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INFLUENCE OF FERTILIZERS OF OSMOCOTE TYPE AND TOP – DRESSING ONTO THE GROWTH AND NUTRITION STATE OF *CAREX COMANS* BERGGR. 'FROSTED CURLS'

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Abstract

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The experiment on the influence of fertilizers of Osmocote type and top-dressing onto the growth and nutrition state of *Carex comans* 'Frosted Curls' was conducted in the years 2008 and 2009 in the greenhouse. The plants were cultivated in pots. During the process of basic fertilization two fertilizers Osmocote (3-4M): Osmocote Exact Standard (OES) 16:11:11 and Osmocote Exact High Start (OEHS) 11:11:19, were applied. Each fertilizer was used at the dosage of 2 and 4 g dm^{-3}. Within each dosage some of the plants were top dressed. Measurements were taken after 9 and 18 weeks of cultivation. Optimal quality of plants was obtained after 18 weeks of cultivation with the use of OEHS at the dosage of $2g \cdot dm^{-3}$ together with the simultaneous use of top dressing. These plants are characterised by longer leaves, higher clump circumference and higher dry matter of their aboveground part while compared to the other plants used in the experiment. The intensive plant growth was observed between 9 and 18 week of cultivation and was totally independent of the plant development at the initial state. The plants cultivated in the substrate with $2g \cdot dm^{-3}$ of OES fertilizer contained the lowest amounts of nitrogen and calcium while those cultivated with $4g \cdot dm^{-3}$ OES fertilizer contained the lowest amounts of potassium.

Key words: slow-release fertilizers, leaves length, fresh matter, growth, nitrogen, potassium

Introduction

Perennials, which are a much diversified group of plants, have been popular with those responsible for creating green belts for years. Search for new taxons in their natural environment, for example in Israel (Halevy, 2003; Halevy, 2005), of striking ornamental value, low cultivation requirements and resistant to stress (Zollinger et al., 2006) is being currently conducted. It is most often different species of grass and carex that are of particular interest. Currently new species and selected cultivars of widely known species of *Pennisetum* genus are being promoted (Hanna et al., 2010). Due to their visual features plant compositions in which they are used refer to nature. Perennial grasses and carexes are planted in gardens, on flower beds, town greenery areas and also in containers (Dana, 2002). According to Bryson and Carter (2008), it is as many as 53% of different carex species that are used in gardening. In the years 1930-1979 only 30-40 carex species were used as ornamental plants while since 2000 this number has grown by 110 species. The authors emphasize the fact that *Carex comans* is used not only as an ornamental plant but also as a fodder plant.

So far research has concentrated on finding different ways and terms for ornamental perennial grasses and carexes cultivation (Brand, 1999), on determining their frost and winter hardiness (Meyer et al., 1994), determining their growth and mineral nutrition in shading conditions (Cole and Cole, 2000), and on determining their resistance to the use of herbicides (Hubbard and Whitwell, 1991; Neal and Senesach, 1991). A lot of research has been conducted into the species used as energetic plants or those characterized by C_4 photosynthesis (Cruz, 1997). Podhale and Groninger (2009) conducted re-

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search into the influence of growth regulators onto the height and tillering of *Carex comans* 'Frosted Curls' and other species of carexes and ornamental grasses. The research into carexes growth with diversified mineral fertilization concerned mainly fodder species in their natural environment, especially in water-logged areas (Konings et al., 1992; Reece et al., 1994; Güsewell, 2005). *Carex comans* 'Frosted Curls' is one of several ornamental carexes offered by seed companies for cultivation in containers or in ground (Pilon, 2006; Armitage, 1997). This species can be found in its natural environment in New Zealand where it grows at 1300 meters above sea level in grassy formations, near flowing water (Jelitto, 2002).

Application of slow-release fertilizers in perennial cultivation in containers is becoming more and more common (Shaviv, 2005). Many scientific papers concern the influence of different dosages of those fertilizers onto plant growth, however they do not take into account comparison of different types of fertilizers, including top-dressing. Due to different requirements of particular ornamental species and even cultivars, it is essential to develop fertilization recommendations for newly introduced species.

The purpose of the following paper is to determine the influence of two types of Osmocote fertilizers used in different dosages together with or without top-dressing onto the growth of *Carex comans* Berggr. 'Frosted Curls', when cultivated in containers in greenhouses.

Materials and Methods

The experiment was conducted in the years 2008 and 2009 at the experimental station Marcelin of Poznań University of Life Sciences. Plant material consisted of *Carex comans* Berggr. 'Frosted Curls' seedlings produced by Syngenta Sp. z o.o, in multi-pot trays with 250 cells. 6 up to 8 seedlings with the average leaf length of 16-17.5 cm were planted into one cell. In both 2008 and in 2009 on 20 May the seedlings were bedded out into pots of 0.5 dm^3 capacity (stage I) and then on 20 July they were replanted into the pots of 1.0 dm^3 capacity (stage II). Cultivation in both stages lasted for 9 weeks (stage - I from 20 May to 20 July, stage II - from 20 July to 20 September). The substrate used in cultivation was peat substrate TS2 of Klasmann Company, designed for perennial cultivation. This substrate of pH 5.8 (H_2O), consists of peat of 0-25 mm fraction, 40 g dm^{-3} granulated clay R.H.P. and of 1.5 g dm^{-3} multi component fertilizer PG Mix (14:16:18).

Two Osmocote (3-4M) fertilizers, one with higher content of nitrogen - Osmocote Exact Standard (OES) 16:11:11, and the other one with higher content of potassium Osmocote Exact High Start (OEHS) 11:11:19, were used in the experiment for plant cultivation. Each of the fertilizers was applied at the dosage of 2 and 4 g dm^{-3}. Within each dosage some plants were top-dressed, during stage I at the concentration of 0.1% (50 cm^3 per pot) and during stage II - at the concentration of 0.2% (100 cm^3 per pot). In plants cultivated with the use of OES mostly Kristalon fertilizer 20:5:10 was used as top dressing, while with those fertilized with OEHS Peters Professional Special 15:11:29 was used. Top dressing was applied five times, every week, starting from the fourth week of the cultivation. The amount of various ingredients provided at different stages of cultivation is presented in Table 1.

In 9th and 18th week of cultivation in 2008 and 2009 plant measurements were taken. The length of three fully developed leaves from randomly selected shoots, the circumference of clumps (cm) measured at the plant base just above the

Table 1
The amount of various ingredients provided at different stages of cultivation in each pot

Basic fertilization		Top-dressing	Ingredient dose (mg per pot)								
			N			P			K		
Fertlizer	Dosages, g dm^{-3}		Stage I	Stage II	Sum I + II	Stage I	Stage II	Sum I + II	Stage I	Stage II	Sum I + II
OES* 16:11:11	2	-**	265.0	265.0	**530.0**	101.2	101.2	102.4	203.4	203.4	**408.6**
		+	315.0	465.0	**780.0**	106.7	123.2	229.9	224.1	286.4	**510.5**
	4	-	425.0	425.0	**850.0**	149.6	149.6	299.2	294.7	294.7	**589.4**
		+	475.0	625.0	**1100.0**	155.1	171.6	326.7	315.4	377.7	**693.1**
OEHS 11:11:19	2	-	215.0	215.0	**430.0**	101.2	101.2	102.4	269.8	269.8	**539.6**
		+	252.5	365.0	**617.5**	106.7	123.2	229.9	329.9	510.5	**840.4**
	4	-	325.0	325.0	**650.0**	149.6	149.6	299.2	427.5	427.5	**855.0**
		+	362.5	475.0	**837.5**	155.1	171.6	326.7	487.6	668.2	**1156.8**

* OES Osmocote Exact Standard; OEHS Osmocote Exact High Start
** - without top-dressing; + with top dressing

ground, and the fresh matter of the aboveground part of the plant (g) - cut just above the ground - were determined. In 18^{th} week of cultivation additionally random samples of aboveground parts of the plants were taken to analyse the content of macro elements and sodium. The samples were dried at the temperature of 50°C, and then were homogenized, and after mineralization the contents of N- by means of Kjeldahl method, of P – coulometrically with ammonium molybdate, of K, Ca, Na - photometrically, and finally of Mg – by means of atomic absorption, were determined.

Three-factor experiment (type 2 x 2 x 2) in a completely randomized design was conducted. The factors of the experiment were as follows: fertilization with OES 16:11:11 and OEHS 11:11:19 (factor A), two dosages (2 g and 4 g per dm^3 – factor B) and top dressing (with or without top dressing - factor C). There were two stages of experiment. In each out of eight combinations in the first 9 weeks there were 5 replications with 5 pots with plants, and in subsequent 9 weeks of cultivation - 4 replications with 5 pots with plants. Biometrical measurements were taken upon these plants. The leaf length and the clump circumference were observed in all the plants while the fresh matter of the aboveground part of the plant was analyzed in five randomly selected plants from each combination at both stages of the experiment.

The obtained results were analyzed statistically. Variance analysis for three-factor experiment at each stage and in each year separately (fixed model was assumed) and synthesis of both years (mixed model was derived) were conducted. Newman –Keuls multiple comparisons procedure at the significance level $\alpha = 0.05$ was applied. In order to determine the correlation between observed variables regression analysis was conducted. Backward stepwise regression (α=0.05) was used in order to match the simplest regression function. Cluster analysis with the use of Euclidean distance in multidimensional space was applied in order to classify eight experimental combinations under analysis.

Results

In July in both years *C. comans* 'Frosted Curls' leaves were from 38 cm to 64.5 cm long, and in September - from 49 cm to 82 cm long. The clump circumference in July was between 4.5 cm and 15 cm, and in September between 6.5 cm and 17 cm. Fresh matter of the aboveground part of the plant in July was from 6.47 g to 27.5 g, and in September from 19.85 g to 50.94 g.

Experiment results synthesis from both years (mixed model) for the experiments of 2 x 2 x 2 type, proved that the combination of basic fertilization (OES or OEHS) and the top dressing application or its lack (F_{BC}=9025; df = 1 & 1; p=0.007) had a significant effect onto *C. comans* 'Frosted Curls' leaves in 9^{th} week of cultivation. Longer leaves (Table 2) were obtained with the use of a lower dosage of the fertilizer and with the application of top dressing. Moreover, significant influence of top dressing onto the fresh matter of the aboveground part of the plant (table 4) in both 9^{th} week (F_C=194; df = 1 & 1; p=0.046) and in 18^{th} week of cultivation (F_C=855; df = 1 & 1; p=0.022) was observed.

The interaction between the examined factors for *C. comans* 'Frosted Curls' leaf length measured in 9^{th} week of cultivation in 2008 was insignificant – fixed model (Table 2). Simultaneously, however, highly significant differences between the application of OES fertilizer in comparison with OEHS (F_A=43.2; df = 1 & 192; p<0.001) and between dosages used were observed (F_B=29; df = 1 & 192; p<0.001). As far as top dressing is concerned, no statistically significant differences between its presence and absence were observed in the leaf length. The differences mentioned above were small, however, with lower dosages of basic fertilization and top dressing leaves were slightly longer on average. The smallest average leaf length was obtained after the application of OEHS in the dosage of $4g \cdot dm^{-3}$ regardless of the application of top dressing. The greatest average leaf length, on the other hand, was obtained after the application of OES at the dosage of $2\ g \cdot dm^{-3}$ regardless of the top dressing application. As far as the leaf length measured in 9^{th} week of the cultivation in 2009 is concerned no interaction between the factors under examination was observed as well. However, highly significant influence of particular factors onto the leaf length of *C. comans* 'Frosted Curls' (F_A=92.8 and df = 1 & 192 and p<0.001; F_B=68.5 and df = 1 & 192 and p<0.001; F_C=16.2 and df = 1 & 192 and p<0.001) was observed. Plants cultivated in the substrate with OEHS fertilization developed longer leaves when compared to those cultivated with OES, at a lower dosage ($2\ g \cdot dm^{-3}$) and with top dressing application.

As far as the leaf length measured in 18^{th} week of cultivation in 2008 is concerned, a significant interaction between the factors under examination (F_{ABC}=6; df = 1 & 152; p=0.016), a highly significant influence of the fertilizer dosage (F_B=30.6; df = 1 & 152; p<0.001) and the influence of the application of top dressing (F_C=23.7; df = 1 & 152; p<0.001) were observed. Plant reaction, as far as the combination of factors A and B (basic fertilization in various dosages) is concerned, towards the change of factor C variant (application of lack of application of top dressing) while taking into consideration the leaf length was statistically significant in two cases, while in the remaining two it was not statistically significant. However, one must bear in mind that with the application of top dressing the average leaf length was greater (Table 2). As far as the leaf length measured in 18^{th} week of cultivation in 2009 is concerned no interaction between the examined factors was

Table 2
Influence of two types of Osmocote fertilizers used in different dosages together with or without top-dressing on the length of the leaves *C. comans* 'Frosted Curls' in 9th and 18th week of cultivation; the average for the eight combinations and the combination of boundary

Basic fertilization		Top-dressing	Length of the leaves, cm			
			9th week		18th week	
Fertilizer	Dosages, g dm^{-3}		2008	2009	2008	2009
OES 16:11:11	2	-	44.9 bc#	49.5 b	59.9 ab	65.2 b
		+	45.8 c	51.6 bc	63.9 c	66.4 b
	4	-	43.6 ab	45.4 a	59.8 ab	57.7 a
		+	42.7 a	47.1 a	60.4 ab	60.0 a
OEHS 11:11:19	2	-	42.8 a	53.5 c	62.3 bc	70.4 c
		+	43.4 ab	56.2 d	64.1 c	70.9 c
	4	-	41.8 a	50.6 b	58.1 a	65.7 b
		+	41.6 a	51.8 bc	61.2 b	66.3 b
	2	-	43.9 b	51.5 c	61.1 b	67.8 b
		+	44.6 b	53.9 d	64.0 c	68.7 b
	4	-	42.7 a	48.0 a	58.9 a	61.7 a
		+	42.2 a	49.5 b	60.8 b	63.1 a
OES 16:11:11	2		45.3 c	50.5 b	61.9 b	65.8 b
	4		43.5 b	46.3 a	60.1 a	58.8 a
OEHS 11:11:19	2		43.1 b	54.9 c	63.2 c	70.7 c
	4		41.7 a	51.2 b	59.6 a	66.0 b
OES 16:11:11		-	44.2 b	47.5 a	59.8 a	61.4 a
		+	44.3 b	49.3 b	62.1 b	63.2 a
OEHS 11:11:19		-	42.3 a	52.0 c	60.2 a	68.0 b
		+	42.5 a	54.0 d	62.6 b	68.6 b
OES 16:11:11			44.4 b	48.4 a	61.0 a	62.3 a
OEHS 11:11:19			42.4 a	53.0b	61.4 a	68.3 b
	2		44.2 b	52.7 b	62.5 b	68.2 b
	4		42.6 a	48.7 a	59.8 a	62.4 a
		–	43.3 a	49.7 a	60.0 a	64.7 a
		+	43.6 a	51.7 b	62.4 b	65.9 a
Source of variation			F_{emp}			
Fertilizer			43.21 **	92.79 **	0.81	90.63 **
Dosages			28.99 **	68.58 **	30.62 **	84.34 **
Fertilizer x Dosages			0.48	0.42	3.53	3.27
Top-dressing			0.92	16.19**	23.6 **	3.49
Fertilizer x Top-dressing			0.13	0.01	0.03	0.81
Dosages x Top-dressing			2.41	1.00	1.22	0.20
Fertilizer x Dosages x Top-dressing			0.03	0.25	5.98*	0.12

* - Significant differences α = 0.05; ** - Highly significant differences α = 0.01
\# - Average marked with at least one same letter in the highlighted portion of the column are not significantly different at the level of α = 0.05 (Newman –Keuls multiple comparisons procedure)

observed. On the other hand, highly significant influence of factors A and B (F_A=90.6; F_B=84.3, for both tests df = 1 & 152 and p<0.001) was observed. Regardless of the fact that the average leaf length with the application of top dressing was greater, the differences were not statistically significant.

While analyzing **clump circumference** of *C. comans* 'Frosted Curls' in 9th week of cultivation in 2008 highly significant interaction between examined factors was observed (F_{ABC}=16.7; df = 1 & 192; p<0.001) (Table 3). Plant reaction from combination of factors A and B (fertilizer types in dif-

Table 3
Influence of two types of Osmocote fertilizers used in different dosages together with or without top-dressing on the circumference of clumps *C. comans* 'Frosted Curls' in 9th and 18th week of cultivation; the average for the eight combinations and the combination of boundary

Basic fertilization		Top-dressing	Circumference of clumps, cm			
Fertilizer	Dosages, g dm^{-3}		9th week		18th week	
			2008	2009	2008	2009
OES 16:11:11	2	-	13.1 cd#	6.0 b	13.2 a	10.8 b
		+	12.8 bcd	6.2 b	14.6 b	10.8 b
	4	-	13.0 bcd	5.3 a	14.0 b	8.8 a
		+	13.3 d	5.4 a	14.3 b	9.4 a
OEHS 11:11:19	2	-	11.6 a	7.6 d	14.2 a	13.4 cd
		+	12.4 a	7.4 d	14.5 b	13.6 cd
	4	-	12.7 bc	7.1 c	14.8 b	13.0 c
		+	12.6 bc	7.5 d	15.4 c	14.2 d
	2	-	12.3 a	6.8 b	13.7 a	12.1 b
		+	12.6 b	6.8 b	14.5 b	12.2 b
	4	-	12.9 b	6.2 a	14.4 b	10.9 a
		+	12.9 b	6.4 a	14.9 b	11.8 b
OES 16:11:11	2		13.0 c	6.1 b	13.9 a	10.8 b
	4		13.1 c	5.3 a	14.2 a	9.1 a
OEHS 11:11:19	2		12.0 a	7.5 c	14.3 a	13.5 c
	4		12.7 b	7.3 c	15.1 b	13.6 c
OES 16:11:11		-	13.0 c	5.6 a	13.6 a	9.8 a
		+	13.1 c	5.8 a	14.4 b	10.1 a
OEHS 11:11:19		-	12.2 a	7.3 b	14.5 b	13.2 b
		+	12.5 b	7.5 b	14.9 b	13.9 c
OES 16:11:11			13.1 b	5.7 a	14.0 a	9.9 a
OEHS 11:11:19			12.3 a	7.4 b	14.7 b	13.5 b
	2		12.5 a	6.8 b	14.1 a	12.1 b
	4		12.9 b	6.3 a	16.6 b	11.3 a
		-	12.6 a	6.5 a	14.0 a	11.5 a
		+	12.8 b	6.6 a	14.7 b	12.0 b
Source of variation			F_{emp}			
Fertilizer			50.94 **	345.78 **	16.89 **	326.21 **
Dosages			16.65 **	33.13 **	10.76 **	16.43 **
Fertilizer x Dosages			6.61 *	9.6 **	2.16	22.54 **
Top-dressing			3.90 *	2.07	16.27 **	8.11 **
Fertilizer x Top-dressing			2.88	0.01	1.20	1.03
Dosages x Top-dressing			0.97	1.48	1.04	4.71 *
Fertilizer x Dosages x Top-dressing			16.65 **	2.76 **	4.62 *	0.23

Explanation as in Table 2

ferent dosages) to the change of factor C variant (application or lack of application of top dressing) as far as the clump circumference was concerned was statistically significant only in the case of OEHS application in the dosage of 2g·dm^{-3}. Greater clump circumference was obtained with the application of top dressing. Highly significant differences were also observed while applying OES in comparison with OEHS (F_A =50.9; df = 1 & 192; p<0.001) and while using dosage 4g·dm^{-3} in comparison with dosage 2g·dm^{-3} (F_B =16.7; df = 1 & 192; p<0.001) and also while applying top dressing with regard to clump circumference of the plants in which top dressing was not applied (F_C =3.9; df = 1 & 192; p=0.050). Significant interactions between factors A and B (the type and the dosage of the examined fertilizers) (F_{AB} = 6.6; df = 1 & 192; p<0.011) were also observed. Higher clump circumference was obtained after the application of a higher dosage of OEHS. In 9th week of the cultivation in 2009 highly significant interaction between examined factors A and B (F_{AB} =9.6 df = 1 & 192; p=0.002) was observed. Simultaneously, highly significant differences were also observed after the application of OEHS when compared with OES (F_A =345.8; df = 1 & 192; p<0.001) and when comparing the dosage of 2g·dm^{-3} to the dosage of 4g·dm^{-3} (F_B =33.1; df = 1 & 192; p<0.001). Plant reaction to the fertilizer type and its dosage while taking into consideration clump circumference was statistically significant only in the case of OES. Higher clump circumference was obtained after the application of a lower fertilizer dosage.

While analysing clump circumference in 18th week of cultivation in 2008, it turned out that the obtained results were comparable to those from July of the same year (9th week). Significant interaction between the factors was demonstrated (F_{ABC} =4.6; df = 1 & 152; p=0.033). Plant reaction to factors A and B (fertilizer types in various dosages) while changing factor C variant (application or lack of application of top dressing) in terms of clump circumference was statistically significant in the case of OES application at the dosage of 2 g·dm^{-3} and OEHS application at the dosage of 4 g·dm^{-3}. Higher clump circumference was obtained together with top dressing application. Highly significant differences were also observed while comparing fertilizer types and their dosages. Higher clump circumference was obtained after OEHS application when compared to OES (F_A =16.9; df = 1 & 152; p<0.001), the dosage of 4 g·dm^{-3} had a more favourable effect in 2008, while in 2009 - it was the dosage of 2 g·dm^{-3} (F_B =10.8; df = 1 & 152; p=0.001). Significantly higher clump circumference was obtained after the application of top dressing (F_C =16.3; df = 1 & 152; p<0.001). In 18th week of the cultivation in 2009 a highly significant interaction between factors A and B (F_{AB} =22.5 and df = 1 & 152; p<0.001) and a significant interaction between factors B and C (F_{BC} =4.7 and df = 1 & 152; p=0.032) was observed. Highly significant differences between different variants of factors A, B and C separately were also demonstrated (F_A =326.2 and df = 1 & 152; p<0.001; F_B = 19.4 and df = 1 & 152; p<0.001; F_C =8.11 and df = 1 & 152; p=<0.005). The influence of variants of factors A and B was similar to that from July in the same year, however, significant differences regarding top dressing when compared to the clump circumference of the plants in which top dressing was not applied were demonstrated.

During the growing process of the plants in 9th week of the cultivation in 2008 no interaction between all the factors under examination in the case of **fresh matter** of *C. comans* 'Frosted Curls' (Table 4) was demonstrated. However, highly significant differentiation of plant fresh matter after the application of OEHS when compared with OES (F_A =13.8; df = 1 & 32; p=0.001) and significant interaction between factors A and C (F_{AC} =7.3; df = 1 & 32; p=0.011) were demonstrated. After the application of top dressing plant fresh matter was significantly higher when it was OES not OEHS that was used as the basic fertilizer. Similarly, in 9th week in 2009 no interaction between all the factors under examination was demonstrated. However, highly significant influence of particular factors onto the plant fresh matter was observed (F_A =71.9 and df = 1 & 32; p<0.001; F_B = 20.5 and df = 1 & 32; p<0.001; F_C = 8.2 and df = 1 & 32; p=0.007). Higher plant fresh matter was obtained after OEHS application, smaller dosage (2 g·dm^{-3}) together with top dressing.

While analysing plant fresh matter in 18th week of cultivation in 2008 no interaction between the factors under examination was demonstrated, however, the influence of top dressing application was highly significant (F_C = 9.2; df = 1 & 32; p=0.005). As far as the fresh matter of the aboveground part of the plant denoted in 18th week of cultivation in 2009 is concerned, no interaction between all the factors under examination was demonstrated. However, highly significant interactions between factors A and B (F_{AB} = 26.4 df = 1 & 32; p<0.001), A and C (F_{AC} = 13.1 df = 1 & 32; p=0.001) and significant interaction between factors B and C (F_{BC} = 5.6 df = 1 & 32; p=0.025) were demonstrated. Significantly higher plant fresh matter was obtained after the application of OES in the lower dosage (2 g·dm^{-3}) and after the application of OEHS in the higher dosage (4 g·dm^{-3}) together with the application of top dressing. Also highly significant differentiation between variants of factors A, B and C was observed (F_A =35.6 and df = 1 & 32; p<0.001; F_B = 50.2 and df = 1 & 32; p<0.001; F_C =9.3 and df = 1 & 32; p=0.005). Higher fresh matter of the aboveground part of the plant was obtained after the application of OEHS, dosage of 2 g·dm^{-3} together with top dressing application.

Diversified influence of fertilization onto the leaf length, clump circumference and fresh matter of the aboveground part of *C. comans* in the terms and years under examination implies the necessity of explorational analysis techniques of these multi-dimensional data. Cluster analysis, whose main objective is to set the combinations under examination in such a way so that the degree of their correlation within the same group was the highest possible, and with combinations from other groups as low as possible, was applied. While applying Euclidean distance measurement a tree diagram was obtained (Figure 1). On that basis one might state that the structure of influence of particular combinations of fertilization onto *C. comans* growth is more or less similar depending on the adopted value of Euclidean distance. While adopting

Table 4

Influence of two types of Osmocote fertilizers used in different dosages together with or without top-dressing on the fresh matter of the aboveground part of the plant *C. comans* 'Frosted Curls' in 9th and 18th week of cultivation; the average for the eight combinations and the combination of boundary

Basic fertilization		Top-dressing	Fresh matter of the aboveground part of the plant, g			
Fertilizer	Dosages, g dm^{-3}		9th week		18th week	
			2008	2009	2008	2009
OES 16:11:11	2	-	13.0 a#	10.4 a	33.2 a	44.2 cd
		+	15.4 ab	13.3 b	36.1 a	38.7 bc
	4	-	13.4 a	8.6 a	31.3 a	24.0 a
		+	18.4 b	9.4 a	37.4 a	28.0 a
OEHS 11:11:19	2	-	12.8 a	14.2 b	31.0 a	38.9 bc
		+	11.9 a	15.6 b	34.5 a	46.1 d
	4	-	12.0 a	13.5 b	30.8 a	35.2 b
		+	11.4 a	13.8 b	32.7 a	44.8 cd
	2	-	12.9 a	12.3 a	32.1 a	41.5 c
		+	13.7 a	14.4 b	35.3 a	44.2 c
	4	-	12.7 a	11.1 a	31.1 a	29.6 a
		+	14.9 a	11.6 a	35.0 a	34.4 b
OES 16:11:11	2		14.2 ab	11.9 b	34.7 a	41.4 b
	4		15.9 b	9.0 a	32.2 a	26.0 b
OEHS 11:11:19	2		12.4 a	14.9 c	32..8 a	42.5 b
	4		11.7 a	13.6 c	31.7 a	40.0 b
OES 16:11:11		-	13.2 a	9.5 a	32.3 a	34.1 a
		+	16.9 b	11.3 b	36.8 b	33.4 a
OEHS 11:11:19		-	12.4 a	13.9 c	30.9 a	37.1 a
		+	11.7 a	14.7 c	33.6 ab	45.4 b
OES 16:11:11			15.1 b	10.4 a	34.5 a	33.7 a
OEHS 11:11:19			12.0 a	14.3 b	32.2 a	41.2 b
	2		13.3 a	13.4 b	33.7 a	41.9 b
	4		13.8 a	11.3 a	33.1 a	33.0 a
		-	12.8 a	11.7 a	31.6 a	35.6 a
		+	14.3 a	13.0 b	35.2 b	39.4 b
Source of variation			F_{emp}			
Fertilizer			13.77 **	71.89 **	3.76	35.62 **
Dosages			0.39	20.50 **	0.32	50.16 **
Fertilizer x Dosages			2.13	2.96	0.09	26.41 **
Top-dressing			3.42	8.17 **	9.23 **	9.26 **
Fertilizer x Top-dressing			7.32 *	1.18	0.60	13.09 **
Dosages x Top-dressing			0.91	3.06	0.12	5.55 *
Fertilizer x Dosages x Top-dressing			0.55	0.28	1.06	1.98

the distance of 12 the existence of three clusters may be observed. Combinations 3 and 4, that is applying OES at the dosage of 4 g·dm^{-3} with or without simultaneous application of top dressing belongs to the first cluster. For these combinations in cluster analysis lower means were obtained (27.1 and 28.8), which means that the effectiveness of their application has the least favourable effect onto the growth of *C. comans* 'Frosted Curls'. The second cluster comprises combination 6, that is OEHS application at the dosage of 2 g·dm^{-3} together with the simultaneous application of top dressing (mean 32.6). The remaining combinations, that is 1, 2, 5, 7 and 8, belong to the third cluster. These are the combinations in which OES fertilization at the dosage of 2g·dm^{-3} or OEHS fertilization at the dosage of 4 g·dm^{-3} regardless of top dressing application or OEHS fertilization at the dosage of 2 g dm^{-3} without top dressing application, were used. The means obtained for these combinations in cluster analysis were as follows 30.3 and 31.3, and 29.6 and 31.1 or 31.0. It might then be stated that combination 6, that is OEHS fertilization at the dosage of 2 g·dm^{-3} together with the application of top dressing has the most favourable effect onto plant growth parameters, such as leaf length, clump circumference and fresh matter of the aboveground part of the plant.

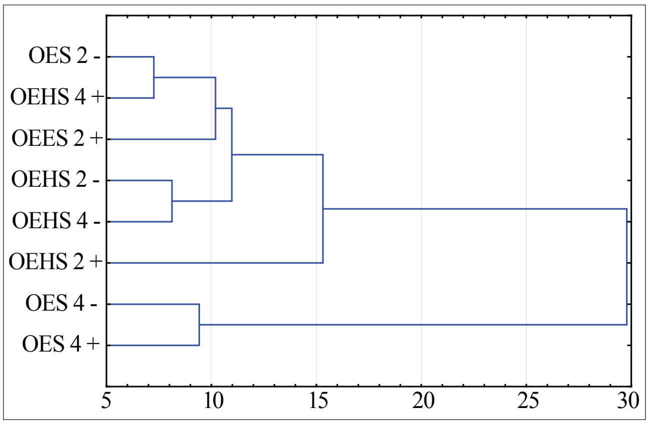

Fig. 1. Cluster analysis - dendrogram using Euclidean distance

It was examined whether the increase in leaf length, clump circumference and aboveground part of the plant weight of *C. comans* 'Frosted Curls' is proportional between week 9 and 18 of plant cultivation. It was proved that the values of these measures is highly significant, bearing in mind, however, on the basis of the coefficient of determination the percentage influence is not very high. The leaf length ($p<0.0001$) in 18th week of plant cultivation is determined by its length in 9th week of cultivation in 33%, plant clump circumference ($p<0.0001$) in 53%, and fresh matter of the aboveground part of the plants ($p=0.0003$) in only 16%. These results indicate that the increase in the leaf length, clump circumference and the fresh matter of the aboveground part of *C. comans* in the examined period is more dependent on other environmental factors than on initial values - those from week 9 of cultivation. This conclusion is verified by the analysis of the relation of these measurements against each other in both terms separately (Figures 2 and 3). The surfaces exhibited depict the relation between the leaf length, clump circumference and fresh matter of the aboveground part of the plant obtained for

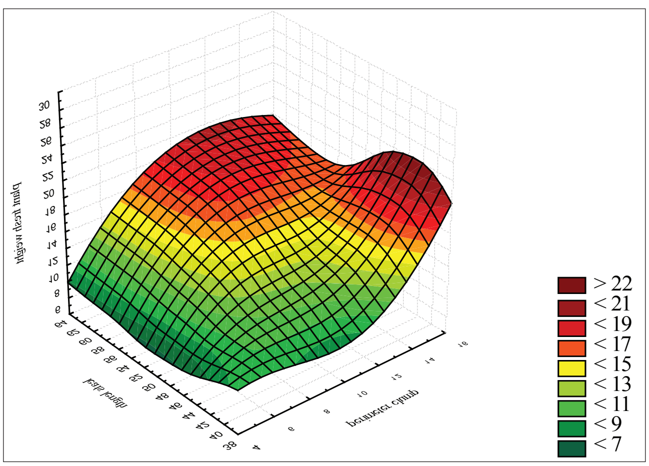

Fig. 2. Multiple Regression - leafs length, perimeter clump and plant fresh weight of aboveground *C. comans* 'Frosted Curls' in the ninth week of development, the results of two years of research

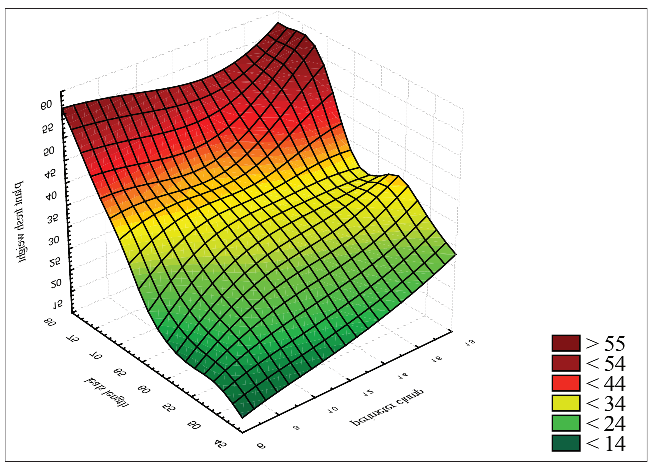

Fig. 3. Multiple Regression - leafs length, perimeter clump and plant fresh weight of aboveground *C. comans* 'Frosted Curls' in the eighteenth week of development, the results of two years of research

their values regardless of the year of examination and fertilizers used their dosages or top dressing application. From the comparison of these surfaces one might draw a conclusion that these relations change significantly between week 9 and 18 of the plant cultivation.

The contents of macro elements and sodium in the leaves of *C. comans* 'Frosted Curls' after 18 weeks (means from both year of the experiment) are presented in Table 5. The lowest amounts of nitrogen and calcium were found in plants cultivated in the substrate with 2 g·dm^{-3} of OES and potassium - with 4 g·dm^{-3} of that fertilizer. The application of OES together with top dressing resulted in the increase in nitrogen and calcium contents. However the dosages of OES (2 and 4 g·dm^{-3}) did not influence the amount of these elements in the leaves. The application of OEHS together with top dressing, on the other hand, resulted in the increase in potassium contents and decrease in calcium contents when compared with the plants which were not top dressed. Diversified fertilization did not seem to have a significant influence onto the contents of phosphorus, magnesium and sodium in *C. comans* 'Frosted Curls' leaves.

Discussion

It was demonstrated in the own experiment that the type of Osmocote fertilizer, its dosage and top dressing application had a significant influence onto the quality of *comans* 'Frosted Curls' plants cultivated in containers. The plants characterised by longer leaves, higher clump circumference and greater fresh matter of the plant aboveground part were obtained while applying OEHS fertilizer in 2009 and while applying OES fertilizer only in 9th week of the cultivation in 2008. Therefore, it was proved that the fertilizer with higher content of potassium had a more favourable effect onto qualitative characteristics of the plants. In the own experiment only once in two year study a favourable influence of OES fertilizer with higher content of nitrogen onto the growth of *C. comans* 'Frosted Curls' in the first 9 weeks of cultivation was observed. Bosiacki (2008), on the other hand, in *Clematis* from Jackmanii group 'John Paul II" cultivation, obtained plants of higher fresh matter while applying 5-6-month OES in comparison with OEHS. Rowe and Cregg (2002) obtained plants of comparable quality in the following species: *Artemisia ludoviciana* „Valerie Finnis', *Gaura lindheimeri* 'Whirling Butterflies' and *Nepeta x fassenii* 'Six Hills Giant' regardless of the nitrogen content in the fertilizers used - Nutricote 13:13:13 type 180 or 18:6:8 type 180.

In the own experiment in 2009, plants cultivated in the substrate with the lower dosage (2g·dm^{-3}) were characterised by longer leaves, greater circumference and greater fresh matter of the aboveground part of the plant. According to general fertilization recommendations it is both the shortage and the surplus of mineral elements in the substrate that can result in plant growth impairment (Bot et al., 1997). The measurement results in the own research indicate that the plants grown in the substrate with higher dosages of both OES and OEHS were characterised by shorter leaves. Aerts and Caluwe (1995) proved that increased nitrogen feeding in the cultivation of four species of carex leads to lowered shoot viability. Fertilizer dosages that are too high result in increased EC of the substrate, which is unfavourable for many plant species. In the research by Scoggins (2005) the species most sensitive to salinity (N dosage - 150 mg·dm^{-3}) were: *Cmapanula carpatica* 'Blue Clips' and *Astilbe chinensis* 'Purpurkarze', the most resistant, on the other hand was *Salvia nemorosa* 'Blue Hill' (N dosage – 250 mg·dm^{-3}). Rowe and Cregg (2002) proved that as far as Nutricote fertilizers dosages between 0.77 and 2. 13 g·dm^{-3} are concerned, it is the dry matter of the shoots that increases but the number and the dry matter of perennial roots remains

Table 5
The content of sodium and macronutrients in the leaves after 18 weeks of cultivation according to the fertilization of plants (average of 2008, 2009)

Basic fertilization		Top-dressing	N	P	K	Ca	Mg	Na
Fertlizer	Dosages, g dm^{-3}		[%]					
OES 16:11:11	2	-	1.83	0.30	2.91	1.04	0.19	0.08
		+	2.20	0.29	2.78	1.35	0.22	0.07
	4	-	2.09	0.33	2.67	1.23	0.28	0.12
		+	2.20	0.35	2.99	1.33	0.28	0.12
OEHS 11:11:19	2	-	2.15	0.30	2.95	1.40	0.23	0.11
		+	2.01	0.29	3.15	1.15	0.15	0.08
	4	-	2.07	0.31	2.89	1.37	0.25	0.10
		+	2.17	0.32	3.26	1.14	0.23	0.10

unchanged. Britton et al (1998), on the other hand, obtained the plants of the finest quality in container cultivation *Hosta* after the application of Osmocote at the dosage of 3 g·3.5 dm^{-3} of the substrate (container) in comparison with 6, 9 and 12 g·3.5 dm^{-3} of the substrate. Bosiacki (2008) obtained also *Clematis* from Jackmanii group 'John Paul II" of the highest fresh matter after OES application at a lower dosage - 6g·dm^{-3} than OHS at the dosage of 8 g·dm^{-3}. The study by Kozik et al. (2004) proved that slow-release fertilizer application in *Coreopsis grandiflora* 'Early Sunrise' cultivation at the dosage of 3.5 g·dm^{-3} of the substrate, has a favourable effect onto the number and the length of lateral shoots and also onto the plant fresh matter. Therefore, it might be concluded that the optimum fertilizer dosage is strictly dependent on the species.

In the own research, regardless of the Osmocote fertilizer type applied (OES or OEHS), it was top dressing that had a significant influence onto all the examined characteristics of *C. comans* 'Frosted Curls' - the leaves were longer and the clump circumference and plant fresh matter were greater. Hanke (2008), in ornamental grass cultivation, recommends the application of top dressing in the form of the solutions at the concentration of 0.05 - 0.1%. In the own research at stage I the concentration of 0.1% was used, and at stage II - the concentration of 0.2%. The process of releasing the ingredients from the slow-release fertilizer is above all dependent upon the temperature and the substrate humidity. The optimal temperature at which the ingredients are released in the correct amounts is 21°C. Low temperature and substrate humidity result in diminished ingredient release (Shaviv, 2005). That is why the use of top dressing in container cultivation might be favourable.

In the following paper the results assessment on the basis of statistical analysis exhibited that the relations between leaf length, clump circumference and fresh matter of the aboveground part *C. comans* 'Frosted Curls' change significantly between week 9 and 18 of plant cultivation. This might indicate stronger plant growth at the second stage of cultivation. The intensive biomass increase of *C. lasiocarpa* in summer in their natural environment in China was also observed by Yang et al. (2010). In the own experiment stage II was in the second half of July and August. According to Newman et al. (2006), the process of releasing ingredients from slow-release fertilizers for the first 15 weeks is extremely unstable. Moreover, EC of the substrate at that time might be from 3 to 5 times as high as later. Apart from that, it is nitrogen in the form of NH_4^+ that is released from Osmocote fertilizers for the first 5 weeks. That might be the reason for a slightly different plant reaction towards fertilization in 9th and 18th week of cultivation in the own experiment.

Diversified fertilization did not seem to have a significant influence onto the contents of phosphorus, magnesium and sodium in *C. comans* 'Frosted Curls' leaves. However, in studies Schroeter-Zakrzewska and Klaiber (2012) was observed significantly better nutrition of *Argyranthemum frutescens* Molimba® group with phosphorus after the application of OES in comparison with Osmocote Exact Hi-K (11:11:18). Moreover, they had not proved significant differences in the contents of the other macro-and microelements in plants.

Conclusions

The type of the fertilizer, its dosage and top dressing had a significant influence onto the growth of *C. comans* 'Frosted Curls'. On the basis of the conducted cluster analysis it might be concluded that OEHS fertilization at the dosage of 2 g·dm^{-3} together with the application of top dressing has the most favourable effect onto the parameters of plant growth, that is onto their leaf length, clump circumference and fresh matter of the aboveground plant part.

The intensive plant growth was observed between week 9 and 18 of cultivation and it is independent of the plant development at the initial stage.

The plants cultivated in the substrate with 2 g·dm^{-3} of OES fertilizer contained the lowest amounts of nitrogen and calcium while those cultivated with 4 g·dm^{-3} OES fertilizer contained the lowest amounts of potassium. Diverse fertilization did not have a significant effect onto the content of phosphorus, magnesium and sodium in leaves.

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