Universidade Federal Rural do Semi-Árido
Pró-Reitoria de Pesquisa e Pós-Graduação
https://periodicos.ufersa.edu.br/index.php/caatinga

ISSN 0100-316X (impresso)
ISSN 1983-2125 (online)
http://dx.doi.org/10.1590/1983-21252019v32n328rc

PHYSIOLOGICAL PERFORMANCE OF *Physalis angulata* L. SEEDS TREATED WITH CHEMICAL PROMOTERS[1]

WILLEN RAMOS SANTIAGO[2], JULIANA SIMÕES NOBRE GAMA[2], SALVADOR BARROS TORRES[3], MOADIR DE SOUSA LEITE[3]*, TIAGO DE SOUSA LEITE[3], FRANCISCO ASSIS NOGUEIRA NETO[3]

ABSTRACT - *Physalis angulata* L. (Solanaceae), popularly known as 'camapu', has high pharmacological and agroindustrial potential. However, because it essentially is a wild species, studies on the physiological quality of its seeds are still scarce. In this sense, the objective was to evaluate the physiological performance of *P. angulata* seeds as a function of pre-germination treatments with chemical promoters. For this, germination, first germination count, germination speed index and seedling emergence tests were performed. The substrate was previously moistened with solutions of gibberellic acid – GA3 (0.00, 0.02, 0.04, 0.06 and 0.08%), potassium nitrate – KNO_3 (0.0, 0.2, 0.4, 0.6, 0.8 and 1.0%) and Stimulate® (0.00, 0.25, 0.50, 0.75, 1.00, 1.25 and 1.50%). Each chemical promoter constituted an independent experiment, in a completely randomised design, with four replicates of 25 seeds each. The three chemical promoters enhanced the physiological performance of *P. angulata* seeds, and the concentrations of 0.05% GA3, 0.4% KNO_3 and 1.0% Stimulate® were most suitable.

Keywords: Solanaceae. Germination. Gibberellic acid. Potassium nitrate. Stimulate®.

DESEMPENHO FISIOLÓGICO DE SEMENTES DE *Physalis angulata* L. TRATADAS COM PROMOTORES QUÍMICOS

RESUMO - *Physalis angulata* L. (Solanaceae), conhecida popularmente como camapu, possui elevado potencial farmacológico e agroindustrial. No entanto, por ser uma espécie essencialmente silvestre, os estudos sobre a qualidade fisiológica de suas sementes ainda são escassos. Neste sentido, objetivou-se avaliar o desempenho fisiológico de sementes de *P. angulata*, em função de tratamentos pré-germinativos com promotores químicos. Para isso, realizou-se testes de germinação, primeira contagem de germinação, índice de velocidade de germinação e emergência de plântulas. O substrato foi previamente umedecido com soluções de ácido giberélico – GA3 (0,00; 0,02; 0,04; 0,06 e 0,08%), nitrato de potássio - KNO_3 (0,0; 0,2; 0,4; 0,6; 0,8 e 1,0%), e Stimulate® (0,00; 0,25; 0,50; 0,75; 1,00; 1,25 e 1,50%). Cada promotor químico constituiu um experimento independente, em delineamento inteiramente casualizado, com quatro repetições de 25 sementes. Os três promotores químicos estimularam o desempenho fisiológico de sementes de *P. angulata*, e as concentrações de 0,05% de GA3, 0,4% de KNO_3 e 1,0% de Stimulate® foram as mais adequadas.

Palavras-chave: Solanaceae. Germinação. Ácido giberélico. Nitrato de potássio. Stimulate®.

*Corresponding author
[1]Received for publication in 12/19/2018; accepted in 06/19/2019.
Paper extracted from the doctoral thesis of the first author.
[2]Instituto Federal de Educação, Ciência e Tecnologia do Pará, Castanhal, PA, Brazil; willen.santiago@ifpa.edu.br - ORCID: 0000-0001-9475-5145, juliana.gama@ifpa.edu.br - ORCID: 0000-0002-5716-4917.
[3]Center of Agricultural Sciences, Universidade Federal Rural do Semi-Árido, Mossoró, RN, Brazil; sbtorres@ufersa.edu.br - ORCID: 0000-0003-0668-3327, moadir@outlook.com - ORCID: 0000-0003-0432-0522, tiagosousa@usp.br - ORCID: 0000-0003-0398-4968, assis-neeto@hotmail.com - ORCID: 0000-0001-7037-6941.

INTRODUCTION

Physalis angulata L. (Solanaceae) is popularly known in the Amazon region as 'camapu'. It is an annual herbaceous plant with high pharmacological and agroindustrial potential (GUIMARÃES et al., 2010; OLIVEIRA et al., 2011) and propagated by seeds (OLIVEIRA et al., 2015). However, because it essentially is a wild species, with continuous flowering and irregular maturation, the occurrence of seeds with different levels of physiological quality (SANTIAGO et al., 2019), as well as low expression of their quality (CARVALHO et al., 2014), is common.

In some species, both cultivated and wild, seed treatment with phytoregulators has been effective in promoting greater expression of physiological quality, as reported by Prado Neto et al. (2007) for *Genipapa americana* L. and by Vendruscolo et al. (2016) for *Solanum lycopersicum* L. Phytoregulators, also called "plant bioregulators", are exogenously applied synthetic substances which alter plant morphology and physiology and may lead to qualitative and quantitative changes in agricultural production (VIANA et al., 2015).

Gibberellic acid (GA3) is a commercially available phytoregulator with physiological functions similar to those of gibberellins (GUERRA; RODRIGUES, 2012). According to Taiz et al. (2017), these phytohormones are associated with the synthesis or activation of enzymatic systems, contributing to protein degradation and nutritional reserves, energy release, decrease in cell wall stiffness and increased cell division, elongation and water intake, thus favouring the growth of the seed embryo.

The mixture of two or more phytoregulators, or of these with other substances such as amino acids, vitamins or nutrients, is also known as "biostimulant" or "plant stimulant" (PRADO NETO et al., 2007). Recent studies evaluating the effects of seed treatment with phytoregulators showed promising results regarding dormancy breaking, increases in germination and germination speed, better uniformity and higher seedling length and dry weight (SANTOS et al., 2013).

In addition to phytoregulators, one of the most widely used chemical promoters for pre-germination treatment is potassium nitrate (KNO_3) (CARVALHO; NAKAGAWA, 2012). The nitrate ion present in KNO_3 is associated with the pentose phosphate pathway, which is an important route in the electron transport system in the early stages of germination (MARCOS-FILHO, 2015). Both GA3 and KNO_3 are recommended by the Rules for Seed Analysis for pre-germination treatment (BRASIL, 2009). Nevertheless, there is no information in the literature about the influences of these chemical promoters on the physiological quality of *P. angulata*.

In view of the above, the objective of this work was to evaluate the physiological performance of *P. angulata* seeds previously treated with gibberellic acid, potassium nitrate and biostimulant (Stimulate®).

MATERIAL AND METHODS

This research was conducted in the Seed Analysis Laboratory of the Federal Institute of Education, Science and Technology of Pará (IFPA), Castanhal, PA, Brazil. Mature *Physalis angulata* L. fruits, with green calyx (CARVALHO et al., 2014), were collected manually from 20 spontaneous plants growing in an area of the IFPA's Castanhal campus (1°17′49″S, 47°55′19″W, 41 m above sea level).

After harvesting the fruits, the seeds were manually extracted, rinsed under running water and placed to dry on paper towel in a shaded environment at room temperature (25 °C) for 24 hours. After drying, the seed moisture content was determined by oven-drying at 105 ± 3 °C for 24 hours (BRASIL, 2009), obtaining a mean value of 7%.

For the pre-germination treatments of *P. angulata* seeds, three chemical promoters were used in increasing concentrations: gibberellic acid – GA3 (0.00, 0.02, 0.04, 0.06 and 0.08%); potassium nitrate – KNO_3 (0.0, 0.2, 0.4, 0.6, 0.8 and 1.0%); and Stimulate® (0.00, 0.25, 0.50, 0.75, 1.00, 1.25 and 1.50%). The latter is a commercial biostimulant consisting of 0.005% indolebutyric acid (auxin), 0.009% kinetin (cytokinin) and 0.005% gibberellic acid. The concentration ranges of GA3 and KNO_3 were determined based on the dose indicated in the Rules for Seed Analysis for these promoters (BRASIL, 2009), while the concentration ranges of Stimulate® were determined based on the manufacturer's recommendations.

Since there are no recommendations for the germination test of *P. angulata* seeds in the Rules for Seed Analysis, we adopted the guidelines used for *Physalis pubescens* L. (BRASIL, 2009). Each chemical promoter was applied separately, thus constituting three independent experiments, where the following variables were analysed:

First germination count and germination - four replicates of 25 seeds were sown on two sheets of paper towel (Germitest®) in Petri dishes. The substrate was moistened with distilled water (control) or solutions with the different concentrations of the chemical promoters, at a ratio of 2.5 times the dry weight of the paper. The seeds were placed to germinate in the dark at a constant temperature of 35 °C (SANTIAGO et al., 2019). The evaluations were performed at 7 and 28 days after the beginning of the test (BRASIL, 2009), when germination stabilised and the primary root protrusion (> 0.2 mm) was adopted as a criterion, with the results expressed as percentages.

Germination speed index - it was performed simultaneously with the germination test, with daily counts of the germinated seeds, during the 28 days of the test, using the formula proposed by Maguire (1962):

$$GSI = \sum \frac{G1}{N1} + \frac{G2}{N2} + \frac{Gn}{Nn} \quad \text{Eq. 1}$$

where GSI = germination speed index, G1, G2 and Gn = number of germinated seeds at the first, second and last counts, respectively, N1, N2 and Nn = number of days from sowing to the first, second and last counts, respectively.

Seedling emergence - four replicates of 50 seeds were sown in plastic containers (13 x 10 x 5 cm) containing sterilised sand moistened with 60% of its retention capacity, using distilled water (control) or solutions with the different concentrations of each chemical promoter. The containers were kept under natural light, protected from direct sunlight and without temperature and relative humidity control. When necessary, the substrate was remoistened with distilled water (control) or with the abovementioned solutions (for each treatment). The evaluation was performed at 15 days after sowing, counting the number of emerged seedlings, with the values expressed as percentages.

The experiments were carried out in a completely randomised design. First, normality and homogeneity of variances were tested by the Kolmogorov-Smirnov ($P < 0.01$) and Bartlett ($P < 0.01$) tests, respectively. Subsequently, the data were subjected to polynomial regression analysis ($P < 0.05$), using the statistical program System for Analysis of Variance – SISVAR (FERREIRA, 2011).

RESULTS AND DISCUSSION

The mean values of the analysed variables, after treatment of *P. angulata* seeds with increasing concentrations of gibberellic acid, are shown in Figure 1.

The first germination count (Figure 1A), germination (Figure 1B) and germination speed index (Figure 1C) were not significantly influenced by the use of GA3, and the mean values obtained for the concentrations were statistically similar to those obtained in the control treatment.

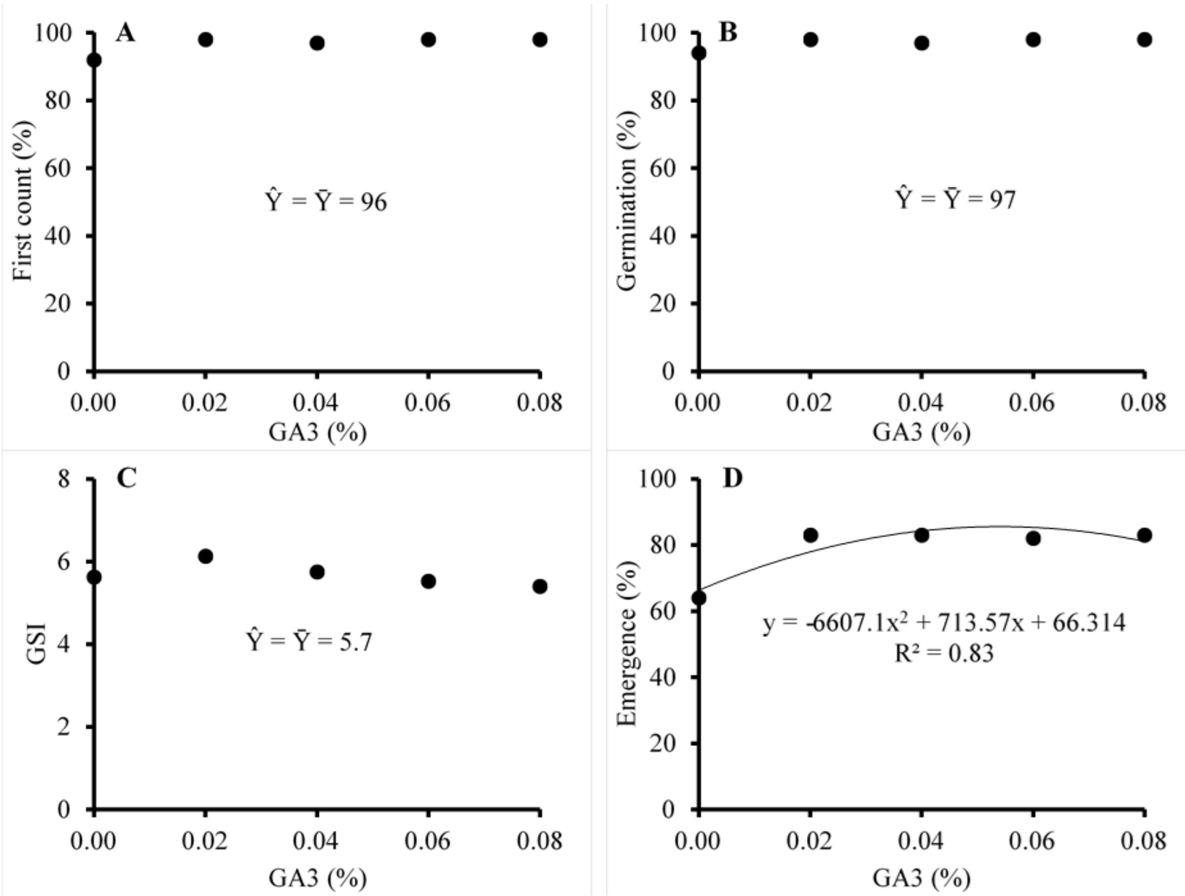

Figure 1. First germination count (A), germination (B), germination speed index - GSI (C) and seedling emergence (D) of *Physalis angulata* L. as a function of pre-germination treatment with gibberellic acid (GA3).

Although *P. angulata* is a wild species, studies show that, according to the maturation stage as well as storage conditions and time, its seeds can present high germination potential in the laboratory (CARVALHO et al., 2014; SOUZA et al., 2014). According to Marcos-Filho (2015), the control of environmental conditions during the germination test can also contribute to the expression of a high physiological potential, which may have made the use of GA3 ineffective for the variables obtained from the germination test.

For seedling emergence (Figure 1D), there was a quadratic response to the increase in GA3 concentration, and the peak of the curve occurred at 0.05%, with a 19% increase in seedling emergence in relation to the control treatment. The Rules for Seed Analysis (BRASIL, 2009) recommend GA3 concentrations between 0.02 and 0.1%, depending on the physiological condition of the seed, with 0.05% GA3 being within the suggested range.

Despite the beneficial effect of GA3 on the emergence of *P. angulata* seedlings in the present study, the effectiveness of this chemical promoter on seeds of other species is still controversial. As emphasised by Taiz et al. (2017), when the endogenous concentration of gibberellins in seeds is at an adequate level to perform physiological activities, treatment with GA3 may be ineffective or even negatively affect seed germination and vigour. Silva et al. (2009a) verified a significant reduction in germination and seedling emergence in sand after the use of GA3 in *Bertholletia excelsa* (Humb. & Bonpl.) seeds.

Regarding the treatment of *P. angulata* seeds with KNO_3, there were significant effects on the first germination count (Figure 2A) and the germination speed index (Figure 2C), with an increase in the values obtained for these variables for up to 0.4% KNO_3, followed by a decrease with the use of higher concentrations. At 0.4% KNO_3, there was a 6% increase in the first count and germination speed index in relation to the control treatment.

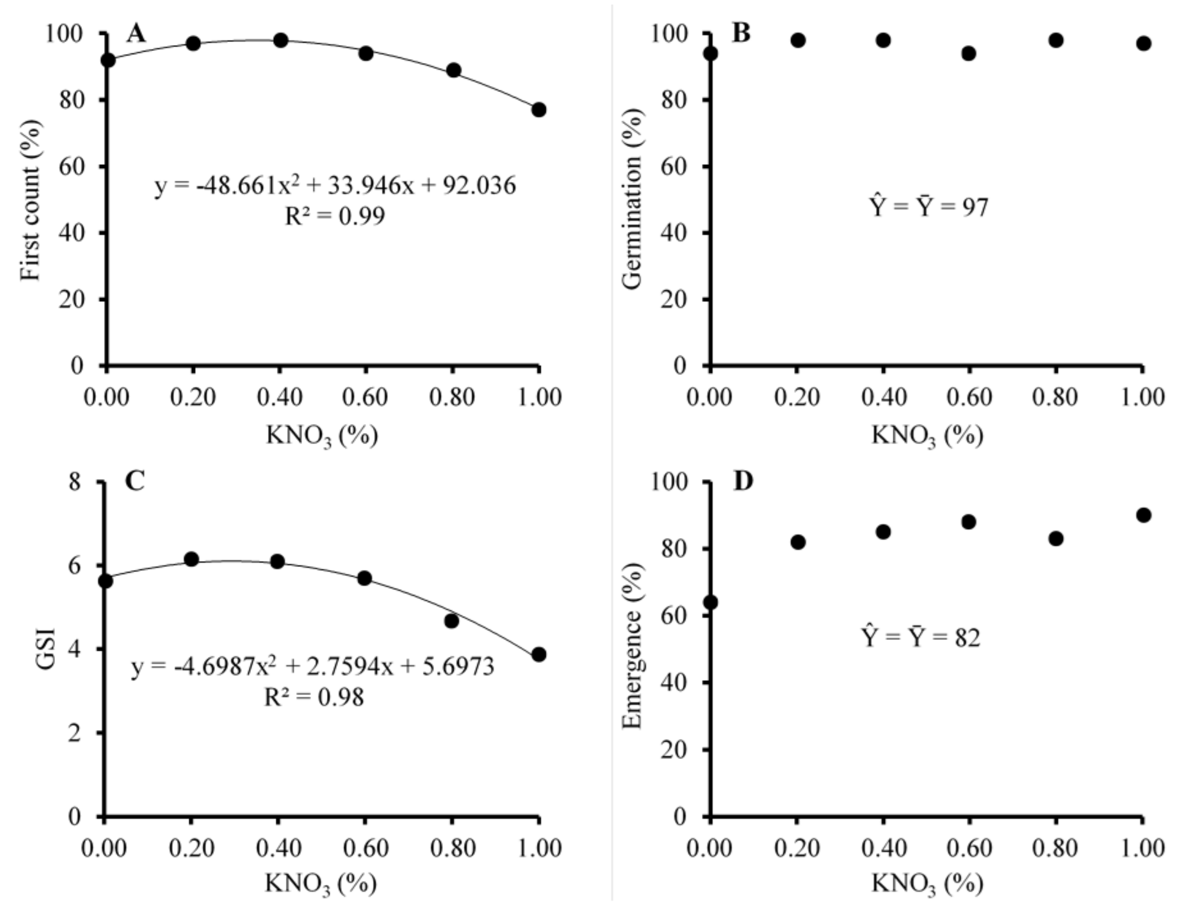

Figure 2. First germination count (A), germination (B), germination speed index - GSI (C) and seedling emergence (D) of *Physalis angulata* L. as a function of pre-germination treatment with potassium nitrate (KNO_3).

Usually, the KNO_3 concentration of 0.2% is the most used in seed treatment (BRASIL, 2009). However, concentrations close to 1.0% may also be used, depending on the physiological state of the seed (MARCOS-FILHO, 2015). The effectiveness of KNO_3 as a chemical promoter is associated with the reduction of this compound to nitrite, inside the cells, acting as an electron receptor and facilitating the pentose phosphate cycle (MARCOS-FILHO, 2015). For *P. angulata*, possibly, KNO_3 concentrations above 0.4% tend to cause nitric nitrogen saturation in the cells.

As for seed germination, there was no significant effect of KNO_3 (Figure 2B). Similar to the present study, Silva, Guimarães and Yamashita (2009b), evaluating the germination of *Chloris barbata* L. seeds as a function of dispersion units and initial substrate wetting, did not obtain significant results with the use of KNO_3 when moisture and light conditions were suitable for the species. In turn, Santos et al. (2011) verified the effectiveness of KNO_3 only on the vigour of *Brachiaria brizantha* Hochst. seeds, with little influence on the final percentage of germinated seeds.

According to Carvalho and Nakagawa (2012), the beneficial effect of KNO_3 on germination is more evident in seeds with restricted oxygen entry, especially when substances that retain this element are present in the seed coat or embryo.

Although there was no significant effect of KNO_3 on seedling emergence, the highest mean values for this variable were obtained after treatment with KNO_3 (Figure 2D).

It should be noted that the physiological response of seeds to KNO_3 may vary depending on the species, within the same genus or even among cultivars of the same species (BINOTTI et al., 2014), making it difficult to fully understand the action of this chemical promoter. In addition, similar to that of GA3, the action of KNO_3 on seed physiology is also influenced by external abiotic factors, mainly light and temperature, as well as storage time (SILVA et al., 2009a; CARVALHO; NAKAGAWA, 2012; NUNES et al., 2015).

For seeds treated with Stimulate®, there were significant effects on the first germination count (Figure 3A), germination speed index (Figure 3C) and seedling emergence (Figure 3D). Nevertheless, as for the other chemical promoters studied, there was no significant increase in the final percentage of germinated seeds (Figure 3B).

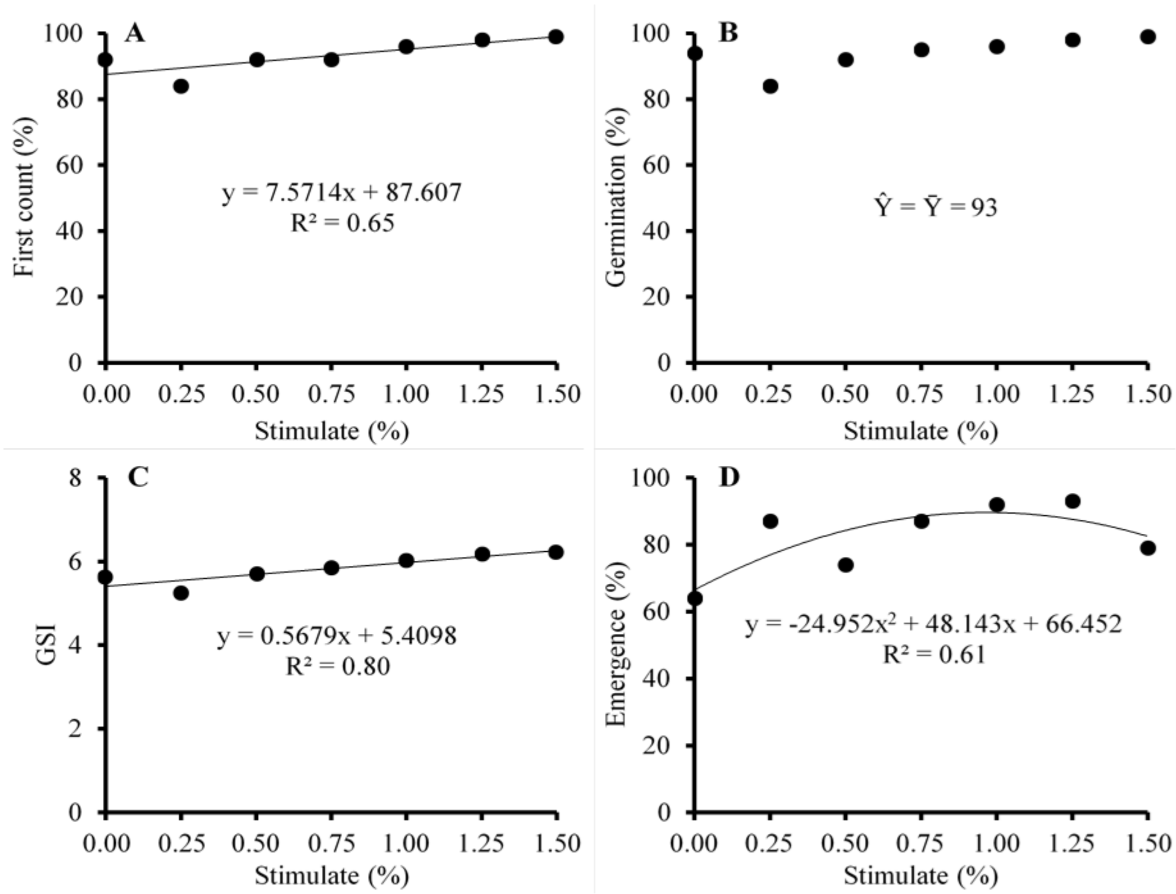

Figure 3. First germination count (A), germination (B), germination speed index - GSI (C) and seedling emergence (D) of *Physalis angulata* L. as a function of pre-germination treatment with Stimulate®.

Germination speed increased proportionally with the concentration of Stimulate®. As evidenced by the first count and the germination speed index, the maximum speed was reached at a concentration of 1.50%, leading to increases of 11 and 13%, respectively, in relation to the control treatment. As for seedling emergence, there was a quadratic effect, with the peak observed at 1.0% Stimulate®, followed by a decrease after the use of higher concentrations.

Similar to *P. angulata*, Mortele et al. (2011) also verified a greater expression of the vigour of *Glycine max* L. seeds treated with Stimulate®, without, however, obtaining significant increases in the final germination percentage. Similar results were obtained by Prado Neto et al. (2007) and Soares et al. (2012) for *Genipa americana* L. and *Lactuca sativa* L. seeds, respectively.

Nonetheless, in studies with *Helianthus annuus* L. (SANTOS et al., 2013) and *Citrullus lanatus* Thunb. (SILVA et al., 2004), the use of Stimulate® favoured both seed germination and vigour. As highlighted by Mortele et al. (2011), the action of plant biostimulants depends not only on their chemical composition and concentration, but also on other factors such as the contact surface of the seed, the sensitivity of the plant tissue and the interaction with abiotic factors, mainly light and temperature, besides the hormonal balance of the seed, factors that explain the different responses obtained for different species.

In addition to gibberellic acid, Stimulate® is composed of indolebutyric acid and kinetin, which are phytoregulators with physiological actions similar to those of auxins and cytokinins, respectively. Auxins and cytokinins are among the main substances associated with the permeability, differentiation, division and elongation of plant cells (TAIZ et al., 2017). Therefore, the effectiveness of Stimulate® on the vigour of *P. angulata* seeds is associated with the joint action of the three phytoregulators, contributing to a greater hormonal balance in the seeds.

CONCLUSIONS

Pre-germination treatments with GA3, KNO_3 and Stimulate® enhance the physiological performance of *P. angulata* seeds.

The concentrations of 0.05% GA3, 0.4% KNO_3 and 1.0% Stimulate® are most suitable for treatment of *P. angulata* seeds.

REFERENCES

BINOTTI, F. F. S. et al. Tratamentos pré-germinativos em sementes de brachiaria. **Revista Brasileira de Ciências Agrárias**, v. 9, n. 4, p. 614-618, 2014.

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. **Regras para análise de sementes**. Brasília: MAPA/ACS, 2009. 399 p.

CARVALHO, N. M.; NAKAGAWA, J. **Sementes: ciência, tecnologia e produção**. 5. ed. Jaboticabal, SP: Funep, 2012. 590 p.

CARVALHO, T. C. et al. Germinação de sementes de *Physalis angulata* L.: estádio de maturação do cálice e forma de armazenamento. **Pesquisa Agropecuária Tropical**, v. 44, n. 4, p. 357-362, 2014.

FERREIRA, D. F. Sisvar: a computer statistical analysis system. **Ciência e Agrotecnologia**, v. 35, n. 6, p. 1039-1042, 2011.

GUERRA, M. P.; RODRIGUES, M. A. Giberelinas. In: KERBAUY, G. B. (Ed.). **Fisiologia vegetal**. Rio de Janeiro: Guanabara Koogan, 2012. v. 2, cap. 11, p. 235-254.

GUIMARÃES, et al. Effects of seco-steroids purified from *Physalis angulata* L., Solanaceae, on the viability of Leishmania sp. **Revista Brasileira de Farmacognosia**, v. 20, n. 6, p. 945-949, 2010.

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

MARCOS-FILHO, J. **Fisiologia de sementes de plantas cultivadas**. 2. ed. Londrina, PR: ABRATES, 2015. 660 p.

MORTELE, L. M. et al. Efeito de biorregulador na germinação e no vigor de sementes de soja. **Revista Ceres**, v. 58, n. 5, p. 651-660, 2011.

NUNES, A. S. et al. Nitrato de potássio e retirada do pericarpo na germinação e na avaliação do vigor de sementes de crambe. **Semina. Ciências Agrárias**, v. 36, n. 3, p. 1775-1782, 2015.

OLIVEIRA, J. A. R. et al. Caracterização Física, Físico-Química e Potencial Tecnológico de Frutos de Camapu (*Physalis Angulata* L.). **Revista Brasileira de Tecnologia Agroindustrial**, v. 5, n. 2, p. 573-583, 2011.

OLIVEIRA, J. A. R. et al. Tipos de estacas e uso de AIB na propagação vegetativa de fisális. **Revista Agroambiente On-line**, v. 9, n. 3, p. 342-346, 2015.

PRADO NETO, M. et al. O. Germinação de sementes de jenipapeiro submetidas à pré-embebição em regulador e estimulante vegetal. **Ciência e Agrotecnologia**, v. 31, n. 3, p. 693-698, 2007.

SANTIAGO, W. R. et al. Physiological maturity of *Physalis angulata* L. seeds. **Revista Ciência Agronômica**, v. 50, n. 3, p. 431-438, 2019.

SANTOS, L. D. C. et al. Germinação de diferentes tipos de sementes de *Brachiaria brizantha* cv. BRS Piatã. **Bioscience Journal**, v. 27, n. 3, p. 420-426, 2011.

SANTOS, C. A. C. et al. Stimulate na germinação de sementes, emergência e vigor de plântulas de girassol. **Bioscience Journal**, v. 29, n. 2, p. 605-616, 2013.

SILVA, A. N. et al. Germinação de sementes de Castanheira-do-Pará armazenadas em areia úmida. **Pesquisa Agropecuária Brasileira**, v. 44, n. 11, p. 1431-1436, 2009a.

SILVA, J. L.; GUIMARÃES, S. C.; YAMASHITA, O. M. Germinação de sementes de *Chloris barbata* (L.) Sw. em função da luz. **Revista de Ciências Agro-Ambientais**, v. 7, n. 1, p. 23-34, 2009b.

SILVA, M. J. R. et al. Formação de mudas de melancia em função de diferentes concentrações e formas de aplicação de mistura de reguladores vegetais. **Scientia Plena**, v. 10, n. 10, p. 1-9, 2014.

SOARES, M. B. B. et al. Efeito da pré-embebição em solução bioestimulante sobre a germinação e vigor de sementes de *Lactuca sativa* L. **Biotemas**, v. 25, n. 2, p. 17-23, 2012.

SOUZA, M. O. et al. Preconditioning of *Physalis angulata* L. to maintain the viability of seeds. **Acta Amazonica**, v. 44, n. 1, p. 153-156, 2014.

TAIZ, L. et al. **Fisiologia e desenvolvimento vegetal**. 6. ed. Porto Alegre, RS: ARTMED, 2017. 858 p.

VENDRUSCOLO, E. P. et al. GA3 em sementes de tomateiro: efeitos na germinação e desenvolvimento inicial de mudas. **Revista de Agricultura Neotropical**, v. 3, n. 4, p. 19-23, 2016.

VIANA, R. S. et al. Aplicação de fitorreguladores químicos na qualidade tecnológica do sorgo sacarino cv. biomatrix 535. **Revista Brasileira de Milho e Sorgo**, v. 14, n. 3, p. 326-334, 2015.