

Table 1. Morphological properties of vegetative organs depending on the concentration, application method and frequency of chitosan use (mean for the years 2010–2012)

Trait	Concentration (C) (%)	Application method (A)		Frequency of use (F)		Mean
		watering	spraying	I*	II	
Plant height (cm)	0.0	87.9	88.2	87.5	88.6	88.1
	0.2	92.0	92.3	93.2	91.1	92.2
	0.4	92.3	94.1	94.7	91.7	93.2
Mean		90.7	91.5	91.8	90.5	
LSD _{0.05}	A – n.s., C – 1.52, F – 1.03, A × C – n.s., A × F – n.s., C(F) – 2.15, F(C) – 1.79, A × F × C – n.s.					
Number of shoots (pcs.)	0.0	1.7	1.7	1.6	1.7	1.7
	0.2	2.2	2.4	2.2	2.4	2.3
	0.4	2.3	2.2	2.4	2.2	2.3
Mean		2.1	2.1	2.1	2.1	
LSD _{0.05}	A – n.s., C – 0.27, F – n.s., A × C – n.s., A × F – n.s., C × F – n.s., A × F × C – n.s.					
Number of leaves set on main shoot (pcs.)	0.0	9.9	10.0	10.0	9.9	10.0
	0.2	10.1	10.3	10.0	10.4	10.2
	0.4	10.3	10.9	10.5	10.7	10.6
Mean		10.1	10.4	10.2	10.3	
LSD _{0.05}	A – 0.17, C – 0.25, F – n.s., A(C) – 0.29, C(A) – 0.35, A × F – n.s., F(C) – 0.29, C(F) – 0.35, A × F × C – n.s.					
Total number of leaves per plant (pcs.)	0.0	16.4	16.3	16.1	16.6	16.4
	0.2	21.5	23.8	22.3	23.1	22.7
	0.4	22.5	22.3	22.0	22.9	22.4
Mean		20.1	20.8	20.1	20.9	
LSD _{0.05}	A – n.s., C – 3.08, F – n.s., A × C – n.s., A × F – n.s., C × F – n.s., A × F × C – n.s.					
Greenness index of leaves (SPAD)	0.0	54.9	54.9	55.1	54.7	54.9
	0.2	58.3	59.6	59.9	58.0	59.0
	0.4	59.3	59.2	59.7	58.8	59.2
Mean		57.5	57.9	58.2	57.2	
LSD _{0.05}	A – n.s., C – 0.92, F – 0.62, A × C – n.s., A × F – n.s., C × F – n.s., A × F × C – n.s.					

* – explanations: I – every 7 days, II – every 14 days, n.s. – not significant difference

Table 2. Characteristics of flowering depending on the concentration, application method and frequency of chitosan use (mean for the years 2010–2012)

Trait	Concentration (C) (%)	Application method (A)		Frequency of use (F)		Mean
		watering	spraying	I*	II	
Total length of main inflorescence shoot (cm)	0.0	48.6	52.6	50.7	50.6	50.6
	0.2	50.9	51.9	51.5	51.3	51.4
	0.4	53.3	54.4	53.9	53.8	53.9
Mean		50.9	53.0	52.0	51.9	
LSD _{0.05}	A – 1.13, C – 1.67, F – n.s., A × C – n.s., A(F) – 1.60, F(A) – 1.60, C × F – n.s., A × F × C – n.s.					
Length of main inflorescence shoot (cm)	0.0	11.3	11.3	11.3	11.3	11.3
	0.2	12.0	12.1	12.5	11.5	12.0
	0.4	13.2	12.3	12.9	12.6	12.8
Mean		12.2	11.9	12.2	11.8	
LSD _{0.05}	A – n.s., C – 0.94, F – n.s., A × C – n.s., A × F – n.s., C × F – n.s., A × F × C – n.s.					
Length of main inflorescence spike (cm)	0.0	7.7	7.7	7.7	7.6	7.7
	0.2	7.5	7.1	7.5	7.2	7.3
	0.4	8.7	6.8	8.3	7.3	7.8
Mean		8.0	7.2	7.8	7.4	
LSD _{0.05}	A – 0.36, C – n.s., F – 0.36, A(C) – 0.62, C(A) – 0.74, A × F – n.s., C × F – n.s., A × F × C – n.s.					
Number of flowers in main inflorescence spike (pcs.)	0.0	9.4	9.4	9.7	9.1	9.4
	0.2	10.1	9.3	9.3	10.1	9.7
	0.4	10.7	9.0	10.0	9.6	9.8
Mean		10.0	9.2	9.7	9.6	
LSD _{0.05}	A – 0.27, C – 0.39, F – n.s., A(C) – 0.46, C(A) – 0.55, A × F – n.s., C(F) – 0.55, F(C) – 0.46, A × F × C – n.s.					
Diameter of the first flower in the main inflorescence spike (cm)	0.0	5.9	5.9	6.0	5.8	5.9
	0.2	6.0	6.0	5.9	6.0	6.0
	0.4	6.2	6.1	6.3	6.0	6.2
Mean		6.0	6.0	6.1	5.9	
LSD _{0.05}	A – n.s., C – 0.18, F – 0.12, A × C – n.s., A × F – n.s., C × F – n.s., A × F × C – n.s.					
Number of lateral inflorescence shoots (pcs.)	0.0	1.3	1.3	1.2	1.3	1.3
	0.2	1.6	1.8	1.7	1.7	1.7
	0.4	1.6	1.7	1.6	1.7	1.7
Mean		1.5	1.6	1.5	1.6	
LSD _{0.05}	A – n.s., C – 0.19, F – n.s., A × C – n.s., A × F – n.s., C × F – n.s., A × F × C – n.s.					

* – explanations as in the table 1

Table 3. Yield of corms depending on the concentration, application method and frequency of chitosan use (mean for the years 2010–2012)

Trait	Concentration (C) (%)	Application method (A)		Frequency of use (F)		Mean
		watering	spraying	I*	II	
Coefficient of new corms number increase	0.0	1.14	1.19	1.18	1.16	1.17
	0.2	1.70	1.79	1.73	1.76	1.75
	0.4	2.03	1.94	2.24	1.73	1.99
Mean		1.62	1.64	1.72	1.55	
LSD _{0.05}	A – n.s., C – 0.197, F – 0.134, A × C – n.s., A × F – n.s., C(F) – 0.278, F(C) – 0.232, A × F × C – n.s.					
Coefficient of new corms weight increase	0.0	3.39	3.40	3.42	3.37	3.40
	0.2	3.04	3.06	3.06	3.04	3.05
	0.4	3.02	2.87	2.99	2.90	2.94
Mean		3.15	3.11	3.16	3.10	
LSD _{0.05}	A – n.s., C – 0.173, F – n.s., A × C – n.s., A × F – n.s., C × F – n.s., A × F × C – n.s.					
Coefficient of corms number increase total	0.0	2.94	3.18	3.06	3.06	3.06
	0.2	3.96	4.09	4.23	3.82	4.03
	0.4	4.37	4.11	4.65	3.84	4.24
Mean		3.76	3.79	3.98	3.57	
LSD _{0.05}	A – n.s., C – 0.478, F – 0.325, A × C – n.s., A × F – n.s., C × F – n.s., A × F × C – n.s.					
Coefficient of corms weight increase total	0.0	3.62	3.69	3.67	3.63	3.65
	0.2	4.78	4.13	4.87	4.04	4.46
	0.4	4.59	4.27	4.76	4.10	4.43
Mean		4.33	4.03	4.43	3.92	
LSD _{0.05}	A – 0.283, C – 0.415, F – 0.283, A × C – n.s., A × F – n.s., C(F) – 0.588, F(C) – 0.489, A × F × C – n.s.					

* – explanations as in the table 1

Beach' variety. However, the frequency of chitosan application was confirmed to affect plant height. Freesias treated every 7 days were higher than those exposed to chitosan every 14 days. A significant correlation between concentration and application frequency was also identified (tab. 1). Żurawik and Bartkowiak [2009 b] used chitosan of 20 000 g·mol⁻¹ molecular weight and 0.2% concentration and demonstrated its stimulating effect on freesia shoot formation that depended on the application method. In our study, when chitosan of 8 000 g·mol⁻¹ molecu-

lar weight was used, neither its method of application, nor treatment frequency significantly affected the investigated parameter. However, both concentrations of chitosan increased the number of shoots by 35.3%. Treating *Curcuma* 'Laddawan' plants with chitosan solution did not change the number of developed leaves [Tamala et al. 2007]. In our research, this information was not confirmed and our results are compatible those published by Żurawik and Bartkowiak [2009 b], who claimed that freesias treated with chitosan solution of 20 000 g·mol⁻¹ molecu-

weight and 0.2% concentration developed fewer leaves than control plants. In the reported experiment, 'Summer Beach' freesias produced more leaves when chitosan was applied by spraying than by watering, irrespective of chitosan concentration. More leaves on the main shoot were also obtained by using 0.4 than 0.2% solution. The relationships between application method and concentration and treatment frequency and concentration were variable. Our study did not confirm the report by Żurawik [2013], who claimed that the greatest number of leaves in 'Silver Beach' freesia were developed as a result of spraying the plants every 7 or 14 days with chitosan solution of 10 000 g·mol⁻¹ molecular weight. Total number of leaves produced by the plants was not significantly affected by either frequency or method of chitosan application. However, the use of chitosan at 0.2 or 0.4% significantly increased total number of leaves per plant. When compared with controls, these differences were 38.4 and 36.6%, respectively. Salachna and Bartkowiak [2008] reported an increase of leaf greenness index following corm soaking in 0.2% chitosan. However, they linked this effect to molecular mass of the solution. In our study, chitosan of molecular weight 8 000 g·mol⁻¹ significantly improved leaf greenness index irrespective of the application method, treatment frequency or concentration (0.2 and 0.4%). As compared with control plants, the differences were 4.1 and 4.3 SPAD, respectively. Independent of concentration and application method, plants treated every 7 days with chitosan solution were distinguished by stronger intensity of leaf greenness than the ones treated every 14 days (tab. 1).

According to Win et al. [2005], chitosan application enhanced inflorescence length in *Dendrobium* 'Misten'. This finding was not confirmed by Tamala et al. [2007] in *Curcuma* 'Laddawan'. In our study, the plants sprayed with chitosan produced inflorescence stems of greater total length than those watered with chitosan solution. The plants treated with higher concentration of chitosan (0.4%) produced the inflorescence stems of the greatest total length, as compared with control and those treated with 0.2% chitosan. A different relationship was reported for the length of the main inflorescence shoot. Regardless of the application method and treatment frequency,

longer shoots developed only in plants treated with 0.4% chitosan, as compared with control. Spraying freesia with chitosan solution resulted in shortening of the main inflorescence when compared with the plants watered with this compound. Treating freesia with chitosan every 7 days enhanced the length of the main inflorescence by 5.4%, as compared with the plants exposed to chitosan every 14 days. According to Żurawik [2013], treating 'Silver Beach' freesia with chitosan solution of 10 000 g·mol⁻¹ molecular weight, irrespective of the application method and concentration, increased the number of flowers. This was confirmed in 'Summer Beach' freesia treated with a solution of chitosan of lower molecular weight. More flowers in the main inflorescence than in the control plants were noticed only in the variant treated with 0.4% of chitosan. With reference to this trait, a significant correlation was reported between concentration and application method and between concentration and application frequency. The freesias treated with chitosan at 0.4% produced also flowers of greater diameter than those treated with chitosan at 0.2% and control ones. However, neither the method of chitosan application nor treatment frequency affected freesia flower diameter. Irrespective of the application method and frequency, the plants treated with 0.2 and 0.4% chitosan produced more side branches of the inflorescence than the control plants. The differences reached up to 30.8% (tab. 2).

According to Hasegawa and Kanechika [2005], Ramos-Garcia et al. [2009], Żurawik and Bartkowiak [2009 a], chitosan stimulated the yield of underground organs in geophytes. Salachna et al. [2008] linked this to the molecular weight of chitosan. Żurawik [2013] reported that both in the controlled environment and in production, irrespective of the group of cultivated freesia, chitosan of 10 000 g·mol⁻¹ molecular weight increased the total number and weight of corms and the coefficient of daughter corm number gain. Our research confirmed this report when chitosan of 8 000 g·mol⁻¹ molecular weight was applied in the cultivation of 'Summer Beach' freesia. Irrespective of chitosan application method and treatment frequency, it improved total corm weight and number gain at both concentrations. Chitosan used in our research reduced the coefficient of daugh-

ter corm weight gain. As compared with control plants, in freesias treated with 0.2 and 0.4% chitosan it was by 10.3 and 13.5% lower. In a study on ‘Silver Beach’ freesia, Żurawik [2013] reported an increase in the coefficient of total corm number and weight gain as well as in daughter corm number in plants treated with 0.4% chitosan. These reports were confirmed only for the coefficient of daughter corm number gain. Application of chitosan of lower molecular weight and 0.4% concentration resulted in this coefficient growth by 13.7% than as compared with 0.2% chitosan. Chitosan treatment every 7 days resulted in 10.9% higher coefficient of daughter corm number gain, 11.5% higher coefficient of total corm number gain, and 13.0% higher coefficient of total corm weight gain than in the plants exposed to chitosan every 14 days (tab. 3).

CONCLUSIONS

1. Chitosan of 8 000 g·mol⁻¹ molecular weight affected the beginning of spike formation of ‘Summer Beach’ freesia in unanimous manner. Its effect depended on the conditions prevalent during cultivation. It accelerated spike formation at lower temperatures and delayed it at higher temperatures.

2. Irrespective of the application method and treatment frequency, freesia exposure to 0.2 and 0.4% chitosan stimulated plant growth, improved leaf greenness index and increased total number of produced shoots and leaves.

3. The effect of chitosan on the quality of inflorescences depended on its application method. Watering the plants increased the length of the main inflorescence and the number of flowers, while spraying improved total length of the inflorescence stem.

4. Chitosan application at 7-day intervals positively affected vegetative traits and increased daughter corm yield, as compared with treatments at 14-day intervals.

5. Chitosan application in the reproduction of propagating material improved the growth of freesia daughter corm number gain coefficient, total corm number and weight gain coefficient but it also reduced daughter corm weight gain coefficient.

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