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Article

Growth and Development of Sourgrass Plants from Vegetative Parts of Clumps

Crescimento e Desenvolvimento de Plantas do Capim-Amargoso Oriundas de Partes Vegetativas das Touceiras

GAZOLA, T.[1]*
DIAS, M.F.[1]
BONATTO, V.M.[1]
BELAPART, D.[1]
CARBONARI, C.A.[1]
VELINI, E.D.[1]

ABSTRACT - Sourgrass (*Digitaria insularis*) is a perennial plant with high infestation potential, has fast and aggressive development, and reproduces by seeds and rhizomes. *D. insularis* infestations have increased in agricultural areas without cover crops established between the main crop seasons. The control of this species has become one of the most expensive in these areas in Brazil. The present work evaluated the growth and development of *D. insularis* plants from different vegetative parts of clumps. Two greenhouse experiments were conducted in a completely randomized design, with four replications. A 5 × 4 factorial arrangement was used, with factor A corresponding to the different propagation methods, and factor B corresponding to the biotypes used (experiment 1) and the different planting depths evaluated (experiment 2). The parameters evaluated in all experiments were: rate of tiller emergence, number of tillers, flowering time, number of inflorescences, and shoot dry weight. Fragments of different parts of the sourgrass clumps, planted at up to 7 cm depth, can generate a new plant. The management of perennial plants of sourgrass by using plows, harrows, or cultivators favors the dispersal of this species.

Keywords: *Digitaria insularis*, weeds, resistance to herbicides.

*RESUMO - O capim-amargoso (**Digitaria insularis**) é uma planta perene com elevado potencial de infestação, possui desenvolvimento rápido e agressivo e se reproduz tanto por sementes quanto por rizomas. A infestação de **D. insularis** tem aumentado nas áreas agrícolas onde não há culturas de cobertura estabelecidas na entressafra. Nessas áreas, vem se tornando uma das espécies de plantas daninhas de maior custo de controle no Brasil. Neste trabalho foram avaliados o crescimento e o desenvolvimento de plantas de **D. insularis** oriundas de diferentes partes vegetativas das touceiras. Realizaram-se dois experimentos em casa de vegetação no delineamento inteiramente casualizado com quatro repetições. Adotou-se o esquema fatorial 5 x 4, sendo o fator A correspondente aos diferentes métodos de propagação e o fator B, aos biótipos utilizados (ensaio 1) e às diferentes profundidades de plantio (ensaio 2). Os parâmetros avaliados em todos os experimentos foram: índice de velocidade de emissão do perfilho, número de perfilhos, época de florescimento, número de inflorescências e matéria seca da parte aérea. Conclui-se que fragmentos das diferentes partes das touceiras do capim-amargoso, quando expostas em até 7 cm de profundidade, podem dar origem a uma nova planta. Concluiu-se que o manejo de plantas perenizadas do capim-amargoso utilizando arados, grades ou cultivadores favorece a dispersão dessa espécie.*

Palavras-chave: *Digitaria insularis*, plantas daninhas, resistência a herbicidas.

*** Corresponding author:**
<tiago-gazola@hotmail.com>

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[1] Universidade Estadual Paulista "Júlio de Mesquita Filho", UNESP, Botucatu-SP, Brazil.

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INTRODUCTION

Several species of the genus *Digitaria* (Haller) are found among weeds infesting areas of Brazil and other countries (Canto-Dorow, 2001). Twenty-six native species and 12 exotic species of this genus have been found in Brazil (De Maria et al., 2006). *Digitaria insularis* (L.) Mez ex Ekman (sourgrass) stands out among these species; it is widely disseminated in the country. Carvalho and Pitelli (1992), Brighenti et al. (2003), and Pereira and Velini (2003) reported the presence of this species in pasture and grain production areas in the Cerrado biome. Oliveira and Freitas (2008) reported sourgrass infesting banana and sugarcane crops and pasture areas in the state of Rio de Janeiro. The presence of *D. insularis* has also been reported in several areas in the state of São Paulo (Kuva et al., 2008).

Sourgrass is a perennial erect grass with striated stems and long internodes, reaching 50 to 150 cm in height; its leaves have a long and hairy sheath, with membranous ligule (Kissmann and Groth, 1997; Lorenzi, 2000). Its panicles have a high number of seeds, which are hairy and have a high germination percentage. Its seeds can be spread over long distances by wind practically all year round. Sourgrass plants have fast and aggressive development, are highly competitive, and reproduces by seeds and vegetative parts, forming clumps. They adapt and develop well in poor and acidic soils (Mondo et al., 2010).

D. insularis infestations have increased in recent years, mainly in grain production areas. The use of large-scale glyphosate-resistant crops allows the use of several application of this herbicide in the same area and crop season. This resulted in the selection of glyphosate-resistant weeds (Koger and Reddy, 2005). There are several reports of glyphosate-resistant sourgrass in Brazil (Carvalho et al., 2012; Barroso et al., 2015; Galeano et al., 2016; Martins et al., 2016; Gazola, 2017). Sourgrass populations resistant to fenoxaprop-p-ethyl and haloxyfop-p-methyl herbicides have recently been reported in the State of Mato Grosso (Heap, 2018), which is a major concern to producers, as ACCase inhibitors are the main herbicides for controlling post-emergent *D. insularis*. All these factors contributed to make the species one of the most important weeds in Brazil.

The use of only one application of herbicide is not satisfactory to control this species because of its persistence in areas with adult plants forming clumps. In such cases, it is believed that mechanical control with plows, harrows, or cultivators may be a control alternative. However, the improper use of these practices can be a risk, increasing the dispersal of weed species due to fragmentation of their vegetative parts that can generate new plants.

Moreover, the implements available for tillage cause changes in the soil chemical, physical, and biological properties, changing organic matter contents, cation exchange capacity, pH, ion dynamics, and soil aggregation (Falleiro et al., 2003), undermining the benefits of a no-till system, which takes years to consolidate. Thus, these management practices need to be better studied to be safely implemented by producers.

Therefore, the present work evaluated the growth and development of *D. insularis* plants from different vegetative parts of clumps.

MATERIAL AND METHODS

Two greenhouse experiments were conducted in two different periods: October 2016 to January 2017, and October 2017 to January 2018. The experiments were carried out in a completely randomized design, with four replications, using a 5 x 4 factorial arrangement. In the experiment 1, factor A corresponded to propagation methods (RIZ = only rhizome, RIZ + RO = rhizome plus root; RIZ + CT = rhizome plus one tiller cut above the first internode; RIZ + RO + CT = rhizome plus root plus one tiller cut above the first internode; and RIZ + RO + WT = rhizome plus root plus one whole tiller), and factor B corresponded to the resistant (R1 and R2) and susceptible (S1 and S2) biotypes used. In the second experiment, factor A corresponded to the same propagation methods, and factor B corresponded to planting depths (1, 3, 5, and 7 cm).

The experimental units in experiment 1 consisted of *in vivo* preserved biotypes proven to be resistant or susceptible to glyphosate, according to Gazola (2017). For the second experiment,

plants of *Digitaria insularis* were collected in rural areas of Botucatu, SP, Brazil (22°81'36"S, 48°42'81"W; 22°83'91"S, 48°42'26"W; 22°84'26"S, 48°42'44"W; and 22°50'39"S, 48°26'42"W). Thus, sourgrass biotypes were used in experiment 1 and sourgrass populations were used in experiment 2 to evaluate possible variations in the results. In both experiments, the clumps were fragmented according to the parts described for the propagation methods, and transplanted to 2 liter pots containing a commercial substrate (Carolina II®). This substrate was composed of sphagnum peat, expanded vermiculite, roasted rice husk, dolomitic limestone, agricultural gypsum, and NPK traces; it presented electrical conductivity of 0.7±0.3 mS cm^{-1}, pH of 5.5, density of 155 kg m^{-3}, and 55% water retention capacity.

Each pot represented an experimental unit, and all of them were kept on a metal tray containing 5 cm of water depth during the experiments; thus, all plots had the same water supply condition.

The evaluations consisted of rate of tiller emergence (RTE), number of tillers (NT), flowering time (FT), number of inflorescences (NI), and shoot dry weight (SDW). RTE was determined by counting the number of emerged tillers daily until the emergence stabilization, which was calculated using the formula proposed by Maguire (1962) with modifications:

$$RTE = E1/N1 + E2/N2 + ...En/Nn$$

where: RTE = rate of tiller emergence; E1, E2, ...En = number of normal tillers computed at first, second, and last counts; and N1, N2, ...Nn = number of days, after planting, at first, second, and last counts.

NT was evaluated at the end of the counting of number of emerged tillers. FT was evaluated by daily counting of panicles, as soon as the first fully expanded inflorescence was emitted, until their stabilization. Then, the final number of inflorescences emitted was considered as the NI. The SDW was quantified after stabilization of inflorescence emission in each experiment. Thus, the shoot of each experimental unit was taken and dried in a forced-air circulation oven at 65 °C until constant weight. The whole tiller of plants propagated by RIZ + RO + WT was not measured for any evaluation, since it could affect the results because it is a complete plant in formation.

The data showed normal distribution and were subjected to analysis of variance by the F test; the means were compared by the Tukey's test at $p<0.05$, using the AgroEstat 1.1.0.712 rev 77 program.

RESULTS AND DISCUSSION

The interaction between propagation methods and sourgrass biotypes was significant for rate of tiller emergence (RTE). The RTE of the S1 biotype was higher using the RIZ + RO propagation method; and the RTE of the S2 biotype was similar in all propagation methods used (Table 1). Tillers of the R1 biotype emerged faster when using the RIZ propagation method, and the R2 biotype showed similar results for all propagation methods (Table 1). Although the interaction was significant, it was not possible to distinguish the best treatments due to the plants resistance/susceptibility to glyphosate. However, the S1 and S2 biotypes presented, on average, higher RTE (3.30 and 3.71, respectively) than R1 and R2 (2.09 and 2.28, respectively) (Table 1).

Regarding the planting depth of sourgrass populations in experiment 2, no significant interaction between propagation methods and planting depths was found (Table 1). However, at 5 and 7 cm depth, the initial development was faster when using the RIZ + RO + CT propagation method, presenting the highest mean for RTE (Table 1). The RTE was, on average, higher in the planting at 3 cm depth (Table 1).

Similar results of seed propagation system are found in the literature. According to Barbosa et al. (1991), seed depth in the soil also affects plant emergence; however, the highest percentages and speeds of seedling emergence for *Digitaria* spp. were found in the soil surface, at 2 cm depth.

Regarding the *D. insularis* seed viability, the seeds present approximately 80% germination when planted up to 3 cm depth (Pyon et al., 1977), and lower viability only when planted with at least 5 cm depth (Reinert, 2013). Unlike seeds, vegetative organs can be planted up to 7 cm

Table 1 - Rate of tiller emergence (RTE) in glyphosate-resistant and susceptible biotypes of *Digitaria insularis* (experiment 1) and in *D. insularis* populations from different vegetative parts of clumps planted at different depths (experiment 2)

Vegetative parts Experiment 1	Biotypes				Propagation mean
	RTE				
	S1	S2	R1	R2	
RIZ	1.86 bAB	3.50 aA	3.59 aA	1.44 aB	2.59
RIZ + RO	6.21 aA	4.40 aAB	1.60 abC	3.17 aBC	3.84
RIZ + CT	2.50 bA	2.89 aA	1.50 abA	1.61 aA	2.12
RIZ + RO + CT	3.36 bA	4.53 aA	2.83 abA	2.66 aA	3.34
RIZ + RO + WT	2.60 bAB	3.24 aA	0.94 bB	2.54 aAB	2.33
Biotype mean	3.30	3.71	2.09	2.28	
F Methods	7.24**				
F Biotypes	11.06**				
F M x B	3.48**				
CV (%)	37.65				
Vegetative parts Experiment 2	Planting depths (cm)				Propagation mean
	RTE				
	1	3	5	7	
RIZ	2.56 a	2.10 a	2.60 ab	1.72 ab	2.24
RIZ + RO	1.76 a	4.09 a	0.86 b	0.64 b	1.83
RIZ + CT	2.41 a	2.36 a	0.40 b	0.33 b	1.37
RIZ + RO + CT	2.08 a	4.87 a	5.33 a	3.06 a	2.83
RIZ + RO + WT	1.37 a	1.79 a	2.53 ab	1.95 ab	1.91
Depth mean	2.03	3.04	2.3 4	1.54	
F Methods	4.27**				
F Depths	2.37^{ns}				
F M x D	1.38^{ns}				
CV (%)	81.33				

RIZ = Rhizome; RIZ + RO = Rhizome + Root; RIZ + CT = Rhizome + Tiller cut above the first internode; RIZ + RO + CT = Rhizome + Root + Tiller cut above the first internode; RIZ + RO + WT = Rhizome + Root + Whole Tiller. R1 and R2 = glyphosate-resistant biotypes; S1 and S2 = glyphosate-susceptible biotypes. ^{ns} = not significant; ** = significant at 1% probability by the F test. Means followed by the same letter, lowercase in the column and uppercase in the row, for each experiment, do not differ significantly by the Tukey's test ($p \leq 0.05$).

depth without compromising their viability (Table 1). However, the RTE was, on average, slightly lower when using the RIZ + RO and RIZ + CT propagation methods, with the highest indexes found with planting at 3 and 5 cm depth, respectively (Table 1).

The emergence of tillers began, in general, at 2 days after planting (DAP) in both experiments, and stabilized at 14 DAP (experiment 1) and 17 DAP (experiment 2). The results indicate that tiller emission occurs from the tillers present in the plant and from the rhizome, because tiller emission also occurred even when only this organ was planted up to 7 cm depth (Table 2).

Understanding the emergence process of sourgrass is important for decision making. According to seed viability results found by Pyon et al. (1977) and Reinert (2013), soil tillage using plows, harrows, or cultivators could be effective in controlling the dispersal of the species because it would place its seeds in deeper soil layers, which could prevent their germination. However, this control method should be done with caution for perennial sourgrass, since all plants evaluated showed tiller emergence regardless of the propagation method used (Table 1), which allowed their growth and development. Under field conditions, this could increase the dispersal and density of population of the species.

The interaction between the factors was not significant for the number of tillers (NT) in any of the experiments (Table 2). Thus, all propagation methods adopted presented similar NT. However, the R2 biotype in experiment 1 had higher NT when using the RIZ + RO + WT propagation method (Table 2). In experiment 2, the RIZ + RO + CT method presented plants with higher NT with planting at 3 cm, and RIZ + RO + WT presented higher NT with planting at 7 cm (Table 2).

Table 2 - Number of tillers (NT) in glyphosate-resistant and susceptible biotypes of *Digitaria insularis* (experiment 1) and in *D. insularis* populations from different vegetative parts of clumps planted at different depths (experiment 2)

Vegetative parts Experiment 1	Biotypes				Propagation mean
	NT				
	S1	S2	R1	R2	
RIZ	2.25 a	3.50 a	2.33 a	1.00 b	2.27
RIZ + RO	5.50 a	4.50 a	1.75 a	2.50 ab	3.56
RIZ + CT	2.50 a	3.00 a	2.00 a	2.66 ab	2.54
RIZ + RO + CT	3.75 a	4.50 a	1.50 a	2.66 ab	3.10
RIZ + RO + WT	4.50 a	3.25 a	1.75 a	3.25 a	3.18
Biotype mean	3.70	3.75	1.86	2.41	
F Methods	2.98*				
F Biotypes	12.02*				
F M x B	1.88^{ns}				
CV (%)	41.4				
Vegetative parts Experiment 2	**Planting depths (cm)**				**Propagation mean**
	NT				
	1	3	5	7	
RIZ	1.00 a	1.00 b	1.75 a	2.00 ab	1.43
RIZ + RO	1.50 a	2.25 ab	1.00 a	1.00 ab	1.43
RIZ + CT	2.00 a	2.00 ab	0.75 a	0.25 b	1.25
RIZ + RO + CT	1.75 a	5.00 a	5.00 a	2.00 ab	3.43
RIZ + RO + WT	3.25 a	3.75 ab	4.75 a	3.50 a	3.81
Depth mean	1.90	2.80	2.65	1.75	
F Methods	8.92**				
F Depths	2.01^{ns}				
F M x D	1.34^{ns}				
CV (%)	73.11				

RIZ = Rhizome; RIZ + RO = Rhizome + Root; RIZ + CT = Rhizome + Tiller cut above the first internode; RIZ + RO + CT = Rhizome + Root + Tiller cut above the first internode; RIZ + RO + WT = Rhizome + Root + Whole Tiller. R1 and R2 = glyphosate-resistant biotypes; S1 and S2 = glyphosate-susceptible biotypes. ^{ns}= not significant; * and ** = significant at 5% and 1% probability, respectively, by the F test. Means followed by the same letter, lowercase in the column and uppercase in the row, for each experiment, do not differ significantly by the Tukey's test ($p \leq 0.05$).

Susceptible sourgrass biotypes had, on average, more tillers than the resistant ones, indicating that susceptible plants are more adapted to stress conditions; therefore, the development of plants with different fragmentation may be affected by their characteristics of resistance and susceptibility to herbicides (Table 2).

This information is important for weed management, since the mechanical control methods using plows, harrows, or cultivators is used to eliminate remaining (resistant) plants. In addition, plants with higher NT will probably have greater leaf areas, which may benefit sourgrass control through contact herbicides that require larger cover area for a satisfactory control. However, these herbicides do not translocate in the plants and do not reach the rhizome and vascular system of the sourgrass; thus, regrowth of shoots of these plants is frequent (Melo et al., 2012), hindering the management of the species.

The interaction between the factors was significant for flowering time (FT) in both experiments (Table 3). In experiment 1, the FT of resistant biotypes was faster (42 and 48 DAP) than that of susceptible biotypes (50 DAP) when plants were propagated by rhizome (RIZ); in plants propagated by the other methods, the resistance or susceptibility of biotypes had no effect on this parameter, with FT occurring between 35 and 50 DAP (Table 3).

In experiment 2, FT of plants propagated by RIZ occurred between 32 and 41 DAP; it was faster when using planting at 7 cm depth (Table 3). However, the plants did not flower when using the RIZ method with planting at 1 and 5 cm depth, and the RIZ + CT method with planting at 1 cm depth (Table 3). This was probably because the plants did not have sufficient vegetative structure and time for emission of reproductive organs during the experiments.

Table 3 - Flowering time in days after planting (DAP) in glyphosate-resistant and susceptible biotypes of *Digitaria insularis* (experiment 1), and in *D. insularis* populations from different vegetative parts of clumps planted at different depths (experiment 2)

Vegetative parts Experiment 1	Biotypes				Propagation mean[(1)]
	Flowering time (DAP)				
	S1	S2	R1	R2	
RIZ	50.66 aA	50.00 aA	42.33 bcB	48.00 aAB	47.74
RIZ + RO	46.75 aA	0.00 cB	45.66 abA	49.00 aA	47.13
RIZ + CT	35.00 bB	45.00 abA	50.00 aA	50.66 aA	45.16
RIZ + RO + CT	49.50 aA	40.00 bB	45.00 abcAB	41.00 bB	43.87
RIZ + RO + WT	39.00 bA	39.75 bA	38.25 cA	36.25 bA	38.31
Biotype mean[(1)]	44.18	43.68	44.24	44.98	
F Methods	34.55**				
F Biotypes	37.75**				
F M x B	43.97**				
CV (%)	8.25				
Vegetative parts Experiment 2	Planting depths (cm)				Propagation mean[(1)]
	Flowering time (DAP)				
	1	3	5	7	
RIZ	0.00 cC	41.00 aA	0.00 cC	32.00 bcB	36.50
RIZ + RO	34.5 aA	36.00 abA	40.00 aA	41.00 abA	37.87
RIZ + CT	0.00 cC	30.00 bB	34.50 abAB	42.00 aA	35.50
RIZ + RO + CT	21.00 bC	33.00 abB	27.00 bBC	42.00 aA	30.75
RIZ + RO + WT	35.75 aA	35.00 abAB	32.50 abAB	26.50 cB	32.43
Depth mean[(1)]	30.41	35.00	33.50	36.70	
F Methods	39.01**				
F Depths	65.28**				
F M x D	24.78**				
CV (%)	16.07				

RIZ = Rhizome; RIZ + RO = Rhizome + Root; RIZ + CT = Rhizome + Tiller cut above the first internode; RIZ + RO + CT = Rhizome + Root + Tiller cut above the first internode; RIZ + RO + WT = Rhizome + Root + Whole Tiller. R1 and R2 = glyphosate-resistant biotypes; S1 and S2 = glyphosate-susceptible biotypes. [(1)] values 0 not considered when calculating the means. ** = significant at 1% probability by the F test. Means followed by the same letter, lowercase in the column and uppercase in the row, for each experiment, do not differ significantly by the Tukey's test ($p \leq 0.05$).

In general, flowering occurred faster in experiment 2, with plants emitting inflorescences between 21 and 42 DAP, against 35 and 50 DAP in experiment 1 (Table 3). These results may be related to the genetic variability of the species, since the methodologies and environmental conditions during the experiments were the same for all plants.

These characteristics express the response of sourgrass plants to natural selection and the selection pressures of techniques adopted for weed management (Li et al., 2007). Independent selection of herbicide-resistant populations is generally more frequent in autogamous species, such as sourgrass, because gene flow in autogamous species is lower (Ng et al., 2004) and their spread to new areas depends on seed dispersal or reproductive structures, such as rhizomes. Thus, the vegetative propagation of *D. insularis* can contribute significantly to the dispersal of resistant populations.

Similar results were found by Martins et al. (2016), who evaluated the growth of *D. insularis* and found faster development for resistant plants, which reached the flowering stage first than glyphosate-susceptible plants. In addition, seed-propagated sourgrass emits inflorescence between 63 and 70 days after sowing (Machado et al., 2006), which is much slower when compared to that from vegetative propagation–between 21 and 50 DAP (Table 3).

The flowering of resistant sourgrass plants is faster than that of susceptible ones (Martins et al., 2016), which may affect the natural resistance selection process. Thus, plants with fast flowering may have more germinating seeds in the soil and, consequently, generate new individuals more quickly. This explanation is important because sourgrass is perennial and, as

observed in the present work, presents faster inflorescence emission than young plants from seeds, as in the studies of Machado et al. (2006). This reinforces that this species should be controlled before the formation of rhizomes, which occurs, on average, at 45 days after emergence (Machado et al., 2006). In addition, after perennialization, sourgrass will flower and disperse seeds with low dormancy throughout the year (Gemelli et al., 2012), thus, increasing dispersion of seeds and difficulty of control.

In addition, the main factors that contributed to the rapid spread of resistant sourgrass in Brazil are related to the biological characteristics of the species and the increased use of glyphosate for weed management (Lopez-Ovejero et al., 2017). The results of the experiments show that the use of plows, harrows, or cultivators to manage this species can contribute to the dispersal of sourgrass because of its diverse forms of vegetative propagation, which generates new plants that rapidly reach the reproductive stage.

The interaction between the factors was significant for number of inflorescences (NI) in experiment 1 (Table 4). Plants of the biotype S1 propagated by RIZ + RO, RIZ + CT, and RIZ + RO + WT showed the highest NI, differing significantly from the plants propagated with the other methods (Table 4). However, the highest NI in experiment 1 were found in plants propagated by RIZ + RO + WT, which produced between 4 and 8 panicles per plant (Table 4). The biotype and propagation method with the highest NI were S1 and RIZ + RO + WT, respectively (Table 4).

In experiment 2, the interaction between the propagation methods and planting depths was not significant for NI (Table 4). The RIZ + RO + WT method resulted in the highest NI in plants

Table 4 - Number of inflorescences (NI) in glyphosate-resistant and susceptible biotypes of *Digitaria insularis* (experiment 1), and in *D. insularis* populations from different vegetative parts of clumps planted at different depths (experiment 2)

Vegetative parts Experiment 1	Biotypes				Propagation mean[(1)]
	NI				
	S1	S2	R1	R2	
RIZ	1.25 cA	1.25 bA	1.50 abA	0.50 bA	1.12
RIZ + RO	4.25 bcA	0.00 bB	0.50 bB	0.25 bB	1.66
RIZ + CT	5.00 bA	1.00 bB	1.25 abB	1.00 bB	2.06
RIZ + RO + CT	2.50 bcA	3.25 abA	2.75 abA	2.75 bA	2.81
RIZ + RO + WT	8.75 aA	5.50 aB	4.25 aB	6.25 aAB	6.18
Biotype mean[(1)]	4.35	2.75	2.05	2.15	
F Methods	24.34**				
F Biotypes	8.74**				
F M x B	1.99*				
CV (%)	62.49				
Vegetative parts Experiment 2	Planting depths (cm)				Propagation mean[(1)]
	NI				
	1	3	5	7	
RIZ	0.00 b	0.25 a	0.00 a	1.50 b	0.87
RIZ + RO	0.75 b	1.75 a	1.25 a	0.25 b	1.00
RIZ + CT	0.00 b	4.00 a	2.50 a	0.25 b	2.25
RIZ + RO + CT	0.25 b	3.50 a	3.00 a	0.25 b	1.75
RIZ + RO + WT	4.50 a	3.75 a	1.75 a	4.75 a	3.68
Depth mean[(1)]	1.83	2.65	2.12	1.4	
F Methods	4.11**				
F Depths	1.54[ns]				
F M x D	1.23[ns]				
CV (%)	141.48				

RIZ = Rhizome; RIZ + RO = Rhizome + Root; RIZ + CT = Rhizome + Tiller cut above the first internode; RIZ + RO + CT = Rhizome + Root + Tiller cut above the first internode; RIZ + RO + WT = Rhizome + Root + Whole Tiller. R1 and R2 = glyphosate-resistant biotypes; S1 and S2 = glyphosate-susceptible biotypes. [(1)] values 0 not considered when calculating the means. * and ** = significant at 5% and 1% probability, respectively, by the F test. Means followed by the same letter, lowercase in the column and uppercase in the row, for each experiment, do not differ significantly by the Tukey's test ($p \leq 0.05$).

planted at 1 and 7 cm (Table 4). However, in some cases, the plants did not emit panicles during the evaluation period, as occurred when using the RIZ and RIZ + CT methods with planting at 1 cm, and RIZ at 5 cm. This was probably because they did not have enough vegetative structure and time for emission of reproductive organs during the period of the experiments (Table 4).

Plants that emit higher NI are expected to produce more seeds. NI is not as important as the viability of these propagules. However, the seeds of this species have a high germination percentage (Pyon et al., 1977) and are covered by hairs, which help their dispersion over long distances, allowing this plant to spread easily (Kismann and Grouth, 1997).

Thus, the RIZ + RO + WT propagation method will benefit from this issue at depths of up to 7 cm, regardless of the susceptibility or resistance of the species (Table 4). Furthermore, as observed in the present experiments, inflorescence emission occurs faster when the plant is propagated asexually (Table 3) when compared to results of other studies using sexual propagation (Pyon et al., 1977; Reinert, 2013), which may contribute to increase the sourgrass dispersion.

The interaction between propagation methods and biotypes was significant for shoot dry weight (SDW). Thus, it is not possible to infer that the resistant *D. insularis* plants had more SDW than the susceptible ones (Table 5). According to Machado et al. (2006), sourgrass plants propagated by seeds produces approximately 3 to 4 g of SDW (stems + leaves) at 56 days after emergence. In the present work, the SDW accumulation was 255.25% to 692.25% higher than their result, with plants presenting, on average, 10.21 to 27.69 g of SDW at 53 DAP (Table 5). Thus, perennial sourgrass plants have greater infestation potential, increasing the difficulty of controlling them. Therefore, the ideal sourgrass management time should be before the formation of rhizomes.

Table 5 - Shoot dry weight (SDW) in glyphosate-resistant and susceptible biotypes of *Digitaria insularis* (experiment 1), and in *D. insularis* populations from different vegetative parts of clumps planted at different depths (experiment 2)

Vegetative parts Experiment 1	Biotypes				Propagation mean
	SDW – 53 DAP				
	S1	S2	R1	R2	
RIZ	9.91a	16.28a	11.26a	10.61bc	12.01
RIZ + RO	13.66a	7.21b	9.12a	10.86bc	10.21
RIZ + CT	14.61a	12.88ab	11.88a	12.71ab	13.02
RIZ + RO + CT	13.87a	15.14ab	14.02a	20.64a	15.91
RIZ + RO + WT	17.48a	17.57a	12.29a	17.01ab	16.08
Biotype mean	13.90	13.81	11.71	14.36	
F Methods	7.73**				
F Biotypes	1.24^{ns}				
F M x B	2.63^{ns}				
CV (%)	30.87				
Vegetative parts Experiment 2	**Planting depths (cm)**				**Propagation mean**
	SDW – 45 DAP				
	1	3	5	7	
RIZ	0.07b	2.92c	4.27b	6.36b	3.04
RIZ + RO	6.35b	6.30c	5.52b	2.89b	5.26
RIZ + CT	4.51b	15.25bc	2.81b	1.10b	5.91
RIZ + RO + CT	15.48ab	24.43ab	18.66a	13.06a	17.90
RIZ + RO + WT	26.98a	29.87a	30.04a	23.87a	27.69
Depth mean	10.67	15.75	12.26	9.45	
F Methods	39.83**				
F Depths	2.86*				
F M x D	1.65^{ns}				
CV (%)	52.65				

RIZ = Rhizome; RIZ + RO = Rhizome + Root; RIZ + CT = Rhizome + Tiller cut above the first internode; RIZ + RO + CT = Rhizome + Root + Tiller cut above the first internode; RIZ + RO + WT = Rhizome + Root + Whole Tiller. R1 and R2 = glyphosate-resistant biotypes; S1 and S2 = glyphosate-susceptible biotypes. * and ** = significant at 5% and 1% probability, respectively, by the F test. Means followed by the same letter, lowercase in the column and uppercase in the row, for each experiment, do not differ significantly by the Tukey's test ($p \leq 0.05$).

In addition to the results found in all biometric parameters evaluated, the great variability found in the results was also concerning. When evaluating plant populations (experiment 2) rather than biotypes (experiment 1), the coefficient of variation was much higher (Tables 1, 2, 3, 4, and 5). This result is partly explained by the great genetic variability of the species. Martins et al. (2016) evaluated the use of random primers and found that sourgrass has a polymorphism rate of 56.6%, i.e., a sourgrass plant may be 56.6% genetically different from another plant of the species.

This is important because genetic variability among weeds of the same species allows them to evolve and adapt to new locations, which has been occurring with *D. insularis* in Brazil (Lopez-Ovejero et al., 2017). It is believed that this plant arrived in Brazil through Paraguay (Timossi et al., 2006; Machado et al., 2006), since the first case of resistance of sourgrass to glyphosate in Brazil, reported in 2008, occurred in a soybean crop in Guaíra, PR (Duke and Powles, 2008), which is close to Brazil's border with Paraguay. Since then, sourgrass has adapted well to the Brazilian conditions, where it is currently dispersed in virtually all grain producing regions (Lopez-Ovejero et al., 2017).

The results indicated that fragments of different vegetative parts of sourgrass clumps (Rhizome; Rhizome + Root; Rhizome + Cut Tiller; Rhizome + Root + Cut Tiller; and Rhizome + Root + Whole Tiller) planted up to 7 cm depth can generate a new plant. Therefore, the management of sourgrass made by plows, harrows, or cultivators in areas infested with perennial plants favors the dispersal of this species.

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