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Sowing depth and light intensity on the emergence and development of weeds[1]

Profundidade de semeadura e intensidade luminosa na emergência e desenvolvimento de espécies de plantas daninhas

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ABSTRACT - Weeds are one of the ecological factors that directly affect agricultural costs. Thus, understanding the emergence and development of these species is essential for the decision-making on weed control strategies. This study aims to evaluate the effect of different sowing depths and luminous intensities under field conditions on the emergence and development of the *Acanthospermum australe* (Loefl.) Kuntze and *Ipomoea grandifolia* (Dammer) O'Donell. Each species constituted one experiment, and the completely randomized design with four repetitions was adopted. 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 luminous intensities (100%, 70%, 50%, and 30% sunlight) obtained using shade cloths. The emergence of seedlings was evaluated daily to obtain the emergence and the emergence speed index. Plant height(length), the period until flower induction, and the dry matter of plants during flowering were also analyzed. *A. australe* and *I. grandifolia* emerge under the luminous intensities of 100, 70, 50, and 30% of solar radiation and in sowings depths up to 12.0 cm. Nevertheless, *A. australe* is the only one affected by luminous intensity, sowing depth, and the interaction between both factors in all the analyzes conducted. Luminous intensity reduction leads to lower development of *I. grandifolia*.

Key words: *Acanthospermum australe*. *Ipomoea grandifolia*. Shading. Luminosity. Solar radiation.

RESUMO - As plantas daninhas são um dos fatores ecológicos que afetam diretamente no custo da produção agrícola. Assim, compreender os aspectos de emergência e desenvolvimento dessas espécies é essencial na tomada de decisão para estratégias de seu manejo. Objetivou-se avaliar, em condições de campo, o efeito de diferentes profundidades de semeadura e de diversas intensidades luminosas na emergência e no desenvolvimento das plantas daninhas *Acanthospermum australe* (Loefl.) Kuntze e *Ipomoea grandifolia* (Dammer) O'Donell. 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, seis profundidades de semeadura (0,5; 1,0; 2,0; 4,0; 8,0 e 12,0 cm) associadas a quatro intensidades luminosas (100%, 70%, 50% e 30% da luz solar) obtidas por meio de sombrites. Avaliou-se diariamente a emergência das plântulas para obtenção da emergência e do índice de velocidade de emergência. A altura/comprimento das plantas, o tempo até a indução floral e a matéria seca das plantas no florescimento também foram avaliadas. As plantas de *A. australe* e *I. grandifolia* emergem sob intensidades luminosas de 100, 70, 50 e 30% de radiação solar e, em semeaduras de até 12,0 cm de profundidade. No entanto, a espécie *A. australe* é a única afetada pela intensidade luminosa, profundidade de semeadura e pela interação destes dois fatores em todas as avaliações realizadas. A redução das intensidades luminosas acarreta menor desenvolvimento de plantas de *I. grandifolia*.

Palavras-chave: *Acanthospermum australe*. *Ipomoea grandifolia*. Sombreamento. Luminosidade. Radiação solar.

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INTRODUCTION

Weeds are one of the ecological factors that permanently affect the agricultural economy. Besides provoking physiological damages to crops, they cause expenses for their control that raise production costs (MONQUERO *et al*., 2015; SANTOS *et al*., 2019). Moreover, weed species, such as Paraguayan starburr [*Acanthospermum australe* (Loefl.) Kuntze] and little bell [*Ipomoea grandifolia* (Dammer) O'Donell], difficult the harvest of large crops, elevate the humidity of grains, and drying costs, besides favoring the fermentation and the incidence of pests during storage (BARROSO *et al*., 2019; MALLMANN *et al*., 2018). These species have high seed production, provoking long infestations even with chemical control measures (GUGLIERI-CAPORAL *et al*., 2011). Hence, alternative methods for these species control under field conditions are required.

One of the limiting factors highlighted to implement an efficient weed control program is the lack of specific knowledge about the biology and ecology of the main species (XIONG *et al*., 2018). Therefore, studies have been developed to understand better germination, emergence, growth, and development of weeds under adverse conditions, aiming to control them more efficiently (MARCHI *et al*., 2019, 2020; MARQUES *et al*., 2019).

Generally, seed germination is regulated by the interaction between environmental conditions and their state of physiological aptitude. Thus, each plant species requires a set of environmental resources for the germination of seeds, such as water availability, light, temperature, and depth (SAHA *et al*., 2020; ZUFFO *et al*., 2014). Therefore, the knowledge about the emergence capacity of seedlings located at different depths in the soil may aid weed control through the adoption of methods that reduce or impede their occurrence (MAQSOOD *et al*., 2020; ORZARI *et al*., 2013). Cultural weed control is one method that uses soil preparation equipment to incorporate seeds in depths unfavorable for the emergence of seedlings (MACIEL, 2014). Also, due to a slight delay in emergence, seedlings of weeds may be under shade and present slower initial growth (MONQUERO *et al*., 2012).

Besides sowing depth in soil affects the germination, emergence, and development of plants, light is also necessary for the germination of a high number of plant species (KLIMEŠ *et al*., 2021; LESSA *et al*., 2013; MARQUES *et al*., 2012; SZYMBORSKA-SANDHU *et al*., 2020). Light controls the initial germination of photosensitive seeds, and the phytochromes are responsible for the perception and transduction of the luminous signal. This chromoprotein has two primary forms: an inactive form, which is active while absorbing the red light, inducing the production of Ga_3 and triggering germination; and an active form, which is inactivated when submitted to far-red light, consequently producing abscisic acid (ABA), and inducing dormancy on seeds (SILVA *et al*., 2019).

The luminous intensity and the sowing depth in the soil profile provide the biological basis for the knowledge about weed propagation and establishment. Such studies are helpful for modeling potential weed invasion, besides giving aid to develop and adopt suitable control practices, reducing and impeding the occurrence of undesirable species on agricultural areas.

Thus, this study aims to evaluate the effect of different sowing depths and luminous intensities under field conditions on the emergence and development of *A. australe* and *I. grandifolia*.

MATERIAL AND METHODS

The study was conducted under field conditions in an area of the Faculdade de Ciências Agronômicas/ UNESP, campus of Botucatu/SP (22°07'56'' S, 74°66'84'' WGr., and altitude of 762 m), during the period from November 2017 to June 2018. The soil of the experimental area is Neossolo Litólico (SERGIO *et al*., 2005) with clayey texture. Soil chemical and particle-size characteristics are shown in Table 1.

Table 1 – Soil chemical analysis of fertility and particle-size of the experimental area

pH $CaCl_2$	OM	P resin	K	Ca	Mg	H+Al	SB	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 (g kg^{-1})									
Clay	Silt	Coarse sand	Thin sand	Total Sand					
449	163	100	288	388					
Classification: Clayey texture									

OM - Organic matter; SB - Sum of bases; CEC – Cation exchange capacity; BS – Base saturation

Each weed species (*A. australe* and *I. grandifolia*) constituted an experiment, and the completely randomized design was adopted 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 luminous intensities (100%, 70%, 50%, and 30% sunlight) obtained through specific shade cloths for agricultural purposes.

Table 2 presents the average sun exposure and soil temperature data on mornings and afternoons collected in the experimental area. The photosynthetically active radiation (PAR) was measured as the density of the flow of photosynthetically active photons (mmol s^{-1} m^{-2}) (DFFFA) at soil height. It was quantified by a quantum meter (Model LI-190 Quantum Sensor, LI-COR, USA) attached to a porometer (Model LI-1600 LICOR Steady State Porometer, LI-COR, USA).

The experimental plots were implemented in flower beds with a height of 1.0 m width and a 2.0 m length, raised with a mechanical bed former (with a rotary hoe). The productive area was standardized in the center of the plots, discounting 25 cm from each extremity. Both seeds of species were acquired from the manufacturer Agro Cosmos, abstaining from methods to overcome dormancy.

Based on the information provided by the company, four repetitions with 25 seeds of each species were sown in the line for every treatment with a distance of 25 cm between rows in each experimental plot. The shade cloths were adjusted at 1.5 m height from the soil to prevent barriers to plant growth. Sowing was conducted following the same pattern of depth arrangement, from the smaller to the larger, for better visualization and evaluation of plants.

Sowing was conducted manually. The sowing depths were obtained through a wood structure with the exact size of each depth. Thus, a uniform sowing depth was guaranteed in the whole extension of the groove. The mains beds were prepared in the North-South direction, and the sowing furrows were made in the East-West direction to prevent possible shading.

The different luminous intensities were obtained with agricultural cloths of black polyethylene (shade cloth), permitting the passage of the luminous intensities of 70, 50, and 30%. Shade cloths were installed on the sowing beds, covering all the surfaces and borders at 80 cm height. This fact permitted evaluations within the structure without letting sunlight enter during the assessments.

The structure was set with the possibility of bilateral opening, keeping the superior and one of the lateral coverings untouched. The choice of the side to be opened ranged according to the solar position at the evaluation moment, guaranteeing plants did not receive solar exposure at any moment during the experimental period.

The emergence of *A. australe* and *I. grandifolia* seedlings was monitored for 26 days after sowing, counting, and removing those that emerged to obtain the emergence percentage and emergence speed index (ESI). The index was measured using the equation proposed by Maguire (1962): $ESI = G1/N1 + G2/N2 + ... + Gn/Nn$; where: ESI = emergence speed index; G1...n = number of normal seedlings emerged; and N1...n = number of days between the sowing and the first, second... umpteenth evaluation. The counts were performed daily in each experimental plot based on the day the first plant emerged.

Three plants in every plot were reserved for each depth. This procedure was conducted to evaluate plant height (length) and the period until the flower induction, besides measuring total and daily dry matter accumulation of plants during flowering. Irrigations occurred three times a week through an automatic sprinkler system with 10 mm water distribution. The results were submitted to the analysis of variance by F-test, and the means were compared by the Tukey test at 5% probability.

Table 2 - Sun exposure and soil temperature in the mornings (09:30) and afternoons (15:30) collected at the experimental area

Hour	Intensity sun	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	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

RESULTS AND DISCUSSION

Acanthospermum australe

The seedlings of *A. australe* emerged in all sowing depths even when submitted to different solar radiation intensities. Both sowing depth and luminous intensity affected the num0ber of days until the emergence of seedlings. There was also an interaction between ($p < 0.05$). In the conditions of 100, 70, and 30% solar radiation, the periods until the emergence were lower in sowings of up to 8.0 cm depth. Nevertheless, in the condition of 50% solar radiation, the shortest periods until emergence were verified in sowing depths of up to 4.0 cm (Table 3).

Within each sowing depth, the luminous intensities affected the period until the emergence of *A. australe*. Nevertheless, in sowings of up to 4.0 cm depth, the lower luminous intensity provided the shortest periods until the emergence of seedlings (Table 3).

Table 3 - Days until the emergence and the seedlings emergence percentage of Acanthospermum australe sown in different depths and submitted to different solar radiation intensities

Sowing depth (cm)	Days until the emergence			
	Solar radiation (%)			
	100	70	50	30
0.5	12.00 Ba	12.00 Ba	11.50 ABCa	9.50 Cb
1.0	11.75 Ba	10.50 Bab	10.75 BCab	9.25 Cb
2.0	11.75 Ba	10.50 Bab	10.00 Cab	9.50 Cb
4.0	11.75 Ba	10.25 Bab	10.00 Cab	9.50 Cb
8.0	11.50 Ba	12.00 Ba	12.25 ABa	12.00 Ba
12.0	16.00 Ab	14.25 Abc	13.00 Ac	20.50 Aa
F RADIATION (R)	5.769**			
F DEPTH (D)	67.477**			
F (R) x (D)	10.077**			
LSD (R)	1.94			
LSD (D)	2.15			
C. V. (%)	8.9			
	Seedlings emergence (%)			
Sowing depth (cm)	Solar radiation (%)			
	100	70	50	30
0.5	21.91 ABb	50.13 Aa	48.38 Aa	56.99 Aa
1.0	37.09 Ab	68.68 Aa	41.67 Ab	58.06 Aab
2.0	23.12 ABb	67.87 Aa	56.72 Aa	55.51 Aa
4.0	32.53 Ab	52.42 Aab	66.94 Aa	32.26 ABb
8.0	17.07 ABa	0.94 Ba	5.78 Ba	8.20 BCa
12.0	0.75 Ba	1.75 Ba	0.50 Ba	0.75 Ca
F RADIATION (R)	9.706**			
F DEPTH (D)	53.244*			
F (R) x (D)	3.951**			
LSD (R)	23.27			
LSD (D)	25.91			
C. V. (%)	37.2			

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

The different luminous intensities did not affect the period until the emergence of *A. australe* seedlings sown up to 8.0 cm depth. However, deepest sowings (12.0 cm) provided the shortest periods for the emergence of *A. australe* seedlings under 70 and 50% solar radiation. The shortest period (20.5 days) for emergence occurred under 30% solar radiation (Table 3).

The emergence of *A. australe* ranged according to the treatment studied. In different sowing depths, solar radiation percentages and the interaction between these factors were significant at $p < 0.05$ (Table 3). The arrangement of *A. australe* seeds between 0.5 and 4.0 cm depth in the soil profile did not affect their emergence percentages with 70, 50, and 30% solar radiation conditions. Under the condition of 100% solar radiation, besides the same depths, the seeds at 8.0 cm depth did not affect the emergence (Table 3).

It is highlighted that the reductions in the seedlings' emergence percentage due to the sowing depth increase observed in this study may have occurred by the lack of light incidence caused by the natural soil barrier or the lack of seeds' material reserves to break such barrier (PACHECO *et al*., 2010; SANTOS *et al*., 2015; SOUZA *et al*., 2011). Moreover, the secondary or induced dormancy process, which refers to the dormancy inductance stage under environmental conditions unfavorable to germination (CHEN *et al*., 2020), and the thermal amplitude observed in different sowing depths (Table 2) may also have influenced directly in the reduction of seedlings emergence of the species *A. australe*.

Due to such reduction in the emergence of *A. australe* seedlings observed in our research, it is worth mentioning that the use of soil tillage processes that promote the incorporation of seeds more deeply in the soil profile may compromise the propagation of this weed species (MARQUES *et al*., 2019).

The different solar radiation levels influenced the emergence of *A. australe* seedlings within each sowing depth evaluated. Only the treatment with 70% solar radiation provided the highest emergence percentages in all sowing depths considered. There was a significant contrast between 70 and 50% solar radiation conditions with the sowing depths under 1.0 cm. About the comparison between 70% and 30% luminosity conditions, there was a significant difference only when the seeds were under 4.0 cm depth. In sowings of 8.0 or 12.0 cm depth, the luminous intensity did not interfere in the emergence of *A. australe* seedlings (Table 3). Thus, seedlings of this species can emerge on superficial layers of the soil profile and under conditions of reduced luminosity.

The 70, 50, and 30% solar radiation conditions provided the highest emergence speed index for *A. australe* seedlings, especially in sowings up to 4.0 cm depth. Therefore, the emergence speed of *A. australe* seedlings, generally, was only affected by the higher depths in the soil profile and under total solar exposure (Table 4). Such data reinforce the better adaptation of this species under shade and better emergence in the superficial layers of the soil.

In evaluating the average requirement of days for the flowering of *A. australe*, it was verified that the plants flowered simultaneously in the two conditions of higher luminous intensity, which corresponded to 62 days after sowing. For the condition of 50% shade, the plants flowered 66 days after sowing, and for 30% luminous intensity, the flowering occurred 76 days after sowing (Table 4). Such data demonstrate a slight difference regarding the number of days required for the flowering of *A. australe* plants under shading reduction conditions.

The 100% solar radiation condition provided the best conditions for the development of *A. australe* since they presented the highest heights in all sowing depths evaluated (Table 5).

Table 4 - Emergence speed index (ESI) and days until the flowering of *Acanthospermum australe* plants sown in different depths and submitted to different solar radiation intensities

	ESI			
Sowing Depth (cm)	Solar radiation (%)			
	100	70	50	30
0.5	3.57 ABb	8.64 Aa	8.45 Aa	9.49 Aa
1.0	6.40 Aa	9.07 Aa	5.64 ABa	9.12 Aa
2.0	3.80 ABb	11.55 Aa	9.88 Aa	8.40 Aa
4.0	5.55 Aa	8.95 Aa	8.57 Aa	5.58 Aa
8.0	2.70 ABa	0.10 Ba	0.95 BCa	0.74 Ba
12.0	0.17 Ba	0.12 Ba	0.09 Ca	0.03 Ba

Continuation table 4

F RADIATION (R)	6.035**			
F DEPTH (D)	41.495**			
F (R) x (D)	2.806**			
LSD (R)	4.25			
LSD (D)	4.73			
C. V. (%)	32.7			
Days until flowering				
Sowing Depth (cm)	Solar radiation (%)			
	100	70	50	30
0.5	62	62	66	76
1.0	62	62	66	76
2.0	62	62	66	76
4.0	62	62	66	76
8.0	62	62	66	76
12.0	62	62	66	76

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

In the higher conditions of luminous intensity (100% and 70% solar radiation), the height in which the *A. australe* plants flowered was not influenced by the depth of seeds in the soil profile. With the solar radiation reduction, the size of plants during flowering was reduced only by the disposition of seeds at 12.0 cm depth for 50% solar radiation and 8.0 and 12.0 cm depth for 30% solar radiation (Table 5).

The condition of 100% solar radiation also provided higher results of total dry matter accumulation. Thus, it can be inferred that *A. australe* plants emerge more and faster under shade conditions (Tables 3 and 4). However, they develop better under total solar exposure (Table 5).

The total dry matter accumulation per *A. australe* plant during flowering was influenced by the sowing depth, the different solar radiation percentages, and the interaction between both factors. The higher mean of dry matter accumulation was obtained with the interaction between the disposition of seeds at 2.0 cm depth and 100% solar radiation (Table 5).

The higher total dry matter accumulation by the *A. australe* plants under 70, 50, and 30% solar radiation conditions were obtained when the seeds were at 12.0, 2.0, and between 1.0 and 4.0 cm depth, respectively (Table 5). Such results demonstrate no response uniformity regarding dry matter accumulation by these species related to sowing depths, but only regarding the availability of sunlight during their development.

Comparing the total dry matter accumulation per *A. autrale* plant (Table 5), the daily dry matter accumulation was higher at 100% solar radiation than other luminous intensities. Moreover, the oscillations verified for the treatments with shading also occurred for this variable (Table 6).

Ipomoea grandifolia

Seedling of *I. grandifolia* emerged in all luminous conditions evaluated and in sowings between 0.5 and 12 cm depth. Nevertheless, it is highlighted that different luminosity levels and sowing depths affected the number of days for emergence, as no interaction was observed between both factors (Table 7).

When *I. grandifolia* seeds were at the depths of 0.5 and 1.0 cm, a considerable period for the seedling emergence of this weed was required (Table 7). The percentage of solar radiation also affected the number of days until the emergence of *I. grandifolia* seedlings, with a higher period for the condition of 100% solar radiation. Shading, regardless of the percentage of sunlight blocked, reduced the period between the sowing and the emergence of seedlings by approximately one day (Table 7).

Therefore, for superficial layers of the soil profile with total sun exposure, a higher period was necessary for the emergence of seedlings. It is important to emphasize that light is required to germinate many weed species (ORZARI *et al*., 2013). Thus, some species have seeds that germinate only under quick sun exposition and others that

Table 5 - Height and total dry matter accumulation during the flowering of *Acanthospermum australe* plants sown in different depths and submitted to different solar radiation intensities

Height (cm)				
Sowing Depth (cm)	Solar radiation (%)			
	100	70	50	30
0.5	28.83 Aa	19.16 Ab	12.00 ABb	15.44 ABb
1.0	32.42 Aa	18.50 Ab	19.67 Ab	20.77 Ab
2.0	31.08 Aa	16.67 Ab	19.33 Ab	15.11 ABb
4.0	28.00 Aa	18.25 Ab	14.83 ABb	16.00 ABb
8.0	28.16 Aa	14.62 Ab	13.08 ABb	7.83 BCb
12.0	26.75 Aa	14.50 Ab	6.12 Bbc	3.50 Cc
F RADIATION (R)	60.179**			
F DEPTH (D)	11.468**			
F (R) x (D)	1.912*			
LSD (R)	8.95			
LSD (D)	9.96			
C. V. (%)	26.6			
Total dry matter accumulation (g plant^{-1})				
Sowing Depth (cm)	Solar radiation (%)			
	100	70	50	30
0.5	2.29 Ca	0.80 Bb	0.29 Cd	0.41 Cc
1.0	2.45 Ba	0.71 Bc	0.52 Bd	1.19 Ab
2.0	2.72 Aa	0.77 Bc	0.83 Ac	1.29 Ab
4.0	2.14 Da	0.81 Bc	0.36 Cd	1.23 Ab
8.0	2.09 Da	0.42 Cc	0.49 Bc	0.89 Bb
12.0	1.64 Ea	1.01 Ab	0.16 Dc	0.04 Dd
F RADIATION (R)	6486.894**			
F DEPTH (D)	434.186**			
F (R) x (D)	143.148**			
LSD (R)	0.09			
LSD (D)	0.10			
C. V. (%)	4.2			

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

Table 6 - Daily dry matter accumulation (g) in *Acanthospermum australe* plants sown in different depths and submitted to different solar radiation intensities

Sowing depth (cm)	Solar radiation (%)			
	100	70	50	30
0.5	0.0370 BCa	0.0130 Bb	0.0045 CDc	0.0055 Cc
1.0	0.0395 Ba	0.0112 Bc	0.0085 Bc	0.0157 Ab
2.0	0.0437 Aa	0.0125 Bc	0.0130 Ac	0.0170 Ab
4.0	0.0347 CDa	0.0130 Bc	0.0060 BCd	0.0160 Ab
8.0	0.0337 Da	0.0070 Cc	0.0080 Bc	0.0115 Bb
12.0	0.0260 Ea	0.0165 Ab	0.0025 Dc	0.0005 Dc

Continuation table 6

F RADIATION (R)	1829.473**
F DEPTH (D)	97.539**
F (R) x (D)	31.956**
LSD (R)	0.0028
LSD (D)	0.0031
C. V. (%)	8.4

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

Table 7 - Days until the emergence and emergence percentage of *Ipomoea grandifolia* seedlings sown in different depths and submitted to different solar radiation intensities

Variable	Period until the emergence (days)	Emergence (%)
	Sowing depth (cm)	
0.5	6.56 A	41.29
1.0	6.12 AB	37.36
2.0	5.44 BC	49.86
4.0	4.25 D	49.86
8.0	4.81 CD	47.76
12.0	5.50 BC	26.83
	Solar radiation (%)	
100	6.04 A	49.72
70	5.21 B	32.30
50	5.37 B	37.23
30	5.17 B	49.46
F RADIATION (R)	6.584**	2.004^{NS}
F DEPTH (D)	18.871**	1.397^{NS}
F (R) x (D)	1.326^{NS}	0.568^{NS}
LSD (R)	0.59	23.20
LSD (D)	0.80	31.63
C. V. (%)	14.2	72.5

** Significant at 1% de probability; ns Not Significant. Means followed by the same uppercase letter in the column do not differ statistically from each other by Tukey's test ($p < 0.05$)

begin this process after a long exposure period. Moreover, there are seeds whose germination occurs only in the dark and those indifferent to light (GUIMARÃES *et al*., 2018).

It is worth mentioning that for the variable percentage of the emergence of *I. grandifolia* seedlings, no significant contrasts were verified at $p < 0.05$ for the factors luminous intensity and sowing depth, isolated or with interaction (Table 7). Nevertheless, Labonia *et al*. (2009) reported that seeds of this species presented higher emergence when on the soil surface due to the higher light availability on such conditions. Such a result differs from our study as we found percentages of *I. grandifolia* emergence similar in all evaluated conditions.

It is highlighted that many weed species germinate only when in the superficial layers of the soil because they need luminous stimulus to begin this process (MARQUES *et al*., 2019). On the other hand, some species do not need solar radiation to start germinating, being able to emerge in the deepest layers, which is supported by our results for the species *I. grandifolia*, which did not present light availability for the process of seedling emergence.

The only factor that affected the emergence speed index of *I. grandifolia* was sowing depth, providing the higher ESI observed when the seeds were at a depth of 4.0 cm, with significant contrast only for the sowing under 12 cm from the soil surface. The different luminous intensities did not affect the emergence speed index of *I. grandifolia* seedlings, and there were no interactions between the factors (Table 8).

The different luminous intensities evaluated affected the period required for the flowering of *I. grandifolia* plants. The first flower inductions presented by plants developing under total solar exposure occurred 45 DAS and for the condition of 30% solar radiation at 145 DAS. Such results reveal how long can be the reproductive cycle of *I. grandifolia* under shade conditions. Although they require prolonged periods, *I. grandifolia* plants usually flower until 30% luminosity (Table 8).

Solar radiation is an essential environmental component that, besides providing luminous energy for photosynthesis, also offers environmental signs for a series of physiological processes on plants that can differ depending on the species (MARCHI *et al*., 2020). The reduction of luminous intensity and, consequently, of temperature culminates in reducing the accumulation of

Table 8 - Emergence speed index (ESI) and days until the flowering of *Ipomoea grandifolia* plants sown under different depths and submitted to different solar radiation intensities

ESI	
Sowing depth (cm)	
0.5	5.07 AB
1.0	4.66 AB
2.0	6.46 AB
4.0	8.37 A
8.0	7.66 AB
12.0	3.25 B
Solar radiation (%)	
100	7.07
70	4.53
50	5.02
30	6.89
F RADIATION (R)	1.691^{NS}
F DEPTH (D)	2.421*
F (R) x (D)	0.321^{NS}
LSD (R)	3.67
LSD (D)	5.03
C. V. (%)	82.6

Flowering (days)				
Sowing depth (cm)	Solar radiation (%)			
	100	70	50	30
0.5	45	111	111	145
1.0	45	111	111	145
2.0	45	111	111	145
4.0	45	111	111	145
8.0	45	111	111	145
12.0	45	111	111	145

* Significant at 5% probability; ns - No significance. Means followed by the same uppercase letter in the column do not differ statistically from each other by Tukey's test ($p < 0.05$)

grade-days by the plant, which directly influences plant phenology and morphogenesis (KLIMEŠ *et al*., 2021). In this case, the plants tend to remain longer in vegetative stages and flower later or unevenly, depending on the different shading levels (SZYMBORSKA-SANDHU *et al*., 2020). Regarding weeds, this can occur as an adaptative response of different species to the environmental conditions to guarantee ideal conditions in the future for the beginning of the reproductive stages, providing the propagation and survival of new generations.

Only the different percentages of solar radiation affected the length of *I. grandifolia* plants during flowering, without significant contrasts when the species was sown between the depths of 0.5 and 12.0 cm. The larger plants of *I. grandifolia* occurred when they were submitted to 100% solar radiation. It is highlighted that shading reduced the length of plants, regardless of the amount of reduction evaluated, so that *I. grandifolia* plants did not present measurements higher than 56.33% (86.91 cm) for the size of plants developed under total solar exposure (Table 9).

The total dry matter and the daily dry matter accumulation from the sowing until the flowering of *I. grandifolia* plants were significantly affected only by the percentage of solar radiation. *I. grandifolia* plants developed under total solar exposure presented the higher total and daily dry matter accumulation until the flowering compared with the plants developed under shading conditions (Table 10).

No significant contrasts were observed between the shading conditions. Thus, it can be inferred that, regardless of the sowing depth between 0.5 and 12.0 cm and the shading between 30 and 70%, the dry matter and its daily accumulation in *I. grandifolia* plants were not affected.

Table 9 – Length (cm) during the flowering of *Ipomoea grandifolia* plants sown in different depths and submitted to different solar radiation intensities

	Sowing depth (cm)
0.5	101.50
1.0	99.12
2.0	108.81
4.0	100.62
8.0	96.44
12.0	111.69
	Solar radiation (%)
100	154.29 A
70	86.91 B
50	85.95 B
30	84.95 B
F RADIATION (R)	59.610**
F DEPTH (D)	1.192^{NS}
F (R) x (D)	1.629^{NS}
LSD (R)	16.47
LSD (D)	22.46
C. V. (%)	21.0

** Significant at 1% probability; ns No significance. Means followed by the same uppercase letter in the column do not differ statistically from each other by Tukey’s test ($p < 0.05$)

Table 10 - Total dry matter accumulation during flowering and daily dry matter accumulation until the flowering of *Ipomoea grandifolia* plants sown in different depths and submitted to different solar radiation intensities

Variable	Total dry matter accumulation (g plant^{-1})	Daily dry matter accumulation (g day^{-1})
	Sowing depth (cm)	
0.5	3.77	0.0618
1.0	3.74	0.0446

Continuation table 10

2.0	3.47	0.0602
4.0	4.14	0.0659
8.0	3.49	0.0596
12.0	4.48	0.0660
	Solar radiation (%)	
100	8.02 A	0.1782 A
70	2.55 B	0.0230 B
50	2.22 B	0.0200 B
30	1.96 B	0.0176 B
F RADIATION (R)	100.331**	163.035**
F DEPTH (D)	2.925^{NS}	1.085^{NS}
F (R) x (D)	1.297^{NS}	0.699^{NS}
LSD (R)	1.08	0.0230
LSD (D)	1.47	0.0314
C. V. (%)	38.4	50.8

** Significant at 1% probability; ns No significance. Means followed by the same uppercase letter in the column do not differ statistically from each other by Tukey's test ($p < 0.05$)

CONCLUSIONS

1. The seedlings of *A. australe* and *I. grandifolia* emerge under the conditions of 100, 70, 50, and 30% solar radiation and in sowings up to 12.0 cm depth;
2. Different levels of luminous intensity and sowing depth affect the emergence and development of *A. austral*;
3. The sowing at 12 cm depth affects the emergence speed index of *I. grandifolia* seedlings. Besides, reductions of 30, 50, and 70% in the solar radiation level affect the flowering period, plants length during flowering, and total and daily dry matter accumulation.

REFERENCES

BARROSO, A. A. M.; FERREIRA, P. S. H.; MARTINS, D. Growth and development of Ipomoea weeds. **Planta Daninha**, v. 37, e019186421, 2019.

CHEN, H. *et al*. AtPER1 enhances primary seed dormancy and reduces seed germination by suppressing the ABA catabolism and GA biosynthesis in *Arabidopsis* seeds. **The Plant Journal**, v. 101, n. 2, p. 310-323, 2020.

GUIMARÃES, L. A. O. P. *et al.* Germinação de sementes e vigor de plântulas de *Myrciaria glazioviana* submetidas a sombreamentos. **Rodriguésia**, v. 69, n. 4, p. 2237-2243, 2018.

GUGLIERI-CAPORAL, A. *et al.* Flora invasora de cultivos de aveia-preta, milho e sorgo em região de cerrado do Estado de Mato Grosso do Sul, Brasil. **Bragantia**, v. 70, p. 247-254, 2011.

KLIMEŠ, A. *et al*. Growth plasticity in response to shading as a potential key to the evolution of angiosperm herbs. **Plant Ecology**, v. 222, n. 3, p. 387-396, 2021.

LABONIA, V. D. S. *et al.* Emergência de plantas da família convolvulaceae influenciada pela profundidade da semente no solo e cobertura com palha de cana-de-açúcar. **Planta Daninha,** v. 27, Número Especial, p. 921-929, 2009.

LESSA, B. F. T. *et al.* Germinação de sementes de *Emilia coccinea* (Sims) G. DON em função da luminosidade, temperatura, armazenamento e profundidade de semeadura. **Semina: Ciências Agrárias,** v. 1, n. 34, p. 3193-3204, 2013.

MACIEL C. D. G. Métodos de controle de plantas daninhas. In: Monquero PA. **Aspectos da biologia e manejo das plantas daninhas.** São Carlos: RiMa Editora, 2014. p. 129-144.

MAGUIRE, J. D. Speed of germination -id in selection and evaluation for seedling emergence and vigor 1. **Crop Science**, v. 2, n. 2, p. 176-177, 1962.

MALLMANN, R. *et al*. Effectiveness of aqueous and hydroalcoholic extracts of *Acanthospermum australe* (Loefl.) Kuntze against diarrhea-inducing bacteria. **Brazilian Journal of Biolog**y, v. 78, p. 619-624, 2018.

MAQSOOD, Q. *et al.* Overviewing of weed management practices to reduce weed seed bank and to increase maize yield. **Planta Daninha**, v. 38, e020199716, 2020.

MARCHI, S. R. *et al.* Potential of greenhouse gas production by guinea grass subjected to weed competition. **Journal of Agricultural Science**, v. 11, n. 8, p. 257-272, 2019.

MARCHI, S. R. *et al.* Straw interference in the emergence of talquezal seeds from different origins. **Planta Daninha**, v. 38, e020223128, 2020.

MARQUES, A. S. *et al.* Emergence of razor grass on the basis of origin and seed depth in the soil profile. **Planta Daninha**, v. 37, e019214034, 2019.

MARQUES, R. P. *et al.* Densidades de palha e condições de luminosidade na germinação de sementes de *Euhphorbia heterophylla*. **Semina: Ciências Agrárias**, v. 33, n. 3, p. 867-872, 2012.

MONQUERO, P. A. *et al.* Interference of weeds on seedlings of four neotropical tree species. **Acta Scientiarum. Agronomy**, v. 37, n. 2, p. 219-232, 2015.

MONQUERO, P. A. *et al.* Profundidade de semeadura, pH, textura e manejo da cobertura do solo na emergência de plântulas de *Rottboellia exaltata*. **Semina: Ciências Agrárias,** v. 33, n. 1, p. 2799-2812, 2012.

ORZARI, I. *et al.* Germinação de espécies da família Convolvulaceae sob diferentes condições de luz, temperatura e profundidade de semeadura. **Planta Daninha**, v. 31, n. 1, p. 53-61, 2013.

PACHECO, L. P. *et al.* Profundidade de semeadura e crescimento inicial de espécies forrageiras utilizadas para cobertura do solo. **Ciência e Agrotecnologia**, v. 34, n. 5, p. 1211-1218, 2010.

SAHA, D. *et al*. Emergence of garden spurge (*Euphorbia hirta*) and large crabgrass (*Digitaria sanguinalis*) in response to different physical properties and depths of common mulch materials. **Weed Technology**, v. 34, n. 2, p. 172-179, 2020.

SANTOS, F. L. S. *et al.* Crescimento inicial de espécies de *Urochloa* em função da profundidade de semeadura. **Journal of Neotropical Agriculture**, v. 2, n. 4, p. 1-6, 2015.

SANTOS, T. A. *et al.* Growth of Tree Species in Coexistence with Palisade Grass *Urochloa brizantha* (Hochst. ex A. Rich.) Stapf cv. Marandu. **Planta Daninha**, v. 37, e019178812, 2019.

SÉRGIO, C. *et al.* Levantamiento físico conservacionista de la cuenca del río Lavapés, Botucatu, SP. **Revista de la Facultad de Agronomía de La Universidad del Zulia**, v. 22, n. 2, p. 167-180, 2005.

SILVA, E. M. *et al*. Germination of *Stigmaphyllon blanchetii* seeds in different temperatures and luminosity. **Planta Daninha**, v. 37, e019197178, 2019.

SOUZA, M. C. *et al.* Efeito da época sobre a emergência de *Sida rhombifolia* e *Solanum viarum* em diferentes profundidades de semeadura. **Revista Ceres**, v. 58, n. 6, p. 749-754, 2011.

SZYMBORSKA-SANDHU, I. *et al.* Effect of shading on development, yield and quality of bastard balm herb (*Melittis melissophyllum* L.). **Molecules**, v. 25, n. 9, p. 2142, 2020.

XIONG, R. C. *et al.* Effects of environmental factors on seed germination and emergence of velvetleaf (*Abutilon theophrasti*). **Planta Daninha**, v. 36, e0182352, 2018.

ZUFFO, A. M. *et al.* Profundidade de semeadura e superação de dormência no crescimento inicial de sementes de *Brachiaria dictyoneura* (Fig. & De Not.) Stapf (1919) cv. Llanero. **Revista Ceres**, v. 61, n. 6, p. 948-955, 2014.