Communications in PLANT SCIENCES

http://cpsjournal.org
e-ISSN 2237-4027
Volume 13 (2023)

RESEARCH ARTICLE

Biology of germination of *Solanum americanum*: a weed ascending in Brazilian crops

Milena Barretta Franceschetti[1], **Leandro Galon**[1]*, **Ubirajara Russi Nunes**[2], **Rodrigo Roso**[2], **André Dalponte Menegat**[1], **Leonardo Brunetto**[1], **Geovana Facco Barbieri**[2], **Alessandra Gallina**[1] and **Cesar Tiago Forte**[2]

[1]Universidade Federal da Fronteira Sul, Erechim, RS, Brasil.
[2]Universidade Federal de Santa Maria, Santa Maria, RS, Brasil.
Correspondence to: leandro.galone@gmail.com

Submitted on May 18, 2022
Accepted on February 13, 2023
Early View on February 13, 2023
Final Publication on February 14, 2023

Authors declare no conflict of interest

KEYWORDS:
Integrated weed control
Osmotic potential
Plant cover of the soil

ABSTRACT

Solanum americanum is a weed found in many important crops and is characterized by high production of fruits and seeds. Knowledge of the biology of the species is essential for efficient weed control so that the best control strategies and combinations thereof can be developed. Therefore, the aim of this study was to determine the environmental factors that affect germination and emergence of S. americanum. Six experiments were conducted in the laboratory, simulating field situations in which germination was tested under different pH conditions, osmotic and saline stress, the effect of aluminum content, and different covers and straw levels. Germination and seedling emergence were evaluated, depending on the objectives of the experiment. We found that the germination changed according to the increase in salinity and the decrease in osmotic potential of the soil. The same was observed to the soil cover and its levels, as the emergence rate decreased with the increase in the amount of straw. Germination was reduced at alkaline pH (9-10). Aluminum had no effect on germination, only on normal seed development.

Highlighted Conclusion

1. Increasing the amount of straw in the soil reduced the germination of *S. americanum*.
2. At alkaline pH, germination of *S. americanum* was reduced.
3. Aluminum had a negative influence on the development of *S. americanum*.

INTRODUCTION

Solanum americanum (Miller) is a species belonging to the family Solanaceae, a weed common in many regions of the world. It is a herbaceous species about 40 to 70 centimeters tall, with oval-lanceolate leaves and berry type fruits containing between 24 and 70 seeds ranging in size from 0.8 to 1.5 mm (Lorenzi 2017).

The loss of productivity of the agricultural crops is affected by the presence of weeds in this environment due to competition for the resources of water, nutrients, light, and CO_2 (Forte et al. 2017; Galon et al. 2018; Galon et al. 2022). The species *S. americanum* has been identified in agricultural environments and different regions of the world, mainly in cereal, vegetable and pasture crops (Schuster et al. 2016; Saha and Datta 2017).

In these environments, germination and establishment of weed species are constantly influenced by factors related to soil properties, such as moisture content, pH and salinity, aluminum content, crop management, and other factors related to climate, such as temperature, wind, and light (Chen et al. 2009; Nosratti et al. 2017; Cochavi et al. 2018). The pH is a confounding factor for the availability of essential nutrients to plants, for the solubility of toxic elements, and for soil microflora (Chauhan and Johnson 2008), which affects weed growth and development. There are reports that pH below 3 and above 8 inhibits germination of some species (Chauhan and Johnson 2008; Forte et al. 2017). Salinity is another factor affecting seed germination, mainly due to limited water uptake (Farooq et al. 2017). Plant responses to high aluminum concentration in soil may be related to metabolic processes, such as protein synthesis, lipid mobilization, cell division, and cell wall synthesis, thus affecting seed germination (Ikka et al. 2013; Kopittke et al. 2015).

Soil cover can act as a physical barrier to weed germination and emergence, once it affects solar radiation incident on the soil surface, water balance, and soil thermal amplitude (Alonso-Ayuso et al. 2018, Forte et al., 2017). For effective weed management, knowledge of species biology is essential for the development of control strategies and their combination. Therefore, the aim of this study was to determine the environmental factors that affect the germination and emergence of *S. americanum.*

MATERIAL AND METHODS

The experiment was conducted in the laboratory of Sustainable Management of Agricultural Systems, at the Federal University of Fronteira Sul (UFFS), Erechim Campus, Erechim, RS, Brazil.

Plant material. *Solanum americanum* seeds were collected manually from fallow areas near corn and soybean crops. Matrix 1 was collected in Santa Maria – RS (29° 42' 55" S and 53° 44' 13" W), in March and April 2017 and matrix 2 was collected in Ibiraiaras – RS (28° 24' 19.1" S and 51° 37' 29.5" W), in the same season. Black fruits were collected, which were easily detached from the mother plant. Then, the seeds were cleaned manually. Seeds were cleaned of impurities, dried in the shade for five days, and stored at room temperature in plastic packaging.

Seeds of matrix plant 1 were used to evaluate the effects of osmotic potential, salinity, pH, aluminum, and soybean (*Glycine max*) cover, and seeds of matrix plant 2 were used to evaluate white oat (*Avena sativa*) cover.

General protocol for the germination tests. Experiments were conducted in a B.O.D. (Biochemical Oxigen Demand) type growth chamber with a 12-hour photoperiod and an alternating temperature of 20-30°C. Experiments were conducted in a completely randomized experimental design, with four repetitions. Fifty seeds were used in each repetition, totalizing 200 seeds per treatment. Seeds were placed in germination boxes over three sheets of filter paper moistened with distilled water in an amount equal to 2.5 times the dry mass of the paper substrate (Forte 2019).

Total germination (G) was calculated using the formula G (%) = (N/100) x 100, where: N = the number of germinated seeds at the end of the experimental period.

Effect of the osmotic potential. To evaluate osmotic stress on *S. americanum* germination, seeds were exposed to polyethylene glycol 6000 (PEG) solution with concentrations of 0.0, −0.1, −0.2, -0.3, −0.4, -0.5, −0.6, -0.7, −0.8, and −1.0 MPa, according to the germination methodology described by Cochavi et al. (2018).

Effect of salinity. The effect of salinity was evaluated in *S. americanum* seeds exposed to 0, 25, 50, 100, 150, 200, 250, 300, 350, 400, 450, and 500 mmol L^{-1} NaCl, according to the methodology described by Chen et al. (2009).

Effect of Ph. The effect of pH on *S. americanum* seeds was evaluated at seven pH values (4, 5, 6, 7, 8, 9, and 10), according to the methodology described by Chen et al. (2009). The pH was adjusted using HCI and NaOH solutions.

Effect of aluminum. The effect of aluminum (Al) on *S. americanum* seeds exposed to Al concentrations of 0, 1, 2, 3, 4, 5, 6, and 7 $cmol_c$ dm^{-3} was evaluated according to the germination methodology described by Chen et al. (2009).

Effect of level of soil cover. Two plant species grown at different seasons of the year, one in winter (*Avena sativa*) and the other in summer (*Glycine max*), were used to evaluate soil cover. Both experiments were conducted in a single-factor 1 x 11 scheme. For each species, 11 levels of soil cover (0, 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 6000, and 8000 kg ha^{-1} dry matter) were used. The methodology for germination was described by Forte (2019).

Statistical analysis. All total germination and emergence data were transformed with arcsine √%/100. Data were subjected to normality and additivity tests, and after demonstrating normality of errors, analysis of variance was performed using the F test ($p \leq 0.05$). When significant, linear and nonlinear regressions were applied for the quantitative factor ($p \leq 0.05$) and the Skott-Knott test for the qualitative experiment ($p \leq 0.05$).

RESULTS AND DISCUSSION

Factors overcoming the numbness of *S. americanum* seeds. Several works published in the literature show that temperature change is the main factor responsible for germination of *S. Americanum* seeds. The light and some chemical agents such as AG_3 and KNO_3 may also contribute to the process of seed germination (Zhou et al., 2005; Wei et al. 2009; Forte 2019).

Effect of the osmotic potential. It was observed that germination of *S. americanum* species was reduced and inhibited according to the decrease in water availability. At -0.1 MPa, germination was reduced to 5.8% and completely stopped at a potential of -0.2 MPa (Figure 1).

When the osmotic potential becomes smaller, there is a decrease in metabolic and biochemical processes, making the germination process impossible, which also affects the soaking and cell expantion of the embryo (Lima et al. 2018). Similar results were observed when *Polypogon fugax* seeds were subjected to osmotic stress; germination of this species was completely inhibited at an osmotic potential of -0.4 MPa (Wang et al. 2016).

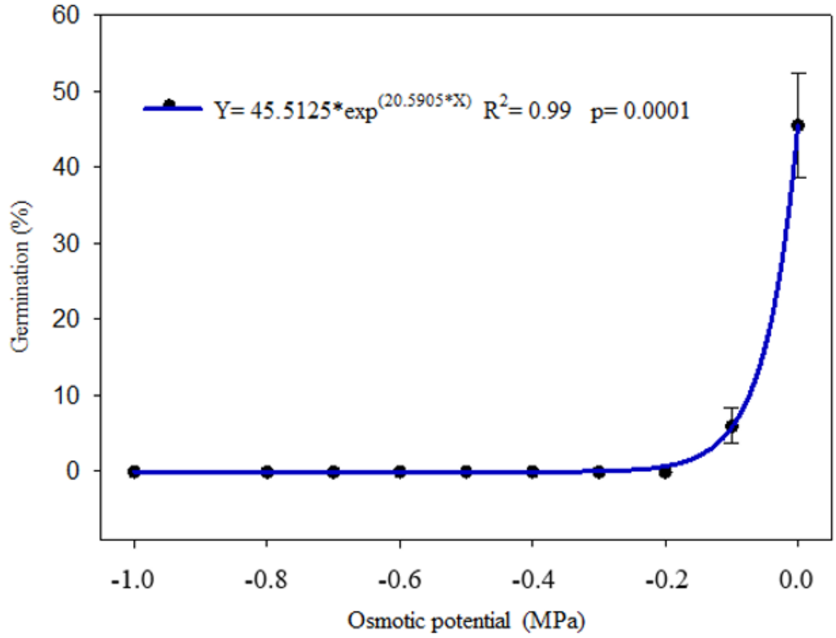

Figure 1. Germination (%) of *Solanum americanum* seeds as a function of solution osmotic potential. The vertical bars represent the standard deviation as a function of the mean.

Effects of Salinity. Germination of *S. americanum* is affected by NaCl concentration (Figure 2). It is observed that germination is less than 5% at the minimum concentration, and at a concentration of 100 mmol L^{-1}, germination is completely stopped. At a concentration of 14.24 mmol L^{-1}, germination decreases by 50%, showing the high sensitivity of the species to germination at low salt concentrations.

This is because salt stress limits water uptake by seeds, so without water uptake, the germination process is reduced or inhibited (Farooq et al. 2017).

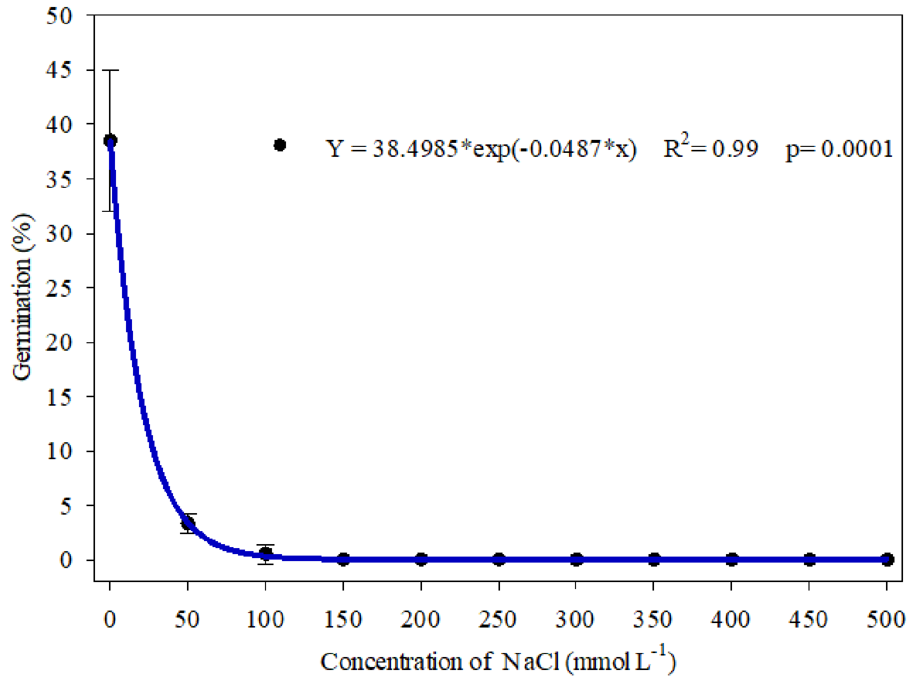

Figure 2. Germination (%) of *Solanum americanum* seeds as a function of solution NaCl concentration (mmol L^{-1}). The vertical bars represent the standard deviation as a function of the mean.

The results of Silva et al. (2018) highlight that salt stress delays germination and that the mechanisms involved need to be clarified in order to make a decision. As it is a weed, these strategies may be useful to adopt more efficient management and reduce the establishment of this species in crops.

Effect of pH. It was found that the seeds of *S. americanum* in solutions with pH of 5, 6, and 8 had a germination percentage higher than 60%, with the maximum value reached at pH 8 (Figure 3). However, at pH 9 and 10, a significant decrease in seed germination was observed, with values below 20%, indicating that very alkaline soils are unfavorable for *S. americanum* germination. In a similar study, Zhou et al. (2005) found similar behavior in *Solanum sarrachoides* seed germination when exposed to a pH range of 4 to 9 and concluded that the optimal range for germination of this species is between 6 and 8, with the percentage of germination decreasing significantly at pH values outside this interval.

Derakhshan and Gherekhloo (2013) observed the maximum germination percentage of *Cyperus difformis* at pH 6 (89%) and concluded that this species does not tolerate alkaline pH conditions and has better germination performance at pH values below 7.

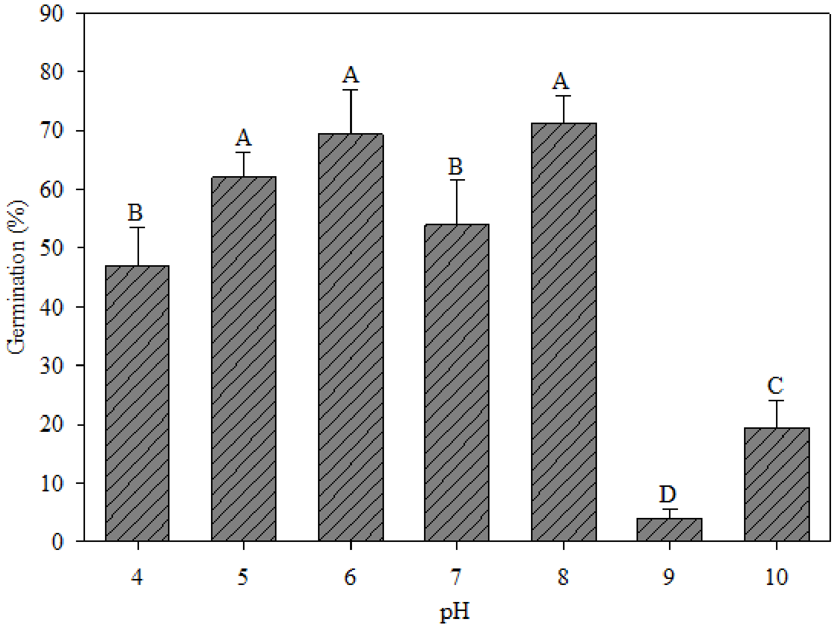

Figure 3. Germination (%) of *Solanum americanum* seeds as a function of solution pH. Gray vertical columns with the same letter do not differ from each other by Skott Knott test, probability of error < 0.05. Vertical bars in each column represent the standard deviation as a function of the mean.

Effect of aluminum content. Figures 4A and 4B show that there was no Al^{3+} effect on the germination of *S. americanum* seeds when radicle emission was considered. The average germination was 58% when this parameter was taken into account. The increase in aluminum concentration did not affect the initial germination process, water uptake, entry of O_2, depletion of reserves, and radicle emission, characteristics pf phases I, II, and III of seed germination (Nonogaki & Nonogaki 2017).

Strikingly, the reduction of normal *S. americanum* plants with the increase of Al^{3+} concentration in the solution, this reduction is observed even at the lowest values (Figure 4A and 4B). The reduction in half of the normal *S. americanum* plants occurs very close to the 1 cmolc dm^{-3} concentration of Al^{3+}, represented by the red dashed line (Figure 4A).

Based on the obtained results, the sensitivity of the species to Al^{3+} can be seen, which is very present in acidic soils and low fertility (Kopittke et al. 2015). The reduction in germination rate in the presence of Al^{+3} can be explained by the fact that Al^{+3} affects metabolic processes such as protein synthesis, lipid mobilization, cell division and cell wall synthesis (Ikka et al. 2013, Kopittke et al. 2015). Similar effects of the phytotoxicity of aluminum observed in Figure 4B were also reported in seedlings of *Lactuca sativa*, where the concentration of 20 mg dm^{-3} reduced the length of the aerial parts in one of the cultivars, but without affecting seed germination (Silva & Matos 2016). This fact was also demonstrated in the species *Conyza canadensis* and *Conyza bonariensis* (Yamashita & Guimarães 2010). Kopittke et al. (2015) concluded that the properties, composition, and mechanisms involved in cell wall loosening are strategies that could overcome the deleterious effects of soluble Al.

Effect of soil cover. The degree of soil cover was found to have a large effect on the percentage of *S. americanum* seedlings in both cover types, with this variable decreasing with increasing soil cover. Soybean cover was found to decrease exponentially, while *Avena sativa* cover decreased linearly, with 12 and 10% less soybean

DOI: 10.26814/cps2023003 | 7 pages

and white oat straw per additional ton of dry matter, respectively, in the result. Using 6 tons ha^{-1} or more reduces species germination to less than 10% (Figure 5).

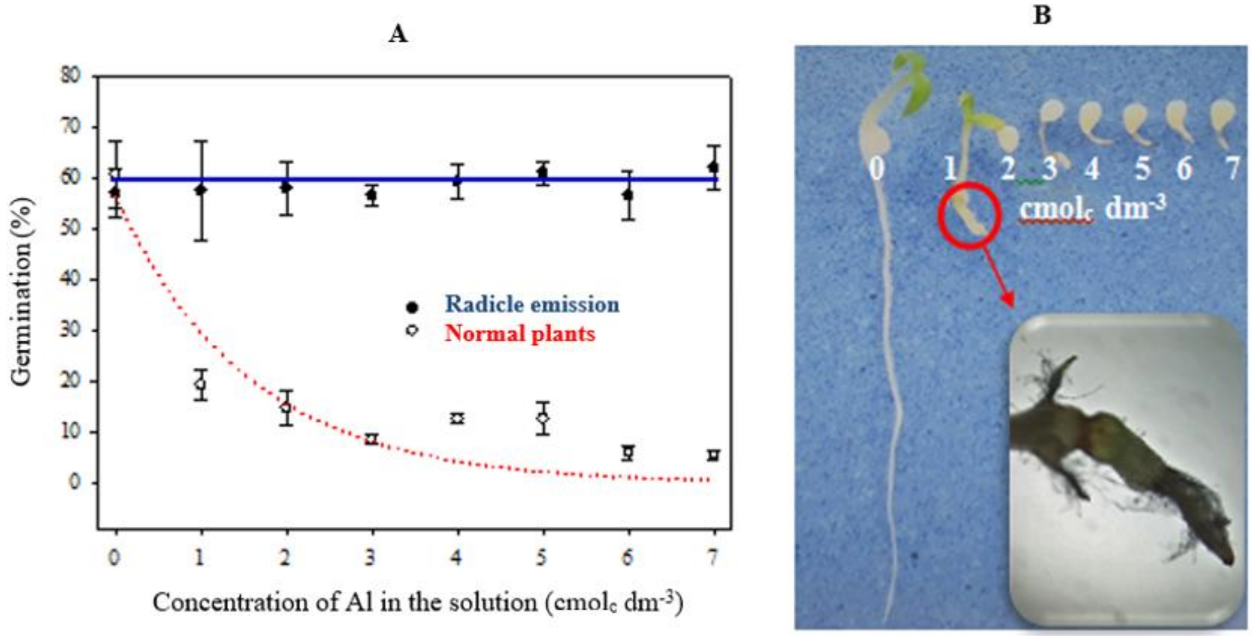

Figure 4. Germination (%) of *Solanum americanum* seeds as a function of Al concentration in solution ($cmol_c$ dm^{-3}). Figure 4A shows the increase in Al concentration and Figure 4B shows the symptoms observed at each concentration. The vertical bars represent the standard deviation as a function of the mean. Equation of normal plants as a result of the increase in aluminum concentration in solution $Y=56.3524*exp^{(-0.6452*X)}$.

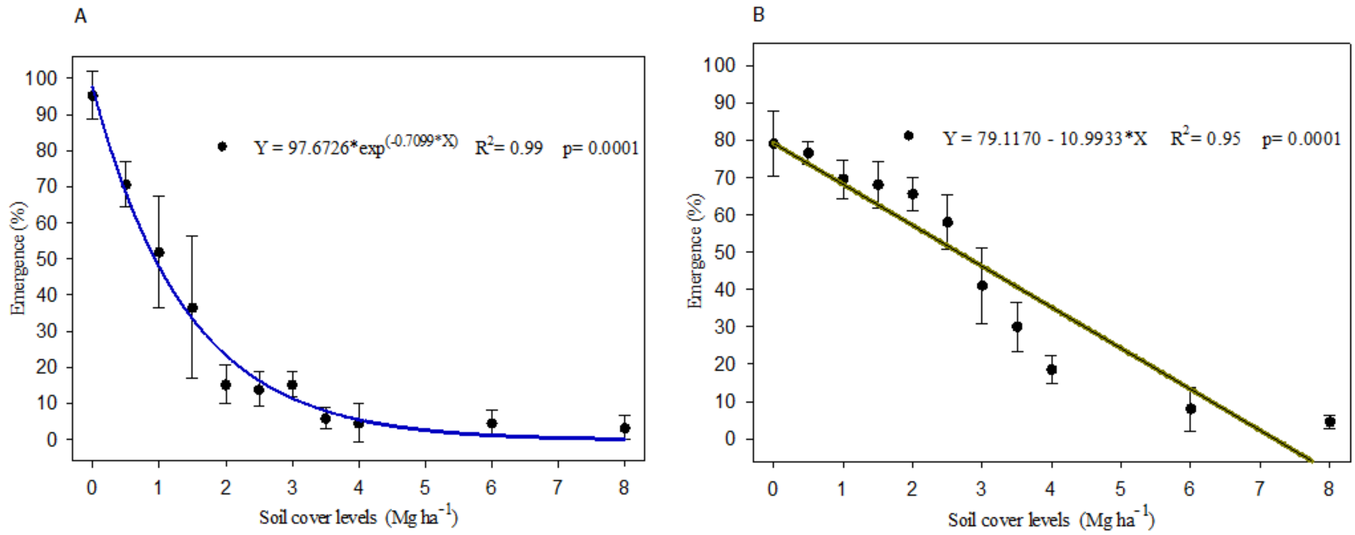

Figure 5. Emergence of *S. americanum* seedlings as a function of soil cover (Mg ha^{-1}), with soybean (*Glycine max*) (A) and white oats (*Avena sativa*) (B). The vertical bars represent the standard deviation as a function of the mean.

Wei et al. (2009) confirmed that photoperiod has an effect on *S. nigrum* germination when they evaluated alternate photoperiod (light/dark); germination in the light period was two times higher than the treatment without light presence. This suggests that light limitation on the soil surface due to the presence of a vegetative cover leads to a reduction in germination of *S. Americanum* seeds.

The main reasons for control of weeds by soil cover crops are: decreased brightness, physical barrier, increased seed decomposition and predation (> organic matter > microbial activity), decreased temperature shift (essential for germination of many weed species, including *S. americanum*), the decrease in germination of *S. americanum* corresponding to the increase in dry matter on the soil is shown in Figure 5. Some studies indicate the importance of the effectiveness of various winter covers, particularly *Avena strigosa*, in suppressing the establishment of mono- and dicotyledonous weeds in no-till systems (Chauhan et al. 2006; Flower et al. 2012; Forte et al. 2017). This behavior highlights the importance of maintaining soil cover with species that provide an unfavorable environment for weed development as a cultural control strategy and as a way to supplement or eliminate chemical control in some agricultural areas.

Applicability in the field. According to the results presented in this study, germination of *S. americanum* is affected under various environmental conditions, except by aluminum. It has been shown that minimal water deficit can reduce germination, and the same is true for increasing salinity.

Under alkaline soil conditions with pH between 9 and 10, germination is affected, and under normal field conditions with pH between 5 and 8, the germination remains above 60%. Different covers amounts were found to affect germination, with reductions noticeable with each additional ton, in soils with straw amounts greater than 6 tons ha^{-1}, with emergence seriously affected. A practical recommendation of this study is that managing the soil with cover crops can be effective in controlling *S. americanum.* Studies published in the literature show that temperature variation is the main factor affecting *S. Americanum* germination, and that light and some chemical such agents as AG_3 and KNO_3 can also contribute to seed germination (Forte 2019).

In conclusion, increased salinity and decreased osmotic potential have a negative effect on seed germination of *S. americanum*. Aluminum content did not affect germination, but does affect normal seedling development. The pH range between 5 and 8 maintains more than 50% germination of *S. americanum*, and alkaline pH has the greatest effect on germination of the species. Increasing the amount of straw decreased the emergence of *S. americanum*, regardless of the vegetative soil cover used.

Acknowledgments
To CNPq, FAPERGS and UFFS, for the financial support to the research and for the granting of scholarships.

Funding
This research was financially supported by the National Council for Scientific and Technological Development (CNPq), Research Support Foundation of Rio Grande do Sul (FAPERGS), and the Federal University of Fronteira Sul (UFFS).

References
Alonso-Ayuso M et al. 2018. Weed density and diversity in a long-term cover crop experiment background. Crop Protection 112:103-111.

Chauhan BS et al. 2006. Factors affecting seed germination of threehorn bedstraw (*Galium tricornutum*) in Australia. Weed Science 54:471-477.

Chauhan BS and Johnson DE. 2008. Influence of environmental factors on seed germination and seedling emergence of Eclipta (*Eclipta prostrata*) in a tropical environment. Weed Science 56:383-388.

Chen GQ et al. 2009. Invasiveness evaluation of fireweed (*Crassocephalum crepidioides*) based on its seed germination features. Weed Biology and Management 9:123-128.

Cochavi A et al. 2018. Impact of environmental factors on seed germination and emergence of wild poinsettia (*Euphorbia geniculata* Ortega). Crop Protection 114:68-75.

Derakhshan A and Gherekhloo J. 2013. Factors affecting *Cyperus difformis* seed germination and seedling emergence. Planta Daninha 31:823-832.

Farooq M et al. 2017. Effects, tolerance mechanisms and management of salt stress in grain legumes. Plant Physiology and Biochemistry 118:199-217.

Flower KC et al. 2012. Nitrogen, weed management and economics with cover crops in conservation agriculture in a Mediterranean climate. Field Crops Research 132:63-75.

Forte CT et al. 2017. Competitive ability of transgenic soybean cultivars coexisting with weeds. Revista Brasileira de Ciências Agrárias 12:185-193.

Forte CT. 2019. Dormência de sementes e manejo de *Solanum americanum* Mill. Santa Maria: Universidade Federal de Santa Maria, Centro de Ciências Rurais, Programa de Pós Graduação em Agronomia. 61p. Tese Doutorado.

Galon L et al. 2018. Interference periods of weeds infesting maize crop. Journal of Agricultural Science 10:197-205.

Galon L et al. 2022. Periods of interference of Alexandergrass on morphophysiological and productive characteristics of transgenic soybean. Communications in Plant Sciences 12:60-66.

Ikka T et al. 2013. Effect of aluminum on metabolism of organic acids and chemical forms of aluminum in root tips of *Eucalyptus camaldulensis* Dehnh. Phytochemistry 94:142-147.

Kopittke PM. et al. 2015. Identification of the primary lesion of toxic aluminum (Al) in plant roots. Plant Physiology 167:1402-1411.

Lima AT et al. 2018. Does discontinuous hydration of *Senna spectabilis* (DC.) H.S. Irwin & Barneby var. excelsa (Schrad.) H.S. Irwin & Barneby (Fabaceae) seeds confer tolerance to water stress during seed germination?. Journal of Seed Science 40:36-43.

Lorenzi H. 2017. Manual de identificação e de controle de plantas daninhas: plantio direto e convencional. Ed. 7, Nova Odessa: Plantarum. 338p.

Nonogaki M and Nonogaki H. 2017. Germination. Encyclopedia of Applied Plant Science 1:509-512.

Nosratti I et al. 2017. Seed germination and seedling emergence of Iberian starthistle (*Centaurea iberica*). Weed Biology and Management 17:144-149.

Saha M and Datta BK. 2017. Diversity of *Solanum* L. (Solanaceae) in Tripura (India) including new records. Pleione 11:85-96.

Schuster MZ et al. 2016. Grazing intensities affect weed seedling emergence and the seed bank in an integrated crop–livestock system. Agriculture, Ecosystems & Environment 232:232-239.

Silva ALD et al. 2018. Salinity tolerance in *Senna macranthera* (DC. ex Collad.) HS Irwin & Barneby seeds with sodium nitroprusside (SNP) promoted by cyanide. Journal of Seed Science 40:323-330.

Silva P and Matos M. 2016. Assessment of the impact of Aluminum on germination, early growth and free proline content in *Lactuca sativa* L.

Ecotoxicology and Environmental Safety, 131:151-156.
Wang L et al. 2016. Influence of environmental factors on seed germination and emergence of Asia Minor bluegrass (*Polypogon fugax*). Weed Technolology 30:533-538.
Wei S et al. 2009. Seed germination of a newly discovered hyperaccumulator *Solanum nigrum* L. affected by illumination and seed-soaking reagent. Journal of Hazardous Materials 170:1256-1259.
Yamashita OM and Guimarães SC. 2010. Germination of *Conyza Canadensis* and *Conyza bonariensis* seeds in function of water availability in the substrate. Planta Daninha 28:309-317.
Zhou J et al. 2005. Factors affecting germination of hairy nightshade (*Solanum sarrachoides*) seeds. Weed Science 53:41-45.