EFFECTS OF TRINEXAPAC-ETHYL ON TURFGRASS GROWTH AND FREQUENCY OF MOWING

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Abstract. The maintenance of grass lawns is not easy, especially in the summer when their use is greatest. The biggest problem during the whole period of vegetation is intense growth of grass. One way to limit it is the use of various types of natural and synthetic growth regulators. In the present study experimental factors included: 1. growth regulator: a) trinexapac-ethyl (TE), b) control object with no TE (C); 2. mineral fertilizers: a) Pokon (N1); b) Travovit Komplet (N2); c) Azofoska (N3); d) specially-formulated fertiliser (N4). A four-species mixture of grass was used in the experiment. After each mowing to a height of 6 cm (from July to October), grass growth was measured (in centimetres) using the grass height meter. The results showed that trinexapac-ethyl significantly suppressed, in relation to the control, the growth of grass on the lawns. Slower growth contributed to a reduction in mowing frequency by 43%, compared to the control.
Keywords: *growth regulator, fertilizing, lawn, frequency of mowing, grass growth*

Introduction

Lawns enrich the air with oxygen, have an impact on the water balance in the area, neutralize some atmospheric pollutants, but also reduce wind, dust, and noise. They are also places to relax for people of all ages, helping to recover physical and mental health. Keeping a lawn in good condition, particularly in the period of its maximum use, which coincides with intense grass growth, may be a serious problem (Jankowski et al., 2012). However, it is possible to slow grass growth through the use of growth regulators, both natural and synthetic (Ervin and Ok, 2001).

In order to suppress its growth, grass can be treated with synthetic regulators like trinexapac-ethyl, which can also be applied on cereals (Syngenta, 2001). According to March et al. (2013) trinexapac-ethyl *(*ethyl 4-[cyclopropyl*(*hydroxy*)*methylidene]-3,5-dioxocyclohexane-1-carboxylate) is absorbed through leaves and can slow the growth of many lawn grass species. Beam (2004) found that trinexapac-ethyl suppresses the growth of cells and, consequently, slows grass growth. In many studies (Fagerness and Yelverton, 2000; Ervin and Ok, 2001; Ervin et al., 2002; McCann and Huang, 2007; Heerden, 2014) trinexapac-ethyl was used in the cultivation of the following species of grass: *Agrostis capillaris* L.*, Poa pratensis, Lolium perenne* L.*,* and *Festuca pratensis* Hudson.

The aim of this paper is to study effects of trinexapac-ethyl on growth suppression and reduction of mowing frequency of a mixture of lawn grasses.

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Materials and methods

The experiment with lawn grass was set up in the autumn of 2001. The study was carried out between 2002 and 2004 on experimental plots of the Department of Grassland and Creation of Green Areas, the University of Natural Sciences and Humanities in Siedlce, Poland (52° 17' N; 22° 28' E). The experiment was conducted on plots of 4 m^2, in randomised blocks of four replications. The following experimental factors were taken into account: 1. growth regulator: a) trinexapac-ethyl (TE), b) control (C); 2. mineral fertilizers: a) Pokon (N1); b) Travovit (N2); c) Azofoska (N3); d) specially-formulated fertilizer (N4). The mixture of grass species consisted of: *Lolium perenne* (20%), *Festuca rubra* (55%), *Festuca ovina*, (15%), and *Poa pratensis* (10%).

In the experiment Moddus 250 SC, a growth regulator with the active substance of trinexapac- ethyl (TE), produced by the Swiss company Syngenta Crop Protection AG, was applied. It was sprayed in the amount of 0.06 $cm^3 \cdot m^{-2}$. The fieldwork was done between July and October. After mowing the grass to a height of 6 cm, the growth of grass was measured using the grass height meter (Jankowski et al., 2012). Measurements were made at three-day intervals, with the last one taken when the grass reached the height of 12 cm. On the experimental plots where the spray was not applied the grass grew quicker, and so it reached the height of 12 cm earlier and was mown to a height of 6 cm. Before each mowing the individual growth values as well as the number of days were added up. In each year of the experiment, from 19 July to 11 October, two rounds of measurements were taken.

In all the plots mineral fertilizers were applied within the NPK ratio of 6:2:4. In the study, four types of fertilizers were used: Pokon (N1), Trawovit (N2), Azofoska (N3) and specially-formulated fertilizer (N4). The first three are typical compound fertilizers for lawns, available on the market, and the fourth was a mixture of one-component fertilizers proposed by the authors of the experiment, optimal for fertilizing lawns. Mineral fertilizers applied in the experiment were different in both release rate and chemical composition. Pokon and Trawovit Komplet belonged to the group of quick-release fertilisers and were used in two identical doses, while Azofoska, as a slow-release fertilizer, was applied once during the season. The doses of fertilisers were specified by the manufacturer. In turn, the specially-formulated fertiliser (N4) was based on ammonium nitrate. Due to the high nitrogen content it was classified as a quick-release fertiliser. Irrespective of the dose of a mineral fertilizer the amount of nitrogen applied was 120 kg N per hectare, the same for each plot.

The experiment was carried out on soil classified as the culture earth soil order of the hortisole type, formed from loamy sand (Systematics of Polish Soil). The soil was characterised by a neutral pH (*Table 1*), moderately high levels of humus, a very high content of phosphorus, potassium, and magnesium, but a low content of nitrogen (Grzebisz, 2009).

Table 1. *Chemical composition of soil substrate in experiment*

pH	Content of assimilated components in $mg \cdot kg^{-1}$ of soil			Content in $g \cdot kg^{-1}$		Content $mg \cdot kg^{-1}$ DM	
KCl	P	K	Mg	N- total	Humus	$N\text{-}NO_3$	$N\text{-}NH_4$
6,99	39.2	15.8	84	0.18	3.78	10.10	7.47

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Meteorological data from 2002 to 2004 were provided by Meteorological and Hydrological Station in Siedlce. In order to determine the time and spatial variation of weather conditions and to evaluate their impact on grass growth, Sielianinov's hydrothermical coefficient (K) (Skowera and Puła, 2004) was calculated by dividing the sum of monthly precipitation by one-tenth of the sum of the mean daily temperatures for a month (*Table 2*).

Table 2. *Selianinov's hydrothermal index (K) in individual months of growth season*

Month	Year		
	2002	2003	2004
April	0.85	0.42	1.30
May	0.52	0.47	0.67
June	1.30	1.48	1.22
July	0.89	0.91	0.72
August	1.32	0.52	1.10
September	0.81	0.83	0.92
October	2.58	2.69	2.78

0.5 – serve drought; 0.51 – 0.69 drought; 0.70- 0.99 poor drought; over 1 – no drought

The results were statistically analysed using the computer programme Statistica version 10.0, StatSoft. The differences between means were verified by using analysis of variance, and Tukey's test was used with the significance level of $\alpha = 0.05$.

Results and discussion

Analyzing growth of the lawn grasses (*Table 3*), it can be concluded that there were differences among its rate depending on whether the growth regulator was applied or not and on the type of fertilizer applied. During all the years of research (2002-2004), the growth of grass on plots treated with the regulator, compared to the control, was considerably slow, suppressed by trinexapac-ethyl. Lickfeldt et al. (2000) showed that lawns treated with TE demonstrated better quality than lawns where TE had not been applied, regardless of the type of fertilizer used.

Comparing the years of the present experiment, the differences in the growth of grass between the plots where the regulator was applied and the control were 15.4 cm in 2002, 6.2 cm in 2003, and 12.0 cm in 2004, and were statistically significant. Additionally, the average difference for that period of 11.2 cm was also statistically significant.

The experiment proved that different types of fertilizer did not significantly differentiated the growth of grass, although the values of this characteristic during individual years of research were different and so were the means for the whole period. In each experimental year there were no significant differences in the growth suppression between each type of fertilizer, applied together with the growth regulator (TE), and the control. The biggest reduction of grass growth was obtained in 2002 because of the most favourable weather conditions (*Table 2*). In the same year, the grass growth was, on average, 14.6 cm higher on the control plot than on the plot with the Azofoska fertilizer and the growth regulator (TE), and 16 cm higher on the control than on the plot where the Pokon fertiliser and the growth regulator (TE) were applied. The smallest differences (with the grass 3.5 cm to 9 cm higher on the control plot) in growth

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suppression as a result of the impact of both these factors were obtained in 2003. The results of the tests could have been largely dependent on the weather conditions. In August 2003 those conditions were the worst of all experimental years because of drought (*Table 2*). A small amount of rainfall and high temperature could have reduced the differences in grass growth rate between the plots with the regulator and the control plot. The highest growth of grass on the plots with the growth regulator compared to those where it was not applied was in 2002 with its most favourable weather. This indicates a high impact of weather conditions on turf lawn. However, Xu and Huan (2011) and Mohammadi et al. (2017a), Etemadi et al. (2015) reported that plants treated with a growth regulator (TE) had a higher tolerance to drought. They found that plants treated with the growth regulator reduced the rate of water use, which is associated with a reduction in stalk growth and the increase in osmotic pressure due to the accumulation of inorganic substances and soluble sugars (McCann and Huang, 2007; Bian et al., 2009; Arghavani et al., 2012; Mohammadi et al., 2017b).

Table 3. *Average increase (cm) of lawn grasses in different study years, depending on the growth regulator and the kind of fertilizer*

Kind of fertilizer	Growth regulator	Study year			Mean
		2002	2003	2004	
N1	C	35.4^{Aa}	20.1^{Ab}	25.4^{Aab}	27.4^{A}
	TE	19.4^{Ba}	16.6^{Bab}	13.6^{Bb}	16.6^{B}
	C-TE	16	3.5	11.8	10.8
N2	C	34.6^{Aa}	20.4^{Ab}	25.8^{Aab}	27.0^{A}
	TE	18.8^{Ba}	16.6^{Ba}	14.0^{Bb}	16.4^{B}
	C-TE	15.5	3.8	11.8	10.6
N3	C	34.2^{Aa}	23.6^{Ab}	25.6^{Aab}	27.8^{A}
	TE	19.6^{Ba}	14.6^{Bb}	13.6^{Bb}	15.8^{B}
	C-TE	14.6	9.0	12.0	12.0
N4	C	34.2^{Aa}	20.4^{Ab}	25.2^{Aab}	26.6^{A}
	TE	19.4^{Ba}	13.0^{Bb}	13.4^{Bb}	15.3^{B}
	C-TE	14.8	7.4	11.8	11.3
Mean for fertilizers					
	N1	27.4^{Aa}	19.0^{Ab}	19.4^{Ab}	21.8^{A}
	N2	26.6^{Aa}	18.6^{Ab}	20.0^{Ab}	21.6^{A}
	N3	26.8^{Aa}	19.2^{Ab}	19.6^{Ab}	21.8^{A}
	N4	26.8^{Aa}	16.8^{Ab}	19.4^{Ab}	21.5^{A}
Mean for growth regulator					
	C	34.6^{Aa}	21.4^{Ab}	25.6^{Ab}	27.2^{A}
	TE	19.2^{Ba}	15.2^{Bab}	13.6^{Bb}	16.0^{B}
	C-TE	15.4	6.20	12.0	11.2
	Mean	27.0^{a}	18.4^{b}	19.6^{ab}	

Mean values marked with the same small letters do not differ significantly.
Mean values marked with the same capital letters do not differ significantly.

These findings are confirmed by the results of the present experiment, comparing the average height increase during one round of measurements of the grass on plots with and without the regulator (*Figure 1*). These data show that the growth reduction depends on both the use of the trinexapac ethyl regulator and the year of research. The biggest reduction in grass growth as a result of the application of growth regulator was

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in 2002 (about 8 cm) and 2004 (about 7 cm). These years were characterised by better weather conditions than in 2003. Heckam et al. (2002) studied effects of a growth regulator (TE) on the growth of *Poa pratensis* L. and found that plants treated were less tolerant to hot weather than plants not treated. They explain that in different plant species the cell electrolytes deficiency can affect the thermal stability of the cell membrane, which is related to the relative tolerance of heat.

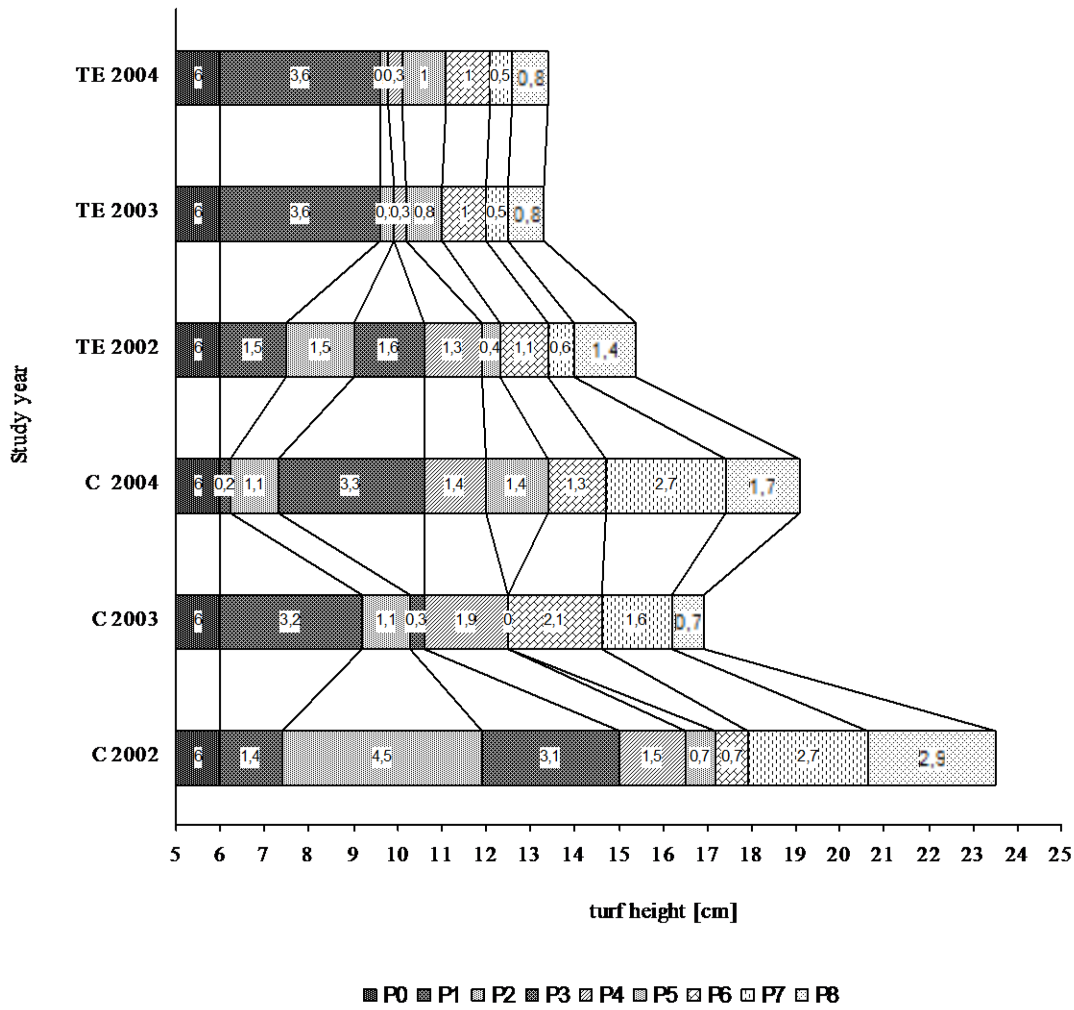

Figure 1. *Increase of turf height in study measurement cycle in each study year depending on growth regulator*

The results of the research (*Table 3*) also show that out of three years of research, the interaction between the fertilizer Azofoska and the growth regulator was, on average, the highest, with the reduction of growth by 12 cm, while it was the lowest (10.6 cm) on the plots where the fertilizer Trawovit Komplet and the growth regulator (TE) were applied together.

Application of trinexapac ethyl resulted in suppression of grass growth and frequency of mowing. During the annual cycle, which included 51 days (*Table 4*), the grass was mown only 8 times on the plots where trinexapac-ethyl was applied, while, at the same time, lawns on the control plots were mown almost 14 times (13.6), on average. However,

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according to March et al. (2013), trinexapac-ethyl is a growth regulator absorbed by leaves, and it can cause growth reduction with maximum efficiency in many species of lawn grass within 14 to 21 days after the spray is applied. In turn, Beam (2004) found that biomass reduction of *Lolium perenne* L. growing in greenhouse conditions was higher in the first and fourth week after the application. Describing a similar experiment, also with *Lolium perenne* L. in greenhouse conditions, Jiang and Fry (1998) reported that trinexapac-ethyl reduced its growth until the fourth week after the application.

Table 4. *The total number of lawn grasses mowing in the measurement period, depending on the growth regulator and the kind of fertilizer (total from three years)*

Kind of fertilization	Growth regulator			Mean
	C	TE	C- TE	
N1	13.8	8.2	5.6	11.0
N2	13.6	8.2	5.4	10.8
N3	14.0	8.0	6.0	10.6
N4	13.4	7.6	5.8	10.4
Mean	13.6	8.0	5.6	

Growth reduction of lawn grass as a result of the application of growth regulator can contribute to significant savings in both energy (electricity or fuels) and labour (Arghavani et al., 2012; Mohammadi et al., 2017b; Etemadi et al., 2015). An additional benefit of the application of growth regulator is also an environmental factor. In their study, Mccullough et al. (2005) found that TE reduced mowing frequency by 67%, as compared to the control, while the same frequency increased with increasing doses of nitrogen fertilizer, irrespective of the regulator used.

Taking into account various types of fertilizers applied, it can be concluded that the biggest difference in mowing frequency was between the control, with mowing 6 times more frequent there, and the plots where the grass was treated with the regulator and the Azofoska fertilizer, while it was the smallest (5.4 times), when the Trawovit fertilizer was applied. Whatever the type of fertilizer (*Table 4, Fig. 2*), mowing frequency on the plots with the growth regulator was reduced, on average, by 43%, compared to the control. The results indicate that the reduction in grass growth should be studied together with other characteristics, in order to fully understand the impact of TE. Further studies are needed to develop more comprehensive results and evaluate the impact of different doses of TE and frequency of application on the growth of grass.

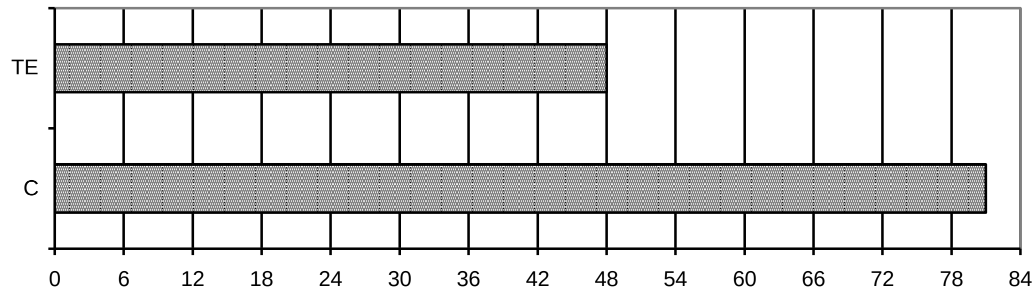

Figure 2. *The increase [cm] of turf lawn height in the study period regardless of the kind of fertilizer (total from three years). Vertical lines on the graph represent the order of performed mowing.*

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Conclusions

1. Trinexapac-ethyl applied in the study as a growth regulator considerably reduced the growth of grass, in relation to the control.
2. As regards growth suppression, there were various interactions between the growth regulator and the four types of mineral fertilizers. The biggest reduction of grass growth was when the Azofoska fertilizer was applied together with trinexapac-ethyl.
3. Apart from slowing down grass growth, trinexapac-ethyl reduced mowing frequency by 43% in comparison to the control object.
4. Reduction of grass growth and mowing frequency as a result of the application of trinexapac ethyl can contribute to saving energy used by lawn mowers (environmental factor), as well as to saving labour (social factor) by lowering mowing frequency.

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