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Emergence and development of weeds according to the sowing depth and light intensity

Emergência e desenvolvimento de plantas daninhas em função da profundidade de semeadura e intensidade luminosa

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ABSTRACT - Understanding weed emergence and development aspects is essential in decision-making for management strategies. The study evaluated the effects of different sowing depths and light intensities on the emergence and development of the weeds *Sida rhombifolia* and *Senna obtusifolia* under field conditions. Each species constituted an experiment, and the experimental design used was completely randomized, with four replications. The treatments were arranged in a 6 x 4 factorial scheme, with the first factor corresponding to the six sowing depths (0.5; 1.0; 2.0; 4.0; 8.0, and 12.0 cm) and the second at four light intensities (100%, 70%, 50%, and 30% of sunlight). The seedling emergence was evaluated daily to obtain the emergence and emergence speed index. The height, time to floral induction, and dry matter of plants at flowering were also evaluated. When submitted to different levels of shading, *S. rhombifolia* seedlings emerge up to 12.0 cm deep. *S. obtusifolia* seedlings emerge at all sowing depths, even when subjected to different solar radiation intensities. Seedlings of *S. rhombifolia* and *S. obtusifolia* emerge less and slower in sowings between 8.0 and 12.0 cm depth and develop better under full sunlight in sowings between 1.0 and 4.0 cm depth. Therefore, greater depths delay the development of both species, which is important information for managing these weeds.

Keywords: *Sida rhombifolia*. *Senna obtusifolia*. Shading. Luminosity. Solar radiation.

RESUMO - Compreender os aspectos de emergência e desenvolvimento de plantas daninhas é essencial na tomada de decisão para estratégias de manejo. Neste trabalho foram avaliados em condições de campo, os efeitos de diferentes profundidades de semeadura e intensidades luminosas na emergência e no desenvolvimento das plantas daninhas *Sida rhombifolia* e *Senna obtusifolia*. Cada espécie constituiu um experimento e o delineamento experimental utilizado foi o inteiramente casualizado, com quatro repetições. Os tratamentos foram dispostos em esquema fatorial 6 x 4, sendo o primeiro fator correspondente as seis profundidades de semeadura (0,5; 1,0; 2,0; 4,0; 8,0 e 12,0 cm) e o segundo a quatro intensidades luminosas (100%, 70%, 50% e 30% da luz solar). Avaliou-se diariamente a emergência das plântulas para obtenção da emergência e do índice de velocidade de emergência. A altura, o tempo até a indução floral e a matéria seca das plantas no florescimento também foram avaliadas. Quando submetidas a diferentes níveis de sombreamento as plântulas de *S. rhombifolia* emergem em até 12,0 cm de profundidade. As plântulas de *S. obtusifolia* emergem em todas as profundidades de semeadura, mesmo quando submetidas a diferentes intensidades de radiação solar. As plântulas das espécies *S. rhombifolia* e *S. obtusifolia* emergem menos e em menor velocidade em semeaduras entre 8,0 e 12,0 cm de profundidade e se desenvolvem melhor em condições de luz solar plena em semeaduras entre 1,0 e 4,0 cm de profundidade. Portanto, maiores profundidades atrasam o desenvolvimento de ambas as espécies, sendo uma importante informação para o manejo dessas plantas daninhas.

Palavras-chave: *Sida rhombifolia*. *Senna obtusifolia*. Sombreamento. Luminosidade. Radiação solar.

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INTRODUCTION

Weeds are one of the ecological factors that most affect the agricultural and livestock economy permanently since, besides causing physiological damage to crops, their control also entails expenses that raise the production cost (MONQUERO et al., 2015; SANTOS et al., 2019). Added to this, weed species, such as arrowleaf sida [*Sida rhombifolia* L.] and sicklepod [*Senna obtusifolia* (L.) Irwin & Barneby], can hinder the harvest of major crops, drastically reduce the physiological reserves of forage grasses, and also increase the formation and recovery time of pastures and cause injury and/or poisoning to animals (MARCHI et al., 2019; LOURENÇO et al., 2019). These species have high seed production, ensuring them infestations for a long period, even with chemical control measures (GUGLIERI-CAPORAL et al., 2011), making alternative methods of managing these weeds in the field necessary.

One of the biggest limitations to implementing an effective weed management program is the lack of specific knowledge about the biology and ecology of the main species (XIONG et al., 2018). Because of this, studies have been developed to understand better the aspects related to germination, emergence, growth, and development of weeds under adverse conditions, aiming to manage them more efficiently (MARQUES et al., 2019; MARCHI et al., 2020).

Seed germination is regulated by interacting environmental conditions with its physiological fitness state. In this sense, each plant species requires a set of environmental resources necessary for seed germination, such as the availability of water, light, temperature, and depth at which they are located (ZUFFO et al., 2014; SAHA et al., 2020). Thus, knowledge of the ability of seedlings to emerge from seeds located at different depths in the soil can assist in the management of weed species by adopting methods that reduce or prevent their occurrence (ORZARI et al., 2013; MAQSOOD et al., 2020). Additionally, due to delayed emergence, weed seedlings may be shaded and exhibit slower initial growth (MONQUERO et al., 2012).

Just as the depth at which seeds are in the soil profile affects germination, emergence, and plant development, light is also required for the germination and development of a large number of plant species (LESSA et al., 2013; SZYMBORSKA-SANDHU et al., 2020; KLIMEŠ et al., 2021). Light controls the onset of photosensitive seed germination, and phytochromes are responsible for light signal perception and transduction (SILVA et al., 2019).

Studies on light intensity and the depth in the soil profile at which the seedling can emerge provide the biological basis for knowledge of weed propagation and establishment. This understanding is useful for modeling the potential invasion of weed species and providing input for developing and adopting pertinent management practices, reducing or preventing the appearance of undesirable species in farm areas. Thus, the present study aimed to evaluate, under field conditions, the effect of different sowing depths and light intensities on the emergence and development of *S. rhombifolia* and *S. obtusifolia*.

MATERIAL AND METHODS

The study was conducted under field conditions in an area belonging to the School of Agriculture/UNESP, Campus of Botucatu/SP (22°07'56'' S, 74°66'84' 'W, and altitude of 762 m) from November 2017 to June 2018. The soil of the experimental area is clayey, classified as Neossolo Litólico (USDA soil taxonomy = Oxisol) (MARQUES; MARCHI; MARTINS, 2021), whose physical and chemical characteristics are shown in Table 1.

Table 1. Chemical fertility and particle size analysis of the soil in the experimental area.

pH $CaCl_2$	O.M.	P_{resin}	K	Ca	Mg	H+Al	S	CEC	BS
(0.01 mol L^{-1})	g dm^{-3}	mg dm^{-3}	-------------------- mmol$_c$ dm^{-3} --------------------						%
4.8	22	11	1.6	33	14	46	48	94	51
Particle Size Composition (g kg^{-1})									
Clay	Silt	Coarse Sand	Fine Sand	Total Sand					
449	163	100	288	388					
Classification: Clayey									

Each weed species (*S. rhombifolia*, *S. obtusifolia*) constituted an experiment, and the experimental design used was entirely randomized, with four repetitions. The treatments were arranged in a 6 x 4 factorial scheme, with six sowing depths (0.5, 1.0, 2.0, 4.0, 8.0, and 12.0 cm) associated with four light intensities (100%, 70%, 50%, and 30% of sunlight) obtained through specific agricultural shades.

The average data on the amount of light and soil temperature in the morning and afternoon periods, collected in the experimental area at the time of setting up the experiment, are shown in Table 2. Photosynthetically active radiation (PAR) was measured as photosynthetically active photon flux density (mmol s^{-1} m^{-2}) (PAPFD) at ground height and was quantified using a quantimeter (Model LI-190 Quantum Sensor, LI-COR, USA) coupled to a porometer (Model LI-1600 LICOR Steady State Porometer, LI-COR, USA).

The experimental plots were made up of 1.0 m wide by 2.0 m long beds, raised with a rotary hoe, with a standardized, usable area in the center of the plots, discarding 25 cm at each end. The seeds of both species were purchased from the company Agro Cosmos without using methods to overcome dormancy.

Based on the information provided by the company, four repetitions were sown with 25 seeds of each species per row for each treatment, 25 cm apart between rows in each experimental plot. The shades were set at a height of 1.5 m from the ground to avoid barriers to plant growth. Sowing was done following the same pattern of depth arrangement, from the smallest to the largest, for better visualization and evaluation of the plants in the field.

Table 2. Amount of light and soil temperature data collected in the experimental area in the morning (09:30) and afternoon (15:30) periods.

Time	Solar Intensity	Light mmol s^{-1} m^{-2}	Soil temperature (°C)					
			0.5 cm	1.0 cm	2.0 cm	4.0 cm	8.0 cm	12.0 cm
09:30	100%	1830	34	34	34	33	28	26
09:30	70%	840	31	31	31	30	26	25
09:30	50%	760	30	30	30	28	26	25
09:30	30%	660	30	30	30	29	26	25
15:30	100%	1920	42	42	42	40	36	33
15:30	70%	920	34	33	32	31	30	28
15:30	50%	840	33	33	32	31	30	28
15:30	30%	710	32	31	31	30	29	28

The sowing was performed manually, and the sowing depths were obtained using a wooden structure with the exact size of each depth. Thus, the uniformity of the sowing depth was maintained throughout the length of the furrow. The main beds were prepared in a north-south direction, and the planting furrows were made in an east-west direction to avoid possible shading.

The different light intensities were obtained utilizing agricultural screens made of black polyethylene (Sombrite®), allowing light intensities of 70, 50, and 30% to pass through. These screens were installed over the sowing beds, covering the entire surface and its sides at the height of 80 cm so that the evaluations could be conducted inside, not to allow the passage of light during the evaluations.

The structure was set up with the possibility of bilateral opening, always keeping the top cover and a side cover intact. The site will be opened depending on the solar position during the evaluations, ensuring that the plants did not receive sunlight during the experiment.

The emergence of *S. rhombifolia* and *S. obtusifolia* seedlings was monitored for 26 days after sowing by counting and removing the emerged ones to obtain the emergence percentage and the emergence speed index (ESI). The index was calculated using the equation proposed by Maguire (1962), where: ESI = G1/N1 + G2/N2 +...+ Gn/Nn, where: ESI = emergence speed index; G1...n = number of normal seedlings emerged computed in the counts; and N1...n = number of days from sowing to the first, second ... nth evaluation. Counts were performed daily in each experimental plot from when the first plant emerged.

For each depth, three plants were set aside in all plots so that the height and the period until the flowering induction of the species could be measured, as well as the accumulation of total dry matter at flowering. Irrigation occurred three times a week via an automated sprinkler system with a distribution of 10 mm of water. The results were submitted to variance analysis using the "F" test, and the means of the treatments were compared using the Tukey test at 5% probability.

RESULTS AND DISCUSSION

Sida rhombifolia

The *S. rhombifolia* seedlings emerged at all sowing depths when subjected to different levels of shading (70, 50, and 30% solar radiation). However, no seedling emergence of this species was observed when the seeds were arranged 12 cm deep for full sunlight (100% solar radiation). It should be noted that both sowing depth and light intensity affected the number of days to seedling emergence alone, and there was an interaction between these factors at $P<0.05$ (Table 3).

The positioning of *S. rhombifolia* seeds between 0.5 and 4.0 cm depth did not affect the time to seedling emergence, regardless of the solar radiation intensities applied. Sowing deeper than 4.0 cm increased days for *S. rhombifolia* seedling emergence under all solar radiation conditions (Table 3). These results show greater efficiency in the emergence of seedlings of this species in sowings that are more superficial in the soil profile (0.5 to 4.0 cm). Notably, the highest temperatures were observed at these depths, with the lowest thermal variations compared to sowing depths greater than 4.0 cm (8.0 and 12.0 cm) (Table 2).

The different shading levels (70, 50, and 30% solar radiation) conditioned the shortest periods for the emergence of *S. rhombifolia* seedlings when the seeds were positioned at depths between 0.5 and 4.0 cm. Generally, the greatest time requirements for seedling emergence of this species were found when the seeds were sown in full sunlight (100% of solar radiation) and at depths of 8.0 and 12.0 cm (Table 3).

Both factors studied in this research and the interaction between these factors, at $P<0.05$, affected the percentage of the emergence of *S. rhombifolia* seedlings. The highest percentages of seedling emergence of this species were observed in shading conditions (70, 50, and 30% of solar radiation) and sowings between 0.5 and 2.0 cm deep. For the full sunlight condition (100% of solar radiation), the highest emergences were found when seeds were sown at 2.0 and 4.0 cm depths (Table 3).

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Table 3. Days to emergence and emergence percentage of *Sida rhombifolia* seedlings sown at different depths and submitted to different solar radiation intensities.

Period for emergence (days)				
Sowing depth (cm)	Solar radiation (%)			
	100	70	50	30
0.5	10.50 ABa	6.00 Cb	6.00 Cb	6.00 Bb
1.0	10.00 ABa	7.50 Cab	6.00 Cb	6.00 Bb
2.0	9.50 Ba	6.00 Cb	6.00 Cb	6.00 Bb
4.0	10.50 ABa	6.00 Cb	6.00 Cb	8.00 Bab
8.0	12.00 Ab	12.00 Bab	10.00 Bb	15.00 Aa
12.0	-- --	19.00 Aa	15.00 Ab	17.00 Aab
F RADIATION (R)	4.552**			
F DEPTH (P)	37.660**			
F (R) x (P)	20.178**			
m.s.d. (R)	3.41			
m.s.d. (P)	3.91			
C. V. (%)	20.3			
Seedling emergence (%)				
Seeding depth sowing (cm)	Solar radiation (%)			
	100	70	50	30
0.5	24.17Bb	62.71Aba	60.00Aa	59.37ABa
1.0	52.71Ab	74.79Aa	68.54Aab	79.79Aa
2.0	50.83Aa	69.79Aab	65.83Ab	72.29ABab
4.0	30.62ABa	39.17Ba	25.00Bb	51.87Ba
8.0	0.42CDa	3.54Ca	1.67BCa	0.83Ca
12.0	0.00Da	0.41Ca	0.62Ca	1.04Ca
F RADIATION (R)	3.794**			
F DEPTH (P)	124.662**			
F (R) x (P)	4.314**			
m.s.d. (R)	21.44			
m.s.d. (P)	23.86			
C. V. (%)	28.9			

** Significant at 1% probability; * significant at 5% probability. m.s.d. minimum significant difference. Means followed by the same uppercase letter in the column and lowercase in the line do not differ statistically by the Tukey test ($p < 0.05$).

Gasparim et al. (2005) report in their research that soil temperature is one of the most important factors for seed germination since temperatures near the soil surface are very similar, being significantly attenuated only after 5 cm depth. Cardoso (1990) complements that temperatures of approximately 30 ºC are defined as optimal for the beginning of the germination process of the species *S. rhombifolia*. When relating this information to the results found in this study, it can be seen that the highest percentages and the least time required for the emergence of this species occurred in sowings between 0.5 and 4.0 cm deep (Table 3), which presented temperatures between 28 and 34 ºC in the morning period (Table 2), inferring that soil temperature may have been a factor that interfered with the emergence of *S. rhombifolia* seedlings.

The reductions in seedling emergence percentage according to increased sowing depth observed in this study may also have occurred because the amounts of seed reserve material were insufficient to break the natural soil barrier (SOUZA et al., 2011; SANTOS et al., 2015). It should be added that the process of secondary or induced dormancy, which refers to the state of dormancy induction under environmental conditions not favorable for germination (CHEN et al., 2020), may also have directly influenced the reduction of seedling emergence of the species *S. rhombifolia*.

The sowings made between 0.5 and 2.0 cm deep in shaded conditions (70, 50, and 30% of solar radiation) and between 2.0 and 4.0 cm deep in conditions of 100% of solar radiation provided the highest values of the emergence speed index of *S. rhombifolia* seedlings. It is noteworthy that, regardless of the imposed solar radiation condition, the greatest reductions in the emergence speed of this species were observed when the seeds were placed at a depth of 8.0 and 12.0 cm (Table 4).

Table 4. Emergence speed index (ESI) and days to flowering of *Sida rhombifolia* plants sown at different depths and submitted to different solar radiation intensities.

ESI				
Sowing Depth (cm)	Solar radiation (%)			
	100	70	50	30
0.5	2.49BCb	7.33Aa	5.78Aa	7.46ABa
1.0	4.36Bb	8.66Aa	8.24Aa	9.93Aa
2.0	7.42Aa	7.70Aa	7.67Aa	8.61ABa
4.0	4.98ABab	4.41Bab	2.76Bb	5.81Ba
8.0	0.03Ca	0.33Ca	0.15Ba	0.09Ca
12.0	0.00Ca	0.04Ca	0.07Ba	0.11Ca
F RADIATION (R)	10.676**			
F DEPTH (P)	107.621**			
F (R) x (P)	3.505**			
m.s.d. (R)	2.53			
m.s.d. (P)	2.82			
C. V. (%)	31.2			
Days to flowering				
Sowing Depth (cm)	Solar radiation (%)			
	100	70	50	30
0.5	124	163	163	163
1.0	124	163	163	163
2.0	124	163	163	163
4.0	124	163	163	163
8.0	124	163	163	163
12.0	--	163	163	163

** Significant at 1% probability. m.s.d. minimum significant difference. Means followed by the same uppercase letter in the column and lowercase in the line do not differ statistically by the Tukey test ($p < 0.05$).

When evaluating the average number of days needed for *S. rhombifolia* to flower, it can be seen that in the three shading conditions (70, 50, and 30% of solar radiation), the plants flowered at the same time, which corresponded to 163 days after sowing. For the 100% solar radiation condition, the plants of this species required a shorter time to start the flowering process since the first floral inductions were observed 124 days after sowing (Table 4). These data show a significant difference in the time required for the flowering of *S. rhombifolia* plants in situations of reduced light levels (39 days), which can perhaps be seen as a survival strategy of the species.

Solar radiation is an important environmental component that, in addition to providing light energy for photosynthesis, also provides environmental signals for many physiological processes in plants that can differ depending on the plant species (MARCHI et al., 2020). The reduction in light intensity and, consequently, in temperature culminates in a decrease in the accumulation of degree days by the plant, which directly influences phenology and plant morphogenesis (KLIMEŠ et al., 2021). In this case, the plants tend to stay longer in vegetative stages and flower later or unevenly, concerning different shading levels (SZYMBORSKA-SANDHU et al., 2020).

The 100% solar radiation provided the best development conditions for *S. rhombifolia* plants since the plants presented the greatest heights at flowering, at sowings between 1.0 and 4.0 cm deep. With the reduction of solar radiation, the flowering height of this species was reduced, regardless of the depth at which the seeds were placed in the soil. Notably, the smallest plants were observed when *S. rhombifolia* seeds were sown at 8.0 and 12.0 cm in all light conditions imposed (Table 5).

The total dry matter accumulation per *S. rhombifolia* plant at flowering was influenced by the sowing depth, the different percentages of solar radiation, and the interaction between these two factors. The 100% solar radiation condition provided the highest results for the total plant dry matter accumulation in sowing between 1.0 and 4.0 cm depth. For the shading conditions, it can be seen that there were no significant contrasts between the sowing depths (Table 5).

Table 5. Height and the total accumulation of dry matter at the flowering of *Sida rhombifolia* plants sown at different depths and submitted to different solar radiation intensities.

Plant height (cm)				
Sowing Depth (cm)	Solar radiation (%)			
	100	70	50	30
0.5	20.41Aa	12.58ABCa	16.33ABa	11.92Aa
1.0	30.83Aa	16.83Ab	13.67ABCb	12.17Ab
2.0	24.25Aa	16.67Aab	18.83Aab	10.17Ab
4.0	25.75Aa	15.25ABab	13.67ABCb	10.92Ab
8.0	6.75Ba	1.25Ca	4.67BCa	6.33Aa
12.0	----	3.75BCa	2.52Ca	1.37Aa
F RADIATION (R)	11.449**			
F DEPTH (P)	26.154**			
F (R) x (P)	2.035*			
m.s.d. (R)	10.58			
m.s.d. (P)	11.77			
C. V. (%)	46.2			
Dry matter accumulation (g plant^{-1})				
Sowing Depth (cm)	Solar radiation (%)			
	100	70	50	30
0.5	1.51BCa	Aa	0.19Aa	0.29Aa
1.0	4.46ABa	0.43Ab	0.14Ab	0.15Ab
2.0	6.88Aa	0.22Ab	0.33Ab	0.12Ab
4.0	7.69Aa	0.18Ab	0.14Ab	0.13Ab
8.0	0.23CDa	0.04Aa	0.03Aa	0.09Aa
12.0	0.00Da	0.09Aa	0.03Aa	0.01Aa
F RADIATION (R)	18.784**			
F DEPTH (P)	3.952**			
F (R) x (P)	3.493**			
m.s.d. (R)	3.35			
m.s.d. (P)	3.74			
C. V. (%)	143.6			

**Significant at 1% probability; * significant at 5% probability. m.s.d. minimum significant difference. Means followed by the same uppercase letter in the column and lowercase in the line do not differ statistically by the Tukey test ($p < 0.05$).

There was a significant difference in dry matter accumulation between the shaded and full sunlight conditions. This difference is up to 98.3% when comparing the interactions between the highest and lowest values obtained at a depth of 4.0 cm and in the treatments with 100 and 30% solar radiation, respectively (Table 5). It is inferred, therefore, that *S. rhombifolia* plants emerge less and at a slower rate at sowings deeper than 4.0 cm (Tables 3 and 4) and develop better in full sunlight conditions (Table 5).

Due to this information on the emergence and development of *S. rhombifolia* seedlings observed in the present research, it is important to highlight that the use of soil tillage processes that promote the incorporation of seeds at higher depths in the soil profile can compromise the propagation of this weed species (MARQUES et al., 2019), causing an increase in the mechanical resistance imposed by the soil, besides reducing the temperature, the availability of O_2 and increasing the accumulation of CO_2, forming fermented compounds during the respiratory process (TAIZ; ZEIGER, 2013; ZUFFO et al., 2014). Added to this, there will be a possible delay in the processes of weed development, favoring the development of the crop of interest (MARCHI et al., 2020). Consequently, the crops will promote a natural barrier of solar radiation based on the plant canopy, leading to a cultural control of species such as *S. rhombifolia*, which develop less in shaded conditions.

Senna obtusifolia

The seedlings of *S. obtusifolia* emerged in all light conditions evaluated and in sowings between 0.5 and 12 cm deep. However, different light levels and sowing depths affected the time in days for seedling emergence in isolation since no interaction was observed between these two factors (Table 6).

Table 6. Days to emergence and emergence percentage of *Senna obtusifolia* seedlings sown at different depths and submitted to different solar radiation intensities.

Variable	Period for emergence (days)
Sowing depth (cm)	
0.5	6.06A
1.0	5.94A
2.0	4.87B
4.0	4.19C
8.0	4.12C
12.0	4.94B
Solar radiation (%)	
100	5.21A
70	4.96AB
50	4.75BC
30	4.17C
F RADIATION (R)	3.581*
F DEPTH (P)	36.977**
F (R) x (P)	0.902^{ns}
m.s.d. (R)	0.41
m.s.d. (P)	0.56
C. V. (%)	10.9

Seeding depth sowing (cm)	Seedling emergence (%) – Solar radiation (%) 100	70	50	30
0.5	38.54Aa	42.71Aa	46.88ABa	54.17ABa
1.0	40.62Ab	55.21Aab	65.62Aab	69.79Aa
2.0	34.37Ab	57.29Aab	66.68Aa	40.41ABb
4.0	59.38Aa	48.96Aa	35.42ABa	53.12ABa
8.0	46.87Aa	58.33Aa	37.50ABa	43.75ABa
12.0	33.33Aa	32.29Aa	25.00Ba	29.16Ba
F RADIATION (R)	0.926^{ns}			
F DEPTH (P)	5.769**			
F (R) x (P)	2.137*			
m.s.d. (R)	28.19			
m.s.d. (P)	31.36			
C. V. (%)	32.7			

**Significant at 1% probability; ns Not significant. m.s.d. minimum significant difference. Means followed by the same capital letter in the column do not differ statistically by the Tukey test ($p < 0.05$).

The seeds of *S. obtusifolia* positioned at 0.5 and 1.0 cm depth had a longer time for seedling emergence (Table 6). The percentage of solar radiation also affected the number of days for the emergence of *S. obtusifolia* seedlings, with the greatest time requirements observed for the 100 and 70% solar radiation conditions. Sowing at depths between 2.0 and 12.0 cm reduced the time between sowing and seedling emergence by approximately one day (Table 6).

Therefore, it can be seen that for the more superficial layers of the soil profile and in the conditions of full sunlight and 70% solar radiation, there was a greater need for time for seedling emergence. It is important to highlight that light is necessary to germinate many weed species (ORZARI et al., 2013). Thus, some species have seeds that germinate only under rapid exposure to light and others that initiate this process after ample exposure, besides the seeds in which germination is triggered only in the dark and those indifferent to light (GUIMARÃES et al., 2018).

The percentage of seedling emergence of *S. obtusifolia* was influenced by the depth of the seeds in the soil profile and by the interaction between depth and percentage of solar radiation. The different levels of solar radiation, evaluated separately, did not significantly affect the seedling emergence of *S. obtusifolia* at $P<0.05$ (Table 6).

Higher percentages of the emergence of *S. obtusifolia* seedlings were obtained at sowing depths between 0.5 and 8.0 cm, regardless of solar radiation levels, with the depth of 1.0 cm standing out under 30% solar radiation conditions. Sowing at 12.0 cm depth in shading conditions of 50 and 30% of solar radiation provided the most unfavorable conditions for the emergence of this weed species (Table 6).

Many weed species germinate only when arranged at shallower depths in the soil, as they require light stimulation to initiate this process (MARQUES et al., 2019). On the other hand, some species do not need solar radiation to start the germination process and can emerge from greater depths (IKEDA et al., 2013), highlighting the results observed in this study for the species *S. obtusifolia*, which showed no need for light for the seedling emergence process and was able to emerge even at great depths (up to 8.0 cm).

The conditions of 70, 50, and 30% of solar radiation provided the highest values of the emergence speed index of *S. obtusifolia* seedlings, especially when the sowings were made up to 8.0 cm deep. Because of this, it is inferred that the emergence speed of *S. obtusifolia* seedlings, for the most part, was affected only by the 12 cm depth in the soil profile and full sunlight conditions (Table 7). These data reaffirm the better adaptation of this weed species to shaded conditions and the better emergence in layers up to 8.0 cm deep.

Table 7. Emergence speed index (ESI) and days to flowering of *Senna obtusifolia* plants sown at different depths and submitted to different solar radiation intensities.

ESI				
Sowing Depth (cm)	Solar radiation (%)			
	100	70	50	30
0.5	1.18Ab	1.58ABab	2.51BCa	1.76Aab
1.0	1.27Ab	1.94ABab	3.05ABa	2.16Aab
2.0	1.16Ab	2.59ABab	3.86Aa	2.39Aa
4.0	1.31Ab	2.64Aa	2.79ABa	2.21Aab
8.0	2.04Aa	2.74Aa	2.85ABa	2.09Aa
12.0	1.33Aa	1.15Ba	1.46Ca	1.06Aa
$F_{RADIATION}$ (R)	17.335**			
F_{DEPTH} (P)	8.422**			
F (R) x (P)	1.968*			
m.s.d. (R)	1.17			
m.s.d. (P)	1.29			
C. V. (%)	30.9			
Days to flowering				
Sowing Depth (cm)	Solar radiation (%)			
	100	70	50	30
0.5	45	48	64	65
1.0	45	48	64	65
2.0	45	48	64	65
4.0	45	48	64	65
8.0	45	48	64	65
12.0	45	48	64	65

**Significant at 1% probability. m.s.d. minimum significant difference. Means followed by the same uppercase letter in the column and lowercase letter in the line do not differ statistically using the Tukey test ($p < 0.05$).

The different light intensities affected the time required for the flowering of *S. obtusifolia* plants, regardless of the sowing depth evaluated, with the first floral inductions presented by plants developed under 100 and 70% solar radiation, at 45 and 48 days after sowing, respectively. The highest levels of shading (50 and 30% solar radiation) increased the time to flowering of *S. obtusifolia* plants compared to the conditions of 100 and 70% solar radiation, 64 and 65 days after sowing, respectively. For weeds, this behavior can occur as an adaptive response to environmental conditions to ensure that there are ideal conditions for the onset of reproductive stages, ensuring the propagation and survival of new generations (SOUZA et al., 2021; 2022).

The parameters of plant height and total dry matter accumulation at the time of flowering were affected only by the different solar radiation intensities, and no significant contrasts were observed when the species was sown between 0.5 and 12.0 cm deep. The largest plants and the highest dry matter accumulations per plant of *S. obtusifolia* were obtained when grown in full sunlight (Table 8).

Table 8. Plant height and dry matter accumulation at the flowering of *Senna obtusifolia* plants sown at different depths and submitted to different solar radiation intensities.

Variable	Plant height (cm)	Dry matter accumulation (g plant^{-1})
Sowing depth (cm)		
0.5	54.70	5.16
1.0	55.59	5.47
2.0	53.44	4.71
4.0	55.93	5.35
8.0	54.31	6.28
12.0	50.72	5.05
Solar radiation (%)		
100	72.15A	12.50A
70	33.59C	1.83C
50	37.17BC	4.15B
30	43.55B	2.85BC
$F_{RADIATION}$ (R)	124.139**	83.531**
F_{DEPTH} (P)	0.860^{ns}	0.659ns
F (R) x (P)	0.753^{ns}	0.598ns
m.s.d. (R)	6.18	1.98
m.s.d. (P)	8.43	2.70
C. V. (%)	15.0	48.9

**Significant at 1% probability; ns Not significant. m.s.d. minimum significant difference. Means followed by the same uppercase letter in the column do not differ statistically by the Tukey test ($p < 0.05$).

In general, the results obtained in this study on the emergence and development of *S. rhombifolia* and *S. obtusifolia* sown in different soil depths and light intensities can help in the effective management of these weed species by adopting methods to reduce or prevent their occurrence since greater depths and shading levels delay all the processes studied for both species.

CONCLUSIONS

When subjected to different levels of shading, the seedlings of *S. rhombifolia* emerge in sowings up to 12.0 cm deep. For full sunlight conditions, there is no emergence of seedlings of this weed species with sowing at 12 cm depth.

Seedlings of the species *S. rhombifolia* emerge less and at a slower rate in deeper sowings and develop better in full sunlight conditions in shallow sowings.

The seedlings of *S. obtusifolia* emerge in all conditions of sowing depth and light studied.

Sowing depth affects only the time to emergence of *S. obtusifolia* seedlings. The different levels of solar radiation affect the period for emergence and flowering, plant height, and dry matter accumulation of this weed species, and the full sunlight condition is the treatment that provides the best conditions for developing *S. obtusifolia* plants.

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