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Article

GROWTH AND DEVELOPMENT OF *Ipomoea* WEEDS

*Crescimento e Desenvolvimento de Plantas Daninhas do Gênero **Ipomoea***

BARROSO, A.A.M.[1]*
FERREIRA, P.S.H.[2],
MARTINS, D.[3]

ABSTRACT - Weeds reduce the productive potential of crops. Plants of the *Ipomoea* genus, besides competing for water, light, space and nutrients, create problems in crop harvests due to their volatile stems. The objective of this work was to evaluate the growth and development of five *Ipomoea* species. For such, *Ipomoea grandifolia*, *Ipomoea hederifolia*, *Ipomoea nil*, *Ipomoea purpurea* and *Ipomoea quamoclit* plants were analyzed during the summer and winter season. Five destructive and periodic growth evaluations were carried out for each study, where leaf number, leaves, stems, roots and the total biomass were analyzed. Phenological stages of the plant development were also evaluated for emergence, flowering and maturation sub-periods by degree-days, totalizing five treatments, conducted in a completely randomized design with four replicates. The phenology averages were analyzed according to the Hess scale, and the growth data through nonlinear regressions. *I. quamoclit* and *I. grandifolia* obtained the highest number of leaves in the summer and the winter, respectively. *I. nil* obtained greater accumulation of leaf and stem dry biomass in both seasons. *I. grandifolia* obtained greater root development in both periods. *I. quamoclit* presented reduced cycle times when compared to the other species, especially *I. hederifolia* and *I. grandifolia*, which presented larger cycles. Based on the results, *I. grandifolia* probably shows greater interference with agricultural crops due to high root growth, high leaf production and longer cycle. Shorter-cycle species, such as *I. quamoclit*, when present, should require shorter residual control periods.

Keywords: morning glory species, *Ipomoea grandifolia, Ipomoea hederifolia, Ipomoea nil, Ipomoea purpurea, I. quamoclit.*

*RESUMO - A presença de plantas daninhas reduz o potencial agrícola das culturas. Plantas do gênero **Ipomoea**, além de competirem por água, luz, espaço e nutrientes, criam problemas na colheita de culturas devido aos seus caules volúveis. O objetivo deste trabalho foi analisar o crescimento e desenvolvimento de cinco plantas daninhas do gênero **Ipomoea** durante o inverno e o verão, com a hipótese de que diferentes ciclos e desenvolvimentos ajudariam no manejo das espécies. Para isso, utilizaram-se as espécies **Ipomoea grandifolia, Ipomoea hederifolia, Ipomoea nil, Ipomoea purpurea** e **Ipomoea quamoclit**. Foram realizadas cinco avaliações destrutivas e periódicas de crescimento em duas estações de crescimento, quando se analisaram o número de folhas, a massa seca de folhas, caules, raízes e total. Foram avaliadas também as etapas fenológicas de desenvolvimento das plantas para os subperíodos de emergência, florescimento e maturação através de graus-dia, totalizando, para cada análise, cinco tratamentos, conduzidos em delineamento inteiramente casualizado com quatro repetições. As médias de fenologia foram analisadas segundo a escala Hess, e os dados de crescimento, através de regressões não lineares. **I. quamoclit** e **I. grandifolia** obtiveram maior número de folhas no verão e inverno, respectivamente. **I. nil** atingiu maior acúmulo de massa seca foliar*

*** Corresponding author:**
<arrobas@ufpr.br>

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[1] Universidade Federal do Paraná, Curitiba-PR, Brasil; [2] Adama Brasil, Londrina-PR, Brasil; [3] Universidade Estadual Paulista, Jaboticabal-SP, Brasil.

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e caulinar em ambas as estações. ***I. grandifolia*** *obteve maior desenvolvimento radicular em ambos os períodos.* ***I. quamoclit*** *apresentou nas duas ocasiões ciclo reduzido em comparação às demais espécies, em especial* ***I. hederifolia*** *e* ***I. grandifolia****, que apresentaram ciclos maiores. Com base nos resultados, estima-se que* ***I. grandifolia*** *apresente maior interferência em culturas agrícolas devido ao elevado crescimento radicular, à elevada produção de folhas e ao ciclo mais longo. Espécies de ciclo mais curto, como* ***I. quamoclit****, quando presentes, demandam menores períodos residuais de controle.*

Palavras-chave: cordas-de-viola, *Ipomoea grandifolia, Ipomoea hederifolia, Ipomoea nil¸ Ipomoea purpurea, I. quamoclit.*

INTRODUCTION

The presence of weeds damages agricultural crops, since they take up physical space, compete for light, water and nutrients and may release allelopathic compounds. In addition, there may be an indirect interference by plants that are hosts to pests and diseases and by their interference in processes such as fertilizations and harvests (Sanginga et al., 2003).

The *Ipomoea* genus has different species distributed across the world, popularly known as ivyleaf morningglory. In Brazil, the presence of ivyleaf morningglories infesting agricultural areas has increased over the last years, mainly for the *Ipomoea hederifolia*, *I. quamoclit*, *I. grandifolia* and *I. nil* species (Kuva et al., 2007). Areas where these species prevail have their crop productivity reduced, as observed in the presence of *I. hederifolia*, which reduced the productivity of culms in sugarcane by 46%, and in the presence of *I. grandifolia* and *I. purpurea*, which reduced in up to 80% the soybean productivity (Silva et al., 2009; Pagnoncelli et al., 2017).

The growing use of the direct seeding system, as well as the green sugarcane system (sugarcane without residue burning) collaborated for this gradual importance. Since they have a high amount of reserves, the seeds of these species allow them to germinate even under a large amount of straw (Silva et al., 2009). In addition, the plant development occurs even during the phase of greatest growth of cane fields, and adult plants get intertwined with the culms and leaves of the crops, having a negative interference in the cane development and the crop and harvest practices. Also, during harvest, their fruits and seeds may be connected to the mother plant, favoring their dissemination by the harvester to medium and long distances (Azania et al., 2002).

Basic studies on the biology of weeds, such as the analysis of their growth and development, allow the behavioral analysis of the plants considering the ecological factors, as well as their action on the environment. Knowing the phenological stages, the cycle of the species, as well as the production and distribution of their mass, allows the elaboration of an integrated management of weeds. Knowing how the growth of the species occurs also allows interferences on the competitive ability of the plants (Benincasa, 1988; Carvalho et al., 2008). Therefore, the aim of this study was to evaluate growth and development characteristics of five species of the *Ipomoea* genus, in order to identify unique characteristics that may collaborate in the decision-making for the management of these species.

MATERIAL AND METHODS

Two experiments were installed and conducted in a greenhouse with five species from the *Ipomoea* genus, and they were replicated in two seasons of the year, summer and winter, in 2011 and 2012 (21,24°S; 48,30°W). The studied species were: *Ipomoea grandifolia* (IAOGR), *Ipomoea hederifolia* (IPOHF), *Ipomoea nil* (IPONI), *Ipomoea purpurea* (PHBPU) and *Ipomoea quamoclit* (IPOQU) in the summer, and *Ipomoea grandifolia* (IAOGR), *Ipomoea hederifolia* (IPOHF), *Ipomoea nil* (IPONI) and *Ipomoea quamoclit* (IPOQU) in the winter. The vases were subjected to average temperatures of 19.5 °C in the winter and 24.2 °C in the summer.

Seeds of the species were commercially acquired (Agrocosmos, Arthur Nogueira, SP, Brazil) and left to germinate in 5 L vases filled with Eutrudox Red Latosol with medium textural class, with the following characteristics: pH 6.4 ($CaCl_2$); 15 g L^{-1} of MO; 57 mg L^{-1} of P (resin); V (%) of

94%; and 4.1, 92, 41, 9, 137 and 146.1 $mmol_c\ L^{-1}$ K^+, Ca^{2+}, Mg^{2+}, $H+Al^{3+}$, SB and T, respectively. Due to the high V%, the vases were not fertilized, and the soil was not covered with sugarcane straw. When they reached three completely expanded leaves, the vases were thinned to a density of one plant. The vases were irrigated whenever visually identified as necessary, and all the phytosanitary conditions necessary to the development of the plants were maintained.

In each experiment (summer and winter), for each species, the completely randomized experimental design was used (DIC), with five treatments and four replicates. During the experiment, five growth evaluations (treatments) were conducted, at 15, 32, 47, 64 and 99 days after the emergence of the seedlings, when the leaf dry mass (Mf), stems (Mc), roots (Mr) and total mass (Mt) were evaluated, in addition to the total number of leaves (Nf) by species. The mass was collected by cutting and separating these structures, that were left to dry in a forced air-circulation greenhouse at 60 °C for 72 hours. In the summer, the averages among the species were compared and analyzed log-logistics non-linear regressions, using the Origin program, according to equation 1, except for the regressions related to the dry mass of the roots of *I. hederifolia*, *I. nil*, *I. purpurea* and *I. quamoclit*, which were adjusted in cubic regression.

$$Y = a/1+ e^{-k\,(x-x_c)} \qquad \text{(eq. 1)}$$

were: Y is the response-variable of interest; x, the number of accumulated days; and a, b and c are the estimated parameters of the equation (a is the amplitude between the maximum point and the minimum points of the variable; b corresponds to the number of days needed for 50% of the variable response to occur; and c is the declivity of the curve around b.

In the winter experiment, the averages among the species were compared and analyzed through log-logistics non-linear regressions for the dry mass of stems and roots and "gauss" non-linear regressions (equation 2) for the number of leaves and the dry mass of the leaves, using the Origin program.

$$Y = y0 + a^{(-0.5(x-xc/w)^2)} \qquad \text{(eq. 2)}$$

were: Y is the response-variable of interest; xc, the maximal growth value; and a, w and x, the estimated parameters of the equation.

In the winter, the plants showed a different biological behavior than in the summer for some of the evaluated characteristics; thus, the results were analyzed according to the observed data and discussed separately between the stations.

The phenology of the entire population was also evaluated for each species, using the scale suggested by Hess et al. (1997). The air temperature data were monitored through sensors installed in the greenhouse. The phenological stage was defined when 50% + 1 of the total of plants showed a certain development characteristic. For the evaluations in degrees-day, the base-temperature of 7 °C was considered (Paula and Streck, 2008) and the thermal sums were calculated for the subperiods between sowing and emergence; emergence and flowering; flowering and maturation; and emergence and maturation. The degrees-day (GD) were calculated based on the method suggested by Arnold (1959):

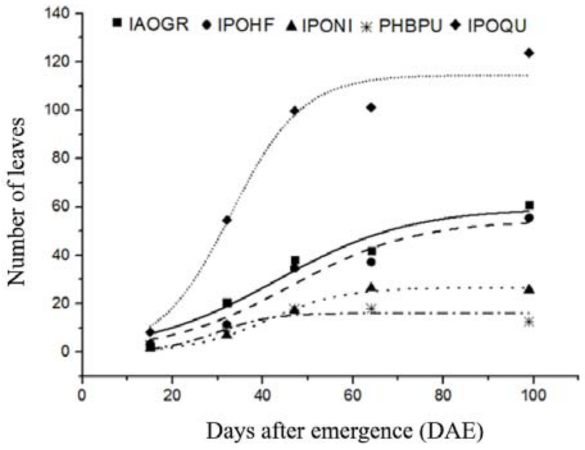
$$GD = \Sigma(Ti\text{-}Tb) \qquad \text{(eq. 3)}$$

were: Ti is the average temperature of the day (°C) and Tb is the lower basal temperature of each subperiod (°C). The average phenology data were analyzed and graphically presented, using the Excel program.

RESULTS AND DISCUSSION

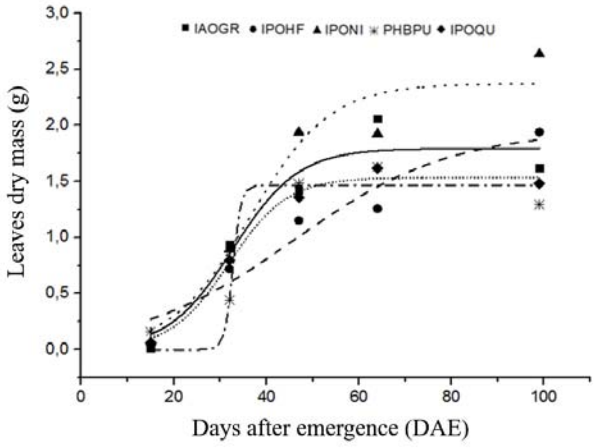
In the summer, observing the number of leaves produced, a growth adaptative advantage shown by *Ipomoea quamoclit* was observed in relation to the other species. The division in three groups related to leaf production was also observed: first, *I. quamoclit*; then, the *I. grandifolia* and *I. hederifolia* species showed an intermediate production of leaves; and, finally, *I. nil* and *I. purpurea*, with lower values (Figure 1).

The *I. quamoclit* species, even with a high leaf production, did not show the largest accumulated mass for these structures. An inverse situation occurred with *I. nil*, which produced few leaves, however, with high mass, that is, larger leaves. Among the analyzed species, it is observed that *I. hederifolia* did not present growth stabilization at the end of the evaluated period, which occurred for the other species, in addition to the fact that the other species showed a decrease in their leaf mass, such as *I. grandifolia* and *I. purpurea* (Figure 2).



■ *Ipomoea grandifolia* (Y=59.57/1+exp(-0.06*(x-43.15))), R^2=0.90; *Ipomoea hederifolia* (Y=54.67/1+exp(-0.07*(x-46.17)))), R^2=0.89; ▲ *Ipomoea nil* (Y=26.72/1+exp(-0.11*(x-41.09))), R^2=0.98; * *Ipomoea purpurea* (Y=16.19/1+exp(-0.16*(x-29.75))), R^2=0.66; ◆ *Ipomoea quamoclit* (Y=114.49/1+exp(-0.12*(x-32.96))), R^2=0.94.

Figure 1 - Number of leaves by plant during the lifecycle of five weed species from the *Ipomoea* genus during the summer.



■ *Ipomoea grandifolia* (Y= 1.79/(1+exp(-0.14*(x-32.75))), R^2=0.86; ● *Ipomoea hederifolia* (Y= 1.95/(1+exp(-0.05*(x-45.92))), R^2=0.86; ▲ *Ipomoea nil* (Y= 2.37/(1+exp(-0.11*(x-36.49))), R^2=0.89; * *Ipomoea purpurea* (Y=1.46/(1+exp(-1.19*(x-32.75))), R^2=0.90; ◆ *Ipomoea quamoclit* (Y=1.53/(1+exp(-0.15*(x-31.86))), R^2=0.98.

Figure 2 - Dry mass of plant leaves during the lifecycle of five weed species from the *Ipomoea* genus during the summer.

The stem growth for the different species highlighted the problem that happens in the indirect competition of cultures with the coexistence of ivyleaf morningglory plants. It was observed that the mass of these structures increased until the evaluated period for all species; the greatest accumulated masses occurred for *I. nil*, repeating the greatest leaf mass accumulation (Figure 3).

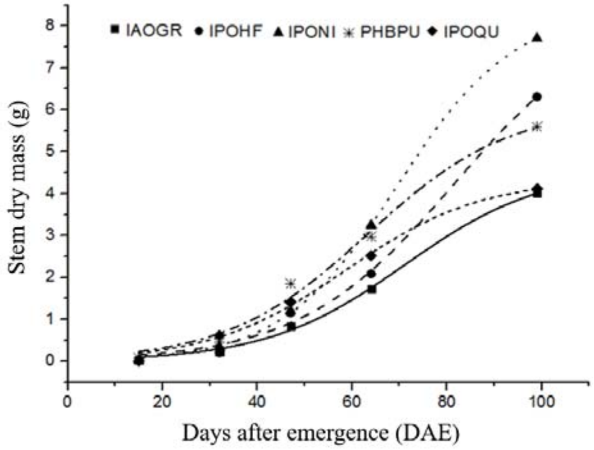
For the dry mass of the roots, a greater plant development was observed for *I. grandifolia* in relation to the others. Then, the roots of *I. nil* and *I. purpurea* developed in an intermediate manner. The less developed roots were the ones from the *I. hederifolia* and *I. quamoclit* species (Figure 4).

As to the total accumulated dry mass, the species showed close values, except for *I. grandifolia*, which accumulated a greater amount of mass from day 60 in comparison to the other species (Figure 5). This greater mass may be attributed mainly to the greater root development observed for the species.

In the winter, *I. grandifolia* was the species that presented the greatest number of leaves in comparison to the others (Figure 6). However, even by producing more leaves, the greatest mass accumulation by leaves occurred for *I. nil,* and the lowest, for *I. quamoclit*, reproducing what occurred in the summer (Figure 7). *I. nil* plants obtained a greater stem mass accumulation, also during that season (Figure 8). In comparison to the summer growing season, both species produced a lower number of leaves, reaching a maximum amount of approximately 80 leaves by plant in the winter, while this value reached 120 in the summer.

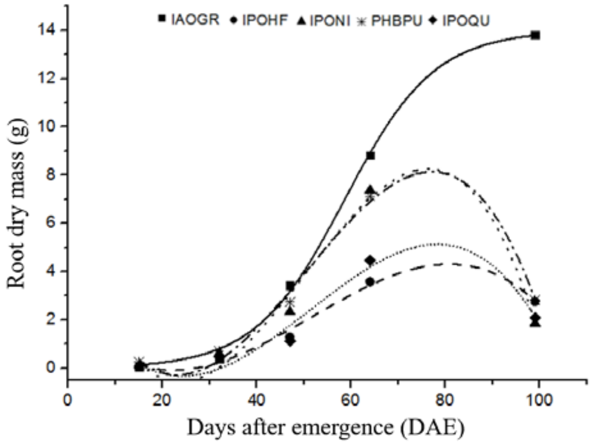
For the dry mass accumulated by the roots, as occurred in the summer, *I. grandifolia* obtained the highest values, followed by *I. nil*. The lowest root mass accumulations occurred for *I. hederifolia* and *I. quamoclit* (Figure 9).

During that season, however, the greatest total dry mass accumulation occurred for *I. nil*. The lowest total mass accumulation repeated for *I. quamoclit* (Figure 10). This inversion occurred due to the greater leaf dry mass accumulation by the *I. nil* species in the winter period (maximal accumulation of 6 grams by plant in the winter and 2.5 grams in the summer).



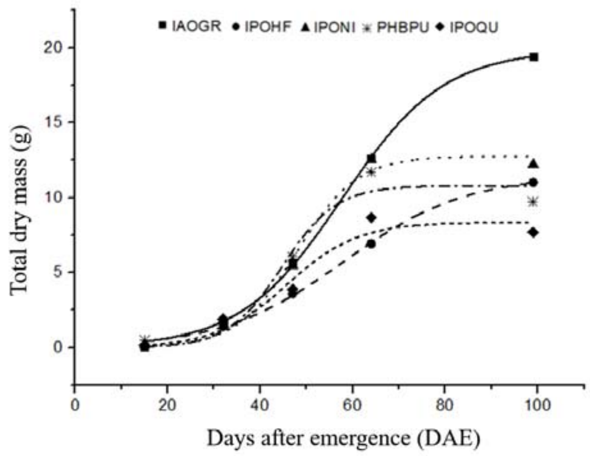
■ *Ipomoea grandifolia* ($Y=4.60/(1+\exp(-0.06*(x-71.09)))$), $R^2=0.99$; ● *Ipomoea hederifolia* ($Y=8.48/(1+\exp(-0.06*(x-81.56)))$), $R^2=0.99$; ▲ *Ipomoea nil* ($Y=8.40/(1+\exp(-0.08*(x-69.59)))$), $R^2=0.99$; * *Ipomoea purpurea* ($Y=6.08/(1+\exp(-0.06*(x-63.33)))$), $R^2=0.97$; ◆ *Ipomoea quamoclit* ($Y=4.34/(1+\exp(-0.07*(x-58.66)))$), $R^2=0.99$.

Figure 3 - Plant stem dry mass during the lifecycle of five weed species from the *Ipomoea* genus during the summer.



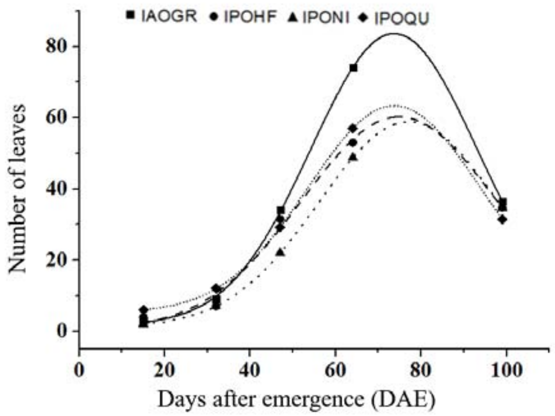
■ *Ipomoea grandifolia* ($Y=19.86/1+\exp(-0.09*(x-57.67)))$), $R^2=0.99$; ● *Ipomoea hederifolia* ($Y=11.47/1+\exp(-0.078*(x-58.04)))$), $R^2=0.99$; ▲ *Ipomoea nil* ($Y=12.76/1+\exp(-0.15*(x-47.91)))$), $R^2=0.97$; * *Ipomoea purpurea* ($Y=10.80/1+\exp(-0.17*(x-44.71)))$), $R^2=093$; ◆ *Ipomoea quamoclit* ($Y=8.36/1+\exp(-0.13*(x-45.66)))$), $R^2=0.91$.

Figure 4 - Root dry mass of the plants during the lifecycle of five weed species from the *Ipomoea* genus during the summer.



■ *Ipomoea grandifolia* ($Y=19.86/(1+\exp(-0.09*(x-57.67)))$), $R^2=0.99$; ● *Ipomoea hederifolia* ($Y=11.47/(1+\exp(-0.07*(x-58.04)))$), $R^2=0.99$; ▲ *Ipomoea nil* ($Y=12.76/(1+\exp(-0.15*(x-47.91)))$), $R^2=0.97$; * *Ipomoea purpurea* ($Y=10.80/(1+\exp(-0.17*(x-44.71)))$), $R^2=0.93$; ◆ *Ipomoea quamoclit* ($Y=8.36/(1+\exp(-0.13*(x-45.66)))$), $R^2=0.91$.

Figure 5 - Total dry mass of the plants during the lifecycle of five weed species from the *Ipomoea* genus during the summer.

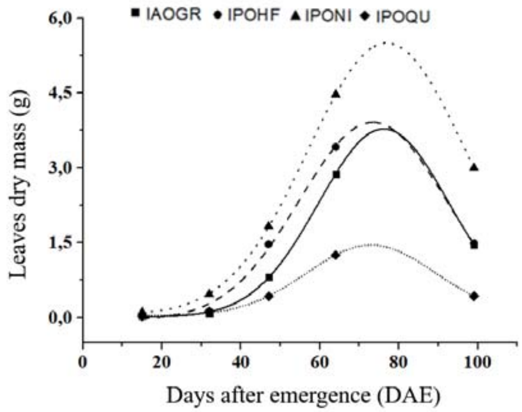


■ *Ipomoea grandifolia* ($Y=1.69+8197*\exp(-0.5*((x-73.63)/19.36)^2)$), $R^2=0.99$; ● *Ipomoea hederifolia* ($Y=0.39+59.90*\exp(-0.5*((x-74.82)/22.79)^2)$), $R^2=0.94$; ▲ *Ipomoea nil* ($Y=1.23+5765*\exp(-0.5*((x-77.08)/21.03)^2)$), $R^2=0.99$; ◆ *Ipomoea quamoclit* ($Y=5.20+58.17*\exp(-0.5*((x-73.68)/20.08)^2)$), $R^2=0.99$.

Figure 6 - Number of leaves by plant during the lifecycle of five weed species from the *Ipomoea* genus during the winter.

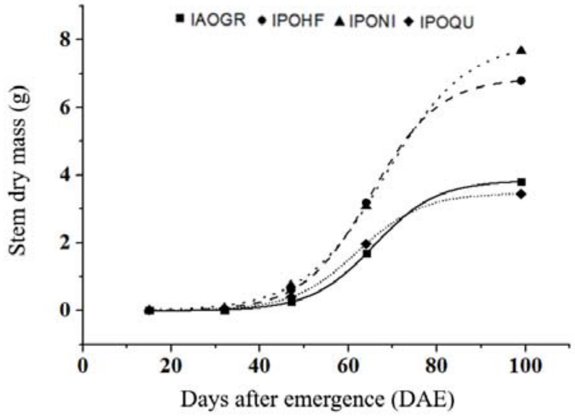
For the development of the species, in the summer, *I. quamoclit* plants were the ones that demanded lower degrees-day for both phases. The most demanding species and, therefore, the ones with a later cycle were *I. hederifolia* and *I. grandifolia*. In relation to the stages, the greatest differences relate to the initial development up to anthesis. In relation to the development cycle of the winter species, again, the shortest cycle occurred for *I. quamoclit*, and the longest ones, for *I. grandifolia* and *I. hederifolia* (Figure 11).

Based on the observed data, it is inferred that, among the species, interference problems by *I. quamoclit* are hardly reported in cultures such as sugarcane or corn, due to their fast



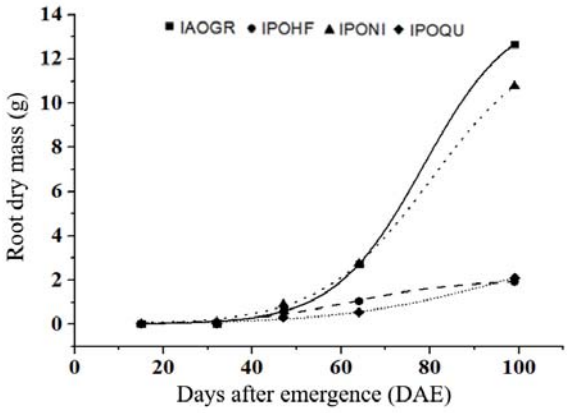
■ *Ipomoea grandifolia* (Y=0.01+3.76*exp(-0.5*((x-76.17)/16.49)^2), R^2=0.99; ● *Ipomoea hederifolia* (Y= -0.04+3.96*exp(-0.5*((x-73.39)/18.55)^2), R^2=0.97; ▲ *Ipomoea nil* (Y=0.05+5.44*exp(-0.5*((x-76.90)/19.91)^2), R^2=0.99; ◆ *Ipomoea quamoclit* (Y=0.04+1.41*exp(-0.5*((x-72.97)/16.21)^2), R^2=0.99.

Figure 7 - Dry mass of the leaves of plants during the lifecycle of five weed species from the *Ipomoea* genus during the winter.



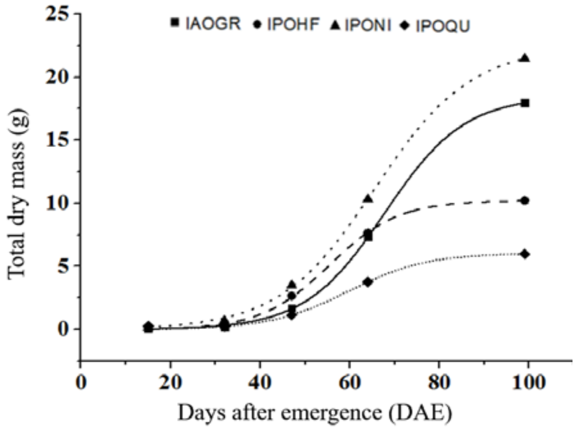
■ *Ipomoea grandifolia* Y=3.47/(1+exp(-0.13*(x-62.01))), R^2=0.99, ● *Ipomoea hederifolia* Y=3.84/(1+exp(-0.14*(x-65.72))), R^2=0.99, ▲ *Ipomoea nil* Y=6.86/(1+exp(-0.13*(x-65.07))), R^2=0.99, ◆ *Ipomoea quamoclit* Y=7.94/(1+exp(-0.10*(x-68.14))), R^2=0.99.

Figure 8 - Dry mass of the stems of plants during the lifecycle of five weed species from the *Ipomoea* genus during the winter.



■ *Ipomoea grandifolia* (Y=14.31/(1+exp(-0.09*(x-78.45))), R^2=0.99; ● *Ipomoea hederifolia* (Y=2.02/(1+exp(-0.08*(x-62.04))), R^2=0.97; ▲ *Ipomoea nil* (Y=13.11/(1+exp(-0.08*(x-80.17))), R^2=0.99; ◆ *Ipomoea quamoclit* (Y=3.89/(1+exp(-0.05*(x-96.02))), R^2=0.99.

Figure 9 - Dry mass of the roots of plants during the lifecycle of five weed species from the *Ipomoea* genus during the winter.

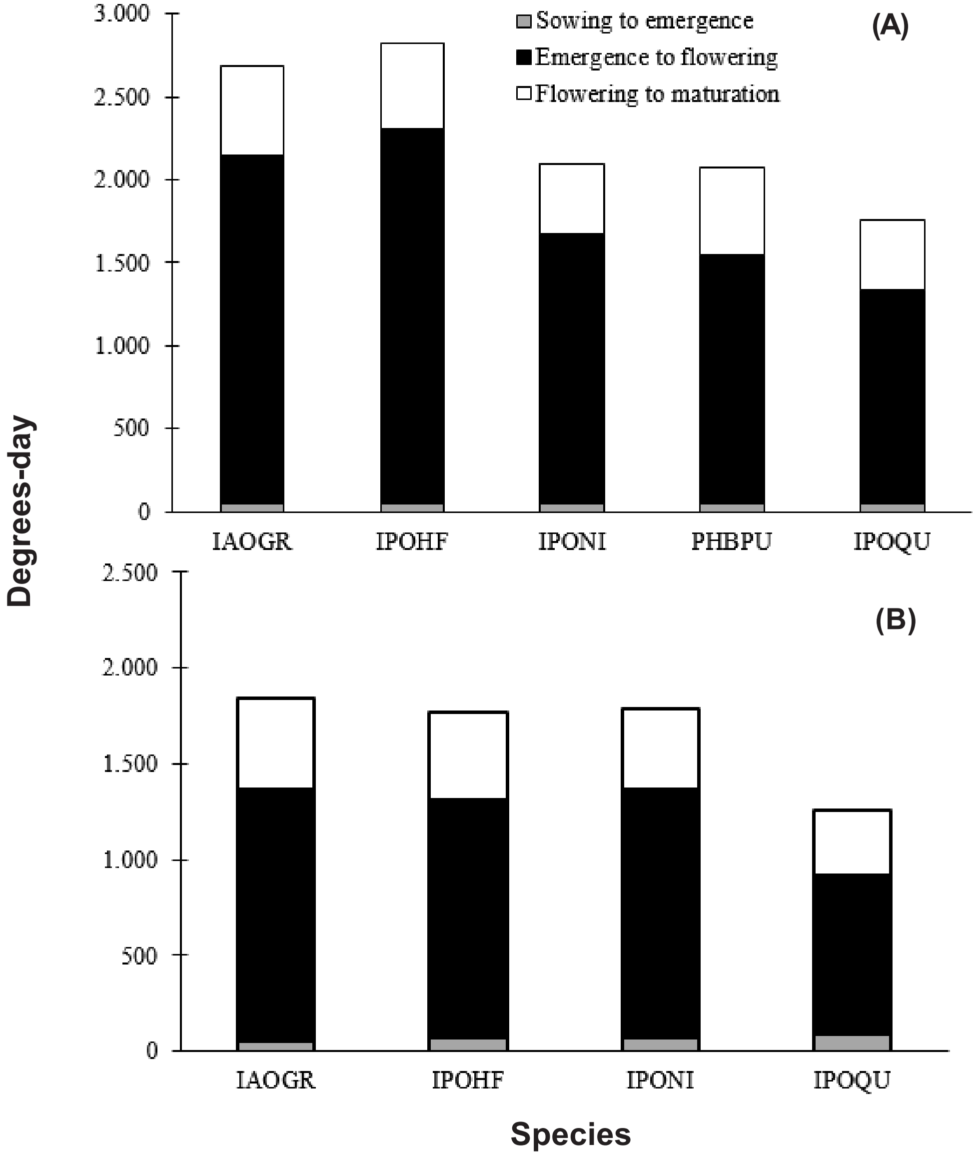


■ *Ipomoea grandifolia* Y=18.49/(1+exp(-0.11*(x-67.77))), R^2=0.99; ● *Ipomoea hederifolia* Y=10.22/(1+exp(-0.13*(x-55.42))), R^2=0.99; ▲ *Ipomoea nil* Y=22.40/(1+exp(-0.09*(x-65.62))), R^2=0.99; ◆ *Ipomoea quamoclit* Y=6.05/(1+exp(-0.11*(x-59.62))), R^2=0.99.

Figure 10 - Total dry mass of the plants during the lifecycle of five weed species from the *Ipomoea* genus during the winter.

development cycle, regardless of the growing season. If, on the one hand, the plant shows a high and accelerated production of leaves, these, due to their foliar limb morphology reduced to filiform projections, showed a small leaf area and low mass (Kissmann and Groth, 1999).

Thus, interferences may be conducted for in field conditions. Due to their fast growth with low mass accumulation, *I. quamoclit* plants have low interference in the extraction of nutrients from the soil in the beginning of their development, showing low competition with the crops (Carvalho et al., 2009). In addition, due to their short cycle, they tend not to stay green for the harvest of crops with soft stems, thus, avoiding an indirect interference by being intertwined in cultivated plants, as commonly occurs for plants from the Convolvulaceae family (Lorenzi, 2000).



IAOGR (*Ipomoea grandifolia*); IPOHF (*Ipomoea hederifolia*); IPONI (*Ipomoea nil*); PHBPU (*Ipomoea purpurea*); and IPOQU (*Ipomoea quamoclit*).

Figure 11 - Thermal sums in degrees-day for the different development sub-periods of five weed species from the *Ipomoea* genus during the summer (A) and winter (B).

Another implication that may be taken into consideration is thinking about the efficiency of herbicides applied for these species. Due to the fast development and leaf morphology of *I. quamoclit*, it is likely that higher doses are recommended in infestations with the other ivyleaf morningglory species. Applications of herbicides during the pre-emergence of the seedlings, in this case, would be a control recommendation, as reported by other researchers (Campos et al., 2009). On the other hand, species with a large leaf area, such as *I. nil*, may present a greater area for the absorption and effect of the herbicides applied post-emergence.

I. nil plants produced few, but large, leaves. For the stem dry mass, *I. nil* also obtained a greater mass accumulation than the other species in both times. Due to the large amount of leaves in comparison to the other species, it is inferred that *I. nil* plants have a better physiology. These results are in agreement with the ones observed for Guzzo et al. (2010), in which *I. nil* accumulated greater mass in comparison to *I. quamoclit* and *I. hederifolia*. Thus, it is presumed a greater interference from this species in agricultural crops in comparison, for example, with *I. quamoclit,* mainly during colder periods, when the species accumulates greater leaf mass, and for shady environments, since these species adapt to high or low lighting conditions (Kissman and Groth, 1999). According to Medeiros et al. (2016), *I. nil* plants were more aggressive in the height reduction with clones of eucalyptus in the beginning of the development if compared to other species, such as *Panicum maximum* and *Commelina difusa*.

Even if *I. nil* has accumulated greater mass than the other studied species, interference problems of *I. hederifolia* and *I. grandfiolia* in crops such as sugarcane are frequently reported (Silva et al., 2009). According to the data found, the greatest cycle for these species may be attributed to these reports under different climate conditions, causing them not to have their harvest cycle closed (Azania et al., 2002). It was also observed that *I. grandifolia* obtained, during the summer and the winter, greater root dry mass accumulation, probably allowing greater extraction of nutrients from the soil, and that *I. hederifolia*, during the summer, over the last evaluations, it also showed a growing accumulation of leaf dry mass, and, in the winter, this species showed the greatest values for this variable (that is, it was not senescent yet).

In the evaluation of *I. purpurea*, it was observed that the species shows intermediate growth and development in relation to other species. It is commonly not found in the sugarcane harvest, however, it may interfere in shorter-cycle crops. According to researchers, *I. purpurea* plants interfered more in soybean crops than *I. grandifolia* plants (Pagnoncelli et al., 2017), reducing the leaf area and the dry mass of crop leaves, in addition to the fact that *I. purpurea* reduced the harvest efficiency and productivity of pepper (Schutte, 2017).

Based on the results, it is estimated that species such as *I. grandifolia* interfere more in agricultural crops regardless of the season, due to a direct and indirect interference, since it has a high root growth and leaf production, in addition to a longer cycle. Shorter-cycle species, such as *I. quamoclit*, when present, indicate that shorter control residual periods may be adopted, in opposition to what occurs for *I. grandifolia* and *I. hederifolia*.

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