Scientific Paper

Stimulant thermotherapeutic effect on *Glycine max* (L.) Merrill seeds for their use in winter sowing

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Abstract

Objective: To analyze the effect of the thermal treatment of five hours of exposure to 50 °C in winter sowing on morphological traits and yield components in seeds of seven cultivars of *Glycine max* (L.) Merrill.

Materials and Methods: The trial was carried out in experimental plots of the Department of Genetics and Plant Breeding of the National Institute of Agricultural Sciences in the Mayabeque province, Cuba. Variables related to plant emergence were evaluated as the main criterion for the evaluation of the effect of seed treatment ten days after sowing. Plant height, number of branches and height of the first pod were determined. During physiological maturity, yield components were evaluated: number of pods per plant, number of grains per pod and mass of grains. From these yield components, the yield in tons per hectare was estimated. All evaluated variables were subjected to factorial analysis and the means of the interactions and treatments were compared by Tukey's test ($p \leq 0,05$).

Results: The thermotherapeutic treatment of five hours of exposure to 50 °C increased the number of plant emergence per linear meter (93,0 and 74,3 % of plants planted with treated and untreated seeds, respectively). It did not affect final plant growth and number of branches, neither were yield components affected, and significantly increased final yield per hectare compared with the control (2,8 and 2,2 t/ha).

Conclusions: The treatment of five hours of exposure to 50 °C improved plant emergence per linear meter of the cultivars under study in winter sowing, which ensured higher potentially productive population per unit area. The treatment did not affect any of the characters of plant development and growth; as well as the yield components evaluated in the different cultivars of *G. max*, and increased the yield of all the studied cultivars.

Keywords: heat treatment, emergence, plants

Introduction

Of the oilseeds produced in the world, *Glycine max* (L.) Merrill ranks first in terms of production and consumption, due to its great diversity of uses, derived from its high protein content and oil quality (USDA, 2021). All this has led to its overwhelming expansion. Today, *G. max* is cultivated in all regions of the planet, and it is estimated that the demand for the grain and its derivatives internationally will have a significant increase in the next ten years (Soria-Acha, 2018).

Currently, as part of the economic policy developed by Cuba in the face of the national and international scenario, characterized by the food crisis, the greatest efforts have been aimed at ensuring higher levels of efficiency in the agri-food sector, as a way to reduce dependence on imports of *G. max* and move towards achieving food sovereignty (Mesa-León, 2017).

G. max has gained great importance in recent times among Cuban imports, due to its highly nutritious characteristics and multiple uses. Since, its import ranges from 250 to 400 million dollars (ONEI, 2020.). In the Cuban industry, the following derivatives are obtained: edible oil, flour for human and animal consumption and concentrate feed for livestock. All concentrate feeds destined for various animal species contain significant percentages of *G. max* cake to achieve satisfactory results in feeding, in the pharmaceutical and dairy industries, among others.

The production of *G. max* has as a critical point the deterioration of its seed during the period from physiological maturity to harvest, adverse climate conditions related to prolonged periods of rainfall, high or low temperatures and high humidity in the environment (ISTA, 2022). Modern agriculture has as its main input high quality seed, which must

Received: April 30, 2024
Accepted: August 24, 2024

How to cite a paper: Mederos-Ramírez, Alejandro & Ortiz-Pérez Rodobaldo. Thermotherapeutic stimulant effect on *Glycine max* (L.) Merrill seeds for use in winter sowing. *Pastures and Forages*. 47:e12, 2024.

meet different attributes: genetic, physiological, physical and sanitary quality (Flórez-Gómez *et al*., 2021). Seeds as a living entity require preserving their viability, germination and vigor to ensure the development of a new plant (Pardo-Varela, 2016). The physiological quality of the seed encompasses the sum of all the properties or characteristics that determine its potential performance and crop establishment (García-López *et al*., 2016).

Agriculture is constantly evolving. The topic of stimulatory treatments, which promote seedling development and prevent or cure diseases, is the order of the day with very important advances for farmers (Alfonso-Crespo, 2015). Seed treatments are generally based on the application of heat (thermotherapy) or chemicals, although the physical method of mutation induction is also used, in which seeds are exposed to different doses of Co^{60} irradiation, depending on the intended purpose (Lanna *et al*., 2020). In the department of genetics and breeding at the National Institute of Agricultural Sciences in Mayabeque, Cuba, thermotherapeutic research is being carried out based on the administration of dry heat to *G. max* seeds to stimulate their germination vigor and achieve more vigorous seeds (Mederos-Ramírez, 2022; Mederos-Ramírez and Ortiz-Pérez, 2022),

In the above-mentioned investigations, it was found that the most effective heat treatment for the studied variables was the one resulting from five hours of exposure of the seeds to 50 °C, which increased their germination capacity and rate. In addition, radicle length and dry mass exceeded the control. In summer sowing, the high effectiveness of the treatment prior to sowing of the cultivars was proven (Ortiz-Pérez and Mederos-Ramírez, 2024).

Based on the above, the objective of this work was to analyze the effect of heat treatment of five hours of exposure to 50 °C, in winter sowing, on morphological traits and yield components in seeds of seven *G. max* cultivars.

Materials and Methods

Location. The experimental trials were conducted during the months of November, 2020, to March, 2021, in areas of the Department of Agricultural Services of the National Institute of Agricultural Sciences (INCA), located at 23.0015148719447, -82.14158683068848 in San José de las Lajas, Mayabeque province, Cuba.

*Climate characteristics. T*he behavior of the climatic variables, temperature, relative humidity and monthly rainfall during the experimental period are shown in Figure 1.

Plant material. Original, certified seeds of six commercial cultivars were used, which were obtained and conserved at INCA: INCASoy-1, INCASoy-2, INCASoy-24, INCASoy-27, INCASoy-35 and INCASoy-36, obtained and conserved by CIGB: CIGB CC6. The seeds showed values of 10 to 11 % of humidity with satisfactory health, related to their original category. The grains were previously analyzed and showed satisfactory germination and development of normal seedlings, free of pathogenic fungi.

Experimental design and treatments. A complete randomized block design with 14 treatments [seven cultivars x treatment (five hours) x exposure temperature (50 °C) and a control of each untreated cultivar and three replicas] was applied. The blocks consisted of seven plots of 10 furrows of five meters (m) in length, separated by 0,75 m and one meter between blocks. The plots consisted of five furrows, sown with treated seeds and five furrows with untreated seeds of each of the seven cultivars under study.

Experimental procedure. To carry out the experiment, seed lots of the seven cultivars of *G. max* were randomly taken with two replicas. One of these seed lots of the seven cultivars of *G. max* were placed in paper envelopes, identified by cultivar, and exposed for five hours at 50 °C in the Boxun oven. After treatment, the seed was allowed to rest for 24 h at room temperature (±25 °C) and the experiment was sown in the field with the treated and untreated seeds.

Planting was carried out on a Ferrallitic Red soil (Hernández-García *et al*., 2021) with good physical properties and good drainage. The soil was prepared by plowing, disc harrowing, crossing, mulching with a disc harrow and, finally, furrowing at a distance of 0,75 m between furrows. The seeds were sown manually, at a rate of 26 seeds per linear meter.

Evaluated variables. Variables related to plant emergence were evaluated as the main criterion for evaluating the effect of the seed treatment. Ten days after sowing, the number of plants was counted per linear meter. Plant height and number of branches were analyzed at the flowering stage (R1) (50% of the plants had at least one pod). A tape graduated in millimeters was used for plant height. For the first pod, cutting height was evaluated with the same tape (mm) at the pod formation stage (R3) (50 % of the plants have at least one pod). During physiolo-

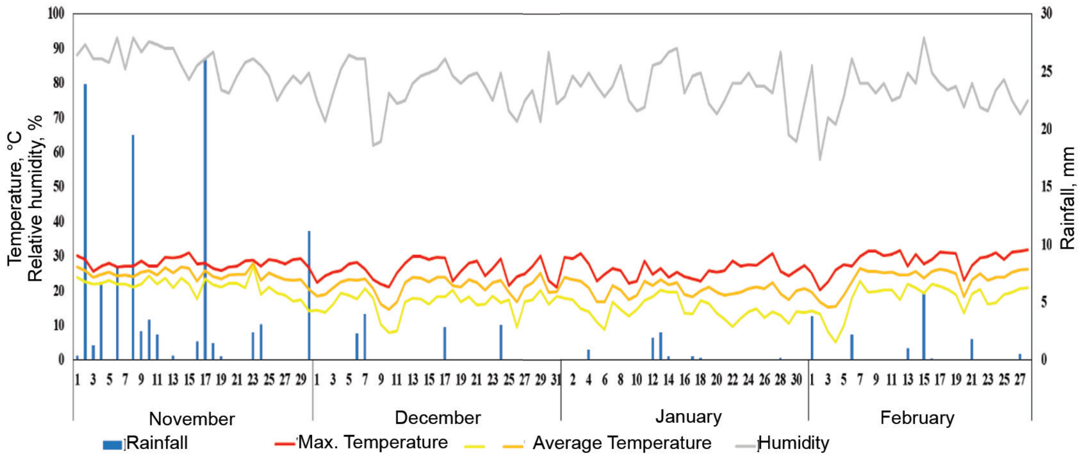

Figure 1. Performance of climate variables in the winter season 2021.

gical maturity (R8), yield components of ten plants were evaluated at each point in one linear meter and the number of pods per plant, the number of grains per pod and the mass of grains (g) were determined.

At harvest, plants from each experimental area were harvested from treated and untreated plants, which were threshed and weighed separately.

Statistical analysis. All studied variables were subjected to factorial analysis (seven cultivars x treatment five hours of exposure to 50 °C and a control of each untreated cultivar) and the means of the interactions and treatments were compared by Tukey's test ($P \leq 0{,}05$) with the application of the IBM statistical package SPSS version 22.

Results and Discussion

Table 1 shows the results of the factorial analysis of emerged plants per linear meter of the cultivars under study. As can be seen, the treatment shows highly significant differences in terms of emerged plants per linear meter. The other factors and their interactions did not show significant differences with regards to the variable in question.

Figure 2 illustrates the difference in the response of the treatment factor for plant emergence per linear meter. It is evident that the treatment of five hours of exposure to 50 °C, applied to the seeds of seven cultivars of *G. max*, had a positive influence in the winter season compared with untreated seeds.

Table 1. Factorial analysis for the variable emergence of plants per linear meter in the winter season, evaluation at 10 days after sowing.

Winter season		
Origin	Quadratic means	P - value
Corrected model	60,9	0,000
Intersection	568 806,6	0,000
Cultivar	1,2	0,881
Treatment	7105,3	0,000
Replica	2,4	0,679
Cultivar x treatment	2,1	0,675
Cultivar x replica	0,9	1,000
Treatment x replica	1,6	0,878
Cultivar x treatment x replica	1,3	1,000
Error ±	3,276	

$R^2 = 0{,}672$ (Corrected $R^2 = 0{,}636$)

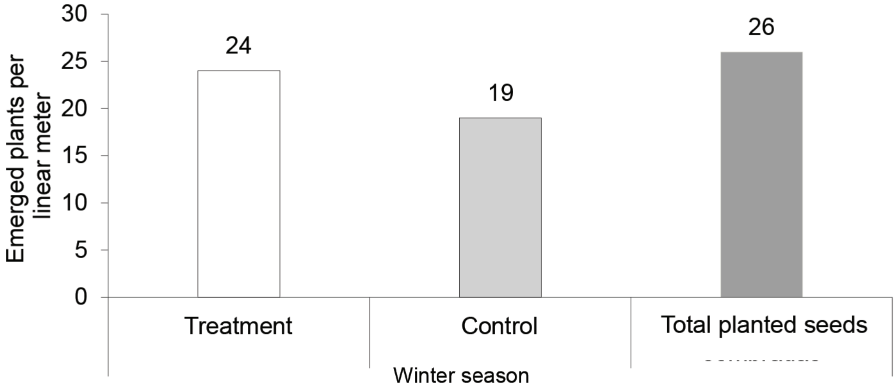

Figure 2. Analysis of emerged plants per linear meter.

At this season, 93,0 % of the plants sown with treated seeds emerged and 74,3 % of the untreated seeds emerged, reflecting an estimated 64 771 more plants per hectare.

The results coincide with those reported by Magallanes-Estala *et al*. (2014), who indicated that for the winter season the recommended optimum planting density is 20 to 25 plants per linear meter.

Variables related to plant growth and development. Table 2 shows the interactions of the factors under study with regards to the variables related to plant growth and development of the seven cultivars of *G. max* at flowering initiation stage (R1) in the different evaluation periods. Seed treatment did not affect the final growth of emerged plants because there was no significance among treatments for plant height, number of branches and cutting height.

As Table 2 shows, the seed treatments did not affect the evaluated growth and development variables. This is positive because plant sprouting was greatly benefited; each cultivar showed its own characteristics and significant differences appeared for the cultivars. Similar results were published by Ortiz-Pérez and Mederos-Ramírez (2022) in summer sowings, who concluded that the heat treatment did not affect plant development, and significantly improved seed sprouting.

Variables related to yield components such as number of pods per plant and number of grains/pod. These variables that contribute to the definition of final yield, as well as the variables related to plant development, are specific to each cultivar. Table 3 shows that there were no significant differences between the heat treatment and the control, only differences

Table 2. Factor analysis for growth and development variables evaluated at the flowering stage (R1).

Season	Plant height		Branches per plant		Cutting height	
Origin	Quadratic mean	P - value	Quadratic mean	P - value	Quadratic mean	P - value
Corrected model	495,0	0,000	1,7	0,000	68,6	0,000
Intersection	7 534 029,9	0,000	24 381,1	0,000	897 16,1	0,000
Cultivar	11 187,4	0,000	26,4	0,000	1 624,1	0,000
Treatment	0,7	0,837	2,0	0,030	0,3	0,327
Replica	21,9	0,252	1,5	0,053	0,4	0,346
Cultivar x treatment	66,6	0,002	0,8	0,079	0,1	0,857
Cultivar x replica	17,0	0,506	0,6	0,079	0,5	0,048
Treatment x replica	32,1	0,055	0,2	0,873	0,4	0,320
Cultivar x treatment x replica	33,0	0,000	0,*6*	0,087	0,3	0,884
Error ±	17,302		0,421		0,351	

R^2 = 0,672 (Corrected R^2 = 0,636) R^2= 0,308 (Corrected R^2= 0,232) R^2= 0,956 (Corrected R^2= 0,951)

Table 3. Factorial analysis of the variables related to yield components at the physiological maturity stage (R8).

Variable	Number of pods/plant		Grains per pod	
Origin	Quadratic mean	P - value	Quadratic mean	P - value
Cultivar	10 393,3	0,000	0,111	0,000
Treatment	24,08	0,158	0,080	0,145
Replica	9,7	0,639	0,011	0,847
Cultivar x treatment	15,6	0,264	0,046	0,043
Cultivar x replica	6,2	0,997	0,008	01,000
Treatment x replica	9,2	0,653	0,007	0,966
Cultivar x treatment x replica	6,9	0,990	0,006	1,000
Error ±	12,070		0,020	

R^2 = 0,802 (Corrected R^2 = 0,780) Square R = 0,072 (Corrected R^2 = 0,031)

between cultivars for both variables. In other words, seed treatment does not affect these two variables.

Lyonet (2022) reported similar results to those of this trial on five cultivars of *G. max* for the winter season. The author emphasizes that the obtained yields are attributed to an adequate planting density for the season.

Unlike the results obtained by Ortiz-Pérez and Mederos-Ramírez (2024), evaluated in summer, in this cold season, the cultivars with the highest number of pods/plant were INCASoy-2 and INCASoy-36. This is logical because of the differentiated performance of the cultivars in the different sowing seasons.

Actual yield in tons per hectare. This last variable, which was obtained by threshing the plants in each treatment and cultivar, is closely related to the population density; that is, to the number of plants per hectare. The variable emerged per linear meter shows significant differences.

Table 4 shows the factorial analysis, which reflects significant differences in final yield between the treated plants and the control: the greater the number of plants per hectare, the greater the number of legumes and grains, which translates into more tons per area.

Figure 5 shows the higher yields compared with the control seeds (2,8 and 2,2 t/ha, respectively) when analyzing the evaluated plants that emerged from treated seeds of the evaluated cultivars. The increase of more than 27,0 % of the yield, due to the effect of the seed treatment has a marked importance.

Under field conditions, the five-hour treatment at 50 °C improved plant emergence and vigor, a fundamental aspect for achieving high yields, since

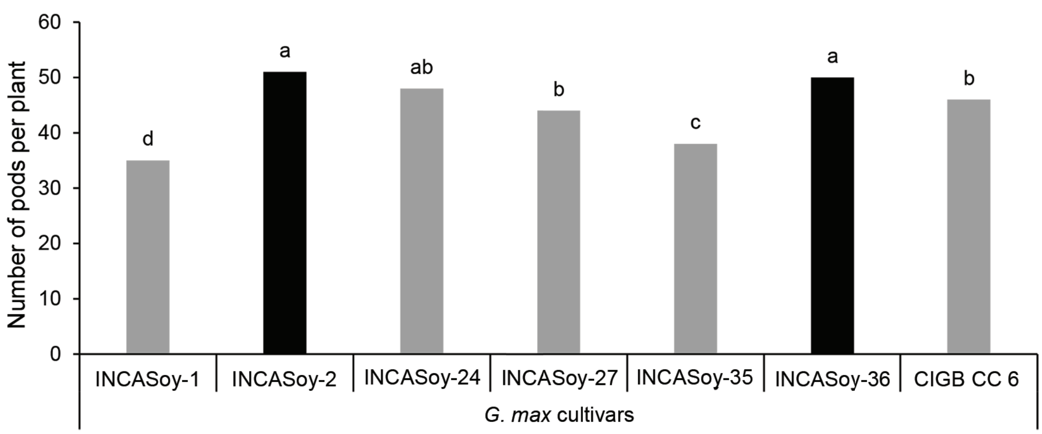

Figure 3. Mean values of the seven cultivars for the number of pods per plant.

Table 4. Factor analysis related to final yield between the treated plants and the control.

Variable	Estimated yield t/ha	
Origin	Quadratic mean	P - value
Cultivar	24,81	0,000
Treatment	0,04	0,000
Replica	109,47	0,820
Cultivar x treatment	0,02	0,019
Cultivar x replica	0,21	1,000
Treatment x replica	0,05	0,779
Cultivar x treatment x replica	0,04	0,996
Error ±	0,077	

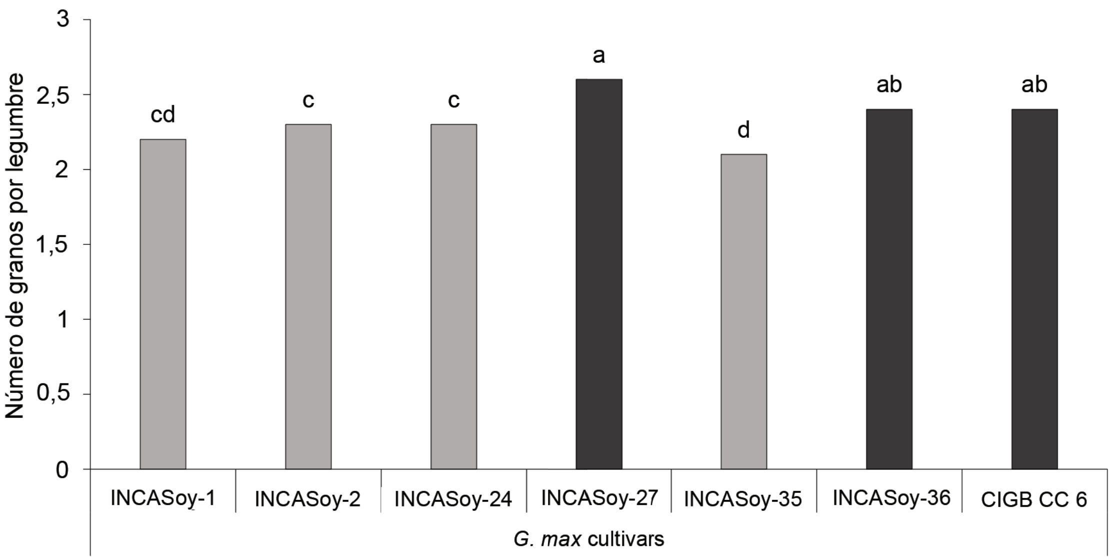

Figure 4. Mean values of the 7 cultivars for the number of grains per pod.

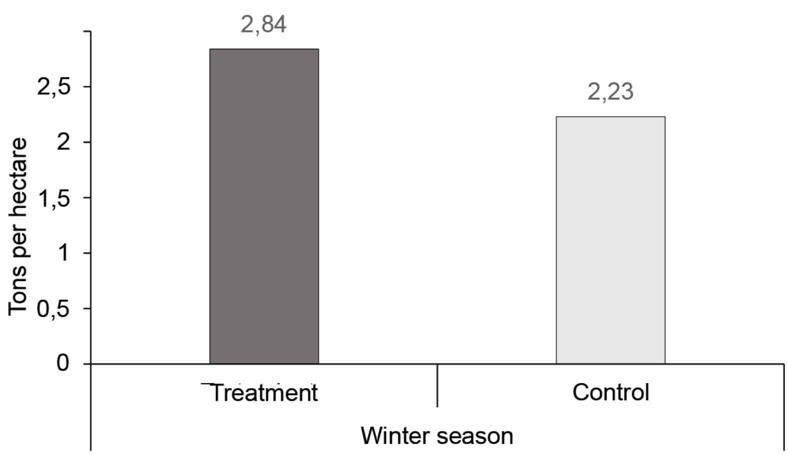

Figure 5. Average actual yield of cultivars with treated and untreated seeds, t/ha.

vigor determines activity and performance in normal plant growth and development (Ortiz-Pérez *et al*., 2023). This is reflected in the first vegetative stages of the crop in greater uniformity, speed and percentage of emergence with regards to later vegetative stages. It can be seen in plants with greater adaptability to the environment and greater survival in the field, which guarantees high potentially productive populations.

Conclusions

The treatment of five hours of exposure to 50°C improved the emergence of plants per linear meter of the cultivars under study in winter sowing, guaranteeing a greater potentially productive population per unit area. It did not affect plant growth and development traits, as well as the yield components evaluated in the different *G. max* cultivars, and significantly increased the yield of all studied cultivars.

Acknowledgments

The authors would like to thank all the members of the Breeding group of the Genetics department of the National Institute of Agricultural Sciences for their support for the harvesting and processing of the different crops obtained, as well as the financers of the international and national MAS project.

Conflict of interests

There is no conflict of interests among the authors.

Authors' contribution

- Rodobaldo Ortiz-Pérez. Conceptualization, data curation, formal analysis, methodology development, research execution, supervision, and drafting-reviewing and editing of the manuscript.
- Alejandro Mederos-Ramírez. Conceptualization, data curation, formal analysis, elaboration of the methodology, execution of the research, writing-revising and editing of the manuscript.

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