SCIENTIA PLENA
www.scientiaplena.org.br
VOL. 20, NUM. 12 2024
doi: 10.14808/sci.plena.2024.120203

Effect of gibberellic acid and *Ascophyllum nodosum* seaweed on the growth and development of *Ornithogalum saundersiae* Baker

Efeito de ácido giberélico e extrato de alga *Ascophyllum nodosum* no crescimento e desenvolvimento de *Ornithogalum saundersiae* Baker

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(Recebido em 17 de maio de 2024; aceito em 18 de novembro de 2024)

Ornithogalum saundersiae Baker is a bulbous ornamental species native to southern Africa, with relatively recent cultivation in Brazil. It is highly valued in floral arrangements and bouquets. *Ornithogalum* has low establishment costs and is easy to manage. One of the main challenges for its cultivation is the scarcity of products that can be used in cultivation, such as plant growth regulators and biostimulants. Gibberellic acid (GA_3) is a plant growth regulator known to promote earlier flowering in various ornamental species, while *Ascophyllum nodosum* seaweed extract has potential for promoting vegetative growth. This study aimed to evaluate the influence of gibberellic acid (Progibb 400®) and seaweed extract (Acadian®) on the growth and development of *Ornithogalum saundersiae*. A completely randomized design was used in a 4 × 3 factorial scheme, with four concentrations of GA_3 (0, 250, 500, and 750 mg L^{-1}) and three concentrations of *A. nodosum* extract (0, 2, and 4 ml L^{-1}), with one plant per plot and six replicates. Before planting, *O. saundersiae* bulbs were immersed in solutions containing the products and distilled water, the twelve combinations for 15 minutes, allowed to dry for one hour, and then planted. There was no significant difference between concentrations in the vegetative growth of *O. saundersiae*. All tested concentrations promoted earlier flowering compared to the control, with the best results observed at 500 mg L^{-1} of GA_3 combined with 2 ml L^{-1} of *A. nodosum* extract, which accelerated flowering by 27 days.
Keywords: biostimulant, ornamental bulbous, plant growth regulator.

O *Ornithogalum saundersiae* Baker é uma espécie bulbosa ornamental nativa do sul da África, com cultivo ainda recente no Brasil. É muito apreciada em arranjos florais e buquês. O Ornitogalo apresenta baixo custo de implantação e fácil manejo. Um dos principais entraves para o cultivo é a escassez de produtos a serem utilizados no cultivo, como reguladores de crescimento vegetal e bioestimulantes. O ácido giberélico (GA_3) é um regulador de crescimento vegetal que tem demonstrado antecipar a floração em diversas espécies ornamentais, enquanto o extrato da alga *Ascophyllum nodosum* tem potencial de promover o crescimento vegetativo. O presente trabalho teve por objetivo avaliar a influência do ácido giberélico e do extrato de alga no crescimento e desenvolvimento de *Ornithogalum saundersiae*. O delineamento utilizado foi inteiramente casualizado em esquema fatorial 4 × 3, sendo quatro concertações de GA_3 (0, 250, 500 e 750 mg L^{-1}) e três concentrações de extrato de *A. nodosum* (0, 2 e 4 ml L^{-1}), com uma planta por parcela e seis repetições. Antes de serem plantados, os bulbos de *O. saundersiae* foram imersos em soluções contendo as doze combinações por 15 minutos, deixados secar por uma hora para então serem plantados. Não houve diferença significativa entre as concentrações no crescimento vegetativo de *O. saundersiae*. Todas as concentrações testadas anteciparam o florescimento em relação ao controle, onde as melhores concentrações foram as de 500 mg L^{-1} de GA_3 combinadas com 2 mL L^{-1} de extrato *A. nodosum*, que anteciparam o florescimento em 27 dias.
Palavras-chave: bioestimulante, bulbosa ornamental, regulador de crescimento.

1. INTRODUCTION

The floriculture sector is a segment of the Brazilian agribusiness that has proven to be very promising, generating $1.7 billion annually in 2021. Based on its growth trajectory since 2012, it is estimated that the sector's growth rate is 7% per year [1].Ornamental bulbous plants constitute

an important segment within the floriculture sector, accounting for 61.7% of the total exported products in 2014 [2]. *Ornithogalum saundersiae* Baker, Asparagus family, popularly known as "ornitogalo", is an ornamental bulbous species native to South Africa, ranking among the top ten plants imported from Europe [3]. *O. saundersiae* is a delicate yet robust bulbous perennial, characterized by its upright, strap-like, dark green basal leaves. In summer, it produces tall, sturdy stems topped with dense racemes of cup-shaped flowers in shades of white or cream, each featuring a distinctive, black, bead-like ovary at its center [4].

In Brazil, the commercial production of ornitogalo flowers is still recent but expanding due to their high demand in floral arrangements and bridal bouquets. They offer high post-harvest durability, low implementation and maintenance costs, and easy management [5]. According to Tombolato et al. (2010) [6], one of the major hurdles in the cultivation of ornamental bulbous plants is the scarcity of products with approved registration for use, such as herbicides, insecticides, growth regulators, and so-called biostimulants. Gibberellic acid is a plant growth regulator belonging to the group of gibberellins. It acts on various plant processes such as stem elongation, seed germination, aerial part growth, vegetative to reproductive stage transition, flowering, flower sex determination, anther development, pollen tube growth, and floral development [7, 8]. However, they do not have registration for ornamental bulbous plants.

The development of bulbous plant cultivation is essential for the ornamental and food sectors, promoting economic value and nutritional benefits. Ornamental species such as Tulip and Lily [9] and Ornithogalum are valued in decoration and landscaping, while edible plants such as onion (*Allium cepa*) [10], garlic (*Allium sativum*) [11] and leek (*Allium ampeloprasum*) [12] are fundamental in world cuisine and have medicinal properties. Improvements in cultivation and management techniques for these species can increase productivity and resistance to pests and environmental stresses, ensuring more sustainable production and an expanded supply of food and flowers.

Products based on seaweed, classified as organ mineral fertilizers, also without registration for ornamental bulbous plants, are being widely used in agriculture, enhancing plant development, increasing productivity, and in some cases, stimulating plant tolerance to biotic and abiotic stresses [12]. The extract based on *Ascophyllum nodosum* (L). Le Jolis, is a natural source of macro and micronutrients (N, P, K, Ca, Mg, S, B, Fe, Mn, Cu, and Zn), amino acids (alanine, aspartic acid, glutamic acid, glycine, isoleucine, leucine, lysine, methionine, phenylalanine, proline, tyrosine, tryptophan, and valine), auxins, abscisic acid, and cytokinin [13, 14].

Nothing is known about the effects of gibberellic acid and algae extract on *O. saundersiae*. However, according to studies conducted by other authors, the application of gibberellic acid can increase the flowering percentage, advance flowering, flower opening, harvest, and improve the quality of floral stems in gladiolus [15, 16], cala lily [17, 18]e chrysanthemum [19]. While the application of *A. nodosum* extract can increase plant weight and height, bulb and stem diameter, root formation, protein content, chlorophyll, and carotenoids [20, 21].

In view of the above, it is clear that there is a need for research into the effects of products such as plant growth regulators and biostimulants in the production process of ornamental bulbous plants. It is believed that treatments carried out on bulbs before planting can improve the productivity and quality of flowers and inflorescences of ornamental bulbous plants. Thus, the present study aimed to evaluate the influence of different concentrations of gibberellic acid and *Ascophyllum nodosum* algae extract on the vegetative and reproductive development of *Ornithogalum saundersiae*.

2. MATERIAL AND METHODS

The experiment was conducted in a greenhouse, located in Curitiba – PR with coordinates 25°25'44" S; 49°16'3" W, with a 50% shade cloth and 100-micron anti-ultraviolet plastic covering. The vernalized bulbs *O. saundersiae* were stored in a B.O.D chamber for 25 days at 10°C until planting. Before planting, they were padronization (Figure 1A) by weight (80 to 106 g) and diameter (47 to 65 mm), and subsequently labeled. The bulbs were evenly distributed across all treatments.

Gibberellic acid solutions were prepared with distilled water, and the commercial product PROGIBB 400®, with a concentration of 40% GA_3, and the commercial product ACADIAN®, with a concentration of 29% *A. nodosum*. The bulbs for each treatment were soaked in the solutions (Figure 1B) for fifteen minutes and left to dry for one hour before being planted [22] in 12-liter flexible plastic pots filled with the commercial substrate Tropstrato HA® (Figure 1C), composed of pine bark, peat, and expanded vermiculite, with a chemical composition of pH H_2O 6,1; N (%) 0,68; P (%) 0,50; K (%) 0,35; Na (ppm) 520; Ca (%) 1,7; Mg (%) 1,18; C (%) 16,80; Dens. Dry (kg m^3) 200; Dens. Damp (kg m^3) 500.

*Figure 1 - **A**. Ornithogalum saundersiae bulbous padronization. **B.** Planting the bulbs in Tropstrato HA substrate and 12L plastic pots. **C.** Bulbs soaked in gibberellic acid and algae extract solutions, according to the treatments. Source: MAMM Medeiros (2017).*

Fertilization was carried out via nutrient solution based on the recommendations of Malavolta and Muraoka (1985) [23] and Hoagland and Arnon (1950) [24], divided into three applications: at planting, 10 days after planting (DAP), and 20 DAP. Nitrogen ($CaNO_3$) 225 mg per pot; Potassium (KCl) 150 mg per pot; Phosphorus (MAP) 150 mg per pot; Magnesium ($MgSO_4$) 70 mg per pot; Sulfur ($MgSO_4$) 85.5 mg per pot; Calcium ($CaNO_3$) 270 mg per pot; Boron (H_3BO_3) 28.5 mg per pot; Manganese ($MnCl_2$.4H2O) 109.1 mg per pot; Zinc ($ZnSO_4$.7H2O) 177.5 mg per pot; Copper ($CuSO_4$.5H2O) 51.5 mg per pot; Molybdenum (Na_2MoO_4.2H2O) 2.8 mg per pot; Iron (Fe EDTA) 50.5 mg per pot.

Irrigation was carried out manually to maintain the pot capacity between 60 and 70% saturation. Pot capacity was estimated by weighing the pot with dry substrate and after saturation. Before irrigation, the pots were weighed, and water was added to achieve 60% of pot capacity [25].

The analyzed variables were plant emergence (E); flowering (F) (Figure 2A); flowering until harvest (FH) (Figure 2B), defined when the inflorescence had four open florets (Figure 2C); number of floral stems (NFS) (Figure 2D); at eighty days after planting, the number of leaves (NL); length (LLL) and width of the largest leaf (WLL), expressed in centimeters; basal plant diameter (BPD), expressed in millimeters with a caliper.

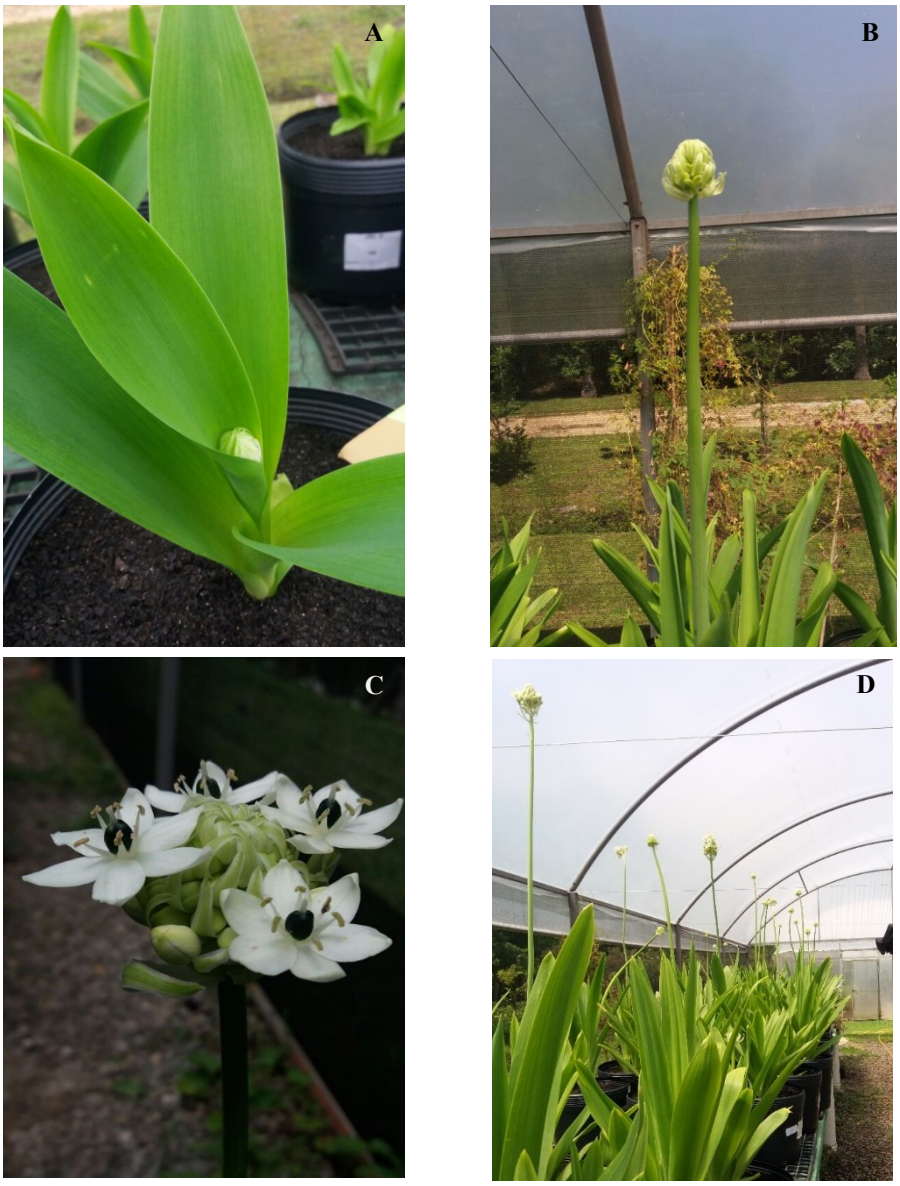

*Figure 2 - **A.** Ornithogalum saundersiae flowering starts from the emission of the floral peduncle, variable (E). **B.** Flowering days: complete emission of the floral stem until harvest (FH). **C.** Stem floral in the harvest point with four open florets. **D.** Floral stems of o. saundersiae 80 days after planting. Source: MAMM Medeiros (2017).*

An entirely randomized experimental design (DIC) in a double factorial scheme 4 x 3 was used, with four concentrations of gibberellic acid (GA_3) (0, 250, 500, 750 mg L^{-1}) and three concentrations of algae extract (0, 2, 4 mL L^{-1}), totaling twelve combinations, with one plant per plot and six replications. The obtained results were subjected to analysis of variance using the F test. When significant, the data were submitted to the Scott-Knott test at the 5% probability level for all analyzed parameters. The Scott-Knott test is particularly useful for comparing treatment means within groups and categorizing them into statistically distinct subsets. It provides precise insights, avoids an excessive number of groupings, and thus facilitates more practical comparisons across treatments. The software used for statistical analysis was Sisvar [26].

3. RESULTS AND DISCUSSION

The analysis of variance demonstrates that, for the days from planting to emergence, the factors gibberellic acid and *Ascophyllum nodosum* seaweed did not show any influence, with an average emergence of the first leaf buds occurring 11 days after planting. In a study conducted with calla lilies (*Zantedeschia aethiopica*), testing the effect of GA_3 on rhizomes by immersion for 10 minutes in solutions of up to 1000 mg L^{-1}, it was observed that there was no difference in the number of days from implantation to emergence of shoots, with an average of 30 days for emergence [27]. A similar result was observed in yellow calla lily (*Zantedeschia elliottiana*) and calla lily (*Zantedeschia rehmannii*) [28]. It is believed that the energy and hormonal reserves for the buds already formed in the bulbs undergo little or no stimulation from exogenous applications of gibberellin for the onset of shoot emergence [28].

For the number of leaves (NL), length (LLL), width of the largest leaf (WLL), and basal plant diameter (BDP) at eighty days after planting, the results did not show significant differences among the tested combinations. The average number of leaves was 8.38, with an average length and width of the largest leaf of 50.94 cm and 5.51 cm, respectively, and an average basal diameter of 35.54 mm. Different results were found from the application of GA_3 in other species. In a study conducted on calla lilies with a concentration of 83 mg L^{-1}, it resulted in taller plants, while a concentration of 64 mg L^{-1} led to a larger pseudostem diameter, and a concentration of 242 mg L^{-1} resulted in plants with a higher number of leaves [27]. However, in a study involving the immersion of gladiolus corms for 15 minutes in a solution with different concentrations of gibberellic acid (0, 250, 500, and 1,000 mg L^{-1}), no significant differences were observed for the number of leaves per plant [16]. Some authors attribute the number of leaves per plant to be a genetic characteristic that is minimally influenced by exogenous stimuli, which may vary among different ornamental species and cultivars [5].

The effects of plant growth regulators depend on various factors and are influenced by environmental conditions, applied concentration, application methods, number of applications, timing of application, as well as the phenological stage of the crop at the time of treatment [29, 30].

Therefore, several possible explanations for the lack of effect of gibberellic acid concentrations on vegetative growth in *O. saundersiae* can be proposed, such as the insufficient duration of fifteen minutes for bulb treatment immersion. In a study conducted with gladiolus corms "Amsterdam," they were immersed in gibberellic acid solutions for twenty-four hours, and a concentration of 100 mg L^{-1} resulted in a significant increase in plant height compared to the control [15]. In a study conducted with calla lily 'Albomaculata' and 'Black Magic,' the rhizomes were immersed in gibberellic acid solutions for 30 to 60 minutes, and differences were observed in the number of leaves for both cultivars [31].

For treatments with *Ascophyllum nodosum* extract, a significant difference in vegetative growth was expected due to the potential enhancement effect of endogenous cytokinin and auxin biosynthesis presented by the biostimulant, in addition to the presence of essential macro and micronutrients for the development of any plant species, such as N, P, K, Ca, Mn, Mo, Zn [20, 21, 32-34]. However, there was no effect of *Ascophyllum nodosum* algae extract on the variables, NFS, LLL, WLL, BPD, NHF.

In studies conducted with onions, a concentration of 5.5 mL L^{-1} of *Ascophyllum nodosum* algae extract resulted in taller plants with more leaves [20]. For chrysanthemums, a concentration of 6 mL L^{-1} showed increased plant height and a larger stem diameter [21]. In an experiment conducted with amaryllis (*Hippeastrum hybridum*), the application of *A. nodosum* increased the number of leaves, length, leaf area, and dry leaf mass [35].

The total number of floral stems produced up to 80 DAP showed no statistical difference in the analysis of variance between the factors gibberellic acid and *Ascophyllum nodosum* extract; all treatments averaged 1.25 stems. A similar result was observed in amaryllis, with no influence of seaweed extract on the number of floral stems [35]. On the other hand, through the action of gibberellic acid in a study conducted with yellow calla lily (*Zantedeschia elliottiana*) and calla lily (*Zantedeschia rehmannii*), a significant increase in floral stems was observed, rising from 1.7 to up to 9.4 in yellow calla lily and from 8.4 to 28.0 floral stems in calla lily [28].

Although there was no statistical difference in vegetative growth variables or in the number or length of floral stems, the application of gibberellic acid (GA_3) and *Ascophyllum nodosum* algae extract advanced flowering (Table 1).

Table 1 - Days to flowering following application of gibberellic acid (GA_3) and Ascophyllum nodosum seaweed extract on Ornithogalum saundersiae Baker bulbs.

GA_3 (mg L^{-1})	***Ascophyllum nodosum*** (mL L^{-1})		
	0	**2**	**4**
0	62,50 Aa	50,50 Ba	48,83 Ba
250	37,50 Ab	48,16 Aa	36,17 Aa
500	43,00 Ab	35,50 Ab	46,50 Aa
750	48,33 Ab	37,50 Bb	52,66 Aa
CV(%)			24,39

Columns = lowercase letters; Rows = uppercase letters. Identical letters do not differ statistically from each other.

All concentrations of gibberellic acid tested advanced the onset of flowering compared to *O. saundersiae* bulbs that were not treated with either GA_3 or *Ascophyllum nodosum* seaweed extract. On average, with the application of gibberellic acid or seaweed extract, the time to flowering was reduced by at least 10 days.

Many studies demonstrate positive results in achieving precocity of flowering through the application of gibberellic acid. In a study conducted by Sajjad et al. (2015) [15], the concentration of 100 mg L^{-1}, also through the immersion method, resulted in the advancement of flowering by 6.17 days for *Gladiolus grandiflorus* "Amsterdam". In a study conducted with gladiolus "White Friendship", flowering was advanced by two days through the application of gibberellic acid [16]. In cut chrysanthemums, the application of 200 mg L^{-1} gibberellic acid advanced flowering by 8 days [19]. On the other hand, in a study conducted with yellow calla lilies and calla lily (*Zantedeschia elliottiana* and *Z. rehmannii*, respectively), no effect of gibberellic acid application on flowering advancement was observed [28].

In *Arabidopsis* sp., the flowering "locus T gene" was identified, and it was found that gibberellin is responsible for receiving external stimuli and converting them into messages for decoding the gene in the apical meristem [36]. Therefore, it is believed that the application of this growth regulator can act to advance the physiological transition of plants from the vegetative stage to the reproductive stage.

Just as gibberellic acid showed an effect on flowering advancement, Ascophyllum nodosum algae extract also demonstrated this effect (Table 1). Studies conducted with amaryllis (*Hippeastrum hybridum*) show that the use of algae extract advanced flowering [35]. However, in a study conducted with the ornamental plant *Celosia cristata*, the effect of *Ascophyllum nodosum* seaweed extract application on its flowering was not identified [37].

The application of biostimulants is gaining ground due to the significant potential demonstrated in impacting nutrition, physiology, stress mitigation, and other agricultural aspects demanded by cultivated species [13]. However, further studies on concentrations and application technology should be employed due to the high employability that the product has in agriculture [20, 34, 38].

4. CONCLUSION

In this study, no significant differences were observed between the concentrations evaluated for the vegetative growth of *O. saundersiae*. All tested concentrations advanced flowering compared to the control. The application of 500 mg L^{-1} of GA_3 with 2 mL L^{-1} of *Ascophyllum nodosum* seaweed extract by soaking the *Ornithogalum saundersiae* bulbs before planting advanced flowering by 27 days. This advancement allows growers to synchronize cultivation with peak demand periods, such as the holiday season or other significant dates in the flower market, providing a competitive edge by making plants available at prime sales times. This technique also

aids in crop scheduling and resource management, as the shortened production time lowers costs associated with factors like irrigation, greenhouse use, and pest control. By accelerating the growth cycle, producers can optimize greenhouse usage, increasing the frequency of harvests and the number of annual cycles, which maximizes productivity and financial returns. In an increasingly demand-driven market, this flowering advancement strategy stands out as an efficient solution to align production schedules with consumer demand, strengthening the ornamental plant sector and expanding profit opportunities.

5. ACKNOWLEDGEMENTS

Special thanks to Capes and CNPq for granting the scholarship.

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