roots were not sufficient to manifest inhibition. Similar results were obtained by Souza Filho et al. (1997b), who showed that the shoot of *Urochloa* is the main source of active substances that promote the allelopathic effect.

Table 1 **-** Average number of pods per plant (unit), mass of 100 grains (M100G) (g) and soybean grain productivity (GP) (1.33 m^2). Jaboticabal, 2009

Treatment	NPP	M100G	GP
5 DAS[1]	2.08 B	17.85 B	805.1 B
5 DAS without shoot	2.43 AB	18.23 AB	1003.7 A
10 DAS	2.48 AB	18.97 A	1030.6 A
10 DAS without shoot	2.68 A	18.20 AB	1005.3 A
0 DAS (apply and plant)	2.12 B	17.68 B	809.1 B
F Treat.	4.41*	3.54*	9.26**
DMS	0.51	1.11	172.61
CV (%)	11.49	3.23	9.69

[1] DAS = days after desiccation of *U. ruziziensis*.

In short, based on what was shown above, it is concluded that the deposition of the plant cover (straw) of *U. ruziziensis* resulting from the glyphosate desiccation on the soil surface favored the nodulation and growth of the shoot of M-SOY 7908 RR genetically modified soybean plants, while the incorporation, from 2.5 ton ha^{-1}, caused deleterious effects. Also, the desiccation of *U. ruziziensis* from 0 to 7 days prior to the seeding of M-SOY 7908 RR genetically modified soybeans was harmful to the crop, mainly due to the shoot of the grass, with a reduction in the dry matter mass of rhizobia nodules and the soybean productivity.

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