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THE EFFECT OF FOLIAGE FEEDING ON THE STRUCTURE OF YIELD, DRY WEIGHT CONTENT AND MACROELEMENTS IN THE CORMS OF *Sparaxis tricolor* Ker-Gawl.

Barbara Marcinek, Jerzy Hetman
University of Life Sciences in Lublin

Abstract. The field study was carried out between 2000 and 2003. The plants of *Sparaxis tricolor* were sprayed twice prior to flowering with a fertilizer called titanium (0.8% Ti) in three concentrations: 0.02, 0.04 and 0.08%. Application of titanium in the concentration of 0.04% increases the total yield of corms by 20% on average and the commercial yield by 7%. Spraying the plants with titanium in the concentration of 0.02% increased the share of corms with > 5cm circumference in total yield and improved yield structure of corms of the first selection. A higher concentration of the preparation (0.08%) had unfavorable effect on the commercial yield of corms. In 2001 titanium applied in the concentration of 0.02% increased the nitrogen content in offspring corms and decreased content of other macro-elements. In 2003 offspring corms of plants treated with titanium in the concentration of 0.02–0.04% had more dry weight, N, P, K, Ca, Mg and Na.

Key words: *Sparaxis tricolor*, titanium, yield of corms, structure of yield

INTRODUCTION

Sparaxis tricolor is an attractive species in the group of corm plants that do not winter in the ground and it is recommended for cultivation in backyard gardens and in the green terrains. Its flowering is very abundant from the end of June to mid August. The plant produces 15–20 inflorescence stems with very characteristic contrasting colors of petals. There are between 3 and 9 flowers in an ear. The flowers are characterized by radial symmetry, they are pink, red, peach, white and purple, and the flower bottom is yellow and brown. The number of inflorescence growing out of corm and their length depend on the size of mother corms and the date of seeding [Marcinek and Hetman 2006a, 2006b]. Corm reproduction on commodities plantation is possible in the Polish

Corresponding author – Adres do korespondencji: Barbara Marcinek, Institute of Ornamental Plants and Architecture of Landscape, University of Life Sciences in Lublin, Leszczyńskiego 58, 20-068 Lublin, Poland, e-mail: barbara.marcinek@up.lublin.pl

climate, however, the yield can be significantly affected by weather conditions, especially by too high air temperature in May and June, and insufficient moisture of soil [Marcinek and Hetman 2005]. Temperature over 16ºC and little rainfall in the first weeks of growth lead to death in an early stage of inflorescence stems [Horn et al. 1989]. As a consequence, flowering is poor, the proper growth and development are inhibited and the yield of offspring corms is lower.

Therefore, besides the proper agro-technique it is necessary to apply preparations that improve plant condition and ease stress factors. The aim of the research conducted in the Department of Ornamental Plants of University of Life Sciences in Lublin was to improve growth and seeding conditions by the application of foliage feeding with the fertilizer called titanium which contained 0.8% Ti.

MATERIAL AND METHODS

The two-factor experiment was conducted between 2000 and 2003 on the Experimental Farm of the University of Life Sciences in Lublin, in a fawn soil containing about 1.6% organic matter (tab. 1). The corms of *Sparaxis tricolor* Ker-Gawl., with 5–6 cm circumference which were imported from the Netherlands, served as the research material. The corms were planted into the ground in the first decade of May. Fields were fertilized in the spring prior to the corms planting with Azofoska (13,6% N, 2,8% P, 15,8% K) in the amount of 25 $g \cdot m^{-2}$. During the vegetation period the plants were reinforced and top dressing twice with ammonium nitrate (34% N) in the amount of 10 $g \cdot m^{-2}$ and Azofoska) in the amount of 25 $g \cdot m^{-2}$ (single doses were applied). Throughout the vegetation period the fields were weeded out manually and plants were sprayed against aphid and grey mould.

Table. 1. The contens of macro- and microelements in soil, $mg \cdot l^{-1}$
Tabela 1. Zawartość makro i mikroelementów w $mg \cdot l^{-1}$ gleby

Year Rok	pH in H_2O	The contess of macroelements in soil, $mg \cdot l^{-1}$ Zawartość makroelementów w $mg \cdot l^{-1}$ gleby					The contess of microelements in soil, $mg \cdot l^{-1}$ Zawartość mikroelementów w $mg \cdot l^{-1}$ gleby					Humus Próchnica %	Sainity Zasolenie g $NaCl \cdot l^{-1}$
		$N\text{-}NO_3$	P	K	Mg	Ca	Zn	Mn	Cu	Fe	B		
2000	6.6	21	140	160	108	580	14.02	15.18	7.98	83.6	0.92	1.77	0.09
2001	6.7	32	161	160	91	600	13.96	37.6	4.65	99.0	0.92	1.38	0.20
2003	5.7	76	111	125	64	400	14.72	269.75	6.58	232.6	0.92	1.59	0.42

The experiment was set up in the system of random blocks in five repetitions. A field with the surface of 1 m^2 was the repetition and 30 corms were planted there. Titanium was applied in three concentrations: 0.02, 0.04 and 0.08% in the form of spraying the plants twice before flowering every 10 days. The plants that were not treated with titanium served as the control.

As the vegetation ended, the corms were dug out of the ground in the first decade of September. Next, they were dried and cleaned and then selection sorted based on their circumference. The corms with > 9cm circumference were in the greatest selection. The corms with < 3 cm circumference were in the smallest selection. The number and weight of corms in the total and commercial yield (which included all the corms with > 4 cm circumference) was determined. In 2001 and 2003 chemical analyses of the offspring corms were conducted to check the content of dry weight, and N, P, K, Ca, Na, and Mg. The results were analyzed statistically by means of variance analysis for double classifications, evaluating the significance of differences by means of Tukey's confidence intervals at the level of significance of $\alpha = 0,05$. The structure of yield was expressed as a percentage share of the particular size corms in the total yield.

RESULTS

On the basis of the statistic analysis it was noted that the *Sparaxis tricolor* sprayed with titanium in the concentration of 0.04% produces more offspring corms by average 20% in relation to the plants that were not treated with the substance. The yield of the commercial corms with the circumference of > 4 cm also increased by average 7% in relation to the control plants. The three years of research show that the effectiveness of foliage feeding with titanium is diverse (tab. 2). In 2000 the total yield of the plants sprayed with titanium in the concentration of 0.04% increased by 52.5%, and the commercial yield increased by 35.7%. It must be noted that the year 2000 had very unfa-

Table. 2. Total and commercial crop offspring corms according to Titanium concentration
Tabela. 2.Plon ogólny i handlowy bulw potomnych w zależności od stężenia Tytanitu

Years Lata	Titanium concentration Stężenie Tytanitu %	Total crop Plon ogólny psc. $\cdot m^{-2}$	Commercial crop Plon handlowy psc. $\cdot m^{-2}$
2000	control	51.8 g*	25.2 e
	0.02	69.8 fg	31.4 e
	0.04	79.0 def	34.2 e
	0.08	72.6 efg	26.0 e
2001	control	128.4 ab	79.4 ab
	0.02	130.6 a	75.0 bc
	0.04	151.8 a	85.2 a
	0.08	144.4 a	74.0 c
2003	control	95.8 cde	51.0 d
	0.02	106.6 bc	53.4 d
	0.04	100.2 cd	47.0 d
	0.08	93.0 c-f	45.8 d
Mean Średnia	control	92.0 b	51.4 b
	0.02	102.3 ab	53.3 ab
	0.04	110.3 a	55.5 a
	0.08	103.3 ab	48.6 b

*means followed by the same letter do not differ significantly at $\alpha = 0.05$
*Średnie oznaczone tą samą literą nie różnią się istotnie dla $\alpha = 0,05$

Circumference of corms – Obwód bulw

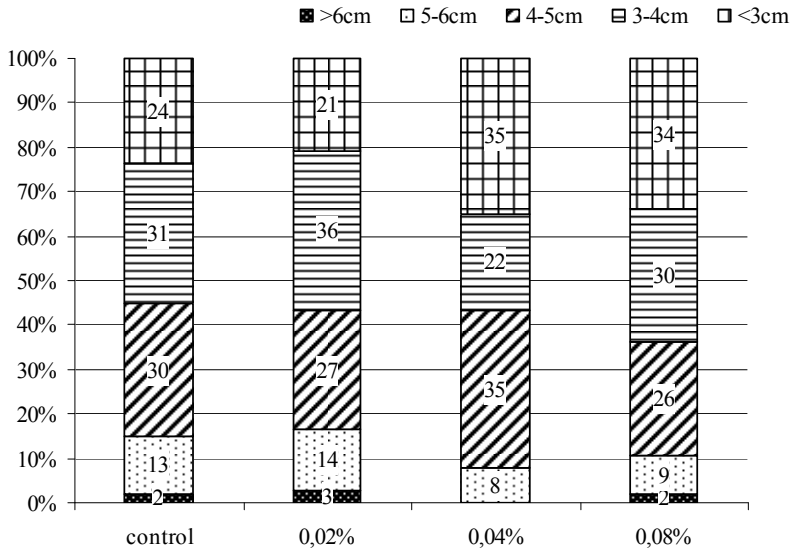

Fig. 1. Percentage of corms of each sort in the *Sparaxis tricolor* offspring corms total crop according to Titanium concentration in the year 2000

Ryc. 1. Udział bulw poszczególnych wyborów w plonie ogólnym bulw potomnych *Sparaxis tricolor* Ker-Gawl. w zależności od zastosowanych stężeń Tytanitu w roku 2000, %

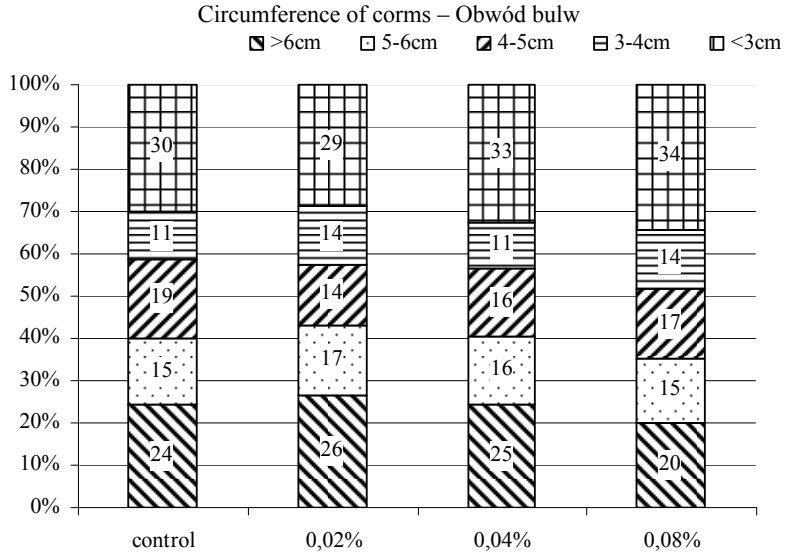

Fig. 2. Percentage of corms of each sort in the *Sparaxis tricolor* offspring corms total crop according to Titanium concentration in the year 2001

Ryc. 2. Udział bulw poszczególnych wyborów w plonie ogólnym bulw potomnych *Sparaxis tricolor* Ker-Gawl. w zależności od zastosowanych stężeń Tytanitu w roku 2001, %

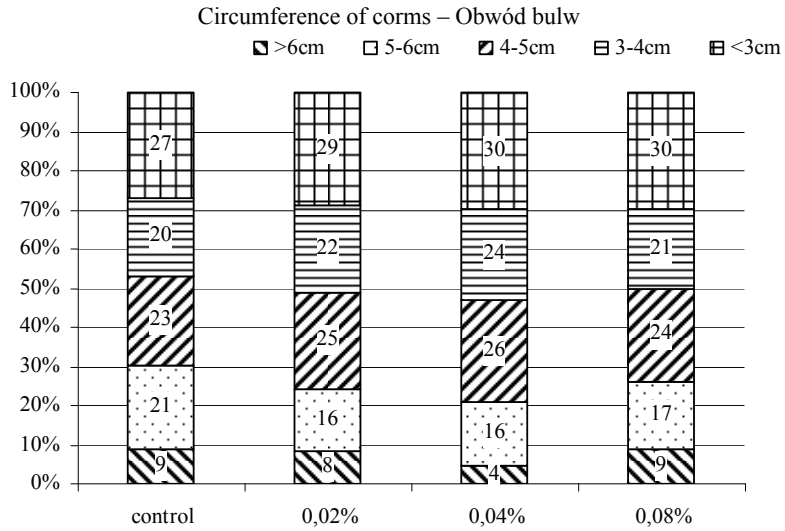

Fig. 3. Percentage of corms of each sort in the *Sparaxis tricolor* offspring corms total crop according to Titanium concentration in the year 2003

Ryc. 3. Udział bulw poszczególnych wyborów w plonie ogólnym bulw potomnych *Sparaxis tricolor* Ker-Gawl. w zależności od zastosowanych stężeń Tytanitu w roku 2003, %

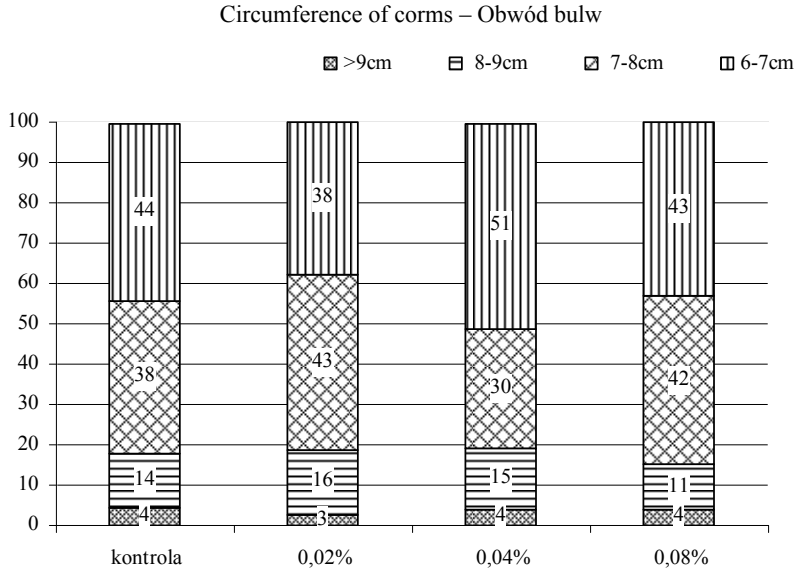

Fig. 4. Percentage of corms of each sort in the *Sparaxis tricolor* offspring corms > 6cm circumference according to Titanium concentration in the year 2001

Ryc. 4. Struktura bulw pierwszego wyboru *Sparaxis tricolor* Ker-Gawl. w zależności od zastosowanych stężeń Tytanitu w roku 2001, %

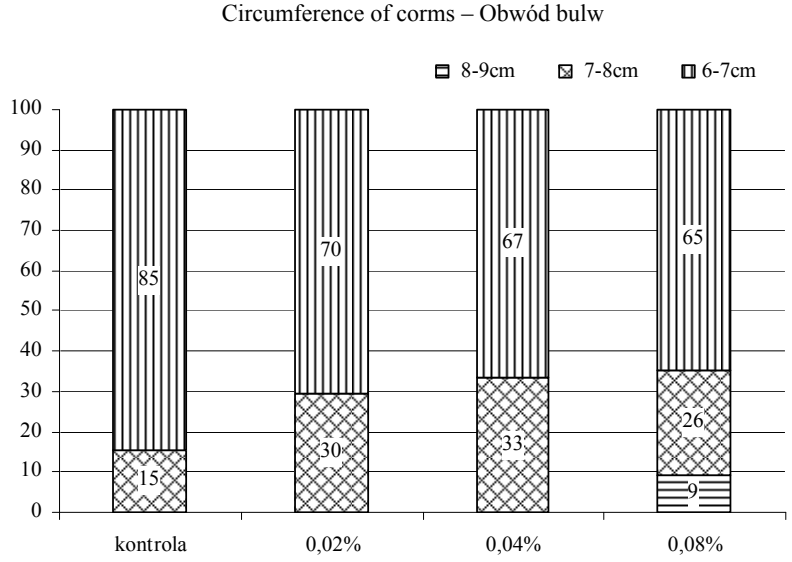

Fig. 5. Percentage of corms of each sort in the *Sparaxis tricolor* offspring corms > 6 cm circumference according to Titanium concentration in the year 2003

Ryc. 5. Struktura bulw pierwszego wyboru *Sparaxis tricolor* Ker-Gawl. w zależności od zastosowanych stężeń Tytanitu w roku 2003, %

vourable weather conditions as the average temperature in May was 14.6°C, and in June 17°C, whereas the total rainfall in that month was by 45% lower than the average of several years. 2001 was characterized by moderate temperatures and even rainfall which was beneficial to the plant growth and was reflected in the number of offspring corms produced by *Sparaxis tricolor*. In that year the total crop of corms increased by 18.2% when the plants were treated with titanium in the concentration of 0.04%, and the commercial crop increased by 7.8%. In 2003, the differences between the total and the commercial yield were not significant. It was noted, however, that the total yield increased by 11.2% and the commercial yield increased by 4.7% as an effect of spraying the plants with titanium in the concentration of 0.02%. The lack of clear effect of the preparation on the plants was a result of exceptionally fast end of plant vegetation in the summer due to very high temperatures and periodical lacks of rainfall. Titanium in the highest of the tested concentrations (0.08%) increase the total crop of offspring corms in 2000 and 2003 but caused a decrease in the commercial crop in all the years of the research.

Based on the total crop of offspring corms analysis in 2000 and 2001, it can be noted that titanium in the lowest of the tested concentrations (0.02%) increased the share of large corms (> 6 cm and 5–6 cm circumference) in the total yield, whereas the share of small corms in this combination (< 3 cm circumference) was the lowest (fig. 1, 2). In 2001, among the yield of offspring corms, corms with the circumference of > 9 cm were 3–4% of the corms with > 6 cm circumference. According to the analysis of the struc-

Table 3. The effect of Titanium concentration on dry weight and macroelements content in *Sparaxis tricolor* offspring corms in the year 2001 and 2003

Tabela 3. Wpływ różnych stężeń Tytanitu na zawartość suchej masy oraz makroelementów w suchej masie bulw *Sparaxis tricolor* Ker-Gawl. w latach 2001 i 2003, %

Titanium concentration Stężenie Tytanitu	Content of macroelements in corms, % of dry weight Zawartość makroelementów w % suchej masy												% of dry weight Zawartość suchej masy, %	
	N		P		K		Ca		Mg		Na			
	2001	2003	2001	2003	2001	2003	2001	2003	2001	2003	2001	2003	2001	2003
0,02%	4.22a*	4.19a	0.77b	1.08a	1.48c	1.98a	0.15b	0.37a	0.10b	0.12a	0.008b	0.015a	45.66b	48.67b
0,04%	3.20b	3.15b	0.72c	0.99ab	1.60b	1.92a	0.19a	0.37a	0.10b	0.12a	0.011ab	0.014a	45.36b	51.08a
0,08%	3.49b	3.31b	0.73c	0.92b	1.46c	1.63c	0.12c	0.39a	0.10b	0.10b	0.009b	0.012b	43.08c	41.20c
Control Kontrola	3.80b	3.52b	0.85a	0.85c	1.84a	1.78b	0.18a	0.30b	0.12a	0.10b	0.012a	0.014a	53.71a	42.08c

*Means followed by the same letter do not differ significantly at $\alpha = 0.05$

*Średnie oznaczone tą samą literą nie różnią się istotnie dla $\alpha = 0,05$

ture of yield of first selection corms, the share of corms with 8–9 cm and 7–8 cm circumference was the highest in case of plants sprayed with titanium in the concentration of 0.02% (fig. 4). In 2003, the most beneficial system of total yield structure was noted in the control combination (fig. 3). However, the analysis of yield of the first selection corms which produce the most flowering plants showed that the share of corms with 7–8 cm circumference was twice the size of the control combination when the plants were sprayed with titanium in the concentration of 0.02–0.04%. In that year corms with 8–9 cm circumference were produced only by these *Sparaxis tricolor* plants which were treated with titanium in the concentration of 0.08% (fig. 5).

Based on the chemical analysis of offspring corms it was noted that after the vegetation season in 2001 offspring corms of *Sparaxis tricolor* contained more dry weight and all other analyzed elements except nitrogen when the plants were not foliage fed with titanium. In 2003 the offspring corms obtained from the plants sprayed with titanium in the concentration of 0.02–0.04% contained significantly more dry weight as well as P, K, Ca, Mg, and Na (tab. 3).

Both in 2001 and in 2003 the highest content of nitrogen was noted in the offspring corms of the plants sprayed with titanium in the concentration of 0.02%.

DISCUSSION

Titanium is not an easily available element for plants because it does not dissolve in the pH range of 4–8 which is good for the growth of majority of plants. This element is not considered a micro-element that is essential for plants because plants contain below 0.01% of it. It is however in the group of trace elements that is elements that are 'beneficial' and which can influence the quantity and quality of yield [Pais 1991]. Titanium moves in the plant mainly in one direction – from shoots to roots [Keleman et al. 1993]. Research conducted on peppers, tomatoes and other plants proves that titanium affects the growth of enzymatic activity in the plant. As a result, the intake of nutrients is greater and metabolism and photosynthesis are increased. In addition, biosynthesis of carbohydrates in plants is growing [Martinez-Sanchez et al. 1991, Sarmiento et al. 1995]. Efficacy of foliage feeding with titanium depends on the species and growth conditions. Spraying various plant species with vegetable titanium chelate resulted in yield growth by average 10 -20%, and in increased dry weight content [Pais 1983]. Titanium increased tomato yield by 74%, pepper yield by 32%, and aubergine yield by 11%. The preparation effect on the plants depended mainly on the concentrations [Kołosowski et al. 2001]. In the cultivation of *Sparaxis tricolor*, titanium in the lower concentrations had the best effect. The yield of corms increased when the plants were sprayed with the preparation in the concentration of 0.04%, whereas the structure of yield was best when the plants were treated with titanium in the concentration of 0.02%. This has been confirmed by the research on *Acidanthera biocolor*, which belongs to the same family as *Sparaxis tricolor*, where the preparation increased the total and the commercial yield when applied in the concentration of 0.02% [Laskowska and Kocira 2003]. In the cultivation of *Panax quinquefolium* the application of titanium in the form

of triple plant spraying in the concentration of 0.04% resulted in 69% growth in the root yield [Kołodziej 2004].

Higher concentrations of titanium had a negative influence on plants as they decreased the number of commercial corms of *Sparaxis tricolor*. Similar effects of high concentrations of the preparation were noted in the cultivation of vegetables [Pais 1983], *Callistephus chinensis* [Górnik et al. 2000] and *Rosa multiflora* [Hetman and Adamiak 2003].

The effect of titanium on the intake of nutrients by plants was ambiguous. Chemical analysis of offspring corms showed that nitrogen content was increased in the offspring corms of plants fed with titanium in the concentration of 0.02%. In 2001 when air temperature and amount of rainfall were favourable for *Sparaxis tricolor* growth, it was noted that the offspring corms of plants foliage fed with titanium had higher content of dry weight and P, K, Ca, Mg and Na. In 2003 offspring corms of plants sprayed with titanium in the concentration of 0.02-0.04% contained more dry weight and other macro-elements in relation to the control plants. Weather conditions in that year caused a 3 weeks shorter vegetation period of *Sparaxis tricolor* as a result of high temperatures in July. Similar effect was observed in peppers cultivation. After titanium application, the dry weight content in roots, leaves, shoots and fruit was higher and also the content of macro and micro-elements was increased. It was also noted that the growth of nutrients intake lowered when the pepper plants were closer to optimal nutrient conditions [Martinez-Sanchez et al. 1991]. In the cultivation of apple tree**,** titanium increased fresh weight production and dry weight content in leaves, shoots and roots. Plant matter analysis showed an increased content of N, P, K, Mg, Ca, Fe, Mn, Cu, Zn and B as a result of spraying the plants with titanium [Klamkowski et al. 1999, Klamkowski and Wójcik 2000].

On the basis of the research it can be noted that titanium applied in the form of fertilizer significantly increased the yield of offspring corms of *Sparaxis tricolor* in those years that had unfavourable weather conditions, when the plants were subject to stress due to high temperature and lack of water in the ground [Hetman and Marcinek 2003].

CONCLUSIONS

1. Titanium applied in the concentration of 0.04% in the form of spraying the plant of *Sparaxis tricolor* twice, increases the number of corms of the total yield by 20% and the number of commercial corms by 7%. An increase of the preparation concentration to 0.08% has unfavourable effect on the yield of commercial corms.

2. Foliage fed titanium in the concentration of 0.02% increases the commercial corms share in the total yield and improves yield structure of the first selection corms with > 6cm circumference.

3. Offspring corms of the plants fed with titanium in the concentration of 0.02–0.04% contain more nitrogen. The content of dry weight and K, P, Ca, Mg and Na in offspring corms of plants treated with titanium depends on the weather conditions during the vegetation season.

4. Foliage feeding of *Sparaxis tricolor* plants with titanium in the concentration 0.02–0.04% can be recommended mainly in the years when weather conditions are unfavourable, especially when there isn't sufficient rainfall and the temperature in the first 6–8 weeks of the plant growth is too high.

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WPŁYW DOKARMIANIA DOLISTNEGO NA STRUKTURĘ PLONU I ZAWARTOŚĆ SUCHEJ MASY ORAZ MAKROELEMENTÓW W BULWACH POTOMNYCH *Sparaxis tricolor* Ker-Gawl.

Streszczenie. Doświadczenie polowe przeprowadzono w latach 2000–2003. Rośliny *Sparaxis tricolor* opryskiwano dwukrotnie przed kwitnieniem nawozem Tytanit (0,8% Ti) w trzech stężeniach: 0,02, 0,04 i 0,08%. Tytanit stosowany w stężeniu 0,04% zwiększa plon ogólny bulw potomnych średnio o 20% i handlowy o 7%. Opryskiwanie roślin Tytanitem w stężeniu 0,02% zwiększyło udział w plonie ogólnym bulw o obwodzie > 5 cm i poprawiło strukturę plonu bulw pierwszego wyboru. Wyższe stężenie preparatu (0,08%) wpływało niekorzystnie na plon handlowy bulw. W roku 2001 Tytanit stosowany w stężeniu 0,02% zwiększył zawartość azotu w bulwach potomnych, a obniżył zawartość pozostałych makroelementów. W roku 2003 bulwy potomne roślin traktowanych Tytanitem w stężeniu 0,02–0,04% zawierały więcej suchej masy, N, P, K, Ca, Mg i Na.

Słowa kluczowe: *Sparaxis tricolor*, tytan, plon bulw, struktura plonu

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