Changes in growth-production parameters of *Lolium perenne* L. turf after application of concentrated polysulfide fertilizer

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The changes in growth rate, daily production of above-ground phytomass and lawn density of turfgrass after application of fertilizer based on polysulfide (Sulka NKS+) were evaluated in Nitra (the Slovak Republic) climatic conditions. The polysulfide preparation was applied 2-times, 4-times and 6-times during the vegetation period in 2015–2017 and the effect was compared with a zero control. Stimulatory effect of Sulka NKS+ was shown in the average daily gain of grass height and average daily gain of above-ground phytomass weight with the most visible expression in the 2nd and 3rd year of cultivation. For the thickening lawn index was found out inhibitory effect of polysulfide fertilizer. The average values of the first two characteristics (average daily gains of grass height and weight of above-ground phytomass) have also increased with the increasing number of Sulka NKS+ applications.

Keywords: polysulfide, *Lolium perenne*, average daily gain of height, average daily gain of weight, lawn density, turfgrass

1   Introduction

As a result of regular lawn mowing is the collection of large amounts of nutrients and water through the phytomass. A sustained decline in individual nutrient reserves in the soil profile leads to a gradual slowdown in turf growth, yellowing and decreasing of density, as well as a decrease in regenerative capacity, resistance to diseases, pests and damage (Gregorová, 2009; Pessarakli, 2014). Grasses, like all plants, need enough nutrients to grow and develop. These are obtained mainly from mineral fertilizers, most often in granular form, but in some cases also in crystalline or liquid form (Carrow et al., 2011). Production of concentrated fertilizers of NPK type (so-called ballast-free), lower nutrient return in organic fertilizers, significant losses by flooding etc. they may result in a large-scale deficit of some elements not only in arable land but also in grassland, including turf (Blake-Kalff et al., 2001; Matula, 2007). Such elements also include sulphur, the content of which in the soil has been gradually decreasing recently. Therefore, sulphur fertilization is becoming increasingly current in several

European countries (Scherer, 2001; Lehmann et al., 2008; Balík et al., 2009).

The issue of sulphur has also not been given due attention in Slovakia in the recent past, as industrial enterprises have produced significant amounts of sulphur dioxide and plants can receive up to 90% of sulphur through leaves if needed. The change occurred in the mid-1990s, when sulphur dioxide production in Slovakia decreased by 58.6% and at the same time consumption decreased significantly agricultural and mineral fertilizers containing a significant proportion of sulphur (eg. ammonium sulphate, simple superphosphate, etc.) (Kováčik, 2014). This led to a gradual reduction in the available sulphur content, and there are signs of deficiency in plants, such as reduced plant growth and the appearance of uniform chlorosis on younger leaves (Havlin et al., 2005).

The sulphur concentration in plant tissues ranges from 0.1 to 0.5% (Havlin et al., 2005). According to Fecenko (2002) and Poláček et al. (2009), the most demanding for sufficient of sulphur are bulbous plants, *Brassica*ceae, Fabaceae, most from them clovers. The grasses are

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classified as medium-demanding species (Jedlovská and Feszterová, 2003).

Sulphur is a vital element for all organisms and plays an important role in the biosynthesis of methionine and cysteine (Kertesz et al., 2007). It is also essential in the synthesis of Coenzyme A, which is important for biosynthesis and fatty acid oxidation, absorption of amino acids, oxidation of citric acid cycle intermediates, and oxidation of ferredoxin, which is essential for photosynthesis and biological fixation of nitrogen. It is also important in the synthesis of vitamins (Havlin et al., 2005).

Lawns absorb sulphur in approximately the same amount as phosphorus. It is part of many fertilizers (sulphates and coated fertilizers), but there may still be a deficit, which is similar to the lack of nitrogen (Kovár and Vozár, 2015). Especially in the nutrition of lawns, there is also a rather serious problem, the essence of which is that in anaerobic conditions (compacted soil), sulphur is involved in the formation of so-called black layer. It is a black-coloured soil layer most often 40–60 mm below the surface with a high content of FeS (toxic to the roots) (Kovár and Vozár, 2015). An alternative to eliminating this problem appears to be a foliar application of sulphur (e.g. using fertilizers with a polysulfide form of sulphur) (Vozár et al., 2018).

Based on the above, the experiment aimed to analyse the effect of the Sulka NKS + polysulfide fertilizer on growth intensity, phytomass formation and vegetation density of *Lolium perenne* L. turf.

2 Material and methods

The experiment was realized in field conditions of Demonstration and Research Base of Department of Plant Production and Grassland Ecosystems of the Slovak University of Agriculture (SUA) in Nitra (48° 18´ 12´´ N, 18° 5´ 42´´ E) in years 2015–2017. The locality is situated at altitude 160 m a. s. l., the annual rainfall is 539 mm, the average annual temperature is +10.2 °C (Špánik et al., 2002). Polláková and Šimanský (2015) classified the soil in the park of SUA campus as Calcaric Fluvisol and cultivated soil in university gardens as Hortic Calcaric Fluvisol. Groundwater level ranges from 1.20 to 2.50 m. The agrochemical properties of the soil of the experimental site are documented in Table 1.

The course of weather conditions in the monitored period (2015–2017) in comparison with the long-term average for 1961–1990 is presented in Table 2.

Perennial ryegrass (*Lolium perenne* L.) "Esquire" was used as a model plant in our experiment. The turf was established by manual sowing in the spring of 2015 (16 April). The plot size was 2.0 – 1.0 m and the seed rate was approximately 25 g m^{-2}. There were 4 treatments without and with polysulfide fertilizer (Sulka NKS+) in the experiment:

Table 1   Agrochemical composition of soil on experimental site

pH/KCl	N_t	P	K	Mg	Ca	C_{ox} (g kg^{-1})
	mg kg^{-1}					
7.09	2,282	54	350	680	4,900	20.82

Used analytical methods: N_t (total nitrogen) – Kjeldahl method; P, Mg (phosphorus and magnesium) – spectrophotometry in the extract according to Mehlich III; K, Ca (potassium and calcium) – atomic emission spectrometry in the extract according to Mehlich III; C_{ox} (soil organic carbon) – determined oxidometrically; pH – determined potentiometrically in 1 M KCl

Table 2   Average monthly temperatures and precipitation amount during vegetation season in 2015–2017 compared to a long-term average of 1961–1990 (www.shmu.sk; modified)

Year/Month		III	IV	V	VI	VII	VIII	IX	X	t/Σ*
Temperature (°C)	2015	6.3	10.4	15.1	19.9	23.6	23.5	17.5	10.5	15.9
	2016	6.2	11.6	16.2	20.5	22.1	19.8	17.7	9.5	15.5
	2017	8.6	9.8	17.1	21.9	22.1	23.0	15.2	10.8	16.1
	long-term normal 1961–1990	5.0	10.4	15.1	18.0	19.8	19.3	15.6	10.4	14.2
Precipitation (mm)	2015	35.4	25.0	69.5	10.2	17.2	57.7	33.2	54.8	303.0
	2016	14.0	20.5	87.1	94.5	154.5	72.3	48.0	79.8	570.7
	2017	18.3	42.8	12.9	23.6	69.8	19.4	87.9	47.7	322.4
	long-term normal 1961–1990	30.0	39.0	58.0	66.0	52.0	61.0	40.0	36.0	382.0

* average temperature (t) and precipitation amount (Σ) for the growing season

V1 – Zero treatment – without Sulka NKS+ and other fertilizing.

V2 – Sulka NKS+ (2×) – application of concentrated (100%) Sulka NKS+ by spray 2-times during vegetation season, [yearly nutrient dose 24.9 g m^{-2} N – 15.3 g m^{-2} K$_2$O – 1.95 g m^{-2} CaO – 24.9 g m^{-2} S].

V3 – Sulka NKS+ (4×) – application of concentrated (100%) Sulka NKS+ by spray 4-times during vegetation season, [yearly nutrient dose 49.8 g m^{-2} N – 30.6 g m^{-2} K$_2$O – 3.90 g m^{-2} CaO – 49.8 g m^{-2} S].

V4 – Sulka NKS+ (6×) – application of concentrated (100%) Sulka NKS+ by spray 6-times during vegetation season, [yearly nutrient dose 74.7 g m^{-2} N – 45.9 g m^{-2} K$_2$O – 5.85 g m^{-2} CaO – 74.7 g m^{-2} S].

Turf in treatments with an application of polysulfide fertilizer (V2 – V4) was fertilized by Amofos NP 12/52 at dose 15.42 g m^{-2} (1.85 g m^{-2} N and 8.02 g m^{-2} P$_2$O$_5$) once during vegetation period in following dates: 25. 6. 2015, 30. 3. 2016 and 21. 3. 2017.

2.1 Characteristics of used fertilizers

Sulka NKS + (13% N – 0% P$_2$O$_5$ – 8% K$_2$O – 1% CaO – 13% S) is a clear, reddish-brown liquid with a sulphur odour. It is a highly concentrated aqueous urea solution with potassium and calcium polysulfides and thiosulfates with unlimited water solubility. The N : S ratio of nutrients is 1 : 1. Polysulfides and thiosulfates effectively suppress nitrification, thereby prolonging the availability of urea nitrogen. Sulka NKS+ also reduces soil acidity and inhibits the activity of soil pathogens (URL1).

Amofos NP 12/52 is a grey-white granulated organomineral fertilizer with the content of 12% N and 52% P$_2$O$_5$. An essential component is ammonium phosphate, which is obtained from the apatite concentrate by neutralizing phosphoric acid with ammonia. Various types with varying nitrogen and phosphorus content are available. Of the total phosphorus content is minimally 40% water-soluble P$_2$O$_5$ (URL2).

The dates for the Sulka NKS + application in 2015–2017 are shown in Table 3.

During the experimental years (2015, 2016 and 2017), the turf was cut total 9-, 12- and 9-times per vegetation season and it was irrigated with a one-time dose in the intensity of approximately 10 mm total 29-, 9- and 20-times in individual years at the dates shown in Figure 1.

The turf was cut (Figure 1) to a height of 50 mm when reached approximately 80–100 mm height in an average. The height of the turf (10 measurements in each plot) was measured close to before each cutting and the above-ground phytomass was taken from an area of 0.1 × 1.0 m in 3 replicates. Based on these data, the average daily gain of height (ADGh) of the turf was calculated according to the relationship of ADGh [mm day^{-1}] = (height in mowing – 50 mm)/number of days of growth. The average daily gain of weight of dry aboveground phytomass (ADGw) was calculated as follows: ADGw [g day^{-1} m^{-2}] = production in the mowing/number of days of growth. The plant density was expressed by the thickening lawn index (TLI; g m^{-2} mm^{-1}), which was calculated as the ratio of ADGw to ADGh (Kovár et al., 2012).

The results were processed in STATISTICA (StatSoft, Inc., 2011) with one-factor analysis of variance followed by Tukey testing – HSD test at 95% significance level. Pearson's correlation coefficient (r) was used to analyse the statistical relationship between the number of applications of the polysulfide fertilizer and other parameters (ADGh, ADGw and TLI).

Table 3 The dates of Sulka NKS+ application on individual variants in years 2015–2017

Treatment	Annual dose (ml m^{-2})	Year	Date of application						
V2 – Sulka NKS+ 100 % (2×)	150	2015*				26.6.			
		2016	30. 3.				2. 8.		
		2017	31. 3.				1. 8.		
V3 – Sulka NKS+ 100 % (4×)	300	2015*				26. 6.		26. 8.	
		2016	30. 3.		30. 5.		2. 8.		28. 9.
		2017	31. 3.		30. 5.		1.8.		29. 9.
V4 – Sulka NKS+ 100 % (6×)	450	2015*				26. 6.	31.7.	26.8.	
		2016	30. 3.	6. 5.	30. 5.	1. 7.	2. 8.	31. 8.	
		2017	31. 3.	4. 5.	30. 5.	30. 6.	1. 8.	31. 8.	

* considering the date of establishment of the stand and the achievement of the required state (ground covering) was an only half number of polysulfide product applications in 2015
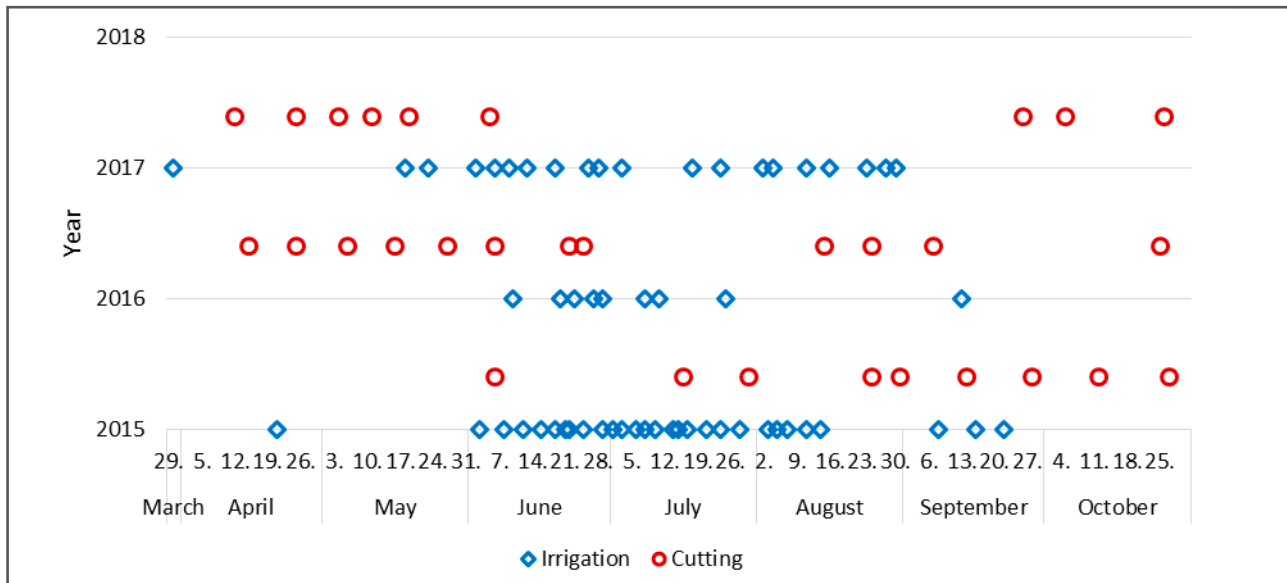
Figure 1   Dates of irrigation and cutting of turf in the years 2015–2017

3   Results and discussion

The values of the average daily gain of height of turf from *Lolium perenne* L. during the evaluated period are documented in Table 4. In the year of sowing (2015), the average growth rate was from 2.67 mm day^{-1} (V1) to 3.65 mm day^{-1} (V2) with insignificant differences (*p* = 0.9967) between treatments. According to the classifier for the *Poaceae* family (Ševčíková et al., 2002), this can be characterized as a "low" to "medium" growth rate. In the second year of cultivation, the daily growth rate in treatments with the application of the concentrated

polysulfide preparation Sulka NKS+ (V2–V4) increased by 2.83–4.55 mm day^{-1} compared to the control. These differences were statistically significant (*p* = 0.0074). In the 3rd year of cultivation, a similar tendency was observed as in the 2nd year, with borderline significance between treatments (*p* = 0.0693). Compared to the above classifier, the growth rate in this period was "very low" (V1) to "high" (V2), respectively "very high" (V3, V4). According to several authors (Gregorová, 2009; Pessarakli, 2014; Kovár and Vozár, 2015), higher daily growth rates are less suitable as they are related to the need for more frequent mowing of

Table 4   Average daily gain of height (mm day^{-1}) of *Lolium perenne* L. turf in evaluated period

Year/Treatment	V1	V2	V3	V4
2015	2.67[a]* ±2.89	3.65[a] ±2.86	3.28[a] ±2.09	3.62[a] ±2.35
2016	1.70[b] ±1.30	4.53[a] ±2.56	5.19[a] ±3.04	6.25[a] ±3.94
2017	1.40[a] ±1.23	4.25[b] ±3.11	5.54[ab] ±4.72	7.79[ab] ±4.19
Average	1.92[b] ±1.81	4.14[a] ±2.84	4.67[a] ±3.28	5.89[a] ±3.49

* different indexes at mean values indicate a statistically significant difference between treatments in lines (Tukey HSD test, α = 0.05). Values are presented as mean ± standard deviation

Table 5   Average daily gain of dry above-ground phytomass weight (g day^{-1}) of *Lolium perenne* L. turf in evaluated period

Year/Treatment	V1	V2	V3	V4
2015	1.57[a]* ±2.07	2.14[a] ±1.94	2.00[a] ±1.80	1.47[a] ±1.94
2016	1.32[b] ±1.81	2.16[ab] ±2.13	2.86[a] ±2.45	3.39[a] ±2.33
2017	1.45[a] ±1.10	2.45[b] ±2.15	2.47[b] ±2.03	3.99[b] ±1.29
Average	1.45[a] ±1.66	2.25[a] ±2.07	2.44[a] ±2.09	2.95[a] ±1.57

* different indexes at mean values indicate a statistically significant difference between treatments in lines (Tukey HSD test, α = 0.05). Values are presented as mean ± standard deviation.

Table 6   Average values of thickening lawn index – TLI (g m^{-2} mm^{-1}) of *Lolium perenne* L. turf in evaluated period

Year/Variant	V1	V2	V3	V4
2015	0.57[a]* ±0.33	0.57[a] ±0.23	0.60[a] ±0.38	0.48[a] ±0.40
2016	0.75[a] ±0.59	0.58[a] ±0.47	0.58[a] ±0.34	0.60[a] ±0.35
2017	1.05[a] ±0.48	0.65[a] ±0.42	0.52[a] ±0.40	0.72[a] ±0.53
Average	0.79[a] ±0.47	0.60[a] ±0.38	0.57[a] ±0.37	0.60[a] ±0.43

* different indices at mean values indicate a statistically significant difference between treatments in lines (Tukey HSD test, α = 0.05). Values are presented as mean ± standard deviation

the lawn. An overall evaluation of this parameter showed the stimulating effect of the polysulfide preparation used, with a more pronounced effect in the second and third years of cultivation. A slight statistically significant correlation was found between the daily growth rate and the number of Sulka NKS+ applications (r = +0.39).

The average daily gain of weight of dry above-ground phytomass (Table 5) had a similar trend as was found out at the average daily gain of height. In the year of sowing, the stimulatory effect was shown only in treatments V2 and V3 (application 2-times and 4-times during the growing season) with no significant differences (p = 0.8308) between the treatments. More significant and statistically significant (p = 0.0105 and p = 0.0095) differences in the daily production of above-ground phytomass between the treatments were observed in the 2nd and 3rd year of cultivation. Also in this period, the daily intensity of phytomass production increased with an increasing number of Sulka NKS+ applications (r = + 0.24). Nutrients can also be absorbed to a lesser extent through plant leaves. This supplementary form of nutrition is mainly used during the drought period. Its advantage is the elimination of unfavourable soil properties, e.g. reaction of sulphur with iron and formation of black layer, which is toxic to the roots (Kovár and Vozár, 2015). For foliar nutrition is important uniformity of application, as with fertilizing with granular fertilizers. Otherwise, the lawn may grow unevenly and may be uneven in colour (colour mosaic), or the lawn may be burned (Carrow et al., 2011). The observed relatively higher standard deviation values (Tables 4 and 5) may indicate precisely the less balanced turf growth that may have occurred after foliar application of the polysulfide preparation.

In addition to the above indicators for evaluating the quality of lawns, we can also use their mutual ratio, the so-called Thickening Lawn Index (TLI) (Kovár et al., 2012). Density is an important qualitative indicator of virtually all grasslands. In ornamental lawns it participates in their aesthetic effect, in soil-conservation lawns it is important from the erosion point of view, in sports lawns it contributes to the creation of a firm and elastic turf sod, etc. (Gregorová, 2009; Kovár et al., 2012). From the

values of this indicator (Table 6), we can see insignificant differences (p = 0.4528) between the treatments. A slight stimulating effect compared to the control was only seen in the year of sowing, in treatments with 2, respectively 4 applications during the growing season (V2, V3). In other treatments, respectively in the years has been shown an inhibitory effect of Sulka NKS+ on the density of *Lolium perenne* turf. This is most noticeable in 2017 when the polysulfide-treated stands had 0.33–0.53 g m^{-2} mm^{-1} lower TLI values compared to control. A total evaluation of this parameter showed a statistically significant negative correlation (r = -0.12) between turf density (expressed as TLI values) and the number of Sulka NKS+ applications.

4   Conclusions

Based on the results obtained from a lawn experiment realized under field conditions, the stimulatory effect of the polysulfide preparation (Sulka NKS+) on the intensity of growth and the daily production of above-ground phytomass can be observed. This was the most noticeable in turf with 2 applications of polysulfide preparation in the year of sowing and with 6 applications of Sulka NKS+ in subsequent years. With the increasing number of Sulka NKS+ applications, the mean values of evaluated parameters also increased. The turf density (expressed by the thickening lawn index) was affected negatively by Sulka NKS+, especially in the 2nd and 3rd year of cultivation. The aim of lawns growing is not to achieve intensive growth (the need for frequent mowing) and high production of above-ground phytomass. Therefore, based on the obtained results, the application of polysulfide preparation Sulka NKS+ twice per vegetation period can be considered acceptable and practically applicable.

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