GROWTH AND MINERAL NUTRITION OF *Solanum americanum*[1]

*Crescimento e Nutrição Mineral de **Solanum americanum***

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ABSTRACT - A greenhouse trial was carried out from November 1995 to April 1996 at FCAV/ UNESP, Brazil, aiming to study the dry matter production and the accumulation and distribution of macronutrients in *Solanum americanum*, an important weed for annual and perennial crops in Brazil. The plants were grown in seven liter pots with sand substrate, irrigated daily with Hoagland & Arnon nutrient solution. The experimental design was completely randomized with four replicates. The treatments corresponded to evaluation times at 14 day intervals, beginning 21 days after emergence (DAE). In each evaluation, the plants of four pots were analyzed for dry matter production and macronutrient content. *S. americanum* had a small dry matter and macronutrient accumulation at the beginning of the experimental stage, increasing after 77 DAE and reaching the maximum theoretical value at 142, 142, 164, 149, 140, 149 and 152 DAE, for dry matter, N, P, K, Ca, Mg, and S, respectively. K and N were the most accumulated macronutrients for *S. americanum* plants.

Keywords: weed, American black nightshade, dry matter, macronutrients.

*RESUMO - Um experimento em casa de vegetação foi conduzido entre novembro de 1995 e abril de 1996 na FCAV/UNESP, Brasil, objetivando estudar a produção de matéria seca, a distribuição e o acúmulo de macronutrientes por **Solanum americanum** – uma importante planta infestante de culturas anuais e perenes no Brasil. As plantas foram cultivadas em vasos de 7 L com substrato de areia, os quais foram irrigados diariamente com solução nutritiva de Hoagland & Arnon. O delineamento experimental foi inteiramente casualizado, com quatro repetições. Os tratamentos corresponderam às épocas de avaliação, em intervalos de 14 dias, iniciando-se 21 dias após a emergência (DAE). Em cada avaliação, as plantas de quatro vasos foram analisadas quanto à produção de matéria seca e ao conteúdo de macronutrientes. **S. americanum** apresentou pequeno acúmulo de matéria seca e de macronutrientes no início da fase experimental. Esses acúmulos intensificaram-se após 77 DAE, atingindo o máximo valor teórico aos 142, 142, 164, 149, 140, 149 e 152 DAE, para matéria seca, N, P, K, Ca, Mg e S, respectivamente. K e N foram os macronutrientes acumulados em maior quantidade por plantas de S. americanum.*

Palavras-chave: plantas daninhas, maria-pretinha, matéria seca, macronutrientes.

INTRODUCTION

Solanum americanum, firstly described by Philip Miller in 1768, is an indigenous plant from North America (Manoko et al., 2007), which is widely distributed in agricultural lands in Brazil and worldwide (Kissmann & Groth, 1999; Lorenzi, 2000). In the last years, the species has been reported infesting horticulture and field crops such as cotton (Corrêa & Sharma, 2004), papaya (Ronchi et al., 2008), onion (Soares et al., 2003, 2004),

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peanut (Nepomuceno et al., 2007a; Dias et al., 2009), potato (Blanco, 2008), red beet (Carvalho et al., 2008a,b; Carvalho & Guzzo, 2008), soybean (Nepomuceno et al., 2007b), sugar cane (Kuva et al., 2007; Monquero et al., 2008), tomato (Nascente et al., 2004; Hernandez et al., 2007) and watermelon (Adkins et al., 2008; Gilbert et al., 2008).

In general, weeds have a specific characteristic that allows their eco-physiological adjustment in different environments, known as phenotypic plasticity; at each environment, weed populations may suffer evolving genetic modifications that may be extended to subsequent generations (Pitelli & Pavani, 2004). For these reasons, weed populations may show different responses to distinct methods of management. Thus, basic studies on the biology of weeds are essential to understand the behavior of weeds growing under different environmental conditions (Bianco et al., 2004a, b) as a support to weed management. Considering the importance of *S. americanum* as weed, basic studies are necessary concerning the biology of this species, regarding some aspects such as reproduction, growth, development and mineral nutrition, as well as management systems. These studies are important to obtain substantial information to help manage this weed.

Information on the nutritional requirements of weeds is important to weed science, since nutrient competition is one of the main ecological factors that affect negatively crop productivity (Andreasen et al., 2006; Olykan et al., 2008). Due to this fact, important studies have already been conducted for *Senna obtusifolia* (Erasmo et al., 2000), *Urena lobata* (Souza Filho et al., 2000), *Cardiospermum halicacabum* (Brighenti et al., 2003), *Richardia brasiliensis* competing with *Glycine max* (Pedrinho Júnior et al., 2004), *Quercus petraea*, *Fagus sylvatica*, *Acer pseudoplatanus* (Kazda et al. 2004), *Brachiaria decumbens* (Bianco et al., 2005), *Euphorbia heterophylla* competing with *G. max* (Bianco et al., 2007), *Brachiaria plantaginea* competing with *Zea mays* (Carvalho et al., 2007), *Ipomoea nil* (Duarte et al., 2008) and *Ipomoea quamoclit* (Carvalho et al., 2009).

No information is available in the literature on growth and mineral nutrition of *S. americanum*. However, efforts must be done to study the biology of this important weed in Brazil. So, the objective of this research was to study the dry matter production and macronutrients distribution and accumulation in *S. americanum* plants, growing under standard nutrient conditions.

MATERIALS AND METHODS

A greenhouse trial was carried out at Faculdade de Ciências Agrárias e Veterinárias (FCAV) of São Paulo State University (UNESP), Jaboticabal-SP, Brazil. The experiment was conducted from November 1995 to April 1996, using seven liter plastic pots and river sand as substrate.

Twenty seeds of *S. americanum* were sown in November 1995. After four leaves were attained, only four *S. americanum* plants per plot were maintained until the end of the experimental stage. The 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. At 35 days after emergence (DAE), the irrigation was performed at a concentration of 25% of this solution; after 35 DAE until the end of the experimental stage, at a concentration of 50%. These concentrations were obtained mixing the original solution with deionized water in proportion of 1:3 (25%) and 1:1 (50%).

The experimental design was completely randomized with four replicates. Treatments were determined by proper evaluation times at 21, 35, 49, 63, 77, 91, 105, 119, 133, 147 and 161 DAE. At each time, plants from the four pots were analyzed, considering each pot as one replicate.

For the evaluations, *S. americanum* plants were collected and partitioned into roots, stems, leaves and reproductive structures (flowers and fruits). These materials were washed according to procedure described by Sarruge & Haag (1974) and dried at 60-70 °C in a forced air convection oven for 96 hours.

Dried materials were weighted to determine the dry matter accumulation, sequentially powdered using a Willey mill grinder with 20-mesh steel screen and stored in glass pots with silicon lid. Ground samples were submitted to different extraction methods for nutrient rate determination in roots, stems, leaves, and reproductive structures. Nitrogen (N) and phosphorus (P) rates were attained according to the methodologies described by Sarruge & Haag (1974). Potassium (K), calcium (Ca) and magnesium (Mg) rates were determined according to the methodologies described by Jorgensen (1977), while sulfur (S) rate was reached according to the methodology described by Vitti (1989).

Macronutrient accumulation in the roots, stems, leaves and reproductive structures was calculated by multiplying the nutrient rate in each structure and the correspondent dry matter 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 rate for each macronutrient was achieved in function of the relation between total nutrient accumulation and total dry matter accumulation.

Accumulation of dry matter and macronutrients was submitted to regression analysis in function of the theoretical exponential model $y=\exp(a+bx+cx^2)$: where y indicates dry matter or macronutrient accumulation and x represents days after emergence. So, points of maximum theoretical dry matter (PMtADM) and macronutrient (PMtAM) accumulation were calculated by the first derivative of the adjusted equation.

RESULTS AND DISCUSSION

Dry matter accumulation for *S. americanum* plants was slow at the beginning of the experimental stage (Figure 1A), but reached a theoretical value of 179.62 g plant^{-1} at the PMtADM (142 DAE). After this period, there was a reduction of total dry matter accumulation due to plant senescence. Growing under same conditions, *D. tortuosum*, *E. heterophylla*, *H. suaveolens*, *I. nil*, *I. quamoclit*, *R. brasiliensis* and *S. obtusifolia* showed the most dry matter accumulation at 161, 116, 145, 123, 146, 147 and 147 DAE, as observed by Gravena et al., (2002), Bianco et al. (2004b), Pedrinho Júnior et al. (2004) Bianco et al. (2007), Duarte et al. (2008), Bianco et al. (2008) and Carvalho et al. (2009), Moreover, dry matter accumulation of these broadleaved weeds was less than that one of *S. americanum*, showing that *S. americanum* may grow more than these weeds.

In general, the broadleaved weeds already studied, such as *D. tortuosum*, *E. heterophylla*, *H. suaveolens*, *I. nil*, *I. quamoclit*, *R. brasiliensis* and *S. obtusifolia*, showed slow dry matter accumulation at the beginning of their life cycle, as verified by Gravena et al., (2002), Bianco et al. (2004b), Pedrinho Júnior et al. (2004) Bianco et al. (2007), Duarte et al. (2008), Bianco et al. (2008), and Carvalho et al. (2009), respectively. It is because plants demand a small amount of environmental resources, as water and nutrients, for initial growth, which increase greatly throughout the plant development (Taiz & Zieger, 2002).

It was ascertained considerable dry matter accumulation from 63 to 119 DAE (Figure 1A). During this period, high dry matter increase occurred mainly as a function of accumulation in stems (Figure 1B). Moreover, by dividing the experimental stage into three parts, the percentage of accumulated dry matter in leaves was higher than in other structures in the first part, while stem percentage was greater than in other structures in the third part (Figure 1B).

The percentage of accumulated dry matter in roots increased from 21 to 49 DAE, decreasing from 49 to 105 and increasing afterwards (Figure 1B). This slight early increase may have allowed the plant to be able to fix itself on the substrate, increasing the contact with the nutrients, thereby leading to their quick uptake (Carvalho et al., 2007).

The percentage of dry matter accumulation in stems increased substantially after 21 DAE, decreasing mainly in leaves (Figure 1B). It provided greater percentage of dry matter accumulation in stems than other structures from 63 to 161 DAE.

Flowering of *S. americanum* occurred between 35 and 49 DAE. The percentage of accumulated dry matter in reproductive structures was small, but the highest value was 8.05% at 105 DAE (Figure 1B).

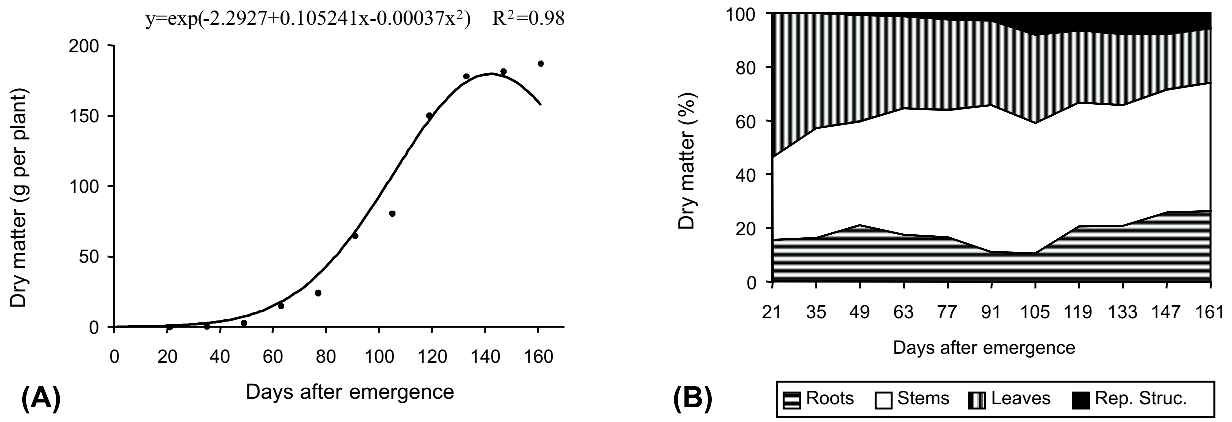

Figure 1 - Regression of dry matter accumulation data (A) and percentage of dry matter distribution (B) in *Solanum americanum* plants grown under standard nutrient conditions.

It is important to point out that there was intense decrease in the percentage of accumulated dry matter in leaves after flowering likely due to the change of the main site of nutrient absorption from the leaves to the reproductive structures. This fact had also been observed in studies with other weeds, according to reports of Bianco et al. (2004b) on *Desmodium tortuosum*, Bianco et al. (2004a) on *Rottboellia exaltata*, Pedrinho Júnior et al. (2004) on *R. brasiliensis*, Bianco et al. (2007) on *E. heterophylla*, Carvalho et al. (2007) on *B. plantaginea*, Duarte et al. (2008) on *I. nil* and Carvalho et al. (2009) on *I. quamoclit*.

The sequence of macronutrients with the highest rates in *S. americanum* plants was K, N, Ca, Mg, P and S, respectively (Table 1). Macronutrients rates oscillated throughout the experimental stage. The highest rates of N, P and K were observed at 21 DAE, whereas the Ca, Mg and S highest rates were verified at 49, 91 and 147 DAE, respectively. When studying mineral nutrition in broadleaved weeds, Bianco et al. (2004b), Pedrinho Júnior et al. (2004), Bianco et al. (2007), Bianco et al. (2008), Duarte et al. (2008) and Carvalho et al. (2009) observed that K and N were the macronutrients presenting the highest rates in plants such as *D. tortuosum*, *R. brasiliensis*, *E. heterophylla*, *S. obtusifolia*, *I. nil* and *I. quamoclit*, respectively.

The accumulation of macronutrients in *S. americanum* plants was small at the beginning of the experimental stage (Figure 2), increasing after the first part of the total stage, reaching the PMtAM at 142 DAE (5,461.94 mg of N per plant), 164 DAE (540.31 mg of P per plant), 149 DAE (6,581.34 mg of K per plant), 140 DAE (3,751.46 mg of Ca per plant), 149 DAE (1,340.59 mg of Mg per plant) and 152 DAE (612.73 mg of S per plant).

Large accumulations of N, K and Mg were observed from 77 to 133 DAE (Figure 2A, 2C and 2E). There were real accumulations of 4,888.84 mg, 5,254.60 mg and 1,044.48 mg of N, K and Mg per plant at 133 DAE, respectively. Nevertheless, a great accumulation of P was verified from 77 to 147 DAE, while it was observed from 77 to 119 DAE for Ca and from 91 to 133 DAE for S (Figures 2B, 2D and 2F). There was a real accumulation of 461.04 mg

Table 1 - Rates of macronutrients (g kg^{-1}) in *Solanum americanum* plants grown under standard nutrient conditions. FCAV/UNESP, Brazil, 2007

DAE	N	P	K	Ca	Mg	S
21	37.31	3.85	53.08	17.69	5.38	1.90
35	31.94	3.30	47.31	19.69	5.90	1.76
49	34.44	3.43	38.80	27.24	5.15	1.73
63	33.58	3.14	37.58	23.22	5.87	1.96
77	33.65	3.58	39.82	23.22	5.45	2.00
91	30.67	2.49	38.27	19.29	6.35	2.47
105	28.32	2.33	35.76	19.78	5.94	2.44
119	27.95	2.04	32.71	21.57	5.62	2.43
133	27.47	2.12	29.53	20.91	5.87	2.39
147	26.86	2.54	28.09	17.09	5.79	2.82
161	25.98	2.58	30.56	18.58	5.48	2.49

DAE – Days after emergence.

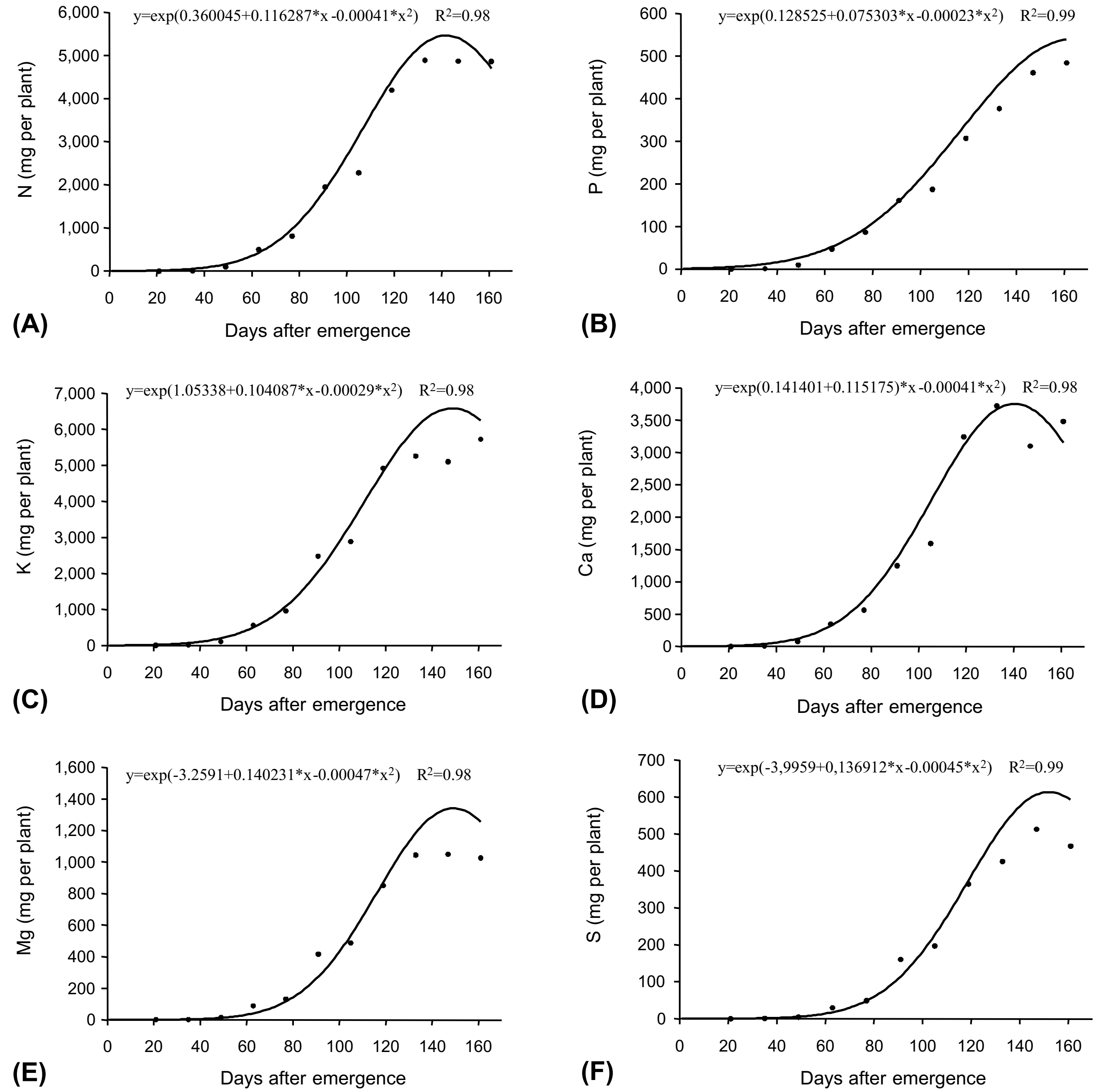

Figure 2 - Regression of the mean data of accumulation of nitrogen (**A**), phosphorus (**B**), potassium (**C**), calcium (**D**), magnesium (**E**), and sulfur (**F**) in *Solanum americanum* plants grown under standard nutrient conditions.

of P per plant at 147 DAE, while 3,239.26 mg of Ca were accumulated per plant at 119 DAE and 425.32 mg of S were accumulated per plant at 133 DAE.

Comparing the results of this research with those obtained on broadleaved weeds, it may be evidenced that, in the PMtAM, *S. americanum* accumulated more N, P, K, Ca, Mg and S than *D. tortuosum* (Bianco et al., 2004b), *E. heterophylla* (Bianco et al., 2007), *I. nil* (Duarte et al., 2008) and *I. quamoclit* (Carvalho et al., 2009), *R. brasiliensis* (Pedrinho Júnior et al., 2004) and *S. obtusifolia* (Bianco et al., 2008). Therefore, *S. americanum* was more demanding for macronutrients than these weeds.

The macronutrients that accumulated the most in *S. americanum* plants were those displaying the highest rates. K accumulated more than N. The uptake sequence was K > N > Ca > Mg > P > S. Bianco et al. (2004b), Pedrinho Júnior et al. (2004), Bianco et al. (2007), Bianco et al. (2008), Duarte et al. (2008) and Carvalho et al. (2009) observed that N and K accumulated the most in the broadleaved weeds already studied. N and K are also known as the most demanded nutrients for most crops of economic interest (Epstein & Bloom, 2005). Thus, competition of *S. americanum* plants for macronutrients is an important biotic factor affecting negatively the crops growth, development and productivity.

Bianco et al. (2004a,b) and Bianco et al. (2007) reported that the period for the greatest competition for nutrients among weeds and most annual crops in Brazil is around 77 DAE; as a result of uptake intensification, which was also observed in this study. During this period, just one *S. americanum* plant accumulated 24.07 g of dry matter, 810.02 mg of N, 160.21 mg of P, 958.54 mg of K, 558.98 mg of Ca, 131.30 mg of Mg and 51.72 mg of S. Comparing these results with those already verified on broadleaved weeds, it may be stated that *S. americanum* is more competitive for macronutrients than *D. tortuosum*, *E. heterophylla*, *I. nil*, *I. quamoclit*, *R. brasiliensis* and *S. obtusifolia* at 77 DAE, growing under standard nutrient conditions.

Therefore: (i) leaves and stems are the main structures accumulating dry matter in the first and second half of the *S. americanum* life cycle, respectively; (ii) N and K are the macronutrients most accumulated by *S. americanum* plants; and (iii) theoretical period of maximum dry matter and macronutrient accumulation for *S. americanum* was between 140 and 164 DAE.

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