Accumulation of Dry Mass and Macronutrients by Sourgrass Plants[1]

Acúmulo de Massa Seca e Macronutrientes em Plantas de Capim-Amargoso

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ABSTRACT - The experiment was carried out aiming to analyze the dry mass production and distribution and the content and accumulation of macronutrients in sourgrass (*Digitaria insularis*) plants cultivated under mineral nutrition standard conditions. Plants grew in 7-liter pots filled with sand substrate and daily irrigated with nutrient solution, being maintained under greenhouse conditions. Treatments consisted of times of evaluation (21, 35, 49, 63, 77, 91, 105, 119, and 133 days after emergence – DAE) and were arranged in a completely randomized design with four replicates. Sourgrass showed small accumulation of dry mass (0.3 g per plant) and macronutrients (3.7 mg of N per plant, 0.4 mg of P per plant, 5.6 mg of K per plant, 0.9 mg of Ca per plant, 0.7 mg of Mg per plant, and 0.3 mg of S per plant) at vegetative growth stage (< 49 DAE). Those accumulations increased mainly after 77 DAE, reaching the maximum theoretical value at 143, 135, 141, 129, 125, 120, and 128 DAE, for dry mass (12.4 g per plant), N (163.2 mg per plant), P (27.1 mg per plant), K (260.5 mg per plant), Ca (47.6 mg per plant), Mg (30.9 mg per plant), and S (13.7 mg per plant), respectively. K and N were found with higher rates and, as a consequence, they were required and accumulated in greater amounts in plant tissues of sourgrass.

Keywords: *Digitaria insularis*, plant growth, mineral nutrition.

*RESUMO - O experimento foi conduzido com o objetivo de analisar a produção e a distribuição de massa seca e os teores e os acúmulos dos macronutrientes em plantas de capim-amargoso (**Digitaria insularis**) cultivadas em condições padronizadas de nutrição mineral. As plantas foram cultivadas em vasos de sete litros, com substrato de areia, irrigadas diariamente com solução nutritiva e mantidas em casa de vegetação. Os tratamentos corresponderam às épocas de avaliação (21, 35, 49, 63, 77, 91, 105, 119 e 133 dias após a emergência – DAE) e foram arranjados em delineamento experimental inteiramente casualizado com quatro repetições. Capim-amargoso apresentou pequeno acúmulo de massa seca (0,3 g por planta) e de macronutrientes (3,7 mg de N por planta; 0,4 mg de P por planta; 5,6 mg de K por planta; 0,9 mg de Ca por planta; 0,7 mg de Mg por planta; e 0,3 mg de S por planta) na fase vegetativa (< 49 DAE). Esses acúmulos se intensificaram, principalmente, após 77 DAE, atingindo o máximo valor teórico aos 143, 135, 141, 129, 125, 120 e 128 DAE, para massa seca (12,4g por planta), N (163,2 mg por planta), P (27,1 mg por planta), K (260,5 mg por planta), Ca (47,6 mg por planta), Mg (30,9 mg por planta) e S (13,7 mg por planta), respectivamente. K e N foram os macronutrientes com maiores teores encontrados e, consequentemente, mais requeridos e acumulados em maiores quantidades nos tecidos vegetais das plantas de capim-amargoso.*

Palavras-chave: *Digitaria insularis*, crescimento de plantas, nutrição mineral.

INTRODUCTION

Digitaria insularis, commonly known as sourgrass, is a weedy species originated from Tropical and Subtropical regions of the American Continent (Correia & Durigan, 2009; Parreira et al., 2010). Sourgrass is a seed and rhizomatous perennial plant species infesting annual and perennial crops in Brazil whose importance has increased in the past years

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due to the evolution of glyphosate-resistant populations (Carvalho et al., 2011, 2012; Heap, 2013). Considering the current importance of sourgrass as a weed, there are needed basic studies on plant biology, regarding aspects such as reproduction, growth, development, nutritional requirements, response to weed control systems, and other issues, aiming to obtain information that allow us to manage this weed efficiently. Those basic studies are essential to understand the behavior of weeds growing under distinct environmental conditions and to provide substantial information for predicting their success as weedy plants when they are being submitted to new agricultural practices or even being introduced into a new environment (Bianco et al., 2010).

Studies on nutritional requirements of weeds have crucial importance to the Weed Science since the competition for nutrients is one of the main ecological factors negatively affecting the crop productivity (Andreasen et al., 2006; Olykan et al., 2008) as well as competition for light. There are many papers on nutritional requirements of weeds emphasizing the importance of this type of research, such as the recent ones published by Bianco et al. (2010) on *Solanum americanum* Mill. (American black nightshade), Guzzo et al. (2010) on *Ipomoea hederifolia* L. (ivyleaf morningglory), Martins et al. (2010) on *Merremia aegyptia* (L.) Urban. (hairy woodrose), and others. No information is available in the literature on growth and mineral nutrition of sourgrass. However, efforts must be done to study the biology of this important weed.

The objective of this research was to analyze the production and distribution of dry mass and the content and accumulation of macronutrients by sourgrass plants growing under mineral nutrition standard conditions.

MATERIAL AND METHODS

The experiment was carried out under greenhouse conditions in Jaboticabal, SP, Brazil (22°15'22" S and 48°18'58" WGr.), from November 2010 to April 2011. After sowing seeds, previously collected from an agricultural land, in a density of 20 seeds per pot, sourgrass plants grew in 7-liter pots containing a washed and sieved river sand substrate. Once four extended leaves developed, four sourgrass plants per pot were kept until 35 days after emergence (DAE) to provide the amount of dry mass needed for initial evaluations. After that, just one well-grown plant per pot was maintained growing until the end of the experimental stage. Pots were irrigated three times a day with the nutrient solution of Hoagland & Arnon (1950), supplying equal amounts of 100 mL at 10 am, 1 pm, and 4 pm. The irrigation was performed at a concentration of 25% of this solution up to 35DAE (to prevent the intoxication of small plants) and at a concentration of 50% afterwards. These concentrations were obtained by mixing the original solution with deionized water in proportions of 1:3 (25%) and 1:1 (50%).

Treatments consisted of different times of evaluation at 21, 35, 49, 63, 77, 91, 105, 119, and 133 DAE. Experimental design was completely randomized, using four replicates. At each time, plants from four pots were analyzed, considering each pot as a replicate.

Evaluations, processes of collecting and washing plant materials, extraction of macronutrients, and statistical analysis were performed according to procedures used by Bianco et al. (2010). At each time of evaluation, plants from four pots were collected and separated into roots, stems, leaves, and reproductive structure (inflorescence, since existing). Following, plant materials were washed by subsequent immersions into diluted solution of neutral detergent, distilled water, and, finally, deionized water. After washing process, plant parts were individually packed in indentified and drilled paper bags for further drying at 60-70 °C in a forced air convection oven during 96 hours. Dried materials were weighted in a semi-analytical balance with precision of 0.01 g for determination of the dry mass accumulation. In sequence, those materials were powdered using a Wiley mill grinder with 20-mesh steel screen and stored in glass pots with silicon lid for further nutrient extraction.

Ground samples were submitted to different extraction methods for nutrient content determination in roots, stems, leaves, and reproductive structures. Nitrogen (N) and phosphorus (P) contents were obtained by using semi-micro Kjeldahl method and phosphor-vanadate-molybdate colorimetry, respectively; potassium (K), calcium (Ca), and magnesium (Mg) contents were determined by using atomic absorption spectrophotometry; and sulfur (S) content was obtained by using turbidimetric method. Macronutrient accumulation in roots, stems, leaves, and reproductive structures was calculated by multiplying the nutrient rate in each structure and the correspondent dry mass accumulation. Total accumulation of each macronutrient was calculated by adding the accumulation of the nutrient in the roots, stems, leaves and reproductive structures. The total content for each macronutrient was achieved in function of the relation between the total nutrient accumulation and the total dry mass accumulation.

Accumulation of dry mass and macronutrients data were submitted to regression analysis in function of the theoretical exponential model $y=exp(a+bx+cx^2)$: where y indicates dry mass or macronutrient accumulation and x represents days after emergence. Regression analysis was performed by using the statistical software Statistica (Statsoft, version 6.0, USA), reflecting on the behavior of sourgrass plants in accumulating dry mass and macronutrient during subsequent days of the plant life cycle. Points of maximum theoretical dry mass (PtMAXdm) and macronutrient (PtMAXmn) accumulation were also calculated by the first derivative of the adjusted equation by using the statistical software Maple (MatLab, version 5.0, USA).

RESULTS AND DISCUSSION

During the vegetative growth stage (< 49 DAE), sourgrass plants initially accumulated a small amount of dry mass (0.3 g per plant) mainly in leaves which showed higher percentage (up to 51%) of dry mass in comparison with other plant parts (Figure 1). The reproductive growth stage started just before 49 DAE. After the inflorescence emission, reproductive structures accumulated a small amount of dry mass, representing less than 0.5% of the dry mass allocated by sourgrass plants at 49 DAE. However, dry mass accumulation by sourgrass inflorescences reached 3.4 g per plant at the end of the experimental stage (133 DAE), representing 13.3% of the dry mass allocated by the weed. In addition, a reduction of the importance of the dry mass accumulation by leaves was observed in the last third of the experimental stage. And then, a reduction of the dry mass accumulation by sourgrass plants after the PtMAXdm (143 DAE) was verified. That behavior is observed due mainly to the senescence of leaves (Taiz & Zeiger, 2006).

Despite the dry mass accumulation was slow at the beginning of the experimental stage, sourgrass plants grew intensively after 50 DAE and reached the PtMAXdm at 143 DAE when 12.4 g per plant of dry mass was accumulated (Figure 1). Increasing dry mass allocation was provided by greater accumulation by stems rather than leaves, since the percentage of the dry mass accumulation by leaves, main organs producing photoassimilates, rapidly reduced after 35 DAE in comparison with other plant parts. That behavior has been observed for all weeds previously studied and it is attributed to a better plant fixation in the substrate, increasing the contact of nutrients by root interception and causing their rapid accumulation by roots (Bianco et al., 2010; Guzzo et al., 2010; Martins et al., 2010).

The content of macronutrients varied during the experimental stage (Figure 2). In general, lower contents were found at 133 DAE, excepting P (49 DAE) and S (77 DAE). On the other hand, higher contents were found at 35 DAE, excepting K (63 DAE). Thus, it is evidenced that a higher nutrient requirement occurred generally at the beginning of plant life cycle. In addition, K and N were required at higher levels by sourgrass plants, while Mg and S were required at lower levels. N and K are also the macronutrients required at higher levels by the most economic interesting crops (Kazda et al., 2004; Epstein & Bloom, 2005). The requirement of these macronutrients at higher levels is attributed to their structural, chemical, and biochemical functions in plant metabolism. Nitrogen shows structural function and constitutes amino acids, proteins, chlorophylls, plant hormones etc., while K is an activator of more than 40 enzymes and also the major cation responsible by the maintenance of cell turgor and cellular electroneutrality (Taiz & Zeiger, 2006).

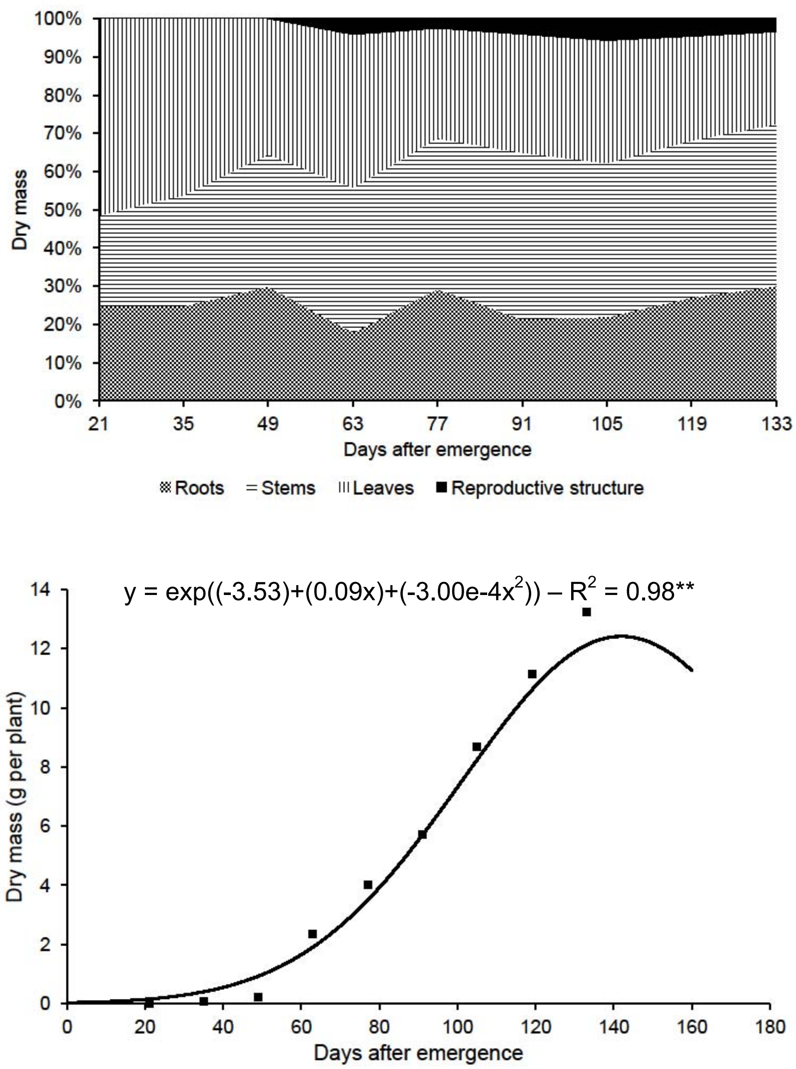

Figure 1 - Distribution of dry mass in different plant structures and regression curves of mean data of dry mass accumulation in sourgrass (*Digitaria insularis*) plants growing under mineral nutrition standard conditions.

The total accumulation of macronutrients was small at the beginning of the experimental stage (Figure 3) as well as dry mass (Figure 1). During the vegetative growth stage (< 49 DAE), sourgrass plants averagely accumulated 3.7 mg of N per plant, 0.4 mg of P per plant, 5.6 mg of K per plant, 0.9 mg of Ca per plant, 0.7 mg of Mg per plant, and 0.3 mg of S per plant. After the reproductive stage started, the accumulation of macronutrients increased, being intensively allocated by sourgrass plants from 77 to 133 DAE. At 133 DAE, sourgrass plants averagely accumulated 154.5 mg of N per plant, 28.9 mg of P per plant, 253.8 mg of K per plant, 45.9 mg of Ca per plant, 26.0 mg of Mg per plant, and 12.9 mg of S per plant.

However, the PtMAXmn occurred at 135, 141, 129, 125, 120, and 128 DAE for N, P, K, Ca, Mg, and S, respectively (Figure 3). At each time, sourgrass plants accumulated 163.2 mg of N per plant, 27.1 mg of P per plant, 260.5 mg of K per plant, 47.6 mg of Ca per plant, 30.9 mg of Mg per plant, and 13.7 mg of S per plant. After these times, the accumulation of macronutrients reduced due mainly to the plant dry mass accumulation had been diminished in function of the senescence of leaves and due additionally to lower contents of macronutrients had been extracted from plant tissues in function of smaller plant nutrient requirement, as discussed by Bianco et al. (2010).

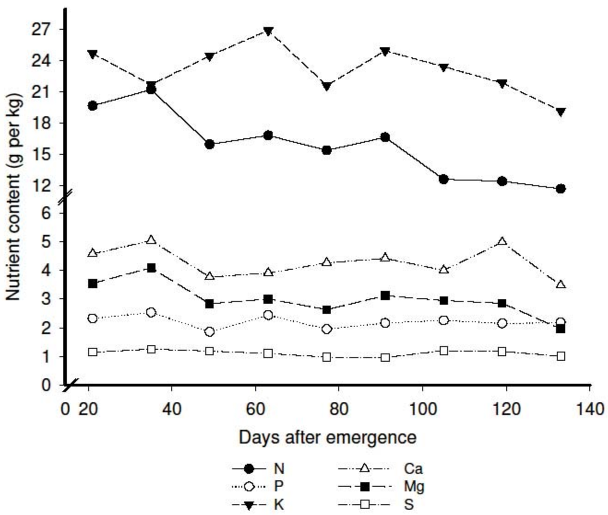

Figure 2 - Variation of contents of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S) in sourgrass (*Digitaria insularis*) plants growing under mineral nutrition standard conditions.

Comparing with other weeds previously studied in experiments conducted at same growing conditions, it was possible to indentify some sourgrass characteristics showing similar behavior of other weeds. Greater dry mass accumulation by stems rather than leaves after the middle third of the experimental stage, higher requirement of macronutrients at the beginning of the experimental stage, K and N as the macronutrients required at higher levels, and Mg and S as the macronutrients required as lower levels in sourgrass plants were similar to results observed for American black nightshade (Bianco et al., 2010), ivyleaf morningglory (Guzzo et al., 2010), and hairy woodrose (Martins et al., 2010). However, different behavior was observed for the time of flowering, the PtMAXdm, the PtMAXmn, and the total amount of accumulation of dry mass and macronutrients.

Sourgrass flowering (< 49 DAE) started before hairy woodrose (< 91 DAE) and ivyleaf morningglory (> 147 DAE), but after American black nightshade (< 35 DAE). Sourgrass plants showed the time for PtMAXdm (143 DAE) close to American black nightshade (142 DAE) and hairy woodrose (146 DAE), while the PtMAXdm of ivyleaf morningglory occurred before those plants (133 DAE). The average time for PtMAXmn of sourgrass plants (131 DAE) was before American black nightshade (152 DAE), ivyleaf morningglory (140 DAE), and hairy woodrose (153 DAE). In addition, the total accumulation of dry mass and macronutrients was generally smaller in sourgrass plants than in those three weeds.

American black nightshade is an annual herbaceous species (Zhou et al., 2005) considered as one of the most important weeds requiring nutrients and accumulating dry mass and macronutrients during the growing season of annual crops (Bianco et al., 2010). Hairy woodrose was also observed requiring great amounts of macronutrients for plant growing (Martins et al., 2010), but it was not verified for ivyleaf morningglory plants (Guzzo et al., 2010). Apart from interfering indirectly with crop productivity due to block the reel of the combine in mechanical harvesting (Moro et al., 2011), climbing plants, such as hairy woodrose and ivyleaf morningglory, can also interfere directly with crop productivity by competition for environmental resources.

In that way, hairy woodrose showed higher capacity of competition than ivyleaf morningglory due to its greater requirement and extraction of macronutrients. In general, American black nightshade, hairy woodrose, and ivyleaf morningglory showed greater extraction of macronutrients than sourgrass plants due probably to be annual plants and, as a consequence, to have shorter life cycle. Therefore, sourgrass plants should accumulate greater amounts of dry mass and macronutrients in more advanced growth stage, becoming potentially competitive with annual crops of long growing cycle or perennial crops.

However, sourgrass plants show fast and intense reproduction by seeds with low dormancy (Melo et al., 2012) and also reproduce by rhizomes (Gemelli et al., 2012), allowing this weed to increase its population density very fast. So, it can provide an expressive increasing in the capacity of competition for environmental resources by sourgrass populations. Remembering that some limitation of rhizome growth occurred in this experiment due to plants were grown

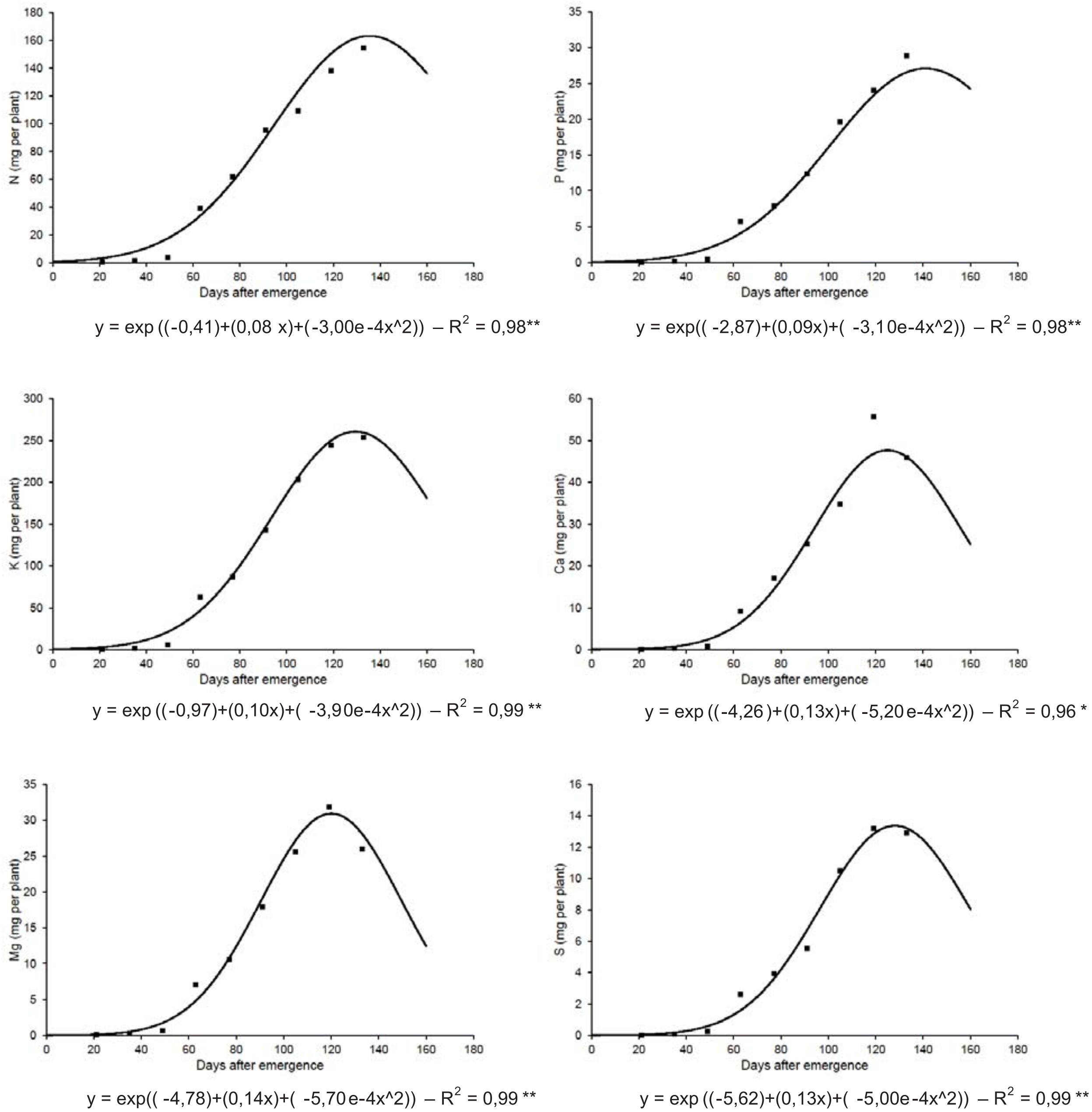

Figure 3 - Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S) accumulation in sourgrass (*Digitaria insularis*) plants growing under mineral nutrition standard conditions.

in 7-liter pots, no limitation for vegetative growth and reproduction is expected in field conditions, so that sourgrass plants can better explore and allocate soil resources, becoming highly competitive with crops.

Considering that the period of higher competition of weeds with the most annual crops is close to 77 DAE (Bianco et al., 2010; Guzzo et al., 2010; Martins et al., 2010), a time for intense increasing in the extraction of the nutrients studied, sourgrass plants showed average accumulation of 15.5 g of dry mass, 58.5 mg of N, 7.6 mg of P, 89.2 mg of K, 14.4 mg of Ca, 10.8 mg of Mg, and 3.6 mg of S by a single plant, at this time of evaluation. In function of the high reproductive capacity by seeds and rhizomes and the perennial life cycle, sourgrass plants can be present in agricultural fields for a long time if not controlled, reducing the amount of nutrients available for crop growing and causing important biotic pressure on both annual and perennial crops. Thus, the sourgrass competition for nutrients can be an important biotic factor negatively affecting the crop growth, development, and productivity.

In addition to the interference with crops, it is important to point out that some glyphosate-resistant sourgrass biotypes were found infesting annual and perennial crops in Brazil (Carvalho et al., 2011, 2012; Heap, 2013). In this sense, a special attention must be given to the sourgrass management to prevent the plant survival and, as a consequence, the increasing of sourgrass competitive potential and sourgrass resistant populations. In addition, managing sourgrass under initial growth stages is recommended because limits the rhizome and seed production and increases the efficacy of the chemical control that cannot kill sourgrass plants after tillering and mainly after flowering (Correia & Durigan, 2009).

In no-till systems, the weed management before planting summer annual crops must be efficient because survival plants can reach advanced growth stages and not be controlled using herbicides. So, no-killed plants can grow and reproduce intensively, increasing their competition capacity. In perennial crops, monitoring sourgrass populations is essential to provide some efficiency of control. Being a perennial species (Gemelli et al., 2012), sourgrass plants can be present for long periods of time in areas of production of perennial crops, reaching advanced growth stages and reproducing intensively by seeds and rhizomes, so that its density and competitive potential increases expressively.

Results allow concluding that: leaves are the main organs accumulating dry mass in the first half of sourgrass life cycle, while stems become the most important ones in the second half; K and N are the macronutrients required at greater amounts by sourgrass plants; and the period of greater accumulation of dry mass and macronutrients by sourgrass plants occurs between 120 and 143 DAE.

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