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Article

GROWTH ANALYSIS OF *Chloris elata*

Análise de crescimento de Chloris elata

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ABSTRACT - In Brazil, in agricultural areas where there is no establishment of cover crops in the off season, as well as in citrus orchards in the state of São Paulo, an increase in the infestation of *Chloris elata* has been observed. This is a perennial species, propagated by seeds and short rhizomes, erect and slightly caespitose. With the objective of evaluating the growth and development of plants from two accessions of *C. elata*, a greenhouse experiment was conducted. The experimental design was completely randomized, in a 2 (accessions of *C. elata*) x 15 (evaluation periods) factorial arrangement, with four replications. Fifteen destructive evaluations were performed 14, 21, 28, 35, 42, 49, 56, 63, 70, 77, 84, 91, 98, 112 and 126 days after sowing (DAS) both accessions of *C. elata* (Itaberaí from Goiás and Matão from São Paulo State). At each evaluation, four plants (replications) were randomly sampled and the height of the main culm, the number of tillers and inflorescences (flower+seed) per plant, the leaf area and dry matter of leaves, culms, roots, inflorescences and total (leaves+culms+roots+ inflorescences) were analyzed. The two accessions showed a slow initial development and growth (up to 63 DAS), mainly in root growth; however, the development of new tillers increased rapidly in the initial phase. During the first 63 DAS, the percentage distribution of dry matter was higher in the foliage, followed by culms and roots. In the final evaluation, the relation was culms followed by leaves, roots and inflorescences. Plants of Matão formed denser clumps, with culms of greater mass, while those from the Itaberaí showed higher height and greater foliage.

Keywords: biotype, tall windmill grass, plant development .

*RESUMO - No Brasil, nas áreas agrícolas onde não há o estabelecimento de culturas de cobertura na entressafra, assim como em pomares de citros no Estado de São Paulo, tem-se observado o aumento da infestação de **Chloris elata**. Trata-se de uma planta perene, propagada por sementes e curtos rizomas, ereta e pouco cespitosa. Com o objetivo de avaliar o crescimento e o desenvolvimento das plantas de dois acessos de **C. elata**, foi desenvolvido um experimento em casa de vegetação. O delineamento experimental foi o inteiramente casualizado, em esquema fatorial 2 (acessos de **C. elata**) x 15 (épocas de avaliação), com quatro repetições. Quinze avaliações destrutivas foram realizadas aos 14, 21, 28, 35, 42, 49, 56, 63, 70, 77, 84, 91, 98, 112 e 126 dias após a semeadura (DAS) dos dois acessos de **C. elata** (Itaberaí-GO e Matão-SP). Em cada avaliação, quatro plantas (repetições) foram amostradas de forma aleatória, sendo analisados a altura do colmo principal, o número de perfilhos e de inflorescências (flor+semente) por planta, a área foliar e a matéria seca de folhas, colmos, raízes, inflorescências e total (folhas+colmos+raízes+inflorescências). Os dois acessos apresentaram desenvolvimento e crescimento iniciais lentos (até os 63 DAS), principalmente da estrutura radicular, porém a emissão de novos perfilhos por planta aumentou rapidamente na fase inicial. Nos primeiros 63 DAS a distribuição percentual de*

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matéria seca foi maior nas folhas, seguido de colmos e raízes. Enquanto na avaliação final, a relação foi colmos seguido de folhas, raízes e inflorescência. As plantas de Matão formaram touceiras mais densas, com colmos de maior massa, enquanto as de Itaberaí tiveram maior altura e maior enfolhamento.

Palavras-chave: biótipo, capim-branco, desenvolvimento de plantas.

INTRODUCTION

In agricultural areas where there is no establishment of cover crops in the off season, as well as in citrus orchards in the State of São Paulo, there has been an increase in the infestation from *Chloris elata* Desv. synonymy *C. polydactyla* (L.) Sw. (tall windmill grass). This species is native to the American continent, occurring from the southern United States to Argentina, and is very common in Brazil, especially in the North and Central West regions (Kissmann and Groth, 1997).

It is a perennial, slightly caespitose plant, with glabrous and sub-cylindrical culm, 50 to 110 cm high at the adult stage and propagated by seeds and short rhizomes (Lorenzi, 2008). It has a slow initial development and growth, with expressive dry matter production and high seed production capacity, about 30,000 per plant (Carvalho et al., 2005a), which are covered in hairs and easily spread by the wind.

Studies on weed growth and development are very important, as they contribute to understand intra- and interspecies interference relations in plant communities. Growth analysis is an accessible and accurate method to infer the contribution of different physiological processes to the behavior of plants; around 90% of the dry matter accumulated by plants along their growth comes from photosynthetic activity, and the rest results from the absorption of mineral nutrients (Benincasa, 2003). In addition, growth analysis represents the initial reference in the analysis of the production of plant species, and its use requires information that can be obtained without the need for sophisticated equipment (Machado et al., 2006), making it possible to understand the physiological responses and morphological characteristics of plants, in relation to environmental factors and their effects on the ecological niche (Martins et al., 2016).

Knowing physiological growth and assimilated compound partitioning characteristics, during plant ontogeny, is an important tool in studies on weed biology and ecophysiology (Aumonde et al., 2013). Plant growth can also vary among populations (or accessions) of the same species. These differences may reflect in the relations of interference or even in the response of the accessions to the application of herbicides. In this regard, accessions of *C. polydactyla* from Matão and Jaboticabal had similar levels of susceptibility to glyphosate and differed from the Palmital and Pallotina biotypes, considered susceptible and with intermediate susceptibility, respectively (Barroso et al., 2014). Concurrently, the first case of resistance of *C. elata* biotypes to glyphosate was reported in Brazil in 2014, whose mechanism of resistance is associated with the lower absorption and translocation of the herbicide by plants (Brunharo et al., 2016, 2017).

In addition to the response variability of *C. elata* accessions to the herbicide, they may also differ as for the growth and development of plants. With the hypothesis that there are differences in the growth analysis of *C. elata* accessions, this study was conducted. Therefore, the objective of this study was to evaluate the growth and development of the two accessions of *C. elata*, coming from citrus orchards and no-tillage area of soybean and maize.

MATERIAL AND METHODS

The experiment was developed in a greenhouse in the period 11/25/2015 to 03/31/2016, in Brasília - Distrito Federal, Brazil. The altitude is 993 meters; latitude is 15°56'02" S, and longitude is 48°08'16" O.

Between September and October 2015, seeds of *C. elata* were collected in Itaberaí - Goias state (no-tillage area of soybean and maize, 752 meters altitude, latitude of 16°00'46" S and longitude of 49°50' 08" O) and Matão - São Paulo (citrus orchard, altitude of 592 meters, latitude of 21°43'25" S and longitude of 48°24'34" O). Seeds were sown in Styrofoam trays and, after

14 days, when plants had two to three leaves, transplant was carried out for the pots, with subsequent thinning, while one plant per pot was maintained.

Each experimental unit consisted of a plastic pot with a capacity of 5.0 dm^3 of soil, filled with a soil, sand and vegetable compost mixture, at the ratio of 3:1:1, which was fertilized with 100 mg of nitrogen, 200 mg of phosphorus and 150 mg of potassium per kg of substrate. Thirty-five and seventy days after transplant, plants were fertilized with a nutritive solution containing 155 mg of nitrogen and 100 mg of potassium per kg of soil, in each season.

The experimental design was completely randomized, in a 2 (accessions of *C. elata*) x 15 (evaluation periods) factorial arrangement, with four replications. Fifteen destructive evaluations were performed 14, 21, 28, 35, 42, 49, 56, 63, 70, 77, 84, 91, 98, 112 and 126 days after sowing (DAS) of the two accessions of *C. elata* (Itaberaí - Goias and Matão - São Paulo). In each evaluation, four plants (repetitions) were randomly sampled, and the height of the main culm, the number of tillers and inflorescences (flower + seed) per plant, the leaf area (determined with a 3100 model LI-COR meter) and the dry matter of leaves, culms, roots, inflorescences and total (leaves + culms + roots + inflorescences) were analyzed.

The plant material was dried in a greenhouse with forced air circulation and renewal at 50 °C, until constant weight, when it was evaluated. Before drying, the roots of the plants were washed with tap water to remove the remaining substrate.

With the total dry matter (TDM) values, the absolute growth rate (AGR, g per day) was calculated from the formula: $AGR= (TDM_2 - TDM_1)/(t_2 - t_1)$, where TDM_2 and TDM_1 are the total dry matter of two successive samples and t_2 and t_1 are the days elapsed between the two evaluations. The relative growth rate (RGR, g g^{-1} per day) was calculated using the formula: $RGR = (\ln TDM_2 - \ln TDM_1)/(t_2 - t_1)$ (Aguilera et al., 2004; Carvalho et al., 2005a).

The obtained data were submitted to the F test of the analysis of variance. The evaluation periods, when significant, were analyzed using non-linear log-logistic regressions, adopting the logistic model proposed by Streibig et al. (1988):

$$y= a + b/[1 + (x-c)^d],$$

where y is the variable of interest; x is the number of accumulated days; and a, b, c and d are the adjustment parameters of the equation; a is the minimum obtained point, b is the difference between the maximum and the minimum point, c is the number of days that provides 50% of the variable response and d is the slope of the curve (Carvalho et al. al., 2008). For absolute and relative growth rates, data were adjusted in 3rd degree and exponential regressions, respectively.

RESULTS AND DISCUSSION

The evaluation periods affected significantly all the evaluated variables (Tables 1, 2 and 3). The interaction accession x period was significant for main culm height, leaf area, number and dry matter of inflorescences and dry matter of culms. When the isolated factor and its interaction were significant for the same variable, it was chosen to unfold the interaction.

During the evaluation periods, the Matão accession had a smaller leaf area than that of Itaberaí (Figure 1). On the other hand, although the height of the main culm and the culm dry matter of the two accessions were similar until 84 DAS, at the final phase, Itaberaí plants had greater height and those of Matão had greater culm dry matter. The growth and development of plants depend on their genetic material or environmental factors. As plants from the two accessions of *C. elata* were established in the same environment, the observed differences can be explained by the genetic variability among them. For the root and total dry matter, there were no differences between the accessions during the development of plants, indicating that mass accumulation by the roots and the total mass balance by plants did not vary between the accessions.

The height of the main culm, leaf area and dry matter of leaves, culms, roots and total dry matter of both accessions of *C. elata* increased slowly up to 63 DAS, but increased faster during the next phase. The root structure growth was even slower, since at 92 DAS only 50% of this variable had developed (parameter c of the equation, Table 4). This feature may promote

Table 1 - Results of the F test of the analysis of variance for height, number of tillers, leaf area and number of inflorescences, throughout the development of plants from two accessions of *Chloris elata*. Brasília, Distrito Federal. 2015/2016

Variation source	Height	Tiller number	Leaf area	Number of inflorescences
Acessions	1.60^{ns}	16.47**	2.61^{ns}	54.21**
Period	797.08**	69.73**	106.97**	187.86**
Acess. x Period	3.30**	1.35^{ns}	2.29*	8.64**
CV (%)	9.04	20.57	24.44	36.02

**, * Significant at 1% and 5% of probability, respectively, by the F test of the analysis of variance. ^{ns} Not significant by the F test of the analysis of variance.

Table 2 - Results of the F test of the analysis of variance for the dry matter of leaves, culms, roots, inflorescences and total (leaves + culms + roots + inflorescences), during the development of plants from two accessions of *Chloris elata*. Brasília, Distrito Federal. 2015/2016

Variation source	Dry matter				
	Leaves	Culms	Roots	Inflorescences	Total
Acessions	8.78**	21.91**	0.02^{ns}	3.30^{ns}	2.12^{ns}
Period	188.23**	664.05**	119.14**	167.23**	463.26**
Acess. x period	1.18^{ns}	3.58**	0.84^{ns}	2.47**	1.39^{ns}
CV (%)	18.03	13.53	25.64	33.31	13.92

**, * Significant at 1% and 5% of probability, respectively, by the F test of the analysis of variance. ^{ns} Not significant by the F test of the analysis of variance.

Table 3 - Results of the F test of the analysis of variance for absolute and relative growth rates, during the development of plants from two accessions of *Chloris elata*. Brasília, Distrito Federal. 2015/2016

Variation source	Growth rate	
	Absolute	Relative
Acessions	0.23^{ns}	0.28^{ns}
Period	11.21**	28.16**
Acess. x period	0.77^{ns}	0.32^{ns}
CV (%)	33.72	27.21

** Significant at 1% probability by the F test of the analysis of variance. ^{ns} Not significant by the F test of the analysis of variance.

competitive disadvantages for the species, since root formation contributes to a better exploitation and consequent capture of the growth resources provided by the medium (Horak and Loughin, 2000; Carvalho et al., 2005b, 2008). In turn, the number of tillers per plant of both accessions increased rapidly at early stages of plant development; at 52 DAS, 50% of the total tillers per plant had already been emitted. Thus, in the first 50 days of the development of *C. elata*, there was a larger partition of photoassimilated compounds for the emission of tillers, compared to the later phase, resulting in plants with many tillers, few leaves and small size. This behavior helps plants getting bigger at the initial stage, for later foliar expansion and growth of the culms.

For both accessions of *C. elata*, there was no stabilization of the leaf area and the culm, root or total dry matter, but the cycle of the plants was considered closed when the dispersion of the produced seeds occurred and the senescence of the main culm began (at 126 DAS). The same was observed by Carvalho et al. (2005a), where the stabilization of the dry matter did not occur due to the emission and growth of new tillers, which contributed to the increase, at a lower speed, in the accumulated mass. This fact is justified by the development cycle of the species, classified as perennial (Kissmann and Groth, 1997; Lorenzi, 2008).

As for the percentage distribution of *C. elata* dry matter throughout the growth cycle, it was found that for both accessions, at 63 DAS, the leaves presented greater accumulations in relation to the other parts of the plants, with 47.3%, followed by culms and roots, with 29.8% and 22.8%, respectively. However, at the end of the cycle, culms had greater participation in the accumulation of mass, with 61.5%, compared to other parts of the plant (19.2% for leaves, 14.4% for roots and 8.1% for inflorescences). These percentages indicate that, at more advanced development stages,

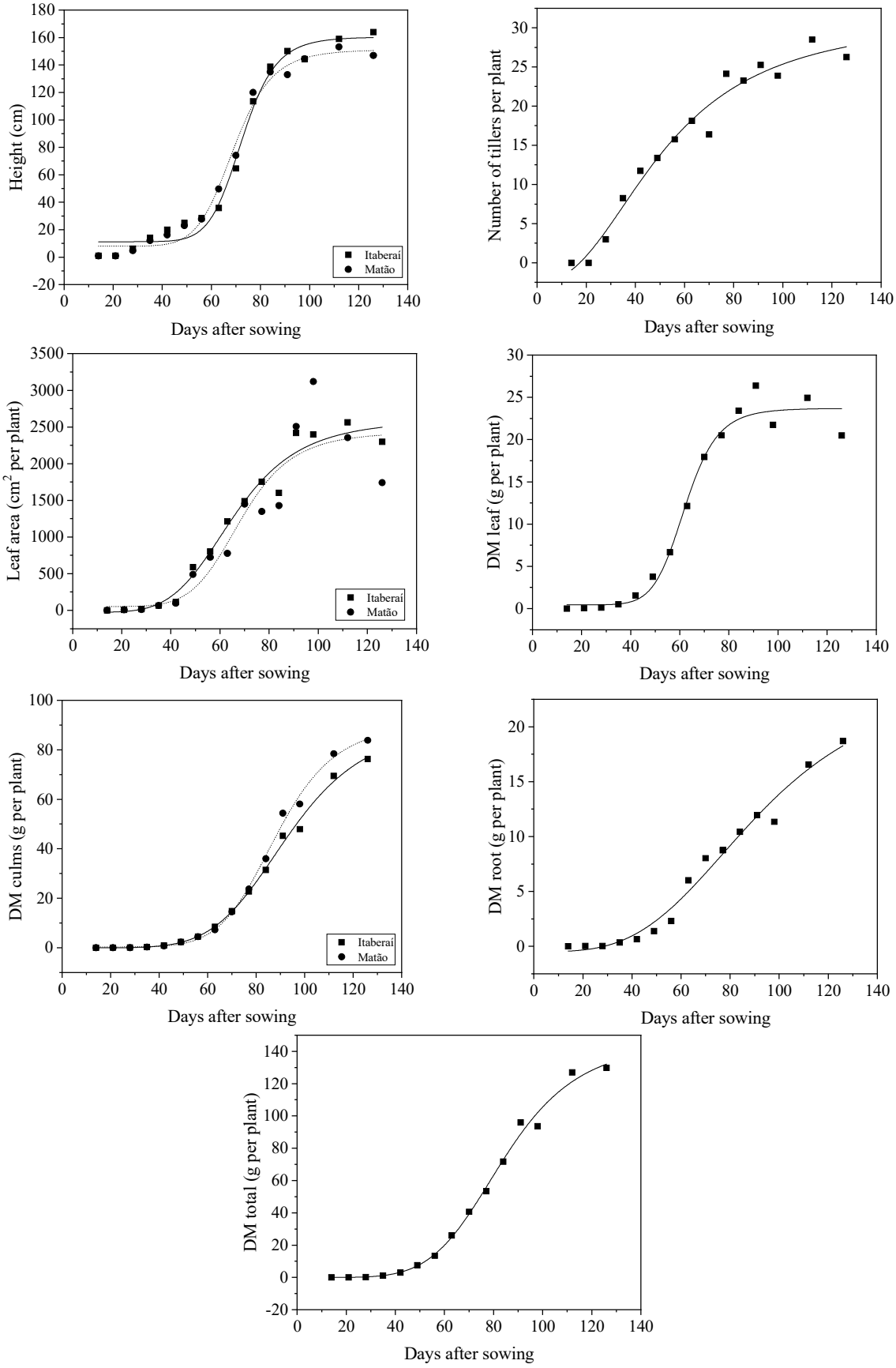

Figure 1 - Height, number of tillers, leaf area, dry matter of leaves, culms, roots and total (leaves + culms + roots + inflorescences) of two accessions of *Chloris elata* or average value, at different evaluation periods. Brasília, Distrito Federal. 2015/2016.

Table 4 - Parameters of the equations[(1)] and determination coefficients (R^2) obtained for the analyzed variables in both accessions of *Chloris elata* (Itaberaí and Matão). Brasília, Distrito Federal. 2015/2016

Variable	Acess.	Parameter				R^2
		a	b	c	d	
Height	Itaberaí	11.269	160.426	72.543	10.613	0.988
	Matão	7.966	151.212	69.228	8.931	0.991
N. of tillers		-2.446	31.369	51.861	2.330	0.973
Leaf area	Itaberaí	-25.422	2602.195	65.756	4.879	0.976
	Matão	51.999	2433.547	68.652	6.540	0.873
DM[(2)] levaes		0.443	23.702	62.202	9.440	0.981
DM culms	Itaberaí	-0.024	90.706	93.250	5.741	0.997
	Matão	0.341	90.784	88.445	7.253	0.997
DM roots		-0.481	24.919	92.546	3.358	0.982
DM inflorescences	Itaberaí	-0.108	11.916	91.756	12.491	0.981
	Matão	-0.030	10.017	83.716	19.595	0.980
Total DM		-0.057	146.736	84.178	5.457	0.994
N. of inflorescences	Itaberaí	-0.061	22.795	102.479	10.612	0.993
	Matão	-0.218	36.937	102.959	8.400	0.995

[(1)] Equation: $y = a + b/[1 + (x/c)^d]$. [(2)] Dry matter.

plants of *C. elata* have more culms than leaves, reflecting in lower spray retention and, consequently, lower absorption of the herbicide, in case of chemical control.

In another study, *Digitaria ciliaris* plants had larger leaf area, number of leaves and tillers and, consequently, higher dry matter during the experimental period, in relation to *D. nuda* plants (Souza et al., 2012). However, the species reached 50% of their maximum produced dry matter only at 57 and 58 DAS, respectively. The accumulation of dry matter during the development cycle of a plant is directly related to its capacity of extraction and use of the resources of the environment, reflecting in its competition potential with other plants.

C. elata accessions differed from each other as for quantity and dry matter of inflorescences. The Matão accession presented a larger number of inflorescences, but with lower accumulation of mass, compared to that of Itaberaí (Figure 2). In addition, Matão plants started their reproductive development, releasing the first inflorescences earlier (77 DAS) than Itaberaí plants (84 DAS), with both accessions remaining in full bloom, through the continuous emission of new inflorescences for tillers until the end of the evaluations. This difference in the beginning of flowering can be justified by the genetic variability between the accessions. The genetic material of a weed, perpetuated in the seed, is the response of years and years of adaptation and selection to agroecosystem pressures, such as edaphoclimatic conditions and management. The environments where seeds were collected differ between them; this may have contributed over the years to the selection of plants with a genetic load that is more or less responsive to flowering. However, this is a hypothesis, and its confirmation is only possible through specific studies on molecular biology.

The absolute growth rate provides an estimate of the average growth rate of the plants throughout the development cycle; the relative growth rate indicates the increase in grams of dry matter per unit of material found in a period of evaluation (Aguilera et al., 2004; Carvalho et al., 2005a). In this sense, for both *C. elata* accessions, the absolute growth rate was slow (mean 0.18 g day^{-1}) at the beginning of the evaluations (up to 49 DAS), with a rapid increase (mean of 1.80 g day^{-1}) (from 56 to 91 DAS) in a parabola model, with its peak close to 91 DAS (3.5 g day^{-1}), and later decline, due to the senescence of old leaves (Figure 3). In the coexistence culture x *C. elata*, the initial slow absolute growth rate undermines the initial competition of the weed with the crop, and, in the competition with other weeds, *C. elata* plants may be inhibited (or even eliminated) by the growth of other species of the weed community. As for the relative growth, the highest rates occurred at the beginning of the plant development, followed by a decline throughout the cycle.

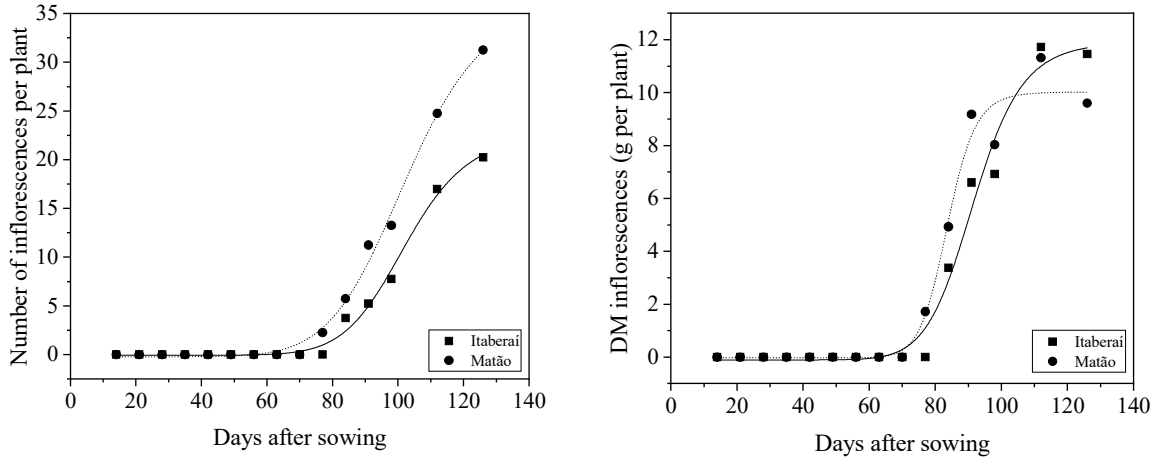

Figure 2 - Number and dry matter of inflorescences of two accessions of *Chloris elata*, at different evaluation periods. Brasília, Distrito Federal. 2015/2016.

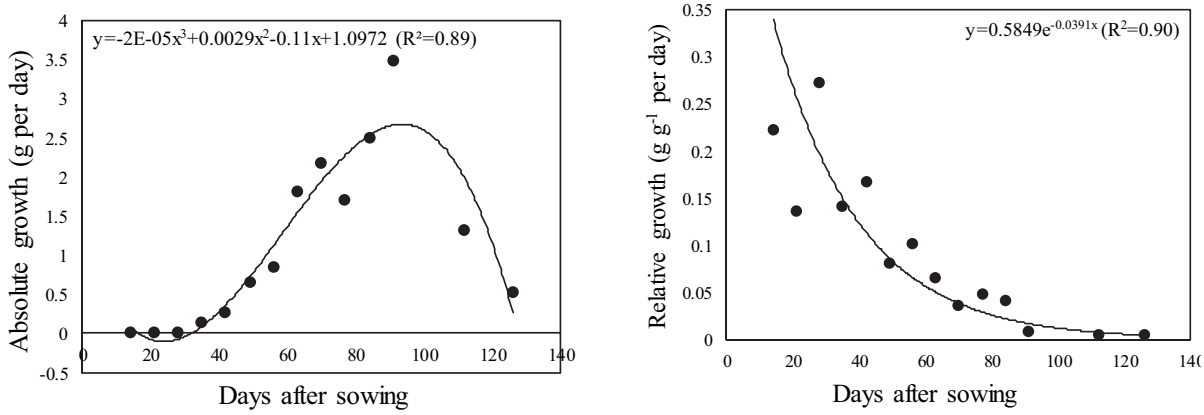

Figure 3 - Absolute and relative growth rates of *Chloris elata* accessions (mean value) at different evaluation periods. Brasília, Distrito Federal. 2015/2016.

C. elata, in another study, also presented a slow initial growth and development, as well as a remarkable final dry matter accumulation (Carvalho et al., 2005a). The same result was observed for plants of *Digitaria insularis* and *Sorghum arundinaceum*, both perennial species from the family Poaceae, which also showed a slow initial growth until the 45th and 57th days after transplanting, respectively (Machado et al., 2006; Martins et al., 2016).

The absolute growth rate of *D. ciliaris* and *D. nuda*, annual cycle grasses, increased slowly during the initial phase of the experimental period, reaching their maximum value at 71 and 73 DAS, respectively (Souza et al., 2012). This contributed to a greater accumulation of mass per plant for *D. ciliaris*, compared to *D. nuda*, also justified by the higher relative growth rate of *D. ciliaris* at the early stage of the cycle. The growth rate is an important characteristic used to describe plants with different ecological strategies (Souza et al., 2012).

At the beginning of growth, especially in shallow or low temperature conditions, being a species with a C4 type photosynthetic metabolism, *C. elata* plants can be suppressed by the faster growth of other species in the weed community. However, if the dosage of the herbicide is not enough to control it, it may become a dominant species, as it is with *D. insularis* in coffee plantations and no-tillage areas, where glyphosate is effective for other species and not enough for its effective control (Machado et al., 2006).

Based on the obtained results, it is possible to conclude that both accessions of *C. elata* showed a slow initial development and growth (up to 63 DAS), especially of their root structure, but the emission of new tillers per plant increased rapidly at the initial stage. During the first 63 DAS, the percentage distribution of dry matter was higher in the leaves, followed by culms and roots. In the final evaluation, the relation was culms followed by leaves, roots and

inflorescences. Matão accession plants formed denser clumps, with higher mass culms, while those from Itaberaí had greater height and leaf formation.

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