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SOWING DEPTH AND LIGHT INTENSITY IN THE EMERGENCE AND DEVELOPMENT OF MONOCOTYLEDONOUS WEEDS

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Abstract
This study aimed to evaluate the effects of different sowing depths and light intensities on the emergence and development of the monocot weed species, *Urochloa decumbens* and *Cenchrus echinatus,* under field conditions. Each species constituted an experiment, and the experimental design was completely randomized with four replicates. 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 solar radiation intensities (100%, 70%, 50%, and 30%) obtained through the use of shading screens. Seedling emergence capacity was evaluated daily to obtain the emergence percentage and speed index. Plant height, floral induction time, and plant dry matter at flowering were measured. Even when subjected to different solar radiation intensities, *U. decumbens* and *C. echinatus* seedlings emerged at all the sowing depths. Sowing between 2.0- and 4.0-cm depths favored the emergence of seedlings of *U. decumbens* and *C. echinatus.* However, sowing at 12-cm depth reduced the emergence of both species regardless of the solar radiation intensity. *Urichloa decumbens* plants grown under conditions of greater shading showed the lowest values of height and dry matter accumulation during flowering. High levels of shading facilitated only the etiolation of *C. echinatus* plants. Increased shading flowering time in both species compared to full sunlight.

Keywords: Brightness. *Cenchrus echinatus.* Field condition. Shading. *Urochloa decumbens*.

1. Introduction

Weeds affect the agricultural economy by causing physiological damage to crops, and their control entails expenses that increase the cost of production (Monquero et al. 2015; Santos et al. 2019). Lack of knowledge regarding the biology and ecology of main weed species is a major challenge in implementing a successful weed management program (Sadeghloo et al. 2013). Thus, only few studies have focused on understanding the behavior of these plants in the environment and managing them more efficiently (Marques et al. 2019; Marchi et al. 2019; Marchi et al. 2020).

Seed germination is regulated by the interaction of environmental conditions with their physiological fitness state. Each plant species requires environmental resources for germinating its seeds, such as water, light, temperature, and appropriate sowing depth (Zuffo et al. 2014). Thus, knowledge of seedling emergence capacity from seeds located at different depths in the soil can assist in weed management by adopting methods that reduce or prevent their occurrence (Orzari et al. 2013). For example, weeds could be controlled using equipment for soil preparation capable of thrusting seeds at depths unfavorable for seedling emergence (Maciel, 2014). Additionally, weed seedlings may be shaded due to delayed emergence, thereby presenting a slower initial growth (Monquero et al. 2012). Similarly, the depth at which the seeds are planted in the soil profile can affect the germination, emergence, and development of the plants.

Light is necessary for the germination of numerous weed species (Canossa et al. 2007; Marques et al. 2012; Lessa et al. 2013). It controls the beginning of germination of photosensitive seeds, and phytochromes are responsible for the perception and transduction of light signals. This chromoprotein has two basic forms: an inactive form, which is activated by absorbing red light, inducing the production of GA_3 and triggering the beginning of germination; and an active form, which is inactivated when illuminated with far-red light, resulting in the production of abscisic acid (ABA), inducing a state of dormancy in seeds (Silva et al. 2019).

Notably, knowledge of light intensity and soil profile depth at which a seedling can emerge provides a biological basis for understanding the propagation and establishment of weeds in an agricultural area. Such knowledge is useful to model the potential invasion of weeds and provides subsidies for developing and adopting relevant management practices and reducing or preventing their growth in agricultural areas.

Thus, the objective of this study was to evaluate, under field conditions, the effects of different sowing depths and different light intensities on the emergence and development of the monocotyledonous weed species *Urochloa decumbens* (Stapf) RD Webster (Brachiaria grass) and *Cenchrus echinatus* L (Southern sandbur).

2. Material and Methods

The study was conducted under field conditions in an area belonging to the School of Agronomic Sciences/UNESP, Botucatu/SP campus (22° 07’56’ ‘S and 74° 66’84 ‘’ W, Gr, and 762 m altitude). The soil in the experimental area is clayey, classified as Neossolo Litólico (Sergio et al. 2005), and its chemical and physical characteristics are as follows: pH in $CaCl_2$ of 4.8; 22.0 g dm^{-3} of organic matter; 11.0 mg dm^{-3} of P resin; 51% of base saturation; 94 of CEC; and 1.6; 33.0; 14.0 and 46.0 $mmol_c$ dm^{-3} of K, Ca, Mg, and H + Al, respectively; 100 g kg^{-1} of coarse sand, 288 g kg^{-1} of fine sand, 163 g kg^{-1} of silt, and 449 g kg^{-1} of clay, which is responsible for the clayey texture.

Both the weed species, *U. decumbens* and *C. echinatus*, were used in the experiment, and the experimental design was completely randomized, with four replications. 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 solar radiation intensities (100%, 70 %, 50%, and 30%) obtained through the use of specific agricultural shading screens (SOMBRITE®).

The average light intensity and soil temperature during the morning and afternoon, recorded at the experimental area, are shown in Table 1. Photosynthetically active radiation (PAR) was measured as the density of flow of active photosynthetic photons (mmol s^{-1} m^{-2}) (DFAPP) at the ground level. It was quantified using a quantum sensor (Model LI-190 Quantum Sensor, LI-COR, USA) coupled to a porometer (LI-1600 LICOR Steady State Porometer, LI-COR, USA).

Table 1. Average light and soil temperature data in the morning and afternoon recorded at the study area.

Time	Solar intensity	Light mmol s^{-1} m^{-2}	T Soil (°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	29	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 depths used in this study were chosen based on a bibliographic review of the non-emergence of most weed species observed at depths greater than 12.0 cm.

The experimental plots consisted of 1.0 m wide and 2.0 m long seedbeds mechanically raised with a rotary hoe. Within these seedbeds, four replicates were sown with 25 viable seeds of each species per row for each treatment, at a spacing of 25 cm between the rows. Sowing was always performed following the same pattern of depth arrangement, from the smallest to the largest, to better visualize and evaluate the plants in the field.

Seeds were sown manually. The stipulated sowing depths were obtained using a wooden structure for drilling the sowing row, which was built with the exact size of each depth to maintain uniformity of the sowing depth across the entire furrow. The seedbeds were prepared in the north–south direction, and the planting furrows in the east–west direction to avoid possible undesirable shading.

The different solar radiation intensities were achieved using agricultural screens manufactured with black polyethylene (shade), allowing the solar radiation intensities of 70, 50, and 30%. These screens were installed on the sowing seedbeds covering the entire surface and sides of the beds at a height of 80 cm. The evaluations were carried out internally to avoid light interference during the assessments. To this end, the structure was assembled to facilitate bilateral opening and facilitate entry from either side, always keeping the top cover and side cover intact. The choice of entry depended on the solar position at the time of evaluation, ensuring that the plants did not receive unwanted direct sunlight at any time during the experiment.

The emergence of seedlings of the studied species was monitored for at least 26 days after sowing (DAS). The plants that emerged were counted and removed to obtain the emergence percentage and emergence speed index (ESI). This index was calculated using the equation proposed by Maguire (1962), where:

$ESI = G1/N1 + G2/N2 + ... + Gn/Nn$, and

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 ... umpteenth assessment. Of note, in each experimental plot, counts were performed daily, starting from the day the first plant emerged.

Three plants of each depth were reserved in all plots that showed emergence at each depth, always the first ones that emerged. The height and period until floral induction could be evaluated, in addition to measuring the total dry matter accumulation during flowering. For this purpose, the samples were placed in paper bags and oven-dried with forced air circulation at 65 ºC until they reached a constant weight, after which, they were weighed on a 0.01-g precision scale.

Plants were irrigated thrice a week with 10 mm of water using a sprinkler system. Undesirable plants were eliminated as required. The results were subjected to analysis of variance and F-tests. The means were compared by Tukey's test at 5% probability.

3. Results

Urochloa decumbens

Urochloa decumbens seedlings emerged at all sowing depths, regardless of the applied solar radiation intensities. Both sowing depth and solar radiation intensity affected the number of days for seedling emergence and the interaction between them ($P < 0.05$) (Table 2).

Under full sunlight (100% of solar radiation), the emergence time was shorter when seeds were sown at depths of 4.0 and 12.0 cm. However, under 70 and 50% solar radiation conditions, the shortest emergence times were observed at the sowing depths of 2.0 and 4.0 cm. Of note, for the 30% of solar radiation condition, the time for emergence was longer when the seeds of *U. decumbens* were placed at depths of 0.5 and 12 cm (Table 2).

Within each sowing depth, different levels of shading decreased the time for the emergence of *U. decumbens* seedlings in sowing depths up to 2.0 cm. However, after sowing depths of 12.0 cm, the shortest time for the emergence of seedlings of *U. decumbens* was observed in the treatment under full sunlight, and a longer time for emergence was observed under 30% solar radiation. Further, there was no effect of solar radiation in sowing depths of 4.0 and 8.0 cm (Table 2).

The emergence percentages of *U. decumbens* ranged based on the treatments. The different sowing depths, solar radiation percentages, and interaction between these two factors were significant at P < 0.05. The arrangement of *U. decumbens* seeds between depths of 0.5 and 4.0 cm did not affect their emergence percentage within each studied solar radiation condition. It is noteworthy that, for the conditions of 100% and 30% of solar radiation, sowing depth of 8.0 cm did not affect the emergence percentage of Brachiaria grass (Table 2).

The different solar radiation conditions influenced the emergence percentages of *U. decumbens* seedlings at each evaluated sowing depth. However, at sowing depths greater than 2.0 cm, different levels of solar radiation intensity did not affect the emergence percentage of *U. decumbens* seedlings. When the seeds were placed at 0.5 cm depth, the emergence percentage was affected only under the condition of 30% solar radiation. For sowing depth of 1.0 cm, 50 and 30% shading reduced the percentage of *U. decumbens* plants' emergence compared to the highest luminosities (Table 2).

The different solar radiation intensities evaluated in isolation did not significantly affect the emergence speed index (ESI) of *U. decumbens seedlings* at P < 0.05. However, ESI values were influenced by sowing at different depths and the interaction of this factor with different solar radiation intensities (P < 0.05) (Table 3).

The highest ESI values were obtained at sowing depths between 1.0 and 4.0 cm, regardless of the solar radiation intensity, and at a sowing depth of 8.0 cm and solar radiation intensities of 100% and 30% (Table 3).

Table 2. Number of days to the emergence and the emergence percentage of *Urochloa decumbens* seedlings sown at different depths and submitted to different solar radiation intensities.

Sowing depth (cm)	*Number of days to the emergence*							
	% solar radiation							
	100		70		50		30	
0.5	6.25	Aa	5.50	Aab	5.50	Aab	5.25	ABb
1.0	6.00	ABa	5.00	ABb	5.50	Aab	4.75	BCb
2.0	5.25	ABCa	4.00	Bb	4.25	Bb	4.25	BCb
4.0	4.75	CDa	4.00	Ba	4.00	Ba	4.00	Ca
8.0	4.00	Da	4.75	ABa	4.75	ABa	4.75	BCa
12.0	5.00	BCDb	5.75	Aab	5.75	Aab	6.00	Aa
F_{light} (L)	3.00*							
$F_{sowing\ depth}$ (D)	26.07**							
F (L) x (D)	3.47**							
d.m.s. (L)	0.93							
d.m.s. (D)	1.03							
C. V. (%)	10.1							
Sowing depth (cm)	*Emergence percentage*							
	% of solar radiation							
	100		70		50		30	
0.5	61.61	Aab	61.61	Aab	75.00	Aa	52.01	Ab
1.0	75.00	Aab	85.49	Aa	51.78	ABc	62.05	Abc
2.0	74.55	Aa	80.35	Aa	70.98	Aa	65.62	Aa
4.0	70.31	Aa	62.50	Aa	59.60	ABa	59.60	Aa
8.0	59.15	Aa	37.14	Bab	40.85	BCab	46.45	ABab
12.0	32.81	Ba	24.11	Ba	24.11	Ca	24.11	Ba
F_{light} (L)	3.66*							
$F_{sowing\ depth}$ (D)	34.66**							
F (L) x (D)	2.17*							
d.m.s. (L)	22.22							
d.m.s. (D)	24.73							
C. V. (%)	21.2							

** Significant at 1% probability; * Significant at 5% probability. Means followed by the same uppercase letter in the column and lowercase letter in the line do not differ statistically from each other according to Tukey's test (p < 0.05).

Table 3. Emergency speed index (ESI) and the number of days to the flowering of *Urochloa decumbens* plants sown at different depths and submitted to different solar radiation intensities.

Sowing depth (cm)	*Emergence speed index*							
	% of solar radiation							
	100		70		50		30	
0.5	6.89	BCa	8.50	Ba	6.64	Ba	6.86	BCa
1.0	8.79	ABb	12.84	Aa	9.15	ABa	9.33	ABb
2.0	9.42	ABb	13.26	Aa	11.38	Aab	11.97	Aab
4.0	10.67	ABa	12.71	Aa	11.89	Aa	11.64	Aa
8.0	10.90	Aa	5.29	BCb	7.24	Bb	8.07	ABab
12.0	4.94	Ca	1.63	Ca	2.78	Ca	3.67	Ca
F_{light} (L)	0.56^{NS}							
$F_{sowing\ depth}$ (D)	47.07**							
F (L) x (D)	4.31**							
d.m.s. (L)	3.42							
d.m.s. (D)	3.81							
C. V. (%)	21.4							

Sowing depth (cm)	*Number of days to flowering*			
	% of solar radiation			
	100	70	50	30
0.5	76	147	147	110
1.0	76	147	147	110
2.0	76	147	147	110
4.0	76	147	147	110
8.0	76	147	147	110
12.0	76	147	147	110

NS, not significant; ** significant at 1% probability. Means followed by the same uppercase letter in the column and lowercase letter in the line do not differ statistically from each other according to Tukey's test ($p < 0.05$).

Evaluation of the average number of days to flowering of the *U. decumbens* revealed that under solar radiation intensities of 70% and 50%, the plants bloomed simultaneously, corresponding to 147 DAS regardless of the sowing depth. Under the 100% solar radiation, the plants bloomed 76 DAS, and for the 30% solar radiation, flowering was verified at 110 DAS. These data show a greater time needed for the flowering of *U. decumbens* plants under shading conditions, noting that 50% and 70% of solar radiation delayed the flowering process more than the lowest solar radiation intensity studied (30% of solar radiation) (Table 3).

Different solar radiation intensities affected the height and total dry matter accumulation during the flowering of *U. decumbens* plants, with no significant differences when the seeds were sown between depths of 0.5 and 12.0 cm, indicating that tested depths did not affect this parameter (Table 4).

The tallest plants of *U. decumbens* were observed under 100% and 70% solar radiation intensities, with a mean height of 109.90 and 114.59 cm, respectively, being superior to those obtained under 50% and 30% solar radiation intensities, with 96.93 and 102.97 cm in height, respectively (Table 4).

The plants of *U. decumbens* developed under 100% and 70% of solar radiation intensities had the highest accumulation of dry matter at flowering compared to those under conditions of lower solar radiation intensity (50% and 30% of solar radiation), and they were similar to each other (Table 4).

Cenchrus echinatus

The seedlings of *C. echinatus* emerged under all evaluated solar radiation intensities and sowing depths between 0.5 and 12 cm. Notably, the different solar radiation intensities and sowing depths affected the time in days for seedling emergence in isolation, and interaction between these factors was observed. The same was observed for ESI ($P < 0.05$) (Table 5).

The different sowing depths evaluated did not affect the emergence time of *C. echinatus* seedlings under 100%, 70%, and 50% of solar radiation intensities. However, only a sowing depth equal to or greater than 4.0 cm, under the highest level of shading (30% of solar radiation), promoted an increase in the emergence time of seedlings of this species (Table 5).

Table 4. Plant height and the total dry matter accumulation at the flowering of *Urochloa decumbens* plants sown at different depths and submitted to different solar radiation intensities.

Sowing depth (cm)	Plant height at flowering (cm)		Total dry matter accumulation (g)	
0.5	103.87		11.63	
1.0	104.67		14.14	
2.0	107.29		15.21	
4.0	106.27		15.60	
8.0	107.04		15.66	
12.0	107.46		14.07	
% of solar radiation				
100	109.90	A	15.74	AB
70	114.59	A	17.37	A
50	96.93	B	11.65	C
30	102.97	B	12.83	BC
F_{light} (L)	18.83**		8.46**	
$F_{sowing\ depth}$ (D)	0.47^{NS}		1.87^{NS}	
F (L) x (D)	0.96^{NS}		0.79^{NS}	
d.m.s. (L)	6.65		3.37	
d.m.s. (D)	9.07		4.59	
C. V. (%)	8.2		30.9	

** Significant at 1% probability; NS - Not significant. Means followed by the same uppercase letter in the column do not differ statistically from each other, according to Tukey's test (p<0.05).

The highest ESI values were verified when the seeds were placed between depths of 2.0 and 12.0 cm under 100% solar radiation; at depths of 0.5, 2.0, and 4.0 cm under the condition of 70% of solar radiation; depths between 1.0 and 8.0 cm under the condition of 50% of solar radiation; and depths between 0.5 to 8.0 cm under 30% of solar radiation (Table 5).

Analysis of the effect of different sowing depths in isolation in sowing at 0.5 cm depth revealed that the treatments under 70% and 30% of solar radiation exhibited the highest ESI of *C. echinatus* seedlings. At a sowing depth of 1.0 cm, besides the treatments with 70% and 30% of solar radiation, the condition of 50% of solar radiation also provided the highest ESI. For sowing depth of 2.0 cm, only the treatment with 70% solar radiation provided the highest ESI to *C. chinatus* seedlings. For sowing depth of 4.0 cm, the conditions of full sunlight, and 70% and 50% of the solar radiation provided the highest ESI. The ESI values of C. *echinatus* seedlings were not affected by different solar radiation intensities for sowing depths greater than 4.0 cm (Table 5).

Although the different levels of solar radiation and sowing depths affected the time (in days) for the emergence and ESI of *C. echinatus* seedlings (Table 5), the percentage of seedling emergence was affected only by the different sowing depths, with no interaction between the factors studied, at $P < 0.05$. Thus, it was observed that sowing depths greater than 4.0 cm negatively affected the emergence percentage of *C. echinatus* seedlings, with the lowest emergence percentage recorded when the seeds were placed 12 cm deep with a value of 26.74%, being 55.80% less than the highest percentage of emergence found in the present study, at a sowing depth of 2.0 cm (60.50%) (Table 6).

Plant height and total dry matter accumulation at flowering were affected only by the different solar radiation intensities. There were no significant contrasts when the species was sown between 0.5 and 12.0 cm deep. The largest *C. echinatus* plants were obtained when they developed under 30% solar radiation, with an average of 76.77 cm in height. However, highest accumulation of dry matter at the flowering stage of *C. echinatus* plants was obtained under full sunlight, with an average of 6.89 g of dry matter (Table 6).

The different luminous intensities also affected the number of days to flowering of *C. echinatus* plants, regardless of the sowing depth. The first floral inductions presented by the plants developed under 100% and 70% of solar radiation occurred at 63 and 64 DAS. The lower intensities of solar radiation increased the number of days to flowering of the *C. echinatus* plants under the conditions of 100% and 70% of solar radiation intensities. This period was 76 and 148 DAS for plants developed under 50% and 30% solar radiation intensities, respectively (Table 6).

Table 5. Number of days to the emergence and emergence speed index (ESI) of *Cenchrus echinatus* seedlings sown at different depths and submitted to different solar radiation intensities.

Sowing depth (cm)	*Number of days to emergence*							
	% of solar radiation							
	100		70		50		30	
0.5	6.50	Aa	5.75	Aa	5.50	Aa	6.75	ABCa
1.0	6.00	Ab	5.25	Ab	5.50	Ab	8.25	Aa
2.0	6.00	Aa	4.75	Ab	5.75	Ab	7.50	ABa
4.0	5.25	Aa	4.50	Aa	5.00	Aa	5.25	CDa
8.0	5.50	Aa	5.00	Aa	5.00	Aa	5.00	Da
12.0	5.25	Aa	5.25	Aa	5.50	Aa	6.25	BCDa
F_{light} (L)	14.33**							
$F_{sowing\ depth}$ (D)	7.17**							
F (L) x (D)	2.13*							
d.m.s. (L)	1.47							
d.m.s. (D)	1.64							
C. V. (%)	13.9							

Sowing depth (cm)	*Emergence speed index*							
	% of solar radiation							
	100		70		50		30	
0.5	2.85	Cb	8.38	ABCa	4.68	BCb	8.11	Aa
1.0	3.33	BCb	5.62	CDab	5.17	ABCab	6.69	Aa
2.0	6.46	ABb	10.93	Aa	7.69	ABb	6.51	ABb
4.0	7.24	Aab	9.02	ABa	8.05	Aab	5.79	ABb
8.0	5.94	ABCa	7.37	BCDa	7.29	ABa	5.77	ABa
12.0	4.17	ABCa	4.19	Da	3.98	Ca	3.31	Ba
F_{light} (L)	9.958**							
$F_{sowing\ depth}$ (D)	13.973**							
F (L) x (D)	3.298**							
d.m.s. (L)	2.93							
d.m.s. (D)	3.26							
C. V. (%)	25.4							

** Significant at 1% probability; * Significant at 5% probability; NS - Not significant. Means followed by the same uppercase letter in the column and lowercase letter in the line do not differ statistically from each other according to Tukey's test ($p < 0.05$).

4. Discussion

In general, *U. decumbens* and *C. echinatus* seedlings emerged at all sowing depths even when subjected to different solar radiation intensities. However, it is important to note that the emergence of seedlings of both species was reduced significantly when the seeds were placed at depths of 8.0 and 12.0 cm in the soil profile. Also, when the seeds of the *U. decumbens* species were sown at depths of 0.5 and 1.0 cm, there was a reduction in the emergence process as the solar radiation intensities decreased, mainly under 50% and 30% of solar radiation (Tables 2 and 6). According to Carvalho and Nakagawa (2000), this is a germinative and adaptive characteristic of some weed species that can occur because sunlight does not act at depths greater than 2.5 cm in the soil profile. In addition, the perception of light quality occurs through phytochromes, which correspond to a class of photoreceptor pigments. The mode of action of these pigments depends on the type of incident radiation, as light with a high red/extreme red (V/VE) ratio induces the active form (FVe), promoting the germination of photosensitive seeds. In contrast, the phytochrome becomes inactive (FV) under light with a low V/VE ratio, inhibiting germination (Vieira et al. 2018).

Thus, it is evident that the percentage of emergence reductions due to the increase in sowing depth observed for both species studied (Tables 2 and 6) may have occurred because of the decrease in solar radiation or other factors. This reduced emergence may be due to the non-incidence of solar radiation imposed by the natural soil barrier on seeds located at greater depths; insufficient seed reserve material of both species to break the physical barrier imposed by the soil (Pacheco et al. 2010; Santos et al. 2015); secondary or induced dormancy, which refers to the state of dormancy induction under environmental conditions not favorable for germination, in non-dormant seeds or in those where primary dormancy has been overcome (Vivian et al. 2008); or even because of the thermal amplitude observed at the different sowing depths, as shown in Table 1.

Table 6. Seedling emergence percentage, plant height, total dry matter accumulation during flowering, and the number of days to flowering of *Cenchrus echinatus* plants sown at different depths and submitted to different solar radiation intensities.

Sowing depth (cm)	*Emergence percentage*	*Plant height (cm)*	*Total dry matter accumulation (g)*
0.5	57.12 A	55.98	4.56
1.0	58.04 A	57.04	4.82
2.0	60.50 A	55.80	3.67
4.0	56.04 A	56.91	4.48
8.0	42.16 B	55.96	5.21
12.0	26.74 C	57.85	5.55
% of solar radiation			
100	45.97	57.07 B	6.89 A
70	54.54	54.71 B	2.92 B
50	52.05	37.81 C	2.05 B
30	47.85	76.77 A	2.19 B
F_{light} (L)	2.38^{NS}	99.103**	38.089**
$F_{sowing\ depth}$ (D)	18.09**	0.172^{NS}	1.545^{NS}
F (L) x (D)	1.27^{NS}	0.985^{NS}	1.523^{NS}
d.m.s. (L)	9.39	5.96	1.59
d.m.s. (D)	12.80	8.13	2.18
C. V. (%)	24.7	13.9	44.6

Sowing depth (cm)	*Number of days t flowering*			
	% of solar radiation			
	100	70	50	30
0.5	63	64	76	148
1.0	63	64	76	148
2.0	63	64	76	148
4.0	63	64	76	148
8.0	63	64	76	148
12.0	63	64	76	148

NS: Not significant; ** Significant at 1% probability. Means followed by the same uppercase letter in the column and lowercase letter in the line do not differ statistically from each other according to Tukey's test (p < 0.05).

Therefore, it is important to highlight that the development of some weed species can be compromised by soil preparation processes that promote the incorporation of seeds at greater depths (Marques et al. 2019). This leads to an increase in the mechanical resistance imposed by the soil, in addition to reducing the temperature and availability of O_2 and increasing the accumulation of CO_2, forming fermented compounds during the respiratory process (Taiz and Zeiger, 2013), which can affect the germination process (Zuffo et al. 2014). Furthermore, reductions in soil temperature can regulate the meristematic activity, which directly interferes with plant growth and development (Marchi et al. 2020), explaining the trends observed in *U. decumbens* and *C. echinatus* in our study.

Therefore, the emergence of *U. decumbens* seedlings was influenced by sunlight. In contrast, the emergence of *C. echinatus* occurred indifferently to the presence of solar radiation (Tables 2, 3, 5, and 6). Klein and Felippe (1991) affirmed that *C. echinatus* seeds could be classified as neutral photoblastic. Thus, the presence or absence of light at the start of the germination process is irrelevant, corroborating the results of this study. However, according to the Rules for Seed Analysis (RSA) (Brasil, 2009), to increase the germination and emergence of species of the genus *Cenchrus,* it is necessary to provide light for 8–16 h/day, which is contrary to the results observed in our study for *C. echinatus*.

Lima and Cardoso (1996) reported that *U. decumbens* seeds are indifferent to the presence of light, contradicting the data observed in our study for this species. Notably, as mentioned by RSA (Brasil, 2009), the supply of light for 8–16 h/day is beneficial for conducting germination and emergence tests of the *U. decumbens* species, corroborating the results found in this study wherein the best emergence values were found in the presence of higher intensities of solar radiation. Therefore, the importance of studies on weed species' behavior at different sowing depths and subjected to different light intensities is emphasized, owing to the lack of studies on the subject. Even the information related to such behavior can be controversial.

The number of days required for *U. decumbens* and *C. echinatus* seedling emergence varied (Tables 2 and 5). For the species *U. decumbens*, the highest number of days for seedling emergence was observed for the most superficial layers of the soil profile (0.5 and 1.0 cm depth) and in the condition of full sunlight. However, this behavior was also observed in C. *echinatus* species when the seeds were sown at depths of 0.5, 1.0, and 2.0 cm under 30% solar radiation. The similarity in the results could be due to the higher soil temperatures recorded at these depths (Table 1).

Most weed species require a certain amount of light for germination (Radosevich et al. 1997). However, it is important to note that light, air, and soil temperatures act as sensors for positioning the seeds in the soil profile and shading conditions. For example, the seeds of some positive photoblastic species located at great depths, besides not receiving light, would not be able to respond quickly to changes in soil temperature, as thermal variations are reduced as they approach the profile of the soil, as can be seen in Table 1. Likewise, seeds of some species positioned on the soil surface, under shading conditions, do not respond as quickly to temperature as they would in a darker environment (Guersa et al. 1992). Thus, this behavioral difference in the species studied may be related to adaptive issues concerning the environment in which they are found (Ikeda et al. 2013).

The plants of *U. decumbens* developed under 50% and 30% solar radiation conditions presented the lowest values of height and dry matter accumulation at flowering compared to plants developed under conditions of lesser shade (Table 4), indicating that greater growth and development are recorded in this species subjected to higher levels of solar radiation, regardless of the seed depth in the soil profile.

The highest level of shading (30% of solar radiation) yielded the highest plant height values and one of the lowest dry matter accumulations at flowering of the *C. echinatus* species (Table 6), indicating that the species was growing in a disorderly manner in search of light, a situation that caused etiolation in an attempt to avoid a high level of shading. It is noteworthy that as the height of some monocotyledonous plants increased in search of light, internode length increased, and the plant produced more stems, increasing the stem proportion and decreasing the leaf/stem ratio, resulting in less dry matter accumulation (Baroni et al. 2010).

An important ecological response was recorded regarding the flowering time in both species (Tables 3 and 6). The two species were influenced only by incident solar radiation, but in different ways; they were similar only when they were subjected to full sun, requiring the shortest time to start flowering. For *U. decumbens*, the application of 70% and 50% of solar intensity led the plants to respond similarly, doubling the time needed to start flowering compared to plants kept under full sunlight. However, when the least amount of light was applied (30% of solar radiation), this time was reduced by 37 days compared to the two intermediate solar radiation intensities, which is possibly a survival strategy for the species.

As for the plants of *C. echinatus*, it was observed that, as the solar radiation on the plants was reduced, the time to the flowering increased, but were highly similar when solar radiation was 100% and 70%. It is noteworthy that the plants needed double the time for flowering under 30% solar radiation compared to the plants placed under full sunlight, which is a strategic response very different from that observed for the species *U. decumbens* (Tables 3 and 6).

Notably, solar radiation is an important environmental component that provides light energy for photosynthesis and environmental signals for a series of physiological processes in plants that can differ depending on the plant species (Marchi et al. 2020). The reduction in light intensity and, consequently, temperature culminates in a decrease in the accumulation of degree-days by the plant, which directly influences plant phenology and morphogenesis, especially for grasses, whose phenology is strongly dependent on the thermal sum. In this case, the plants tend to stay longer in vegetative stages and bloom later or unevenly under different levels of shading (Soares et al. 2009). For weeds, this can also occur as an adaptive response of different species to environmental conditions in an attempt to ensure that, in the future, there are ideal conditions for the beginning of reproductive stages, ensuring the propagation and survival of future generations.

5. Conclusions

Seedlings of *U. decumbens* and *C. echinatus* emerged under all conditions of applied solar radiation and sowing depths of upto 12.0 cm. Sowing depths between 2.0 and 4.0 cm favored the emergence of *U. decumbens* and *C. echinatus* seedlings. The sowing of *U. decumbens* and *C. echinatus* at a depth of 12 cm resulted in the lowest emergence percentage and ESI values, regardless of the percentage of solar radiation. *U. decumbens* plants grown under conditions of greater shading showed the lowest values of height and accumulation of dry matter at flowering compared to plants grown under conditions of less shade. High levels of shading provided the highest plant height values and the lowest accumulation of dry matter at the flowering stage of *C. echinatus*, indicating an effect of etiolation of the plants. In addition, only the increase in shading increased the time for the beginning of flowering of both species compared to full sunlight.

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