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Original Article

Effect of temperature, light, seeding depth and mulch on germination of *Commelina benghalensis* and *Richardia brasiliensis*

Efeito da temperatura, luz, profundidade de semeadura e cobertura morta na germinação de *Commelina benghalensis* e *Richardia brasiliensis*

V. G. Pereira de Moura[a], J. P. U. Salviato Vieira[a], B. F. Schedenffeldt[a], A. C. Silva Hirata[b] and P. A. Monquero[a*]

[a]Universidade Federal de São Carlos - UFSCar, Centro de Ciências Agrárias, Araras, SP, Brasil
[b]Agência Paulista de Agronegócio, Presidente Prudente, SP, Brasil

Abstract

One of the major limitations to proper weed management is the lack of knowledge about the biology of the species. The aim of this study was to understand the influence of temperature and light on the germination and emergence of *Commelina benghalensis* and *Richardia brasiliensis*, as well as the influence of burial depth in the soil and the presence of mulch. The experiment regarding the influence of light and temperature on germination was conducted using a 2x4 factorial design, with two light conditions (presence for 12 hours and absence for 24 hours) and four temperature alternations every 12 hours (20-25 ºC, 20-30 ºC, 20-35 ºC, and 15-35 ºC), with four replications. The second experiment was conducted in a completely randomized design with four replications, testing seven sowing depths (0.0; 0.5; 1.0; 2.0; 4.0; 6.0; 10.0 cm) in clay-textured soil. In the third experiment, millet, black oat, and sun hemp straw were placed on the surface of the pot where the weeds were sown. *R. brasiliensis* showed high germination rates at 15°-35°C and in the presence of light, indicating positive photoblastism, as the germination percentage was 63.50% in the presence of light and 1% without light. *C. benghalensis* showed higher germination rates at 20-35ºC, with a germination percentage of 46.5% under light treatment and 44% in the absence of light. *R. brasiliensis* exhibited the highest germination percentage at a depth of 0.5 cm, with 72.50%. *C. benghalensis* showed better germination at depths of 1 and 4 cm, with 48.33% and 49.16%, respectively. Both crotalaria and millet caused significant inhibition of germination in both weed species. *R. brasiliensis* and *C. benghalensis* exhibit higher seed germination under alternating temperatures, with *R. brasiliensis* displaying positive photoblastism and *C. benghalensis* being neutral. Greater seeding depths negatively influence germination, and cover crops such as crotalaria and millet can be used to suppress these weeds.

Keywords: biology, management, germination, emergence, sowing depth.

Resumo

Um dos grandes limitantes no manejo adequado de plantas daninhas é a falta de conhecimento acerca da biologia das espécies. Assim sendo, objetivou-se entender a influência da temperatura e luz na germinação e emergência de *Commelina benghalensis* e *Richardia brasiliensis*, bem como a influência da profundidade de enterrio no solo e da presença de cobertura vegetal. O experimento sobre influência da luz e temperatura na germinação foi conduzido em esquema fatorial 2x4, com duas condições de luminosidade (presença por 12 horas e ausência por 24 horas) e quatro temperaturas alternas a cada 12 horas (20-25 ºC, 20-30 ºC, 20-35 ºC e 15-35 ºC), com quatro repetições. O segundo experimento, foi conduzido no delineamento inteiramente casualizado com quatro repetições, com 7 profundidades de semeadura (0,0; 0,5; 1,0; 2,0; 4,0; 6,0; 10,0 cm) no solo de textura argilosa. No terceiro experimento, a palhada de milheto, aveia preta e crotalária foram colocadas sobre a superfície do vaso, onde foram semeadas as plantas daninhas. A *R. brasiliensis* apresentou altas taxas de germinação em 15°-35°C e presença de luz, indicando fotoblastismo positivo, pois na presença de luz a porcentagem de germinação foi de 63,50% e sem luz foi de 1%. A *C. benghalensis* apresentou maiores taxas de germinação na alternância 20-35ºC, apresentando porcentagem de germinação de 46,5% no tratamento com luz e 44% com a ausência de luz. *R. brasiliensis* apresentou maior porcentagem de germinação na profundidade de 0,5 cm, com 72,50%. A *C. benghalensis* apresentou melhor germinação na profundidade de 1 e 4 cm com 48,33 e 49,16%, respectivamente. A crotalaria e milheto provocaram grande inibição da germinação de ambas as plantas daninhas. *R. brasiliensis* e *C. benghalensis* apresentam maior germinação de sementes em temperaturas alternadas, sendo fotoblástica positiva e neutra, respectivamente. Profundidades de semeadura maiores influenciam negativamente na germinação e os adubos verdes crotalaria e milheto podem ser utilizados na supressão destas plantas daninhas.

Palavras-chave: biologia, manejo, germinação, emergência, profundidade de semeadura.

*e-mail: pamonque@ufscar.br
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1. Introduction

The current concern with the sustainability, equity and competitiveness of agriculture highlights the need for economically viable, socially acceptable and environmentally balanced agricultural systems, for updating and training farmers and for increasingly productive and efficient commercial crops in the various links of the agricultural production chain (FAO/INCRA, 1995; Vicente, 2004). The presence of weeds in agricultural systems can cause damage to various aspects of agricultural production. Among the damages caused by these species we can mention: reduced productivity and land value, loss of agricultural product quality, spread of pests and diseases, increased costs, greater difficulty in agricultural management and toxicity to animals (Tudi et al., 2021; Carvalho et al., 2014).

Species considered to be weeds have evolved as a result of cultivation practices and systems due to their adaptation and coverage of marginal ecological niches in agricultural areas. On the other hand, cultivated species can only manifest their productive potential if environmental changes are made, since they have lost their favorable characteristics from the point of view of adaptation and competition. Weed species, on the other hand, have kept their favorable characteristics and changes in the environment tend not to influence them (Fontes and Shiratsuchi, 2003).

In order to formulate an effective weed management program, a comprehensive understanding of weed biology and ecology is indispensable. While research into weed biology has seen a recent surge, there remains a lack of fundamental information on numerous significant species. Enhanced insight into the environmental factors influencing weed seed germination is crucial for devising efficient management practices. Strategies aimed at either promoting germination to facilitate seedling eradication or suppressing germination altogether can be developed based on this understanding (Chauhan, 2020).

Seed germination is the initial stage of a plant's life. The germination capacity and speed of these structures are influenced by various intrinsic factors: morphology, viability and dormancy and environmental factors: light, temperature, water potential (Vicente et al., 2020; Haj et al., 2022).

The effect of light and temperature on seeds varies greatly between different species and populations (Liu et al., 2022a). Dias et al. (2009) observed that the optimum temperature for germination of *Commelina benghalensis* (bengal dayflower) was 25 ºC and there was no effect of light on seed germination, while Santos et al. (2001b) found that the larger seeds of *C. benghalensis* germinated best at around 30 ºC.

As well as understanding the biology of weeds, it is important to note that there are other methods of weed control, apart from the use of herbicides, that should be used within integrated management, such as the use of ground covers. Cover crops are one of the requirements of the no-till farming system, and are one of the most important factors in the success of this conservation system (Caires and Milla, 2016). The use of ground cover plants offers various benefits to agricultural production systems. Among the contributions that the use of these species provides are: soil protection; increased soil fertility; increased biological activity in the soil (Chahal and Van Eerd, 2019). In addition, the use of cover crops tends to contribute to the suppression of weeds in the soil (Vincent-Caboud et al., 2019).

Weed suppression can occur as a result of the action of straw, formed by residues from cover crops, whose presence in the soil can promote physical and chemical effects on the weed seed bank present in the soil (Akbari et al., 2019; Liu et al., 2022b).

Among the Commelina species (Commelinaceae), the most important is *C. benghalensis* because it infests crops in many countries, causing significant yield losses in various agricultural crops and making harvesting operations difficult. As this species is tolerant to glyphosate, it represents a major problem in crops that use this herbicide successively, such as transgenic crops, coffee and citrus (Santos et al., 2001a, Monquero and Christoffoleti, 2003; Silva et al., 2019).

Another important weed species is *Richardia brasiliensis* (brazilian pusley) (Rubiaceae), which is quite common in Brazil. *R. brasiliensis* is a herbaceous, annual species that grows spontaneously throughout the country (Moreira and Bragança, 2010). It has great vegetative vigor, completely covering the soil like a carpet, and is considered one of the main weeds of soybean and corn crops in the South and Midwest regions, showing greater interference at the beginning of summer crop cycles (Lorenzi, 2008).

Knowledge of aspects related to seed germination, seedling emergence and the depth at which weeds are able to emerge enables the adoption of alternative practices to the use of herbicides, including cultural methods, through the use of ground cover. Therefore, the aim of this work was to understand how factors that influence germination such as temperature, light and burial depth can influence seed germination and the establishment of *C. benghalensis* and *R. brasiliensis*. Furthermore, to understand how green manure cover can help to suppress or not suppress these weed species.

2. Material and Methods

2.1. Influence of temperature and light on the germination of Commelina benghalensis and Richardia brasiliensis

The weed seeds were purchased from Agrocosmos, a company specializing in the production of weed seeds. The effect of light and temperature on the germination of *C. benghalensis* and *R. brasiliensis* seeds was evaluated. The experimental design was entirely randomized in a 2x5 factorial scheme, with four replications of 50 seeds each.

The factorial was made up of two light conditions (presence and absence) and five temperatures. The temperatures proposed for seed germination were based on the Rules for Seed Analysis (Brasil, 2009), however, as there is no specific indication for the species studied, we opted to study alternate temperatures that stimulate the germination of other weeds: (20-25 ºC, 20-30 ºC, 20-35 ºC and 15-35 ºC).

The experimental unit consisted of transparent acrylic germination boxes (11.0 x 11.0 x 3.0 cm) with two sheets of paper for germination, moistened with distilled water corresponding to 2.5 times the weight of the dry paper. The transparent acrylic boxes allowed light to shine through and in the absence of light they were covered with flexible aluminum film, making it impossible for light to shine through.

For the treatments in the absence of light, the plots were only evaluated in the presence of green light, so that light does not interfere with the germination process. The plates were taken to a BOD germination chamber, with the temperature and photoperiod adjusted according to each treatment. A photoperiod of 12 h of light and 12 h of darkness was used for the treatments in the presence of light.

The evaluation took place until stabilization after the installation of the experiment (DAI), and normal seedlings were counted as those showing the parts of the embryo developed. In addition, the germination percentage (G%) was calculated according to the rules for seed analysis (Brasil, 2009).

2.2. Influence of depth on the germination and emergence of the species C. benghalensis and R. brasiliensis

The experiment was conducted, individually for each weed species, in a completely randomized design with four replications at 7 depths (0.0, 0.5, 1.0, 2.0, 4.0, 6.0, 10.0 cm) of the Red Dystrophic Latosol, clay texture. The chemical analysis of the soil samples used indicates the following values: P mmol dm^{-3} = 15; organic matter = 38%; pH $CaCl_2$ = 5.6; K mmolc dm^{-3} = 5.4; Ca = 53%; Mg = 13%; H+Al = 26; sum of bases (BS) = 71.4; Cation exchange capacity (CEC) = 97.4%; Base saturation (V%) = 73. The plots were made up of five-liter plastic pots filled with soil samples from the arable layer of a dark red latosol.

The bottom of the pots was sealed with filter paper to prevent soil loss, in order to avoid heterogeneity in the plots. Thirty seeds were sown in each pot and distributed at the predetermined depths.

The pots were kept in a greenhouse with controlled irrigation (5 mm per day) in order to maintain soil humidity and ensure germination. The pots were marked out with a corrective pen (white ink) from the standard surface, using a millimeter ruler, to distribute the seeds at the different depths (0.0, 0.5, 1.0, 2.0, 4.0, 6.0, 10.0 cm).

At a depth of 0 cm, the seeds were spread evenly over the soil. After this procedure, the soil surface was homogenized and pressed down with the same force to standardize the depths and improve seed contact with the soil.

Weed emergence was assessed daily until stabilization (more than 10 days without germination) after sowing (DAS), and the emerged plants were counted. The total data on seedling emergence at the last assessment was transformed into percentages, taking into account the total number of seeds in the pots.

2.3. Effect of mulch on weed establishment

The experimental units were made up of plastic pots with a capacity of 5L and a diameter of 11 cm, in which 20 seeds of the weeds *C. benghalensis* and *R. brasiliensis* would be placed, at the depth that provided the greatest germination in the previous experiment. In addition, control units (control) will be set up for both species, where no type of cover will be placed over the seeds and/or soil.

The cover crops will be grown in the field and at the indicated time they will be cut and the biomass chopped up using pruning shears and then applied homogeneously in the amount that corresponds to the total biomass of the agronomic recommendation (Sementes Piraí, 2012) predetermined for each species: crotalaria (*Crotalaria juncea*): 40 t ha^{-1}; millet (*Pennisetum glaucum*): 40 t ha^{-1} and sorghum (*Sorghum bicolor*): 15 t ha^{-1}. Weed emergence was assessed daily until germination stabilized after sowing (DAS), and the emerged plants were counted. The total data on seedling emergence at the last assessment will be transformed into percentages, taking into account the total number of seeds in the pots.

At the end of the germination evaluations, the weeds in the pots were assessed for their aerial part dry biomass (g), after cutting the plants close to the ground and drying them in a forced air circulation oven at 65°C for 48 hours.

2.4. Statistical analysis

The data from all the experiments were subjected to univariate analysis of variance using the F-test, followed by comparison of means using the Scott-Knott test at a 5% probability of error. This analysis was conducted using the statistical software R® version 3.6.1 (R Core Team, 2019).

3. Results

3.1. Influence of temperature and light on the germination of C. benghalensis and R. brasiliensis

With regard to the influence of temperature and photoperiod, the data is shown in Table 1. It was found that *R. brasilienses* showed better germination at temperatures ranging from 15-35 ºC and in the light (63.5%). With regard to photoperiod, in the absence of light the germination was only 1% at 15-35 ºC and practically zero at the other temperatures. In the presence of light, at the different temperatures, germination ranged from 20 to 63.5%.

It should be noted that *C. benghalensis* prefers higher temperatures. This is justified by the higher germination percentage in the treatment involving alternating temperatures, with a variation between 20-35 ºC, with a germination percentage of 46.5% in the treatment with light, and 44% in the absence of light, showing a statistical difference from the other treatments.

In view of this, the treatments with temperatures of 20º-25ºC and 20º-30ºC showed the lowest germination rates, with a statistical difference between the treatments with and without light. In the 15-30ºC treatment, there was no difference between the treatments with or without light, with germination rates of 36 and 31.50%, making it the second temperature alternation that most stimulated the germination of *C. benghalensis*. As germination occurred both in the absence and presence of light, the species can be classified as indifferent or neutral photoblasts.

3.2. Influence of depth on the emergence of C. benghalensis and R. brasiliensis species

The effect of sowing depths on the germination of *R. brasiliensis* was evaluated. The highest germination percentage was observed at a depth of 0.5 cm, with 72.50%. This was followed by a germination rate of 53.33% at 1.0 cm, which was statistically different from the 0, 2, 4, 6 and 10 cm depths (Table 2). The seeds exposed to the soil surface (0 cm) showed a lower germination rate, probably due the seeds are exposed to environmental variations in a more drastic way, since they are not protected in the soil.

From the first assessment at 7 days to the last one at 21 days, germination at a depth of 0.5 cm was higher than in the other treatments, with 72.50% accumulated germination. As the depth increased, the emergence of *R. brasiliensis* decreased. At the greater depths (6 cm and 10 cm), it was possible to see that the plants did emerge, but as the seeds had to use up practically all their energy reserves to germinate, the seedlings showed low vigor, with generalized yellowing and stem stolonization.

With regard to the germination of *C. benghalensis*, the highest germination rates were observed at a depth of 4 cm (49.16%) and 1 cm (48.33%). Although these depths showed the best germination rates, there was a statistical difference only in the 12 cm depth, which showed the lowest total germination rate (Table 2).

3.3. Effect of mulch on weed establishment

In the experiment involving the influence of cover crops on weed germination, it was observed that the control of *R. brasiliensis* with *Crotalaria juncea* (sum hemp) straw and *Pennisetum glaucum* (millet) was statistically the same, with a low germination percentage (Table 3). In the case of *Avena strigosa* (black oat) straw, there was an increase in the germination of *R. brasiliensis* with values reaching 70% germination in the last evaluation. Therefore, the black oat straw had the opposite effect on this weed, increasing germination over time.

Following the experiment, still shown in Table 3, the same procedure was carried out with *C. benghalensis*, using the same straws (crotalaria, millet, and black oats). It was observed that at 7 and 14 DAS, no statistical differences were detected in relation to the control; only at 21 DAS was there an increase in the germination percentage in the treatment involving the absence of straw (33.75%), showing a statistical difference with the treatment with the presence of black oat straw (18.50%). Crotalaria and millet straw reduced the presence of this weed in the last assessment, with 7.50 and 3.75% germination, respectively.

Table 1. Percentage Germination (%) of *Richardia brasiliensis* and *Commelina benghalensis* in different temperatures and conditions of absence or presence of lighting.

Percentage Germination (%) – *Richardia brasiliensis*		
Temperature (°C)	**Presence of light**	**Absence of light**
20-25	20.00 cA	0.50 aB
20-30	20.50 cA	0.00 aB
20-35	40.00 bA	0.00 aB
15-35	63.50 aA	1.00 aB
CV(%)	81.14	
F	A=43.03** B=44.38** AxB=40.83**	
Percentage Germination (%) - *Commelina benghalensis*		
Temperature (oC)	**Presence of light**	**Absence of light**
20-25	5.50 cB	13.00 cA
20-30	3.50 cB	25.00 cA
20-35	46.5 aA	44.00 aA
15-35	36.00 bA	31.50 bA
CV(%)	42.83	
F	A=18.78** B=2.01^{ns} AxB=2.35^{ns}	

Factor A: Temperature; Factor B: Photoperiod. CV: coefficient of variation. **significant at 5% and ^{ns} not significant at the 5% probability level by the F test; means followed by equal lowercase letters in the column and equal uppercase letters in the row do not differ by the Scott-Knott test at 5% probability.

Table 2. Percent germination (%) of *Richardia brasiliensis* and *Commelina benghalensis* as a function of different sowing depths at 7, 14 and 21 days after sowing.

Percent germination (%) - *Richardia brasiliensis*				
Sowing dephts (cm)	Evaluation period - days after sowing (DAS)			
	7	14	21	Total
0	10.83 b	15.00 b	8.33 b	34.16 c
0.5	23.33 a	23.33 a	25.83 a	72.50 a
1	20.00 a	18.33 a	14.99 b	53.33 b
2	15.83 b	14.16 b	8.33 c	38.33 c
4	18.33 b	18.33 a	7.50 c	44.16 c
6	14.16 b	11.66 b	5.00 c	30.83 c
10	10.00 b	9.16 b	7.50 c	26.66 c
CV(%)	31.76	29.08	34.07	26.38
F	3.61**	4.27**	12.56*	6.86**
Percent germination (%) - *Commelina benghalensis*				
Sowing dephts (cm)	**Evaluation period - days after sowing (DAS)**			
	7	**14**	**21**	**Total**
0	8.33 b	11.66 a	18.33 b	38.33 a
0.5	14.16 b	12.5 a	9.16 b	35.33 a
1	20.83 a	15.83 a	11.66 b	48.33 a
2	15.83 b	13.33 a	12.5 b	41.66 a
4	13.33 b	16.66 a	19.17 a	49.16 a
6	15.00 b	10.66 b	10.00 b	35.66 a
10	10.83 b	10.00 b	4.16 b	24.99 b
CV(%)	31.52	24.76	42.77	22.19
F	3.22**	1.85ns	4.08**	1.62ns

CV: coefficient of variation. *significant at 1%; **significant at 5% and ns not significant at 5% probability level by the F test; means followed by the same lowercase letters in the column do not differ by the Scott-Knott test at 5% probability.

Table 3. Percent germination (%) of *R. brasiliensis* and *C. benghalensis* as a function of different types of straw at 7, 14 and 21 days after sowing (DAS).

Percent germination (%) - *Richardia brasiliensis*			
Straw (t ha^{-1})	Evaluation period - days after sowing (DAS)		
	7	14	21
Avena strigosa	31.25 a	62.50 a	70.00 a
Crotalaria juncea	1.25 b	2.50 c	17.50 c
Pennisetum glaucum	0.00 b	0.00 c	0.00 c
Without straw	10.00 b	22.50 b	55.00 b
CV(%)	82.37	71.04	51.08
F	21.26**	25.78**	29.54**
Percent germination (%) - *Commelina benghalensis*			
Straw (t ha-1)	**Evaluation period - days after sowing (DAS)**		
	7	**14**	**21**
Avena strigosa	5.00 a	12.50 a	18.50 b
Crotalaria juncea	8.75 a	8.75 a	7.50 c
Pennisetum glaucum	2.50 a	2.50 a	3.75 c
Without straw	3.75 a	12.50 a	33.75 a
CV(%)	84.16	74.27	48.92
F	1.65ns	1.97ns	5.49*

CV: coefficient of variation *significant at 1%; **significant at 5% and ns not significant at 5% probability level by the F test; means followed by the same lowercase letters in the column do not differ by the Scott-Knott test at 5% probability.

4. Discussion

4.1. Influence of temperature and light on the germination of C. benghalensis and R. brasiliensis

The germination of *R. brasiliensis* in different regions of Brazil with different temperatures demonstrates the adaptability of this species to the natural thermal fluctuations of the environment, making it capable of withstanding adverse climatic conditions. *R. brasiliensis* was favored at temperatures of 15, 20 and 25°C and alternating 20/30°C, in the light presence (Gallon et al., 2018).

The need for light to germinate of certain plant species prevents germination in places and at times that are not favorable for seedling establishment (Fenner and Thompson, 2005). The light requirement of these seeds acts as a mechanism that determines where and when germination occurs and is important for the survival of the plant species in question, as it prevents stored seed reserves from being depleted in a condition that is not favorable for development. Some seeds germinate equally well in light and darkness (neutral photoblastic), while others germinate better only in light (positive photoblastic) or darkness (negative photoblastic) (Chanyenga et al., 2012). According to the phytochrome response theory, red light is responsible for the germination of photoblastic seeds. This is perceived by a protein-bilin photoreceptor, phytochrome, which also controls blossoming and other physiological responses (Tognacca and Botto, 2021). The impact of blue light on germination is considered to be negative (Gubler et al., 2008).

Klein and Felippe (1991) assessed the germination of *Commelina virginica* seeds and reported that it is a positively photoblastic species, i.e. it needs light to germinate. Mondo et al. (2010) found that temperature and light requirements can vary depending on the species within the same genus, as well as the vigor of the seeds, which will reflect the stress caused to the mother plant.

C. benghalensis showed higher germination in response to the 30°C treatment with 72 and 77% germination for aerial and underground seeds, respectively. On the other hand, when exposed to 35°C, the underground seeds showed high levels of germination (maximum germination of 82%), while the aerial seeds (which are smaller) were not as responsive (maximum germination of 50%) (Sabila et al., 2012).

Previous studies on *C. benghalensis* have documented a number of different germination responses to temperature in various locations around the world. Walker and Evenson (1985) reported 55 to 83% germination at 20°C of this plant when naturalized in Australia, while seeds of *C. benghalensis* naturalized in North Carolina did not germinate at this same temperature (Sermons et al., 2008). Dias et al. (2009) found that for aerial seeds of *C. benghalensis* in Brazil, the optimum temperature for germination of *C. benghalensis* was 25°C and there was no effect of light on seed germination.

4.2. Influence of depth on the germination and emergence of C. benghalensis and R. brasiliensis species

Buried seeds may show one of four responses: (i) they may germinate and emerge as seedlings, (ii) they may germinate but the seedlings are unable to emerge above the soil surface, (iii) the seeds may acquire dormancy and become part of the seed bank, or (iv) the seeds may succumb to various mortality factors.

It is extremely important to determine the depth at which seedlings are capable of emerging, as this knowledge enables the implementation of various more efficient management practices, such as soil cultivation and mulching (Brighenti et al., 2003). *R. brasiliensis* seed germination occurred at all burial depths, but as the burial depth increased, seed germination and plant emergence decreased. The exception was seen when the seeds were positioned on the soil surface, in which case germination was lower, probably due to temperature and humidity fluctuations which may have caused the seed to deteriorate more. The same occurred with *C. benghanlesis*, but with a statistical difference only at the greatest depth. The larger size of the seeds and, therefore, the greater amount of reserves allowed for greater germination up to a depth of 8 cm. On the other hand, Sabila et al. (2012) found that the maximum emergence of *C. benghalensis* (71%) occurred with the seed on the soil surface, with an approximate 6% reduction in emergence for each 1 cm increase in planting depth. The weed failed to emerge at a depth of 12 cm. In Brazil, there was a negative linear relationship between *C. benghalensis* emergence and soil depth, with no emergence below 8 cm, using a sand substrate (Dias et al. 2009).

At greater depths, in addition to lower germination, it was observed that the *C. benghalensis* seedlings were smaller due to the consumption of reserves by the seeds for emergence. It is important to remember that *C. benghalensis* has two types of seeds with different sizes: larger underground seeds and smaller aerial seeds and their size can influence their ability to germinate and emerge at greater depths.

4.3. Effect of mulch on weed establishment

The use of successor crops has been an interesting way of managing weeds. In crop planning, the maintenance of green manures directly interferes with competition for light and space, as well as being able to present allelopathy, reducing the likelihood of perpetuation of some weed species.

In southern Brazil, black oats are the predominant cover crop on millions of hectares of no-till soybeans, partly due to their ability to suppress weeds. However, black oat straw does not have the same effect on all weed species, as we can see in this work, there was a stimulus to the germination of *R. brasiliensis*. Black oat plants contain allelopathic substances that can be important in the management of various weed species (Jacobi and Fleck, 2000). However, it is important to remember that allelochemicals can stimulate or inhibit plant germination and/or growth and increase crop resistance to biotic and abiotic stress (Li et al., 2021).

Regarding the use of *C. juncea,* Bundit et al. (2021) observed the phytotoxicity of the soil, planted with *C. juncea* at different timings, did not significantly decrease germination, shoot length, root length and dry weight of weeds. However, the water extracts caused significantly decreased germination and plant growth, especially the shoot extracts exhibited the inhibitory effects more than the root extracts. Interestingly, the extracts from *C. juncea* at 4 weeks after planting had higher inhibitory effects than the extracts from other stages. In Brazil, Monquero et al. (2009), evaluating the potential for suppression of weeds by green manures, found that the most efficient was *C. juncea*, because it grows rapidly, increasing competition, especially for light.

C. juncea can be used in combination with other species for mulching. Araújo et al. (2021) verified the combination of *C. juncea* with *P. glaucum* and observed reduction in the density and dry matter mass of weeds in relation to fallow, especially of *Cenchrus echinathus, Euphorbia heterophylla* and *Digitaria insularis*. The use of cover crops is an important strategy for weed control in agricultural areas.

5. Conclusion

R. brasiliensis germinated best in the presence of light and at a temperature of 15-35°C. It had a higher germination rate at a depth of 0.5 cm, with lower or higher depths reducing the presence of the weed. The *C. juncea* and *P. glaucum* mulches helped to manage this plant, unlike *A. strigosa*, which stimulated germination.

For *C. benghalensis*, the highest germination rate occurred with alternating temperatures of 20-35°C, both in the presence and absence of light. Less germination was observed at the deepest seed burial depths and the straw from the green manures helped in the management of this plant.

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