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THE EFFECT OF CHITOSAN APPLICATION ON GROWTH, DEVELOPMENT, DECORATIVE VALUE AND YIELD OF *Gladiolus hybridus* Hort. CORMS

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ABSTRACT

Along with roses, carnations, and chrysanthemums, *Gladiolus hybridus* Hort. is an important ornamental plant species cultivated worldwide for cut flowers with long vase life. The study was conducted outdoors, in uncovered soil, in the years 2022–2023. The plant material consisted of daughter corms of five *Gladiolus hybridus* Hort. cultivars: Frizzled Coral Lace, Limoncello, Mon Amour, Nova Lux, and Peter Pears. The study used chitosan with a molecular weight of 6000 g · mol^{-1} at a concentration of 0.4%. The compound was applied by soaking the corms before planting and spraying or watering the plants. The corms were planted into the ground in the third decade of May. During the vegetation period, the course of the development phases was assessed, vegetative and generative traits were measured, and the corm yield was evaluated at the end of cultivation. Chitosan determined the course of the development phases, but this depended on the cultivar traits and the application method. The plants treated with chitosan grew taller and produced more leaves, but they did not differ in the number and diameter of the developed flowers from those not exposed to the biostimulant. Other vegetative and generative traits largely depended on the method of chitosan application. Watering and spraying demonstrated the most beneficial effect of the methods evaluated. Regardless of the method of delivering chitosan to the gladioli, it resulted in a higher weight growth index in the daughter corms.

Keywords: biostimulant, cultivar, cut flower, development phases, morphological traits

INTRODUCTION

Gladiolus hybridus Hort. is one of the most decorative and sought-after ornamental plants, holding a leading position in the floriculture market [El-Naggar and El-Nasharty 2016, Dhakal et al. 2017, Bolagam and Natarajan 2020]. It is called the queen of bulbous plants – the flower of splendour and perfection [Parveen and Katiyar 2020]. It can be grown both in open soil [Kumari et al. 2013, Kumar et al. 2016] and undercover [Singh and Kumar 2017], for cut flowers [Amin et al. 2019, Ashwini et al. 2019] or in flower beds in green areas. Currently, numerous cultivars are available on the market, and they differ significantly in terms of their decorative value [Maurya and Kumar 2014, El-Naggar and El-Nasharty 2016] and the length of the production period. Popularity of this plant is mainly due to its low cultivation requirements [Kumari et al. 2013], high ornamental value [Dhakal et al. 2017, Parveen and Katiyar 2020, Kentelky and Szekely-Varga 2021], and considerable durability after cutting [Maurya and Kumar 2014, Ashwini et al. 2019, Bolagam and Natarajan 2020].

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The growing eco-awareness of ornamental plant producers translates into looking for new solutions to obtain high-yield and good-quality crops while reducing production costs. Such a solution may be using natural substances that stimulate plant growth and development [Kisvarga et al. 2022, Stasińska-Jakubas and Hawrylak-Nowak 2022, Rayanoothala et al. 2024]. In addition to their effect on plants, an important characteristic of these substances is their low level of harmfulness for humans [Malerba and Cerana 2016] or the environment [Li et al. 2020, Korbecka-Glinka and Wiśniewska-Wrona 2021]. The use of chitosan can be just such a solution. Chitosan influences the developmental phases of ornamental plants [Żurawik 2013], stimulates their growth [Atteya et al. 2023, Chen et al. 2023] and also significantly determines the size and the quality of the tuber yield [Żurawik et al. 2017]. This compound can be applied by soaking seeds before sowing [Zohara et al. 2019, Stasińska-Jakubas and Hawrylak-Nowak 2022] or bulbs before planting [Ramos-Garcia et al. 2009, Korbecka-Glinka and Wiśniewska-Wrona 2021]. It may also be used for watering or spraying plants during the growing season [Żurawik et al. 2017]. In addition to the properties of chitosan, such as its molecular weight [Stasińska-Jakubas and Hawrylak-Nowak 2022] and concentration [Byczyńska 2018, Zohara et al. 2019], the authors emphasise the importance of the application method for increasing its effectiveness. Still, they strongly highlight its dependence on the species and cultivar [Malerba and Cerana 2017].

Considering the above, it was deemed advisable to check the effect of chitosan application methods on the course of developmental phases, vegetative and generative traits and progeny tuber yield of selected gladiolus garden cultivars. It was hypothesised that chitosan and its application methods would accelerate flowering, enhance ornamental qualities, and obtain good-quality planting material for gladiolus cultivation without using covers.

MATERIALS AND METHODS

Experimental design

The research was conducted in 2022–2023, in uncovered soil, on experimental plots of the West Pomeranian University of Technology in Szczecin (14°31'E and 53°26'N). The plant material consisted of corms of *Gladiolus hybridus* Hort. reproduced locally in our department and belonging to five cultivars: Frizzled Coral Lace – orange-white, fringed and ruffled (Fig. 1), Limoncello – yellow, ruffled (Fig. 2), Mon Amour – pink-white (Fig. 3), Nova Lux – yellow (Fig. 4), and Peter Pears – salmon, ruffled (Fig. 5). In both years of the study, the corms intended for planting were matched in size (Frizzled Coral Lace 17.7–22.1 g; Limoncello 14.5–17.8 g; Mon Amour 15.7–20.5 g; Nova Lux 27.7–33.8 g; Peter Pears 25.9–27.8 g) and health, without mechanical damage, and had a shape typical of the given cultivar. They were covered with dry, fibrous, and tightly adherent enveloping scales. Before planting, the corms had been stored for five months in a cool room at 5–8 °C and relative humidity of 60–70%. Then, on May 20, 2022, and May 29, 2023, they were planted in beds with a spacing of 25 cm between the rows and 15 cm within the rows, to a depth of 10 cm.

A month before the corms were planted, in both years of the study, 10 unit soil samples from a depth of up to 20 cm were taken from the experimental plot using the Egner's stick. They were then combined into collective samples and used to determine pH in H_2O with the potentiometric method, the CP-315M pH meter (Elmetron, Poland), and salinity with the conductometric method and the CC-411 conductivity meter (Elmetron, Poland). N, P, K, Ca, and Mg content was also assessed. Total nitrogen was determined using the Kjeldahl method after prior mineralisation of the samples in concentrated sulphuric acid with the addition of a selenium mixture. Phosphorus was determined by the colourimetric Egner-Riehm method, potassium and total calcium by flame photometry, and magnesium by atomic absorption spectrometry, using Thermo Scientific iCE 3000 Series AA spectrometer (Thermo Fisher Scientific Inc., USA), after mineralisation of the samples in a 1 : 1 mixture of nitric and chloric acids. The results of the analyses are presented in Table 1. Their values were used to supplement nutrient deficiencies in the soil of the experimental plot to the level recommended for *G. hybridus* Hort. cultivation, that is, 60–120 mg · dm^{-3} N-NO_3, 50–100 mg · dm^{-3} P, 150–250 mg · dm^{-3} K, and 80–110 mg · dm^{-3} Mg [Strojny 1993]. Two weeks before corm planting, the soil was enriched with Azofoska (Inco Group S.A.,

Fig. 1. *Gladiolus hybridus* Hort. Frizzled Coral Lace (photo by P. Żurawik)

Fig. 2. *Gladiolus hybridus* Hort. Limoncello (photo by P. Żurawik)

Fig. 3. *Gladiolus hybridus* Hort. Mon Amour (photo by P. Żurawik)

Fig. 4. *Gladiolus hybridus* Hort. Nova Lux (photo by P. Żurawik)

Fig. 5. *Gladiolus hybridus* Hort. Peter Pears (photo by P. Żurawik)

Poland) compound mineral fertiliser (N 13.6, P_2O_5 6.4, K_2O 19.1, MgO 4.5, B 0.045, Cu 0.180, Fe 0.17, Mn 0.27, Mo 0.040, Zn 0.045) at a dose of 30 g · m^{-2}. The top dressing was performed twice, i.e., before earing and during full flowering, with Azofoska fertiliser at 20 g · m^{-2}.

During the growth and development of plants as necessary, essential care treatments, consisting of systematic weeding, topsoil loosening, and irrigation, were performed. Water deficiency was supplemented by drip irrigation. In both years of the study, there was no need to use chemical plant protection against diseases and pests.

The plants were removed from the soil before the first autumn frosts, in the third decade of October. They were then dried without access to light in a well-ventilated room with a relative humidity of 60–70%, at a temperature of 20–24 °C, for 17 (2022) or 21 days (2023). The dried corms were cleaned of dried shoots, leaves, and roots and wet-treated for 30 minutes in a mixture of 0.5% suspension of Captan 50 WP and 0.6% Topsin M 500 SC. Afterwards, they were dried again for 24 hours in a dark room at 18–20 °C. The corms prepared in this way were placed in storage until the experiments in the following year.

The weather conditions during plant growth and development in 2022 and 2023 were assessed based on data from the Institute of Meteorology and Water Management for the Hydrological and Meteorological Station in Szczecin-Dąbie (Tab. 2).

Table 1. Selected chemical properties of the soil from the experimental plot in the subsequent years of research

Year of study	Nutrient content (mg · dm^{-3})					pH in H_2O	Salt concentration (NaCl g · dm^{-3})
	N-NO_3	P	K	Ca	Mg		
2022	47	38	144	6138	127	7.8	0.30
2023	35	26	152	6156	135	7.5	0.25

Table 2. Distribution of air temperature and precipitation for the Hydrological and Meteorological Station in Szczecin-Dąbie, during the *Gladiolus hybridus* Hort. cultivation in the years 2022–2023, as compared with the multi-year period (1991–2020)

Year of study	Months					
	V	VI	VII	VIII	IX	X
Mean daily temperature (°C)						
2022	14.0	18.6	18.9	20.8	13.1	12.1
2023	12.5	17.6	18.8	18.9	18.0	11.3
Multiyear (1991-2020)	13.6	16.8	18.9	18.5	14.3	9.5
Total rainfall (mm)						
2022	33.0	30.0	68.0	74.0	49.0	22.0
2023	6.6	64.0	67.8	88.0	7.8	56.5
Multiyear (1991-2020)	55.8	60.3	76.2	60.3	47.7	43.5

Chitosan application

The study used chitosan with a molecular weight of 6000 g · mol^{-1} at a concentration of 0.4%. The compound was obtained at the Department of Packaging and Biopolymers of the West Pomeranian University of Technology in Szczecin by controlled deacetylation of free-radical chitin derived from shrimp shells through the continuous addition of hydrogen peroxide with a final concentration of 6.2 mmol to a 2.5% chitosan solution. The depolymerised chitosan had a deacetylation rate of 85% [Bartkowiak 2001]. The chitosan solution was used to soak the corms before planting and later to water or spray the plants. At the beginning of the experiment, the corms were soaked in chitosan or tap water and treated for 30 minutes the day before the planting date. After this treatment, the corms were dried for 24 hours in a dark room at 22 °C and a relative humidity of 50%. In the experiments where the plants received chitosan by watering, a biostimulant solution was applied directly to loosen and moist soil near the plants. In other treatments, the chitosan solution was applied using a handheld pressure sprayer to mist both sides of the leaf blade. The initial application took place at the two-leaf stage, with subsequent treatments repeated every 7 days, applying 10 ml of the solution per plant. In total, chitosan was applied 20 times during the growing season. Regardless of the application method, it was dissolved in tap water on the day of application. The control group consisted of plants that were not treated with chitosan.

Plant observations and measurements

The number of days of cultivation was determined as follows: from planting the corms to the start of emergence, from the beginning of emergence to the start of earing, and from the start of earing to the end of flowering. The observations were carried out every 2 days.

The measurements of morphological traits were made during full flowering, and the following parameters were determined: the height of the plants from the ground level to the highest point, the number of developed shoots and leaves on the main shoot, and the plant in general. The leaf greenness index was determined using the Chlorophyll Meter SPAD-502 (Minolta, Japan), which reads SPAD (soil plant analysis development) units. This index is closely correlated with chlorophyll content, as described by Zawadzińska and Salachna [2024]. The SPAD meter is a reliable tool for assessing plant nutritional status and identifying nitrogen deficiencies during later stages of growth [Żurawik 2020]. The measurements were made on 6 mm^2 in the central region of the first properly developed leaf.

The measurements of generative traits were made when the first flowers developed in the inflorescence of successive flowering plants. The following parameters were measured: the length of the inflorescence shoot from its base to its highest point, the inflorescence length, the number of flowers developed, and the diameter of the first flower in the inflorescence. The number of developed inflorescence shoots was also determined at the end of the flowering period.

After drying and cleaning the corms, their yield was evaluated by calculating the number and weight growth indices.

Statistical analysis

The experiments included 20 factors, i.e., 5 cultivars × 4 chitosan application methods. All variants included three repetitions, 8 corms each. A total of 480 plants were evaluated in the study.

The results reflecting chitosan's effects on the developmental phases were processed based on mean values. All statistical analyses were performed using the Statistica Professional 13.3 package (TIBCO StatSoft, Palo Alto, CA, USA). The data on vegetative and generative traits and corm yield were subjected to a two-way analysis of variance (ANOVA) in a complete randomisation system in subsequent years of the study and as a two-year synthesis. The means were compared with Tukey's test for a significance level of $\alpha < 0.05$.

RESULTS AND DISCUSSION

The course of the development phases

The available literature lacks information on the effect of chitosan on the growth and development of ornamental geophytes. Unfortunately, many authors who use this biopolymer do not determine its basic physical and chemical properties, such as molecular weight, which makes it difficult, if not impossible, to compare the obtained research results. The effect of chitosan on the course of the emergence phase depends on the conditions prevailing during plant cultivation [Żurawik 2013]. According to this author, chitosan with a molecular weight of 10 000 g · mol^{-1} and a 0.2% concentration, applied before planting the bulbs of *Freesia* × *hybrida* Lisa, Bon, and Silver Beach, growing in an air-conditioned chamber, with constant temperature and humidity of the substrate, did not determine the date of the bulb germination. On the other hand, changing light, temperature, and humidity slightly delayed the emergence of the main and secondary shoots in Silver Beach freesia. Ramos-Garcia et al. [2009] stated that soaking the corms of *Gladiolus* sp. Blanca Borrego in a 1.5% solution of Biorent before planting accelerated their germination. In our study, soaking the corms before planting in a 0.4% chitosan solution with a molecular weight of 6000 g · mol^{-1} accelerated the emergence phase, but this varied significantly for different cultivars (Fig. 6). In the present experiment, gladiolus cultivars differed during this development phase, which was also observed in other studies [Thakur et al. 2015]. Regardless of the use of chitosan, the corms of Nova Lux were the first to germinate (12.4 days), followed by those of Mon Amour (21.2 days), Fizzled Coral Lace (22.0 days), Peter Pears (22.9 days), and Limoncello (23.4 days). Gladiolus sprouting after 5.6 to 19 days, and the longer emergence period is due to a delayed planting date [Thakur et al. 2015]. In the case of cultivars with a longer sprouting period, i.e., more than 20 days, chitosan accelerated sprouting from an average of 2.2 days in Peter Pears to 5 days in Limoncello. No such dependencies were found for the Nova Lux (Fig. 6).

Soaking corms of *Freesia* × *hybrida* Gompey in a chitosan solution accelerated the formation of inflorescences [Salachna and Zawadzińska 2014], while according to Żurawik et al. [2017], earlier flowering also depended on the frequency and method of this compound application. In the present study, treating gladioli with chitosan shortened their vegetative phase by accelerating the earing (Fig. 6). Regardless of the cultivar, the gladioli treated with chitosan began to ear on average 4.5 days earlier than the control plants. According to Żurawik [2013], the positive effect of chitosan on flowering depends on the length of the cultivation period. Our studies did not confirm this dependency. Earlier earing of the gladioli plants was visible in the cultivars during the shortest and the most extended production period. In the present experiment, the effect of chitosan largely depended on cultivar traits. In the case of earing, it was the weakest for Fizzled Coral Lace and Nova Lux (3.1 days) and the strongest for Limoncello (10.6 days). The Chitosan application method also significantly affected the time of earing. The watered or sprayed plants of Fizzled Coral Lace, Limoncello, Mon Amour, and Peter Pears eared earlier than those obtained from the soaked corms. A different response to the compound application methods was observed in Nova Lux, which may be due to a significant influence of the cultivar traits on the course of this development phase [Thakur et al. 2015].

According to Żurawik et al. [2017], chitosan with a molecular weight of 8000 g · mol^{-1}, prolonged flowering of *Freesia* × *hybrida* Summer Beach regardless of its application method. In the present study, cultivars Fizzled Coral Lace, Limoncello, Mon Amour, and Peter Pears treated with chitosan in any manner flowered longer compared to untreated plants. However, this effect was not observed in Nova Lux (Fig. 6).

Vegetative traits

Treating plants with chitosan positively affected their growth [Van et al. 2013, Malerba and Cerana 2017, Fahmy and Nosir 2021]. The compound increased plant height, but its impact depended on the method of its application (Tab. 3). Spraying *Eleusine coracana* [Sathiyabama and Manikandan 2021], *Calendula officinalis* [Akhtar et al. 2022] or *Withania somnifera* [Jacob et al. 2023] plants stimulated their growth. In the present experiment, the plants sprayed or watered with chitosan were taller than the control group. The differences were insignificant and ranged from 5.2% to 5.4%. The increase in the height of plants watered with chitosan may be due to the effect of chitosan nanoparticles on their biophysical characteristics, among others, the ability to absorb nutrients from the soil [Van et al. 2013]. The height of gladiolus plants also depends on their cultivar traits [Kumar et al. 2016]. The cultivars compared in this experiment also differed in terms of this trait, with Nova Lux being the tallest and Frizzled Coral Lace the shortest. Nova Lux gladioli sprayed with chitosan during the growing season were the tallest, and Frizzled Coral Lace plants grown from the corms soaked in the biopolymer before planting were the shortest (Tab. 3).

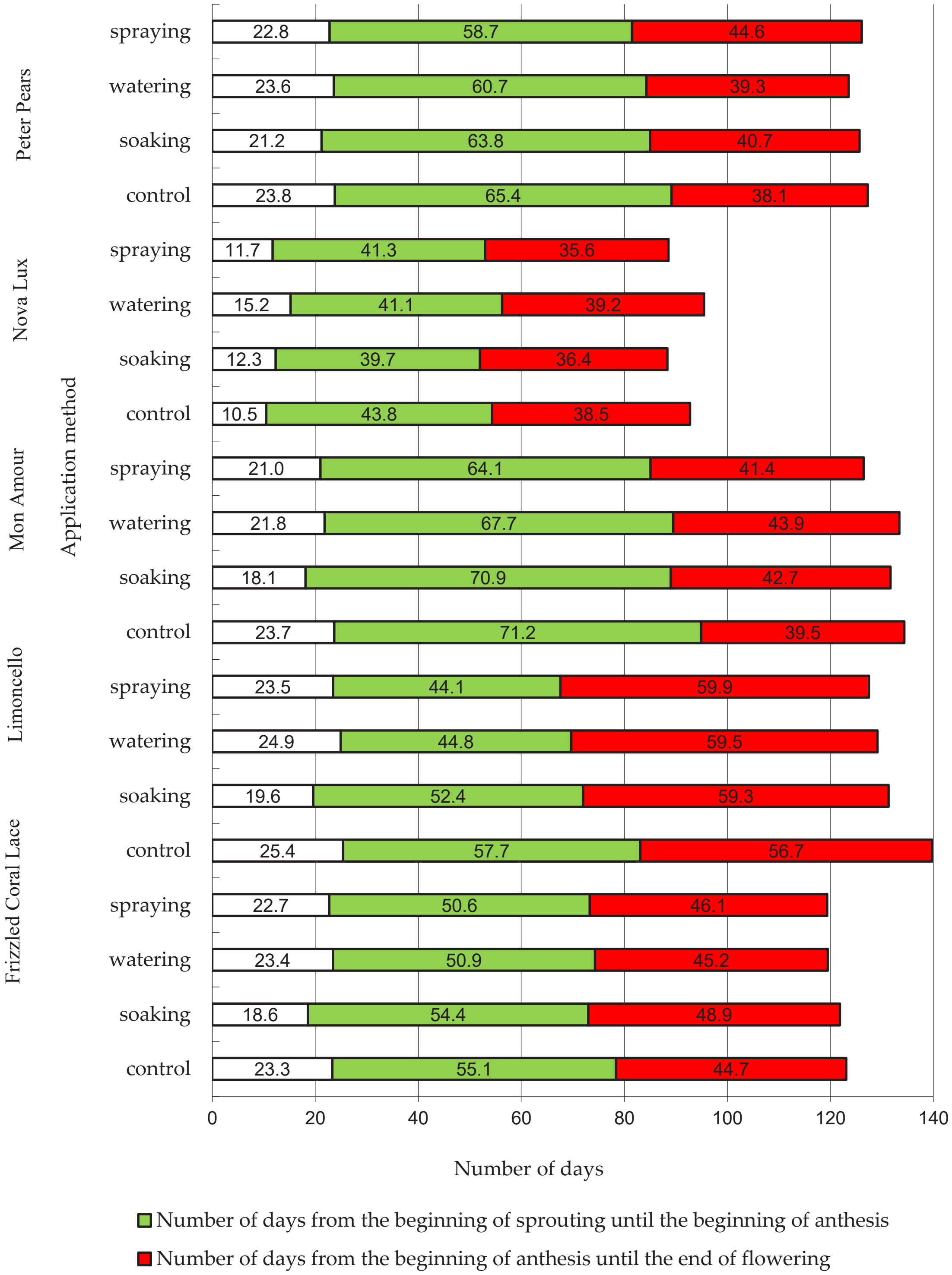

Fig. 6. The number of days from planting the corms to the end of flowering, depending on the *Gladiolus hybridus* Hort. cultivar and chitosan application method

Table 3. Vegetative traits of *Gladiolus hybridus* Hort. depending on the cultivar and chitosan application method (mean for the years 2022–2023)

Trait	Cultivar	Application method				Mean
		I	II	III	IV	
Plant height (cm)	Frizzled Coral Lace	81.0fg	80.0g	82.9efg	82.9efg	81.7C
	Limoncello	84.9defg	87.9defg	89.4def	91.5de	88.4B
	Mon Amour	87.7defg	91.9de	90.1def	93.2cd	90.7B
	Nova Lux	102.3bc	105.1ab	111.9a	107.0ab	106.6A
	Peter Pears	87.5defg	89.5def	93.1cd	91.8de	90.5B
	Mean	88.7B	90.9AB	93.5A	93.3A	91.6
Number of shoots (pcs.)	Frizzled Coral Lace	1.08de	1.00e	1.25cde	1.38cde	1.18C
	Limoncello	1.88abcde	2.42a	2.13abc	2.37ab	2.20A
	Mon Amour	1.17de	1.46bcde	1.37cde	1.35cde	1.34C
	Nova Lux	1.46bcde	1.63abcde	1.96abcd	1.88abcde	1.73B
	Peter Pears	1.25cde	1.46bcde	1.51abcde	1.84abcde	1.52BC
	Mean	1.37B	1.59AB	1.64AB	1.76A	1.59
Number of leaves set on main shoot (pcs.)	Frizzled Coral Lace	8.73ab	8.78ab	8.71ab	8.86ab	8.77AB
	Limoncello	7.63ab	8.72ab	8.18ab	8.70ab	8.31BC
	Mon Amour	7.36b	8.19ab	8.03ab	8.44ab	8.01C
	Nova Lux	7.29b	8.76ab	8.18ab	8.68ab	8.23BC
	Peter Pears	8.87ab	9.10a	8.97a	9.17a	9.03A
	Mean	7.98B	8.71A	8.41AB	8.77A	8.47
Total number of leaves per plant (pcs.)	Frizzled Coral Lace	9.20d	8.78d	10.42cd	11.77cd	10.04C
	Limoncello	13.93abcd	21.04a	17.03abc	20.02ab	18.01A
	Mon Amour	8.55d	11.54cd	10.65cd	11.29cd	10.51C
	Nova Lux	10.60cd	13.94abcd	15.77abcd	15.68abcd	14.00B
	Peter Pears	11.05cd	13.07bcd	13.31bcd	16.84abc	13.57B
	Mean	10.67B	13.67A	13.44A	15.12A	13.22
Greenness index of leaves (SPAD)	Frizzled Coral Lace	62.8cd	62.8cd	65.2abcd	64.7abcd	63.9B
	Limoncello	62.2d	62.5cd	64.1bcd	64.1bcd	63.2B
	Mon Amour	62.7cd	62.4cd	65.4abcd	64.8abcd	63.8B
	Nova Lux	64.1bcd	62.7cd	65.3abcd	64.2bcd	64.1B
	Peter Pears	69.0abc	69.8ab	70.9a	71.2a	70.2A
	Mean	64.2AB	64.0B	66.2A	65.8AB	65.0

I – control, II – soaking, III – watering, IV – spraying
A, B – for the main factor, a, b – for the interaction
Means marked with the same letters do not differ significantly at α = 0.05

Regardless of the cultivar, chitosan application by spaying resulted in an increased number of shoots compared to untreated plants, with a maximum difference of 28.5%. Among the analysed cultivars, Limoncello exhibited the highest shoot production, whereas Frizzled Coral Lace and Mon Amour had the lowest. The study showed cultivar-specific responses to chitosan application methods. Specifically, plants of Limoncello demonstrated the most remarkable shoot proliferation when grown from corms soaked before planting, whereas Frizzled Coral Lace plants subjected to the same treatment exhibited the lowest shoot proliferation (Tab. 3).

Literature reports are inconclusive regarding the effect of chitosan on the number of leaves produced by various species of ornamental plants. Spraying *Pelargonium* × *hortorum* twice with 1 mg · dm^{-3} of chitosan does not determine the number of leaves the plants develop [Liu 2023]. However, a positive effect of chitosan on the number of leaves was demonstrated in the rose Anglina [Ali and Asal 2023]. In *Eucomis bicolor*, this effect depended on chitosan concentration [Byczyńska 2018]. In our experiment, the gladioli obtained from the corms soaked in chitosan and those sprayed with this compound developed 9.1% and 9.9% more leaves on the main shoot, respectively, but only if compared to the control plants (Tab. 3). The Peter Pears plants had the most considerable number of leaves, while those of Mon Amour were the fewest. A significant dependency was demonstrated between the assessed cultivars and the chitosan application methods. Peter Pears plants grown from the corms soaked in chitosan, watered, or sprayed with it developed more leaves only as compared to the control Nova Lux gladioli.

Chitosan also significantly determined the total number of leaves developed by the gladioli. Regardless of the cultivar, the plants treated with chitosan produced 26% to 41.7% more leaves than the control ones. Limoncello plants developed the largest, Frizzled Coral Lace, and Mon Amour had the smallest total number of leaves. The most significant number of leaves was observed in Limoncello plants obtained from the corms soaked in chitosan before planting, and the lowest in the control Mon Amour gladioli. This significant difference amounted to 146.1% (Tab. 3).

Spraying *Rosa bourborniana* Gruss-an-Teplitz with chitosan [Arshad et al. 2022] and treating *E. bicolor* bulbs with this compound before planting [Byczyńska 2018] intensified the green colour of their leaves. Our study did not confirm this, as the SPAD index depended mainly on the cultivar. Compared with all other evaluated cultivars, the leaves of Peter Pears plants had the highest greenness index. Regardless of the cultivar, the SPAD index was higher in the plants watered with chitosan than in those grown from the corms soaked before planting. The cultivars evaluated in the study responded differently to the chitosan application method. The most intensely green leaves were noted in the Peter Pears plants sprayed or watered with chitosan, and the lowest SPAD index was observed in the control Limoncello plants (Tab. 3).

Generative traits

According to Byczyńska [2018], soaking *E. bicolor* bulbs before planting induced an increase in inflorescence length. In our study, longer inflorescences were observed in the plants sprayed with chitosan and control ones than those watered with the compound or grown from the corms soaked in it (Tab. 4). The inflorescence length of gladiolus can vary depending on the cultivar, as reported by Thakur et al. [2015]. The Mon Amour plants had the longest inflorescences, while in Nova Lux they were the shortest.

Chitosan spraying significantly affected the number of inflorescences obtained in *Matricaria recutita* [Abdul-Hafeez and Ibrahim 2021] and the number of flowers in *R. bourborniana* Gruss-an-Teplitz [Arshad et al. 2022]. Additionally, a dependence was found between the diameter of *Polianthes tuberosa* flowers and chitosan concentration [Alsanam and Salih 2021]. In the present study, the treatment of gladioli with 0.4% chitosan with a molecular weight of 6000 g · mol^{-1} did not significantly affect the number of developed flowers or their diameter (Tab. 4). These traits depended mainly on the cultivar, which other studies also confirmed [Thakur et al. 2015]. Reports on the effects of soaking plant bulbs in chitosan on flower production remain inconclusive. Ramos-Garcia et al. [2009] observed a positive impact on flower number in gladioli Blanca Borrego following treatment with a 1.5% Biorent preparation. However, Byczyńska [2018] did not confirm this effect in *E. bicolor*. In the present study, Limoncello plants produced the highest number of flowers per inflorescence, whereas Frizzled Coral

Lace exhibited the lowest. Conversely, flowers with larger diameters were recorded in Frizzled Coral Lace, Nova Lux, Peter Pears, and Mon Amour, while Limoncello plants produced flowers with smaller diameters.

Corm yield

Treating *E. bicolor* bulbs before planting with chitosan at 50 and 100 mg · dm^{-3} increased their weight [Byczyńska 2018]. Chitosan of a molecular weight of 7000 or 10 000 g · mol^{-1} used during the rooting of *Eucomis comosa* Sparkling Burgundy leaf seedlings contributed to increasing the weight of adventitious bulbs [Kukla and Żurawik 2022]. Our study also showed that 0.4% chitosan with a molecular weight of 6000 g · mol^{-1} increased the corm weight growth index, regardless of the application method (Tab. 5). Concerning the plants not treated with this compound, the significant differences ranged from 21% to 41.9%. Żurawik and Bartkowiak [2009] linked the size of this index in garden freesia with the chitosan application method. In the present study, soaking the bulbs before planting had a stronger effect on this trait, only concerning spraying the plants during the growing season. Similar relationships were demonstrated by Kukla and Żurawik [2022] for rooting of *E. comosa* Sparkling Burgundy leaf seedlings. Regardless of the chitosan application method in the present experiment, the highest corm weight growth index was observed in the Nova Lux plants and the lowest in the Peter Pears ones. The investigated cultivars responded differently to the chitosan application methods. The highest corm weight growth index was found in the Mon Amour and Nova Lux plants obtained from the corms soaked before planting, whereas the lowest was in the sprayed Peter Pears plants. These significant differences amounted to 155.8% (Tab. 5).

Byczyńska [2018] observed that the effect of chitosan on the number of developed bulbs in *E. bicolor* depended on its concentration. Moreover, Biorent at a concentration of 1.5% increased the number of daughter corms developed by *G. hybridus* Hort. [Ramos-Garcia et al. 2009]. According to Żurawik [2013], chitosan with a molecular weight of 10 000 g · mol^{-1} stimulated the growth of a more considerable number of buds in garden freesia Silver Beach, which resulted in a rise in the bulb count rate by up to 44.3%. No differences of this magnitude were found in the present study using 0.4% chitosan with a molecular weight of 6000 g · mol^{-1}. Compared with the control plants, a 28.5% higher corm count increase rate was obtained only from spraying the plants with this compound. The rate was the highest in Limoncello plants and the lowest in Mon Amour and Frizzled Coral Lace. The differences were 64.2% and 86.4%, respectively (Tab. 5). There were also differences in the response of the cultivars to the chitosan application methods. The highest corm count increase rate was observed for the Limoncello plants when the corms were soaked before planting, and the lowest for the Frizzled Coral Lace plants for the same chitosan application method. The difference was significant and amounted to 142% (Tab. 5). The increase in the corm weight growth index was due to an increase in the assimilation area, which resulted from the gladioli developing a more significant number of leaves. On the other hand, the rise in the corm count rate was due to the formation of a more significant number of shoots at the base of which the daughter corms were formed.

CONCLUSIONS

Using chitosan with a molecular weight of 6000 g · mol^{-1} at a concentration of 0.4% for soaking corms before planting accelerated their emergence only in the cultivars characterised by a long germination period. The biopolymer also accelerated the development of generative organs and extended the flowering period of gladiolus plants, but these effects depended on the cultivar traits and the application method. The impact was more substantial in the cultivars with a long cultivation period and in the case of spraying or watering the plants. Using chitosan significantly increased the plant height and the number of developed leaves. Among the evaluated gladiolus cultivars, Peter Pears was characterised by more intensely green leaves. The decorative value of the cultivated plants only slightly depended on the use of chitosan. The increase in inflorescence shoots and the inflorescence length were observed only in the plants sprayed with chitosan. The number of developed flowers in the inflorescence and their diameter did not differ significantly from plants not treated with chitosan, and these parameters depended mainly on cultivar traits. Soaking the corms before planting and spraying or watering the plants with chitosan increased the weight growth index of daughter corms.

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