Crop Production

Growth analysis of *Ambrosia artemisiifolia*[1]

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ABSTRACT

We hypothesized that common ragweed has rapid growth and development in shoots and roots, which explains its high potential for establishment in the areas, as well as the high regrowth capacity after cutting or application of contact herbicides. This study aims to evaluate the growth of the specie *Ambrosia artemisiifolia*. The treatments consisted of collection periods of common ragweed plants at fixed intervals of ten days, from 15 to 95 days after emergence (DAE), totaling nine evaluations. In each collection, the aerial part and the roots were evaluated. In the aerial part, stature, leaf area, number of leaves, and dry mass were evaluated. From these data, the absolute growth rate, relative growth rate, net assimilation rate and leaf weight ratio were calculated. The length, surface area, volume, average diameter, number of root tips, and dry mass were evaluated in the root. The common ragweed plants show rapid growth after emergence, with a similar response in aerial parts and roots. The potential for competition with crops is expressive. Furthermore, due to growth and development characteristics, the potential for regrowth is high and impacts the difficulties in controlling this species. Thus, the authors indicate that control should be carried out within a maximum of 25 days after emergence.

Keywords: common ragweed; weed; competition; root development.

INTRODUCTION

The common ragweed (*Ambrosia artemisiifolia* L.) is an annual herbaceous plant, erect, 40-80 cm tall, and propagated by seeds (Essl *et al.*, 2015; Lorenzi, 2008). It is native to North America and has recently been reported as a weed in Rio Grande do Sul/Brazil, whose occurrence has been increasing gradually. There are known species of ragweed belonging to the genus *Ambrosia, Artemisia* and *Parthenium*. The most common species currently in crops is of the genus *Ambrosia*.

There are several reports of common species of ragweed in folk medicine, pest control, allelopathic effect and interference as a weed in crops. In pest control potential, the species *Artemisia absinthium* and *A. verlotorum* cause negative effects on oviposition, fertility, and development of the fall armyworm (*Spodoptera frugiperda*) (Knaak *et al.*, 2012). The species *Parthenium hysterophorus* shows allelopathic potential with soybean (Shehzad *et al.*, 2016), and *Ambrosia artemisiifolia* L. in corn (Bonea *et al.*, 2018). As a weed, common ragweed has already been studied in soybean (Barnes *et al.*, 2018; Coble *et al.*, 1981; Hall *et al.*, 2021), corn (Rehman *et al.*, 2018), and wheat (Brighenti *et al.*, 1994).

This weed exhibits a high potential for competition with crops. Corn competition with *Parthenium hysterophorus* reduced the number of plants per meter, the height and the grain yield from 13.43 m^{-2} to 8.10 m^{-2}; from 228.10 cm to 176.33 cm; and 22.69 ton ha^{-1} to 13.25 ton ha^{-1}, respectively when in competition for 105 days after emergence (Rehman *et al.*, 2018). When in competition with *Ambrosia artemisiifolia* L., soybean presented grain productivity of 4422 kg ha^{-1}, but when free of competition the productivity was 5177 kg ha^{-1} (Barnes *et al.*, 2018).

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Studies evaluating the influence of temperature, photoperiod, and radiation on the development of common ragweed have already been performed (Deen *et al*., 1998). However, information on the growth and development of this species considering aerial parts and roots is unknown. For goosegrass (*Eleusine indica)*, it was observed that between 38 and 43 days after emergence, the plant showed rapid emission of new tillers, exponential accumulation of total dry mass and substantial increase in absolute growth rate. Thus, the authors concluded that the management of this species should preferably be carried out before 38 days after emergence, as afterwards there is an exponential growth, which makes control difficult (Takano *et al.*, 2016). Information like this is not found for the species *Ambrosia artemisiifolia* L., so it is important to understand the growth of this species in order to define effective control strategies and carried out at the right time.

Currently, there are reports of common ragweed infesting agricultural areas in the Rio Grande do Sul/Brazil, with control difficulties due to its tolerance to glyphosate herbicide and significant competitive potential, regrowth capacity, and development of aerial parts and roots. Therefore, there is a need to initially understand common ragweed's growth and development characteristics, the impact on the competition with crops, and the response after herbicide application.

We hypothesized that common ragweed has rapid growth and development in shoots and roots, which explains its high potential for establishment in the areas, as well as the high regrowth capacity after cutting or application of contact herbicides. This study aims to evaluate the growth of the species *Ambrosia artemisiifolia*.

MATERIALS AND METHODS

Plant materials and growth conditions

The experiment was conducted in a greenhouse at the University of Passo Fundo/RS, at latitude 28° 13' S, longitude 52° 23' W, and an approximate altitude of 700 m above sea level, from November 2020 to March 2021. An entirely randomized design with four repetitions was performed. The treatments consisted of collection periods of common ragweed plants at fixed intervals of ten days, from 15 to 95 days after emergence (DAE), totaling nine evaluations. At the end of each treatment, the common ragweed plants were removed from the pots and separated into aerial and root parts for further evaluation.

The experimental units were plastic vases with a volumetric capacity of 4, 9, and 11 l, containing soil from the experimental area of the University of Passo Fundo, classified as humic Dystrophic Red Latosol. The first three evaluations were done in the 4 l pots, then three more evaluations in the 9 l pots, and the last three in 11 l pots. In each experimental unit, six common ragweed seeds were sown, the emergence of the plants occurred ten days after sowing, and these were later thinned to maintain the standard density of two plants per unit.

The pots remained in a greenhouse and were irrigated twice a day with automated irrigation for fifteen minutes from sowing to emergence to ensure uniform emergence of the plants. After an emergence, the plants were kept in a covered greenhouse with shade cloths until the end of the evaluations, with one irrigation per day in addition to the precipitation of the period. The thermal amplitude of the experiment's conduction period was from 14.5 to 29 °C (Embrapa, 2023).

Shoot and root traits

In each collection, the aerial part and the root were evaluated. In the aerial part, stature, leaf area, number of leaves, and dry mass of the two common ragweed plants per experimental unit were evaluated. The stature was measured with a graduated ruler, the leaf area was measured with a leaf area integrator (Licor®), and the number of leaves was measured by manual counting. Subsequently, the plants were separated into stem, leaves, inflorescence, and dead leaves and placed in an oven for drying at 80 °C until constant mass. Each plant part was weighed on an analytical balance (precision of 0.001 g) to determine the dry mass of stem (DMS), leaves (DML), inflorescences (DMI), and dead leaves (DMDL). The aboveground dry mass (ADM) was obtained by the sum of the plant parts (DMS, DML, DMI, and DMDL).

The leaf area and dry mass values were obtained at each collection date. Thus, the absolute growth rate (AGR), relative growth rate (RGR), net assimilation rate (NAR) and leaf weight ratio (LWR) were determined following the formulas suggested by Benincasa (2003).

The absolute growth rate (AGR) represents the growth over a time interval and it is calculated with the formula:

$$\text{AGR} = \frac{P_2 - P_1}{t_2 - t_1} \quad (1)$$

Where: P_1 and P_2 are the dry mass of two successive samplings, and t_1 and t_2 are the evaluation dates. It is expressed in g day^{-1}.

The relative growth rate (RGR) expresses the increment in dry mass, per unit of initial mass, over a time interval, and is calculated using the formula:

$$\text{RGR} = \frac{(lnP_n - lnP_{n-1})}{(T_n - T_{n-1})} \quad (2)$$

Where: lnP_n is the neperian logarithm of cumulative dry mass up to assessment $_n$; lnP_{n-1} is the neperian logarithm of cumulative dry mass up to assessment $_{n-1}$; *Tn* is the number of days after emergence at the time of assessment $_{n-1}$. It is expressed in g g^{-1} day^{-1}.

Net assimilation rate (NAR) is the ratio of dry biomass produced per plant leaf area, for a time interval, calculated by the formula:

$$\text{NAR} = \left[\frac{(P_n - P_{n-1})}{(T_n - T_{n-1})}\right]\left[\frac{(lnA_n - lnA_{n-1})}{(A_n - A_{n-1})}\right] \quad (3)$$

Where: A_n is the leaf area of the plant at the time of the evaluation *n*; and A_{n-1} is the leaf area of the plant at the time of the evaluation $_{n-1}$.

The leaf weight ratio (LWR) is the ratio between the weight of dry mass retained in the leaves and the weight of dry mass accumulated in the whole plant, calculated by the formula:

$$\text{LWR} = \frac{DML}{APDM} \quad (4)$$

Where: *DML* is the dry mass of leaves; and *APDM* is the aerial part dry mass.

Two roots per experimental unit were rinsed and used for morphological evaluation and root dry mass, totaling eight roots per collection. The roots were evaluated using WinRhizo software (Regent Instruments Inc., Sainte-Foy, QC, Canada) (Figure 3F), where the length, surface area, volume, average diameter, and number of root tips were measured. Afterward, the roots were dried in an oven at 80 °C until reaching constant mass. The sample was weighed on an analytical balance (precision of 0.001 g) and the root dry mass (RDM) was determined. The total dry mass was obtained by adding the aboveground dry mass (ADM) and the root dry mass (RDM).

Statistical analysis

The data obtained were submitted to regression analysis and the model was chosen considering the logic of the biological phenomenon, the significance of the regression, and the value of the coefficient of determination.

RESULTS AND DISCUSSION

The common ragweed plants show rapid growth after emergence, similar response in shoots and root, so the control of this species must be carried out within 25 days after emergence (DAE). After 25 DAE, the plants were already large (Figure 3C), after which, a large increase in shoot and root growth was observed, which can be seen between Figures 7B and 7C. This interferes directly with weed control, as the larger the size, the more difficult it is to control.

The number of leaves in the common ragweed plants is very expressive and increases significantly with the passing of days after emergence. At 15 DAE, the plants already had 11 leaves, which characterizes a rapid initial growth, and reached 174 leaves at 95 DAE (Figure 1A). The leaves are associated with a node on the stem, and until 55 DAE they are distributed in a crossed opposite way, and later they assume an alternating distribution. Each node has a larger leaf, and at the insertion of this leaf in the stem, there is a pair of smaller leaves, and the stem has great hairiness (Figure 5C).

The leaf area showed a continuous increase throughout the evaluations, as in the number of leaves. Compared to the previous evaluation, the common ragweed plants showed a 44-fold increase in leaf area at 35 DAE, remaining at a constant high level until 45 DAE (Figure 1B). The maximum leaf area of the plants was reached at 85 DAE with 142.72 cm^2 (Figure 1B). When comparing the images from the 15 and 25 DAE it is possible to verify the significant growth of the aerial part and root that occurred in this interval, characterizing the rapid initial growth of the species, which corroborates with the number of leaves and leaf area data (Figure 3A, 3B and 3C).

The leaf weight ratio (LWR) was maximum in the evaluations of 15 and 25 DAE, decreasing significantly with the passing of the days (Figure 1C). This decrease was expected because there is a greater allocation of assimilates to the developing leaves in the initial evaluations. Subsequently, as the plant develops, there is a decrease in the LWR because photo-assimilated compounds are mobilized to other organs of the plant (Falqueto *et al.*, 2009).

The height growth of this species is very expressive, reaching a maximum of 151 cm at 95 DAE (Figure 1D). Average growth of 20 cm was observed between the evaluation intervals, which characterizes a daily increase of 2 cm in height from the 35 DAE, characterizing a rapid daily growth of the plants.

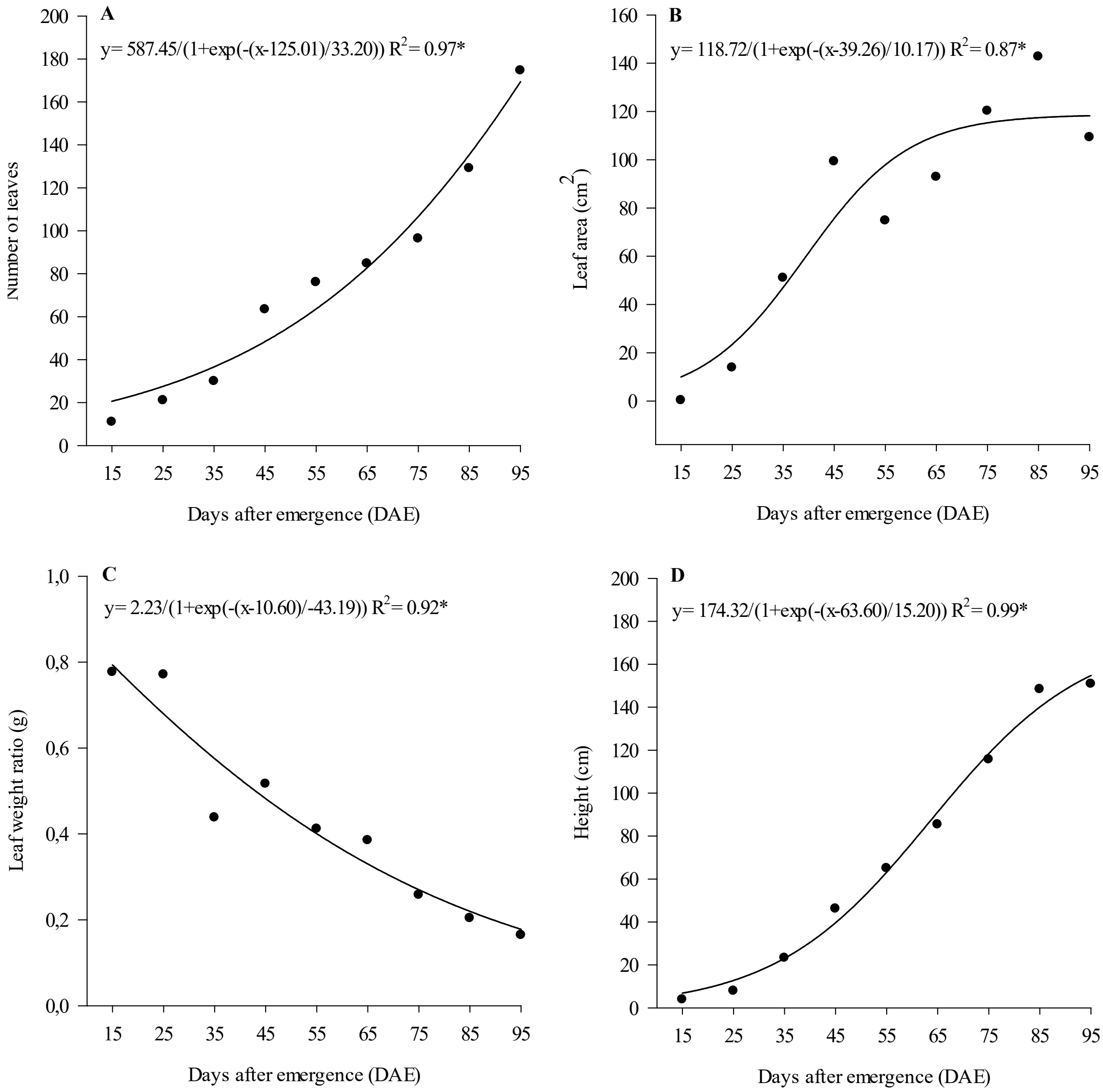

Figure 1: Number of leaves (A), leaf area (B), leaf weight ratio (C) and height (D) of common ragweed plants throughout the growth evaluations.

Coble *et al.*, (1981) measured the height of common ragweed plants in competition with soybean at 6, 8, 10, and 12 weeks after soybean emergence and indicated that these plants presented 8, 25, 33, and 38 cm more than the plants of the crop, which confirmed the elevated growth in the height of this weed. The dry mass of the leaves of common ragweed presents a similar response to the leaf area, where the accelerated growth at 35 DAE and the maximum reached at 85 DAE in the leaf area, also culminated with the response of leaf dry mass (Figure 2A). The stem dry mass shows continuous growth, similar to the height curve, which affirms the considerable growth in height and consequently in stem volume, being five times greater than the leaf dry mass (Figure 2B).

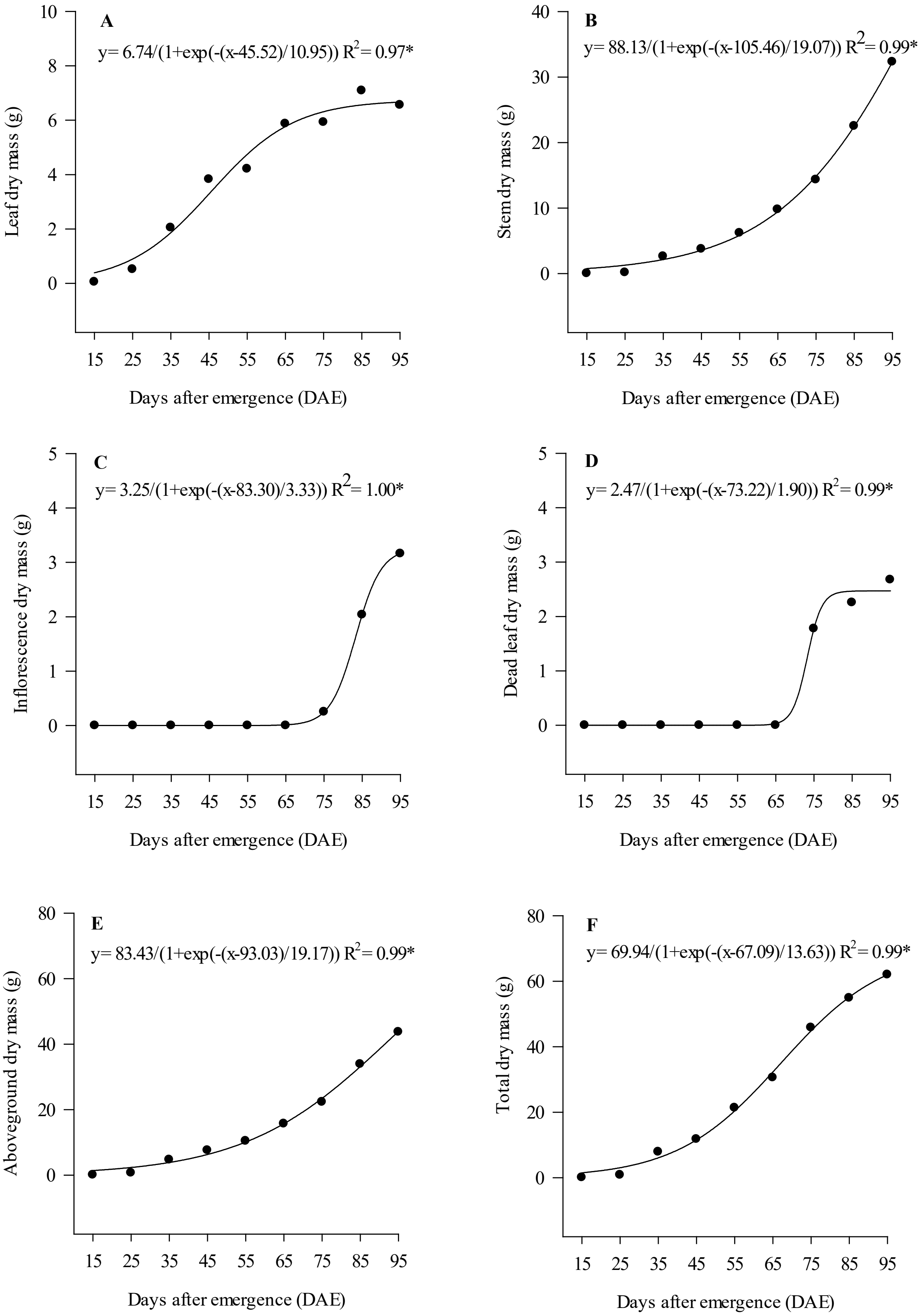

Figure 2: Leaf dry mass (A), stem dry mass (B), inflorescence dry mass (C), dead leaf dry mass (D), aboveground dry mass (E), and total dry mass (F) of common ragweed plants throughout the growth evaluations.

Figure 3: Overview of common ragweed plants at 15 days after emergence (DAE) evaluation (A), detail of plant and root rinsed at 15 DAE evaluation (B), 25 DAE evaluation (C), the reproductive structure at 75 DAE (D), the root of a plant at 75 DAE (E), and the root of a plant evaluated in the scanner at 85 DAE (F).

The inflorescence dry mass and dead leaves started at 75 DAE, characterizing the beginning of flowering and the senescence of leaves in the lower part of the plant (Figures 2C and 2D). The reproductive structures of *Ambrosia artemisiifolia* L. are formed by capitula inflorescence inserted in cylindrical spikes at the apex of the branches and capitula fascicles in the axils of the last leaves. Welded bracts of green color form the capitula. The male part is located from the median portion to the apex of the spikes and is retrorse. The female part is inserted at the base of the spikes and in the axils of the last leaves (Moreira & Bragança, 2010) (Figure 3D).

The aboveground dry mass, which refers to the sum of the dry mass of leaves, stem, inflorescence, and dead leaves, increased steadily. The maximum aboveground dry mass of 43.7 g was reached at 95 DAE, an average increase of 4.8 g at each evaluation (Figure 2E). High production of aerial part and root is observed in common ragweed, reaching 62 g at 95 DAE when considering the total dry mass (aerial part and root dry mass) (Figure 2F). This result confirms the data of the aerial part presented previously and the evaluations performed on the roots, where a considerable increase in the roots was observed throughout the evaluations (Figure 3E and 5). It is possible to see in Figure 5 that the plants presented a large root system and aerial part at 55 (A) and 75 (B) DAE, affirming the excellent competitive potential of this species and its rapid establishment.

In general, weeds show characteristics such as fast initial growth, rapid development in stature and leaf area, and high root density, which are important in the competitive advantage against crops (Swanton *et al.*, 2015). Species such as *Amaranthus spinosus* and *A. viridis* accumulated a total dry mass of 45 - 50 g plant^{-1} (Carvalho *et al.*, 2008). Ipomoea grandifolia is the main species in accumulating total dry mass among the Ipomoea, reaching 20 g at 100 DAE during the summer season (Barroso *et al.*, 2019).

The absolute growth rate (AGR) estimates the velocity at which plants grow throughout the development cycle. A progressive increase was observed in the growth rate for ragweed throughout the development cycle (Figure 4A). The rhizome had a slow initial growth once until 25 DAE the AGR values remained low. After 45 DAE, a greater increase in the AGR was observed, reaching 6.2 g day^{-1} at 95 DAE, indicating the significant growth of this species throughout the cycle.

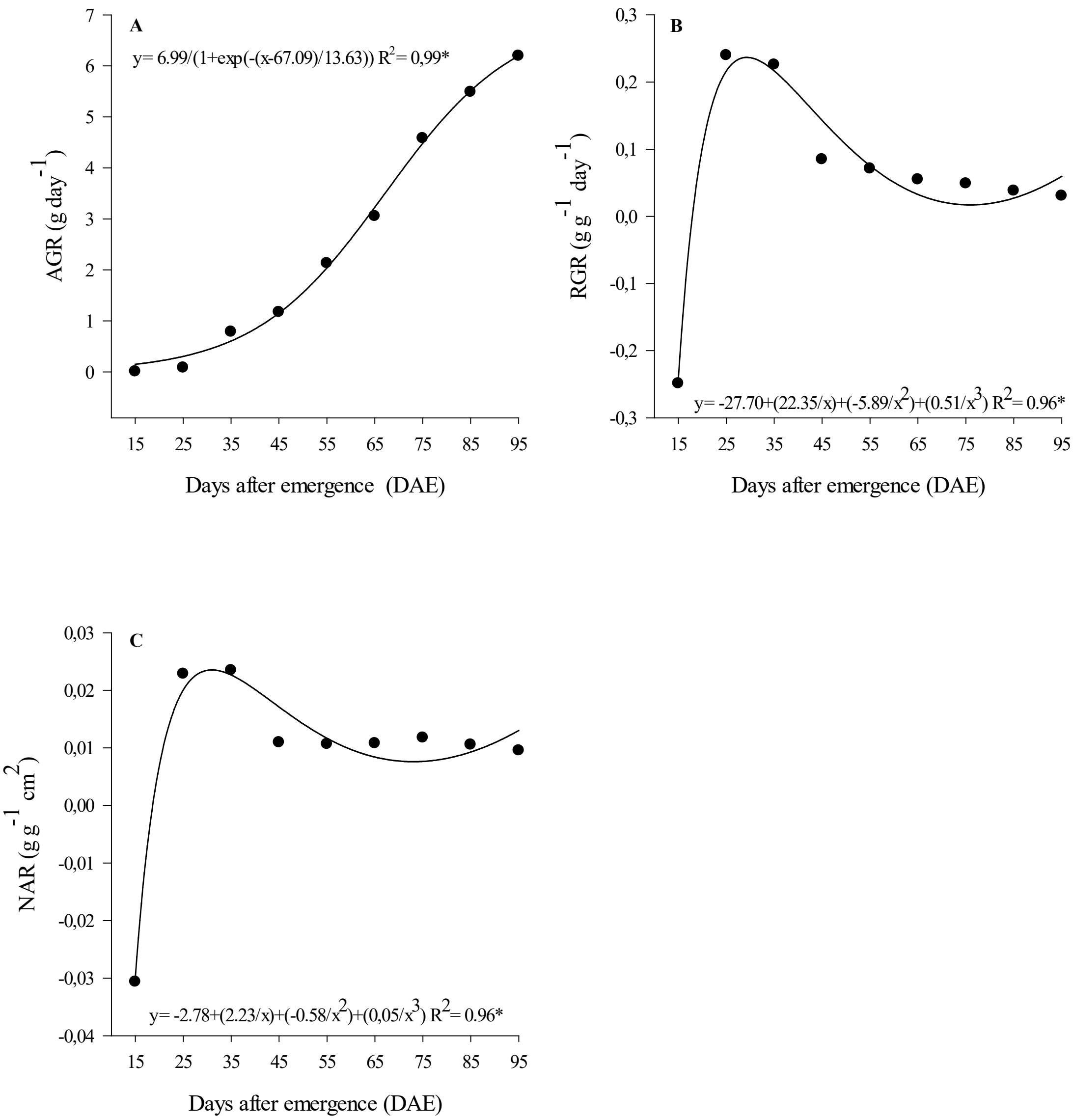

Figure 4: Absolute growth rate (AGR) (A), relative growth rate (RGR) (B) and net assimilation rate (NAR) (C) of common ragweed plants throughout the growth evaluations.

The relative growth rate (RGR) indicates the daily amount of dry matter produced per gram of plant biomass. Initially, the RGR was negative, showing an increase at 25 DAE. However, after 45 DAE, a decrease was observed again and remained constant (Figure 4B). As the plants grow, there is an increase in dry matter and the consequent need for photoassimilates. Therefore, the amount of photoassimilates available for growth tends to be lower, so the RGR decreases over time. The RGR naturally decreases throughout the ontogeny of the plant due to the increase in the proportion of non-photosynthesizing tissues (Benincasa, 2003).

The net assimilation rate (NAR) measures the efficiency of the leaf in biomass production, indicating how many grams of biomass was produced per cm^2 of leaf per day. The NAR was initially negative in ragweed, like the RGR, reaching the highest values at 25 and 35 DAE. Subsequently, the rate remained stable, around 0.01 g g^{-1} cm^2 (Figure 4C). NAR is the most representative composite parameter of plant efficiency because it is an index of plant growth independent of its size (Christoffoleti, 2001).

When analyzing root growth, it was observed that root length reached 4200 cm at 45 DAE, and then there was a decrease, remaining around 2000 cm from 65 to 95 DAE (Figure 6A). A similar response was found for the number of root tips, which reached a maximum value of 7274 at 55 DAE (Figure 6E). Root length is one of the fundamental

Figure 5: Common ragweed plants at 55 days after emergence (DAE) (A), at 75 DAE (B), and highlighted leaves and stem pilosity at 55 DAE (C).

morphological characteristics of the water and nutrient uptake and plant support. Thus, the larger the roots, the greater the potential to uptake water and nutrients in-depth and thus stand out in competition with crops.

Common ragweed roots reached the length of 4200 cm at 45 DAE. In a study evaluating soybean roots, Rockenbach & Rizzardi (2020) observed the length of 4343 cm when soybean was in V6 stage at 30 DAE, the maximum length of 5585 cm at R6 stage. Thus, it is observed how the root of common ragweed presents a great potential for growth and, consequently, a competitive advantage over the co-existing species.

The common ragweed roots volume, surface area, and dry mass reached their maximum at 75 DAE (Figure 6D, 6B, and 6F). The volume of the root of common ragweed at 75 DAE was 290 cm^3, representing 13 times the value found for soybean root at R6 stage. The same goes for the root dry mass, that in common ragweed was 23.54 g at 75 DAE, while the highest root soybean dry mass was 6.63 g at R6 stage (Rockenbach & Rizzardi, 2020). These data reaffirm the large root growth of this species and the high potential for competition for resources in the environment with crops.

In the November emergence cycle, the RS biotype of sourgrass (*Digitaria insularis*) accumulated root and rhizome dry mass of 47.53 g at 119 DAE. In contrast, the MT biotype in the August emergence cycle showed the maximum dry mass of 22, 41 g at 119 DAE (Sossmeier, 2020). This shows the root growth potential of the weed species. Also, as sourgrass, common ragweed presents high regrowth ability, so the high root production confers an excellent ability to regrow.

The root diameter of common ragweed peaked at 95 DAE at 6.95 mm (Figure 6C). By analyzing the images

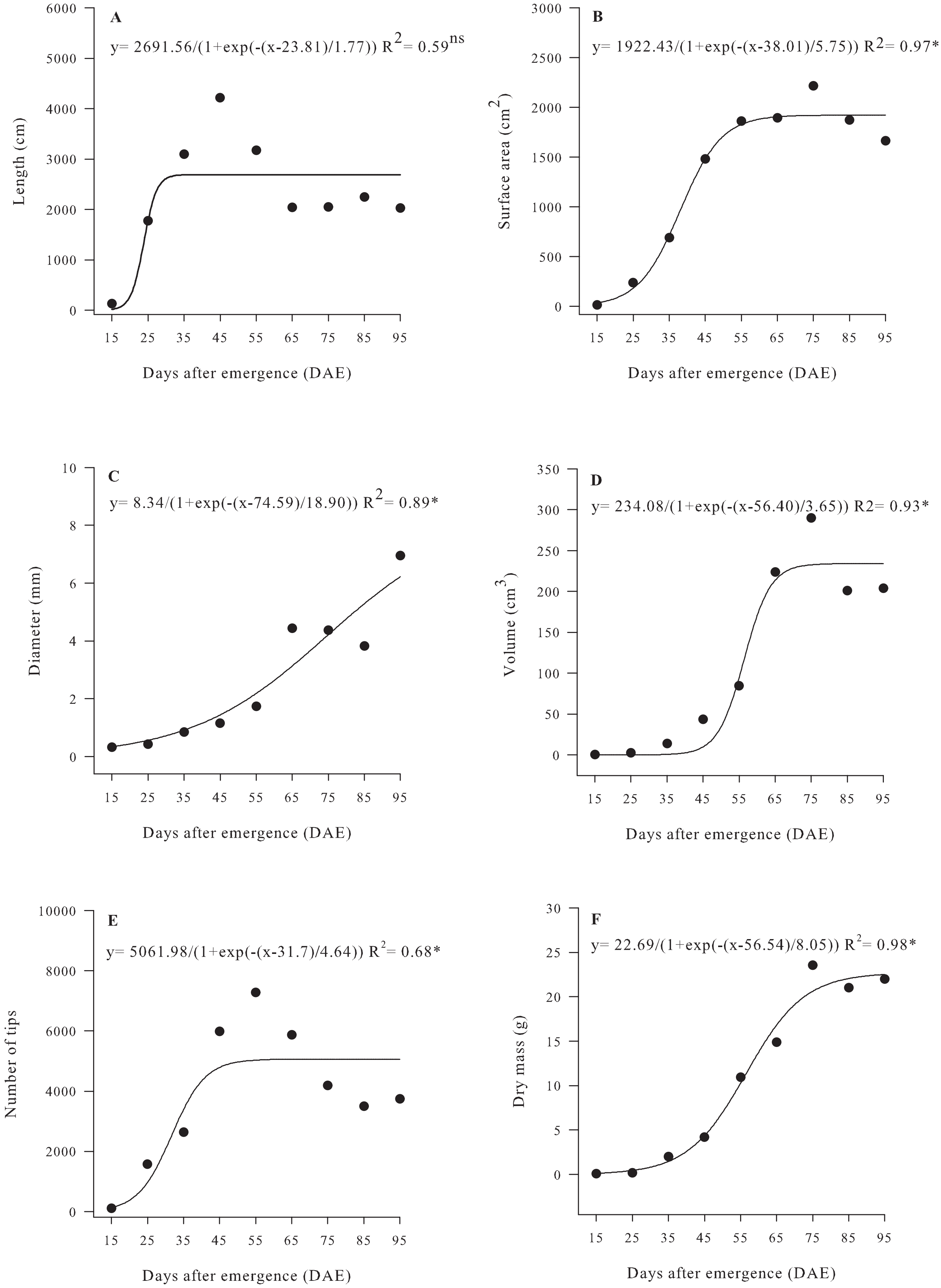

Figure 6: Length (A), surface area (B), diameter (C), volume (D), number of tips (E), and dry mass (F) of common ragweed roots throughout the growth evaluations.

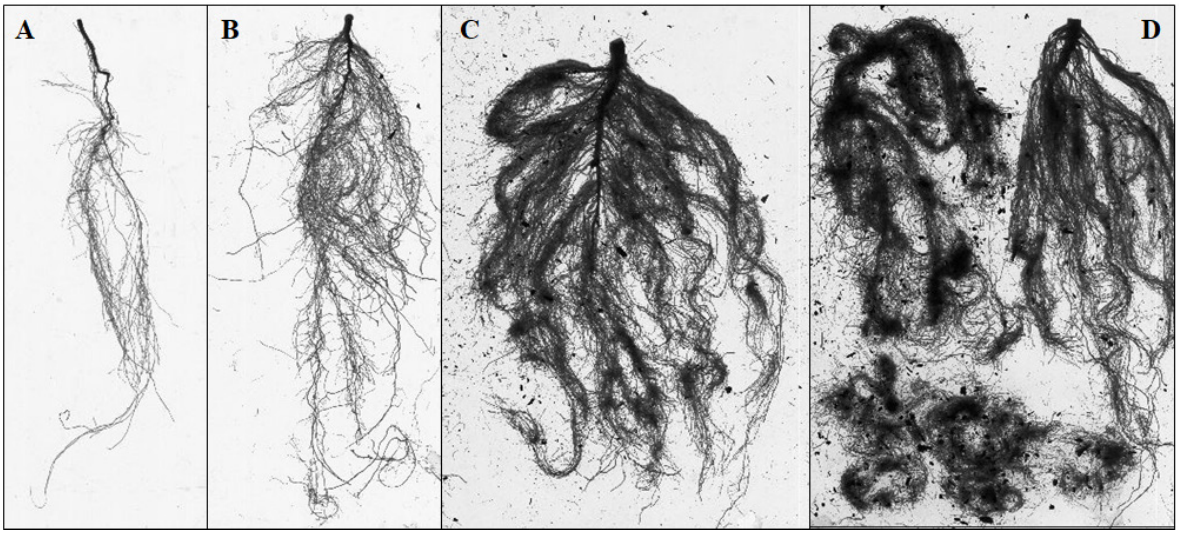

Figure 7: Common ragweed roots images obtained in the evaluations with WinRhizo software at 15 (A), 25 (B), 35 (C) and 45 (D) days after emergence.

from the WinRhizo, it is possible to affirm the data presented because the growth of the roots is very expressive throughout the evaluations (Figures 7 and 8). Thus, it is possible to understand the high capacity for competition that this species presents against crops. Besides the expressive growth of the aerial part, common ragweed presents a voluminous root system providing a high capacity for regrowth when the aerial part is cut or killed by contact herbicides. Thus, it is important to observe the size of the plant when choosing the herbicides to control the weed and to avoid cutting the plants by machinery.

Thus, the authors suggest that the control of this species should be carried out up to 25 DAE, because after that there is a significant increase in plant growth both in shoots and roots, which makes it difficult to control this species.

What can be stated in Figure 9, where the accumulated dry matter for leaves, stems and roots is observed, where the evaluation 35 DAE showed 6.64 g of accumulated dry mass, compared to 0.83 g in the evaluation 25 DAE. This increase of 5.31 g confirms the great growth of this species in a few days and thus represents greater difficulty in controlling the weed.

When relating the root data presented in Figure 6, with the proportion of dry mass of roots in Figure 9, we see how much this species has the potential for root growth, which directly impacts the ability to regrow after herbicide application. Therefore, attention should be paid to the ideal control stage, always considering small plants.

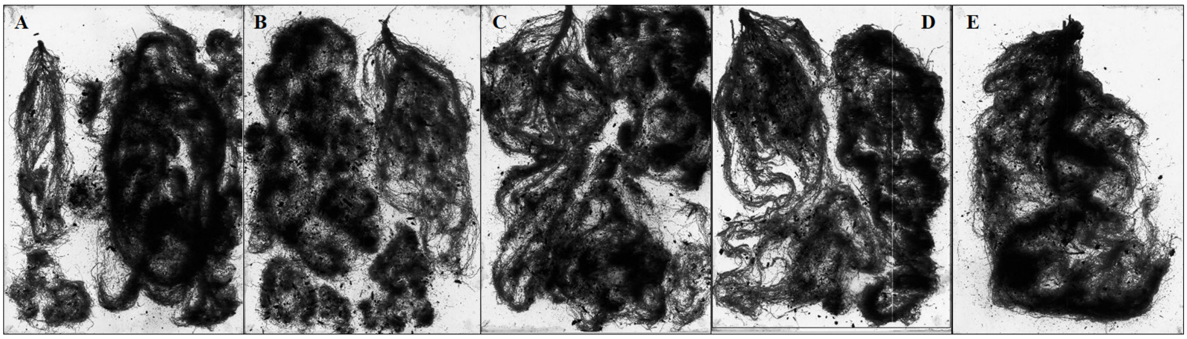

Figure 8: Common ragweed roots images obtained in the evaluations with WinRhizo software at 55 (A), 65 (B), 75 (C), 85 (D) and 95 (E) days after emergence.

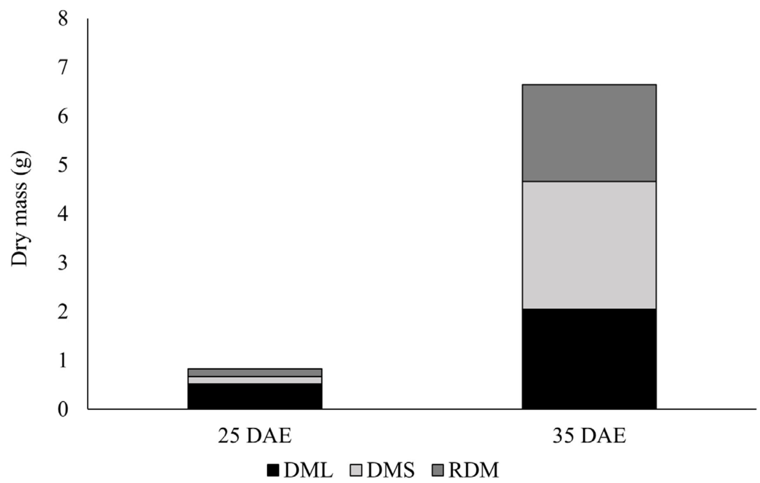

Figure 9: Dry mass of leaves (DML), dry mass of stems (DMS) and root dry mass (RDM) of common ragweed at 25 and 35 days after emergence (DAE).

CONCLUSIONS

The common ragweed plants show rapid growth after emergence, with a similar response in aerial parts and roots. The potential for competition with crops is expressive. Furthermore, due to growth and development characteristics, the potential for regrowth is high and impacts the difficulties in controlling this species. Thus, the authors indicate that control should be carried out within a maximum of 25 days after emergence.

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