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The Role of Plant Stress Hormones (Melatonin and GABA) in Plant Development and Inflorescence

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Abstract | **Original Research Article**

Melatonin and GABA are two stress plant hormones whose mission is to protect plants against saline, thermic or hydric stress. However, there are not studies that analyze the role of these hormones in plant development and inflorescence. Using *Zea mays* (corn) seeds, *Phalaris canariensis* (canaryseed) seeds and *Kalanchoe daigremontiana* seedlings we have demonstrated that melatonin diminishes stem growth and increases root growth. Moreover. We have also exposed that melatonin diminished *Mirabilis jalapa* inflorescences. As a conclusion, melatonin has an important and previously undocumented role in plant growing and inflorescence.

Keywords: melatonin, plant development, inflorescence.

INTRODUCTION

Melatonin and GABA or gamma amino butyric acid have been described by various authors as plant stress hormones with a fundamental role in helping plants survive in the face of various environmental stressors such as drought, excess salinity in the environment or infectious agents. Thus, Ding *et al*., (2018) describe how melatonin at doses of 100 µM is capable of preventing damage to plant growth caused by water deprivation, while Yang *et al*., (2020) show how melatonin prevents growth retardation in relation to hypersaline media. Likewise, Sheteiwy *et al*., (2019) describe how GABA has the same effect described with melatonin in rice plants at doses of 0.5 µM with saline stress.

However, the objective of this work is to evaluate the effect of melatonin and GABA on plant germination and growth, as well as on the development of inflorescences, since there is no study in this regard.

METHODS

Zea mays (corn) and *Phalaris canariensis* (canaryseed) seeds were used, as well as *Kalanchoe daigremontiana* seedlings. All of them were subjected to a dose of 75 µM of melatonin + 30 µM of GABA every day, and there was also a control group for all of them. The experiment lasted between 7 and 10 days depending on the species studied and the growth of stems and roots was analyzed. A statistical analysis was carried out by Chi-square and T-student.

For the study of the inflorescence, *Mirabilis jalapa* seedlings were used, which were subjected to a single dose of 75 µM of melatonin + 30 µM of GABA, with a control group. In this case, the active and total inflorescences of these plants were counted, carrying out a statistical survival analysis by Kaplan-Meyer.

In all cases, SPSS 22 was used for inferential statistical analysis.

RESULTS

In the case of *Zea mays*, the results obtained (Figures 1 and 2) revealed the existence of a greater growth of the root with indications of statistical significance in the case of the treated seeds with respect to the controls, with no statistically significant differences in the case of stem growth.

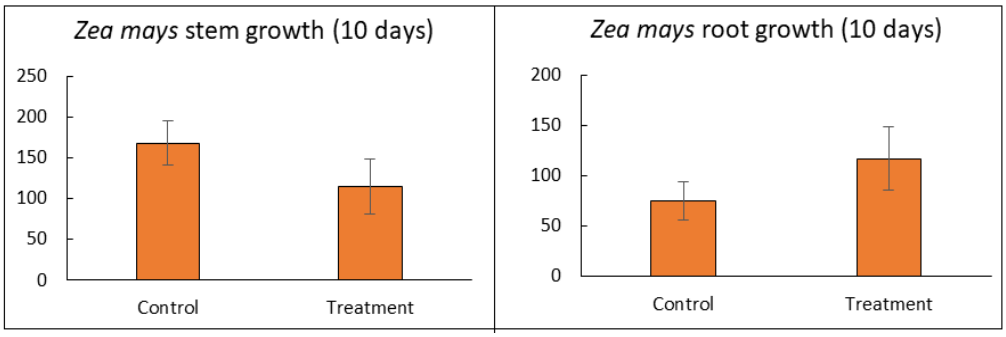

Figure 1: *Zea mays* stem and root growing results at 10 days ("y" axis, mm). Results are represented as mean +/- standard error. * indicates significant statistic results, P < 0,05

Figure 2: *Zea mays* photographic stem and root growing results at 10 days. A, control; B, treatment

If we refer to *Phalaris canariensis* (Figures 3 and 4), statistically significant differences were obtained in both stem and root growth. Specifically, greater root growth and less stem growth were observed in the seeds treated with melatonin + GABA.

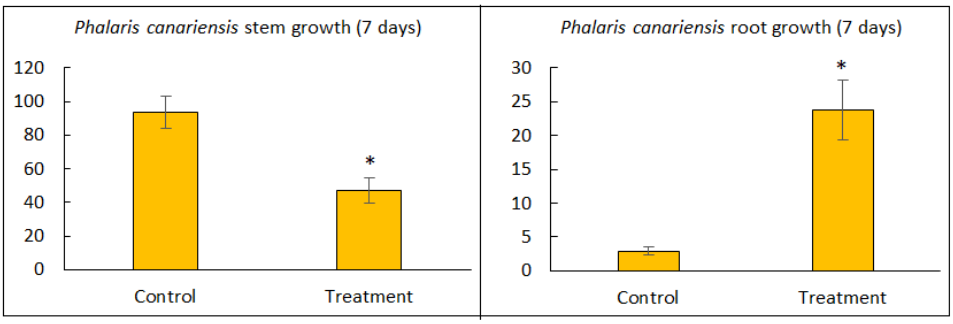

Figure 3: *Phalaris canariensis* stem and root growing results ("y" axis, mm) at 7 days. Results are represented as mean +/- standard error. * indicates significant statistic results, P < 0,05

Figure 4: *Phalaris canariensis* photographic stem and root growing results at 7 days. A, control; B, treatment

In the case of *Kalanchoe daigremontiana* (Figures 5 and 6), the results obtained in the case of canary grass are repeated. A significant reduction in seedling growth and a significant increase in root growth are observed in the melatonin + GABA treated seedlings. In addition, it should be noted that in all the seeds studied, an increase in the complexity of the root is observed in the treated seeds and seedlings compared to the controls.

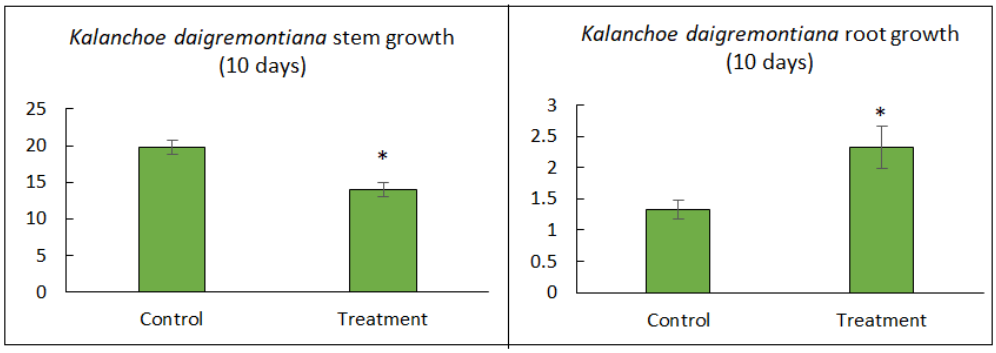

Figure 5: *Kalanchoe daigremontiana* stem and root growing results at 10 days ("y" axis, mm). Results are represented as mean +/- standard error. * indicates significant statistic results, P < 0,05

Figure 6: *Kalanchoe daigremontiana* photographic stem and root growing results at 7 days. A, control; B, treatment

In the experiment carried out with *Mirabilis jalapa* (Figure 7 and 8) a significant reduction was observed (by the Kaplan-Meyer statistical test with which it is tried to evidence the loss of inflorescences with respect to the control) at 48 hours of the active and total inflorescences in seedlings treated with melatonin + GABA. Likewise, a stabilization was also evidenced in the number of green flowering primordia in the treatment group compared to the control.

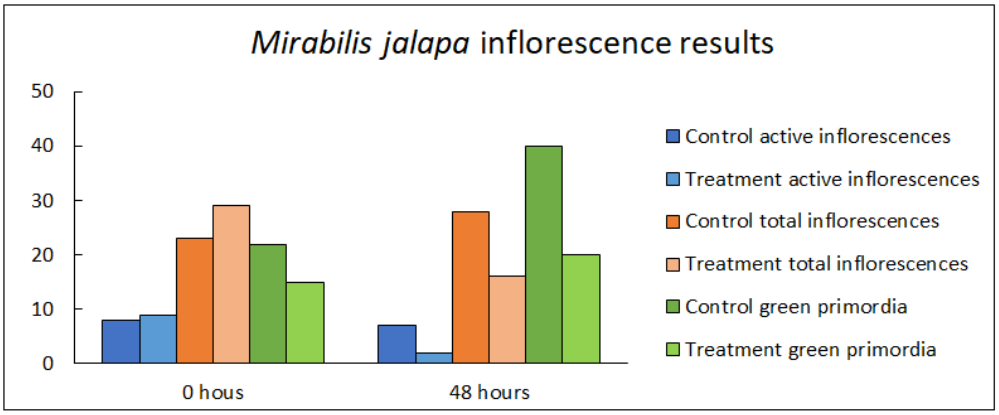

Figure 7: *Mirabilis jalapa* inflorescence results at 48 hours with melatonin + GABA respect to control plants ("y" axis, number of inflorescences/primordia)

Figure 8: *Mirabilis jalapa* photographic inflorescence results at 24 hours. A, control; B, treatment. Time 0, left. 48 hours experiment, right

DISCUSSION

The results obtained clearly show that the combination of plant stress hormones such as melatonin and GABA significantly increase root growth and decrease stem growth. It is quite likely that these agents, which have the mission of preparing the plant against some environmental stress, reduce growth and protein synthesis in the stems with the mission of increasing nutrient reserves while preparing the plant for situations of possible drought increasing root growth. Somehow, they would put the plant on alert against a possible danger or metabolic stress. In the studies analyzed, the doses of GABA used are usually much higher (0.5 mM or 175 mM) compared to those used in our case (0.03 mM) (Sheteiwy MS *et al*., 2019; Wu X *et al*., 2020). In the case of melatonin, the doses used in this experiment are similar to other experiments (75 µM respect to 100 µM) (Ding F *et al*., 2018; Yang H *et al*., 2020). For this reason, we consider that the observed effects are most likely due to the action of melatonin alone.

The fact that no significant differences were observed in the case of corn stem growth could be due either to the need to increase the sample size in this case or to the metabolism of corn, which differs from the rest of the plants used. Corn is a vegetable with a C4-type CO_2 fixation metabolism, which could influence growth response to stress and various hormonal agents (Schäffner AR *et al*., 1992).

In the case of *Mirabilis jalapa* inflorescences, it is very likely that melatonin, being a hormone, whose levels depend on the periods of daily sunlight as Sun *et al*., (2020) described, have a powerful influence on development and flowering. As seen in this experiment, melatonin is capable of slowing down the development of inflorescences and causing the loss of existing ones. Phanerogam plant species most likely depend on melatonin levels, and, above all, melatonin reduction with increased sunlight prepares for flowering and developing inflorescences. It is quite evident that throughout the spring not all plant species bloom at the same time and every year they do so at the same times. It is like a "flowering oligopoly" that makes each species reserve a flowering time to guarantee the necessary resources to reproduce correctly. This could be related to a greater or lesser sensitivity of the melatonin receptors in each species to the reduction in melatonin levels with the increase in periods of sunlight as spring progresses.

CONCLUSION

Melatonin significantly increases root growth and decrease stem growth in the species analyzed, as well as reduces flowering. These findings could have great relevance in the study and understanding of plant metabolism, ecology and physiology.

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