Effect of sulphur fertilization on the rate of photosynthesis and yield of *Lolium* × *boucheanum* Kunth cultivated in monoculture and mixture with *Trifolium repens* L.

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Abstract

The aim of this study was to determine the effect of sulphur fertilization on the rate of photosynthesis and yield of hybrid ryegrass (*Lolium* × *boucheanum*) grown in monoculture and mixture with white clover (*Trifolium repens*). The study was conducted in a split-plot design with four replications. Soil conditions were degraded chernozem formed from loess. The fertilization scheme was 50 and 100 kg N ha^{-1}, 35 kg P ha^{-1}, 83 kg K ha^{-1}, and sulphur at 5, 10 and 15 kg S ha^{-1}. The intensity of photosynthesis was measured in each regrowth at weekly intervals using a portable gas analyser (Li-Cor 6400). Plants were mown 3 times during the growing season. Both nitrogen and nitrogen-with-sulphur fertilization positively influenced the rate of photosynthesis in each regrowth. Sulphur fertilization compared to nitrogen fertilization increased the rate of photosynthesis in hybrid ryegrass grown in monoculture. Total dry matter yields of hybrid ryegrass grown in monoculture were lower than in mixture with white clover, irrespective of the amount of nitrogen or nitrogen-and-sulphur fertilization. The biggest difference in yields between the monoculture and the mixture was found with 100 kg N and 15 kg S ha^{-1}. The smallest difference was shown in treatments fertilized with 50 kg N and 5 kg S ha^{-1}.

Keywords: *Lolium*, sulphur, photosynthesis, yield

Introduction

Sulphur deficiency occurs especially in crop production with intensive nitrogen fertilization. There is concern that the traditionally used NPK fertilization is not balanced and the deficit of sulphur may limit the use of the other ingredients, mainly nitrogen (Morris, 2007). Currently, studies on the reduction and prevention of sulphur deficiency generally focus on species with high demand for this element (Lošak and Richter, 2003). Most studies have been carried out with rapeseed, some with cereals, and only a few studies relate to plants of the families *Fabaceae* and *Poaceae* (Richards, 1990; Sator *et al.*, 2002; Zhao *et al.*, 2006). Hence, the aim of this study was to determine the effect of sulphur fertilization on the rate of photosynthesis and yield of hybrid ryegrass (*Lolium* × *boucheanum*) grown in monoculture and mixture with white clover (*Trifolium repens*).

Material and methods

The study was conducted in 2007-2009 in a split-plot design with four replications, on plots of 12 m^2. The study included hybrid ryegrass (tetraploid variety Gala) grown in monoculture and in mixture (50% of seeding rate) with white clover (variety Romena). Total annual precipitation during the study period ranged from 581 to 700 mm, and during the vegetation period from 358 to 478 mm. Average annual temperature ranged from 7.9 and 8.6 °C and in the vegetation period from 15.2 to 16.0 °C. Long-term (1977-2013) mean total annual precipitation was 690 mm, and during the vegetation period 466 mm. Average long-term annual temperature was 8.4 °C and for the vegetation period 15.2 °C. Soil conditions were as follows: degraded chernozem formed from loess; pH_{KCl} 6.5; organic carbon 24.7 g kg^{-1}; total nitrogen 1.8 g N kg^{-1}; total sulphur 321.5 mg S kg^{-1}; phosphorus 62.5 mg P kg^{-1}; potassium 136.7 mg K kg^{-1}; and magnesium 54.9 mg Mg kg^{-1}. Fertilization treatments included: nitrogen 50 and 100 kg N

ha^{-1}; phosphorus 35 kg P ha^{-1}; and potassium 83 kg K ha^{-1}. Foliar fertilization with sulphur was supplied at 5, 10 and 15 kg S ha^{-1}.

The intensity of photosynthesis was measured using a portable gas analyser Li-Cor 6400. The indicators were determined at 400 ppm CO_2 concentration and the light conditions 1000 µmol m^{-2} s^{-1}. Measurements were performed on the youngest, but fully developed leaves, which were selected randomly from each plot. In each regrowth four measurements were performed at weekly intervals. Plants were mowed 3 times during the growing season. The results were statistically analysed by performing an analysis of variance. The significance of differences was verified by Tukey test with a confidence level α=0.05.

Results and discussion

Both nitrogen and nitrogen-with-sulphur fertilization positively influenced the rate of photosynthesis in each regrowth. Extra sulphur fertilization compared to nitrogen fertilization increased the rate of photosynthesis in hybrid ryegrass grown in monoculture in treatments fertilized with 50 kg N and 100 kg N (Table 1). Additional sulphur fertilization of mixtures resulted in an increase in the intensity of photosynthesis in plants at fertilization rate 100 kg N and 15 kg S ha^{-1} only. Photosynthesis in plants proceeded more intensively in the second regrowth, which could be due to the favourable air temperatures. The intensity of photosynthesis depends on, amongst other things, the temperature at which the plants grow. For most plants a temperature of 26 °C is considered as optimal (Olszewska, 2003).

Total dry matter yields of hybrid ryegrass grown in monoculture were lower than in mixture with white clover irrespective of the amount of nitrogen or nitrogen-and-sulphur fertilization. The biggest difference in yield between monoculture and mixture was found with 100 kg N and 15 kg S ha^{-1} (Table 2). The smallest difference was shown in treatments fertilized with 50 kg N and 5 kg S ha^{-1}. The positive impact of nitrogen and sulphur on the amount of dry matter yield of plants was also shown by Zhao *et al.* (1999).

Conclusions

Both fertilization with nitrogen alone, and nitrogen-with-sulphur, positively influenced the rate of photosynthesis in the analysed plants. The cumulative dry matter yield of hybrid ryegrass grown in monoculture was lower than that of mixtures, regardless of the amount of nitrogen or nitrogen-and-sulphur applied. Practical recommendations of sulphur supply resulted from the highest yield of the crops, and this may be application of 100 kg N with 10 kg S ha^{-1}.

Table 1. Intensity of photosynthesis of the plants (µmol CO_2 m^{-2} s^{-1}).

Fertilization treatment[1]	*Lolium × boucheanum*			*Lolium × boucheanum + Trifolium repens*		
	Cuts			Cuts		
	1	2	3	1	2	3
Control	15.67	16.79	14.57	15.34	17.62	16.53
N_{50}	16.04	19.36	17.61	16.65	20.52	18.90
N_{100}	15.52	18.90	16.53	15.84	19.47	17.12
$N_{50}+S_5$	15.25	17.10	16.84	15.61	18.53	17.67
$N_{50}+S_{10}$	18.74	21.28	20.39	18.07	19.89	18.75
$N_{50}+S_{15}$	15.48	18.37	17.15	15.86	18.20	15.68
$N_{100}+S_5$	16.51	20.13	17.81	16.47	17.88	16.94
$N_{100}+S_{10}$	17.29	20.75	18.47	16.23	19.43	17.07
$N_{100}+S_{15}$	19.32	21.82	18.25	17.30	20.54	18.21
$LSD_{0.05}$	2.60	3.40	2.43	2.60	2.36	2.78

[1] Fertilization: N_{50} = 50 kg N ha^{-1}; N_{100} = 100 N kg ha^{-1}; S_5 = 5 kg S ha^{-1}; S_{10} =10 kg S ha^{-1}; S_{15} = 15 kg S ha^{-1}. LSD = least significant difference.

Table 2. Average dry matter yield (Mg ha^{-1}).

Fertilization treatment[1]	*Lolium* × *boucheanum*			*Lolium* × *boucheanum* + *Trifolium repens*		
	Cuts			Cuts		
	1	2	3	1	2	3
Control	1.65	0.85	0.52	2.02	1.10	0.77
N_{50}	4.15	1.79	0.85	5.21	2.49	1.07
N_{100}	7.97	3.57	1.51	7.89	4.63	2.19
$N_{50}+S_5$	6.14	2.18	1.04	6.52	2.62	1.47
$N_{50}+S_{10}$	5.98	2.47	1.32	7.16	2.95	1.27
$N_{50}+S_{15}$	5.73	2.27	0.96	6.89	2.79	1.36
$N_{100}+S_5$	8.35	4.21	2.03	9.15	4.30	2.16
$N_{100}+S_{10}$	8.53	4.37	2.17	9.53	4.27	2.41
$N_{100}+S_{15}$	7.61	4.45	1.96	9.34	4.52	2.19
$LSD_{0.05}$	1.24	0.88	0.53	1.14	0.70	0.55

[1] Fertilization: N_{50} = 50 kg N ha^{-1}; N_{100} = 100 N kg ha^{-1}; S_5 = 5 kg S ha^{-1}; S_{10} =10 kg S ha^{-1}; S_{15} = 15 kg S ha^{-1}. LSD = least significant difference.

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