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ORIGINAL PAPER

EFFECT OF MINERAL FERTILISERS AND ORGANIC FERTILISATION ON THE CONTENT AND IONIC PROPORTIONS OF MACRONUTRIENTS IN THE BIOMASS OF PERENNIAL RYEGRASS*

Ewa Możdżer[1], Piotr Styrczula[2]

[1] Department of Soil Science, Grassland Mangement and Environmental Chemistry West Pomeranian University of Technology in Szczecin
[2] Mineral Fertilisers Plant Fosfan SA, Szczecin

Abstract

A three-factorial, plant-growing, pot experiment was carried out in 2007-2008. Test plants were seeded in soil representing heavy loamy sand, classified as very good rye complex, soil valuation class IVa in the Polish soil taxonomy. The first factor consisted of series with and without compost made from municipal sewage sludge, the second factor corresponded to types of multi-component mineral fertilisers, and the third factor was composed of doses of mineral fertilisers. Perennial ryegrass (*Lolium perenne*) of the variety Stadion was the test plant. Multi-component mineral fertilisers and urea applied with the use of compost increased the content of macronutrients in perennial ryegrass compared to the treatment from which organic fertiliser was excluded. The increased content of macroelements in the test plant in the compost control treatment did not exceed values that were achieved in the series of trials without compost. The results present the amounts of nutrients introduced into the soil in the form of compost made of sewage sludge and mineral fertilisers. The research indicated that mineral fertilisation applied without and with the use of organic fertilisation contributed to obtaining the optimal ionic ratio of K:(Ca+Mg) and expansion of the K:Ca ratio above the optimal value in perennial ryegrass. Mineral fertilisers with the addition of urea and a dose of compost resulted in the expansion of the K:Ca ionic ratio in the perennial ryegrass compared to the control by 20.4, 24.4 and 22.4%. The purpose of the experiment was to determine the effect of selected mineral multi-component fertilisers (SF 20, SP 25, In 4 and urea) with combined organic (compost) fertilisation on the content of macroelements and shaping the ionic proportions K:Mg, K:Ca, K:(Ca+Mg), N:S in the biomass yield of perennial ryegrass.

Keywords: multi-component mineral fertilisers, sevage, sludge, compost, content of macroelements, ionic relations.

dr hab. inż. Ewa Możdżer, Department of Soil Science, Grassland Mangement and Environmental Chemistry, West Pomeranian University of Technology in Szczecin, Słowackiego 17, Szczecin, Poland, phone: 0914496333, e-mail: ewa.mozdzer@zut.edu.pl
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INTRODUCTION

One of the methods of maintaining an appropriate level of fertility of soils is through the application of municipal waste as fertiliser. Municipal sewage sludge contains much organic matter, including nutrients for plants, and can be used for fertilising purposes. The fertiliser value of municipal sewage sludge has been positively evaluated in many scientific studies, including TORRI et al. (2009), ROCA-PEREZ (2009), KOVÀĆIK et al. (2011). The quality of harvested crops is assessed *inter alia* according to the optimal content of individual elements. The yield-stimulating effect of raw and composted municipal sewage sludge is comparable to that of manure or mineral fertilisers (in long-term experiments) having equivalent NPK doses, owing to the favourable residual effect of organic fertilisation, which has been shown by KALEMBASA and KUZIEMSKA (1999), KRZYWY et al. (2002). Earlier studies have demonstrated that application of supplementary mineral fertilisation with nitrogen and potassium can increase grass yield to about 30% DOMAŃSKI (2004), ŁABĘTOWICZ and STĘPIEŃ (2010).

On the other hand, HARASIMOWICZ et al. (2004) indicate that the effect of municipal sewage sludge compost on plants and soil being evaluated in the second year from the application was more favourable than that of mineral fertilisers alone after an application of an equivalent content of biogenic components. STANKOWSKI and WOŁOSZYK (2008) found that the size of an applied compost dose also affects the quality of crop yields.

Optimum ionic ratios between macronutrients such as K:Mg, K:Ca, K:(Ca+Mg), N:S affect many physiological and biochemical processes within plants. Reliable factors confirming the qualitative characteristics of the harvested biomass crops are the content of macronutrients and the ionic proportions between selected elements, i.e. K:Mg, K:(Ca+Mg), Ca:P and N:S (SZPUNAR-KROK et al. 2009). Research by KRZYWY et al. (2002) shows that the ionic ratios K:(Ca+Mg) and Ca:Mg in the biomass of meadow plants should be close to 1.62 and 3.0, respectively. ŁABUDA et al. (1992) state that the optimal ionic K:Ca and K:Mg proportions in cereal plants should be at the level of 4. Meanwhile, it was found that the N:S (15-16:1) ionic ratio is the one which is most often taken into account when sulfur deficiency occurs in plants (GRZEBISZ, PRZYGOCKA-CYNA 2007).

MATERIAL AND METHODS

In order to achieve the research goal, a three-dimensional, plant growing, pot experiment was carried out in a greenhouse of the West Pomeranian University of Technology. The first factor was a series with and without compost made of municipal sewage sludge, the second factor consisted of types of multi-component mineral fertilisers, and the third factor comprised doses of mineral fertilisers. Perennial ryegrass (*Lolium perenne*) of cv. Stadion was the test plant.

Soil with the grain-size composition of heavy loamy sand, classified as very good rye complex, valuation class IVa in the Polish soil taxonomy system, was used in the experiment. The soil's reaction was neutral (pH_{KCl} 6.50). The chemical analysis of the soil showed that it contained 12.2 g kg^{-1} organic carbon, N – 1.05, P – 1.53, K – 2.85, Ca – 4.51, Mg – 0.46 and S – 2.50 g kg^{-1}. The content of bioavailable forms for plants (P – 64.5 mg kg^{-1}, K – 123.0 mg kg^{-1} and Mg – 48.4 mg kg^{-1}) was moderate. The total content of heavy metals was also determined in the municipal sewage sludge composts to be applied. None of the heavy metals determined exceeded the maximum threshold set up in the *Regulation of the Minister of Environment* (2010) for municipal sewage sludge. The size of a compost dose was set at 100 kg N ha^{-1}, which corresponded to 16.92 Mg of fresh compost per 1 ha. The dose of compost per pot was 50.8 g of fresh weight.

There was a higher N and P total content than total K in the compost used in the trials (Table 1). The content of organic matter and macronutrients was in the standards provided for an organic fertiliser given in the ministerial regulations. The contents of N, P, K, Ca, Mg and S in the multi-component mineral fertilisers used for testing, are summarized in Table 2.

The mineral fertiliser SF 20 did not contain nitrogen. The fertilisers SP 25 and In 4 were characterised by a small amount of nitrogen that did not cover the nutritional needs of the test plant. Therefore, in the experiment, nitrogen was additionally applied in the form of urea. The content of macroelements in the tested fertilisers was in accordance with the content declared by the producer. The experiment was carried out in a randomized

Table 1

Chemical properties of compost

pHH_2O	C_{org}	N	P	K	Ca	Mg
	(g kg^{-1}d.m.)					
7.4	326.0	28.0	12.5	6.0	4.2	1.5

Table 2

Nitrogen, phosphorus, potassium, calcium, magnesium and sulpur content in multi-component mineral fertilisers applied in the experiment

Type of fertiliser	Total content (g kg^{-1}d.m.)					
	N	P	K	Ca	Mg	S
SF 20	-	44.5	168.5	37.2	21.1	56.0
SP 25	49.8	43.7	207.1	15.7	12.1	52,8
In 4	39.8	52.2	165.8	14.9	12.7	62,0

Table 3

Design of the experiment

Fertilisation objects and doses of mineral fertiliser	Without compost	With municipal sewage sludge compost at a dose corresponding to 100 kg N ha^{-1}
Control	+	+
SF 20 + urea – dose I	+	+
SF 20 + urea – dose II	+	+
SP 25 + urea – dose I	+	+
SP 25 + urea – dose II	+	+
In 4 + urea – dose I	+	+
In 4 + urea – dose II	+	+

complete block design, in four replications with a control group being separated. The first factor was a series with and without sewage sludge compost, the second factor consisted of types of multi-component mineral fertilisers, while the third one comprised doses of mineral fertilisers. Table 3 shows the scheme of the experiment.

Doses of mineral fertilisers (SF 20, SP 25, In 4) were set at 200 kg ha^{-1} (single dose) and 400 kg ha^{-1} (double dose). When recalculated per pot, fertilisers were applied in the following quantities: 0.6 g (dose I) and 1.2 g (dose II). Due to the low content of nitrogen in the multi-component mineral fertilisers, the shortage of this element was compenstated for by urea. The amount of pure nitrogen applied in the form of urea depended on the dose and type of the multi-component mineral fertilisers, and ranged from 40 to 100 kg N ha^{-1}.

The multi-component mineral fertilisers and 1/3 of the urea dose in the form of water solution were applied to the soil in spring 2007, before sowing the plants. The remaining 2/3 of the nitrogen dose in the form of urea was halved and applied as water solution after the first and second harvest of grass. In order to maintain the soil moisture at 60% of the full water capacity, the soil and plants in pots were sprayed with redistilled water.

In 2008, the amount of mineral fertiliser doses and plant care treatments were the same as in 2007. In each research year, three cuts of the test plant were harvested. During the experiments in 2007 and 2008, the value of dry matter yields of perennial ryegrass from each replicate for each fertiliser was determined. The plants collected from four replicates of a given fertiliser object were mixed and ground. In this way, an average sample of the test plant was obtained for each fertiliser object. The nitrogen and sulfur content in an averaged sample was determined on a CNS elemental analyzer (Coestech), while potassium, magnesium and calcium were assayed by means of atomic absorption spectrometry on a Perkin Elmer AAS 300 spectrometer. The stock solution was obtained after wet digestion of the plant material in perchloric(VII) and nitric(V) acids mixture, in a ratio of 3:1, according to the Polish standard PN-91 R04014.

Based on the determined content of N, K, Ca, Mg and S in the biomass of perennial ryegrass, the ionic proportions (mmol of load per mass unit) of K:Mg, K:Ca, K:(Mg+Ca) and N:S were calculated.

The experiment was carried out in a completely randomised system with four replications, and with the separation of controls. Statistical calculations of the significance of differences in the macroelement concentrations were made using a three-factorial variance analysis supported by the FR-ANALWAR software developed by Prof. F. Rudnicki. Confidence sub--intervals were calculated at the significance level of $p = 0.05$ using the Tukey test.

RESULTS AND DISCUSSION

Most nitrogen was contained in perennial ryegrass from the object in the series without compost but with SP 25, where its content was higher by 8.99% and 6.18% than in plants from the object with applied SF20 and In 4, respectively (Table 4). In the series of trials with compost, most nitrogen was in the test plant from the object with SP 25. The nitrogen content in the examined grass increased between the object with SP 25 and In 4 and the one with SF 20, by 4.85% and 3.84%, respectively (Table 4). The highest average nitrogen content in perennial ryegrass (21.1 g N kg^{-1} d.m.) was obtained from the object with SP 25, where it was higher by 7.10% and 4.97%than in the grass from the object with SF 20 and In 4, respectively (Table 4). The highest average increase in the nitrogen content in the test plant's biomass was found between the objects with mineral fertilisers applied without and with the use of compost versus the control object, and the difference was 24.8% and 33.7%, respectively. Same as in a study by Tyrczula and Możdżer (2013), no significant effect was found of the types and doses of multicomponent fertilisers and their interaction on the content of nitrogen in ryegrass biomass.

The applied In 4 contributed to the highest potassium content in the biomass of the test plant, reaching 20.4 g K kg^{-1} d.m. (Table 4). The content of potassium in perennial ryegrass was higher by 4.61% compared to the object supplied SF 20. As for the objects without compost, most potassium on average was contained in the biomass of perennial grass supplied In 4, where it was higher by 5.24% and 3.61%, respectively, than in plants receiving SF 20 and SP 25. Taking into account the interaction between types of mineral fertilisers with the addition of urea and their doses, a significant effect of these experimental factors on the potassium content in the perennial grass biomass was found. The highest content of this element in perennial

Table 4

Effect of multi-component mineral fertilisers and urea used with and without compost on the average content of nitrogen, potassium and calcium in perennial ryegrass (g kg^{-1} d.m.)

Specification		Fertilisation objects											
		N				K				Ca			
		fertilisers types (T)											
		SF 20	SP 25	In 4	mean	SF 20	SP 25	In 4	mean	SF 20	SP 25	In 4	mean
		+ urea				+ urea				+ urea			
Without compost	C	18.9	20.6	19.4	**19.6**	19.1	19.4	20.1	**19.5**	3.33	3.36	3.36	**3.35**
With compost	C	20.6	21.6	20.8	**21.0**	19.9	20.8	20.7	**20.5**	3.44	3.46	3.50	**3.47**
Dose I	D	19.3	21.3	19.5	**20.0**	19.1	19.6	19.7	**19.5**	3.37	3.38	3.37	**3.37**
Dose II	D	20.2	20.9	20.7	**20.6**	19.9	20.6	21.0	**20.5**	3.41	3.44	3.48	**3.44**
Mean		**19.7**	**21.1**	**20.1**		**19.5**	**20.1**	**20.4**		**3.39**	**3.41**	**3.43**	
Control without compost		15.7				15.0				3.14			
Control with compost		18.8				17.8				3.38			
LSD $_{0.05:}$													
Fertilisers types (T)		n.s.				n.s.				n.s.			
Fertilisers dose (D)		n.s.				0.205				0.029			
Without and with addition of compost (C)		0.937				0.205				0.029			
Interaction (T) x (C)		n.s.				0.356				n.s.			
interaction (T) x (D)		n.s.				n.s.				n.s.			

ryegrass was found in the treatment with the double dose of SP 25, while the lowest potassium level was in the biomass of plants given a single dose of SF 20.

The average calcium content in the biomass of perennial ryegrass ranged between the tested fertiliser objects from 3.39 to 3.43 g Ca kg^{-1} d.m. (Table 4). The types of mineral fertilisers with the addition of urea did not differentiate significantly the calcium content in the test plant. Doubling a dose of mineral fertilisers significantly increased the calcium content in the biomass of ryegrass as compared to single doses. In the series of experiments without compost, the same calcium content in perennial ryegrass was obtained under the influence of SP 25 and In 4 with urea. The average calcium content in the series with compost was 3.47 g Ca kg^{-1} d.m., being 3.58% higher than in the series in without organic fertiliser. The differences were significant.

The average magnesium content in all fertiliser objects was approximately the same (Table 5). The application of compost did not have any significant impact on differences in the magnesium content in the perennial ryegrass biomass compared to the series of experiments without compost. Doubling the doses of mineral fertilisers and urea did not significantly affect the magnesium content in perennial ryegrass compared to single doses.

Table 5

Effect of multi-component mineral fertilisers and urea used with and without compost on the average content of magnessium and sulfur in perennial ryegrass (in g kg^{-1} d.m.)

Specification		Fertilisation variants							
		Mg				S			
		Fertilisers types (T)							
		SF 20 + urea	SP 25 + urea	In 4 + urea	mean	SF 20 + urea	SP 25 + urea	In 4 + urea	mean
Without compost	C	1.08	1.09	1.09	**1.09**	2.07	2.22	2.06	**2.11**
With compost	C	1.12	1.12	1.11	**1.12**	2.17	2.18	2.20	**2.18**
Dose I	D	1.09	1.10	1.09	**1.09**	2.09	2.15	2.08	**2.10**
Dose II	D	1.11	1.11	1.11	**1.11**	2.15	2.25	2.18	**2.19**
Mean		**1.10**	**1.10**	**1.10**		**2.12**	**2.20**	**2.13**	
Control without compost		1.06				1.64			
Control with compost		1.08				1.67			
$LSD_{0.05}$									
Fertilisers types (T)		n.s.				n.s.			
Fertilisers dose (D)		n.s.				0.079			
Without and with addition of compost (C)		n.s.				n.s.			
Interaction (T) x (C)		n.s.				n.s.			
Interaction (T) x (D)		n.s.				n.s.			

Most sulfur was found in the perennial ryegrass biomass from the pots with SP 25 with the addition of urea, less – in plants treated with SF 20 and In 4 (Table 5). The types of mineral fertilisers with the addition of urea did not significantly differentiate the sulfur content in the examined grass. Doubling the doses of multi-component mineral fertilisers including urea significantly increased the sulfur content in the biomass of perennial ryegrass compared to single doses. Under the influence of a single dose of mineral fertilisers with the addition of urea, the highest sulfur content was obtained from the object with SP 25 (2.15 g S kg^{-1} d.m.), and the lowest one was found in plants under the influence of In 4 (2.08 g S kg^{-1} d.m). The highest sulfur content in perennial ryegrass biomass was obtained under the influence of single and double doses of mineral fertilisers with the addition of urea in the variant with SP 25, and the lowest – under a single dose of In 4. The applied compost did not have any significant impact on the average sulfur content in perennial ryegrass biomass as compared to the experimental objects in which this organic fertiliser was not used. A higher content of macronutrients in the biomass of perennial ryegrass from the control object with compost did not exceed the values that were achieved in the series of experiments with mineral fertilisers without compost. Many authors (Czyżyk et al. 2002, Wołoszyk et al. 2006, Oleszczuk 2007) have indicated that this was associated with the amounts of nutrients introduced into the soil in the form of compost and mineral fertilisers.

The optimal ionic ratios between macroelements such as K:Mg, K:Ca, K:(Ca+Mg), N:S have a decisive influence on many physiological and biochemical processes taking place within plants which can ensure high quality crops. Fertilisers introduced into soil can significantly affect the formation of ionic proportions in plants (Krzywy et al. 2002).

Taking into account the average data from 2007-2008, it can be concluded that the K:Mg ionic proportions in perennial ryegrass of the control (4.56) were narrowed in relation to the optimal value. Mineral fertilisers with the addition of urea and application of compost resulted in the expansion of the K:Ca ionic ratio in perennial ryegrass compared to the control, by 20.4, 24.4 and 22.4% respectively (Table 6).

Table 6

K:Mg, K:Ca, K:(Ca+Mg) and N:S ionic ratios in dry matter of perennial ryegrass expressed in mmol per mass unit obtained under the influence of urea with compost. Data from two years of research.

Ionic ratios	Compost	Fertilisation objects								
		with compost								
		SF 20			SP 25			In 4		
		+ urea								
		dose I	dose II	mean	dose I	dose II	mean	dose I	dose II	mean
K:Mg (6:1)*	5.33	5.64	5.76	**5.70**	5.74	6.11	**5.92**	5.99	6.05	**6.02**
K:Ca (2:1)*	2.73	2.97	3.06	**3.01**	3.02	3.20	**3.11**	3.05	3.08	**3.06**
K: (Ca+Mg)* 1,6-2.2:1	1.80	1.94	1.97	**1.95**	1.83	2.09	**1.96**	2.01	2.03	**2.02**
N:S* (15-16:1)	18.9	16.4	16.3	16.3	16.8	17.2	17.0	16.6	16.5	16.6

* optimum values according to Majcherczak et al. (2006)

Compost introduced into the soil caused the K:Mg ratio to expand in the test plant towards the optimal value. The applied single and double dose of mineral fertilisers and urea resulted in the expansion of the K:Mg ionic ratio in the tested plant towards the optimal value (Table 7). Introduction

Table 7

K:Mg, K:Ca, K:(Ca+Mg) and N:S ionic ratios in dry matter of perennial ryegrass expressed in mmol per mass unit obtained under the influence of multi-component mineral fertilisers and urea used without compost. Data from two years of research

Ionic ratios	Control	Fertilisation objects								
		without compost								
		SF 20			SP 25			In 4		
		+ urea								
		dose I	dose II	mean	dose I	dose II	mean	dose I	dose II	mean
K:Mg (6:1)*	4.56	5.53	5.69	**5.61**	5.63	5.74	**5.68**	5.61	6.03	**5.82**
K:Ca (2:1)*	2.50	2.85	2.98	**2.91**	2.98	3.03	**3.00**	3.02	3.17	**3.09**
K: (Ca+Mg)* 1,6-2.2:1	1.62	1.91	1.96	**1.93**	1.95	1.98	**1.96**	1.96	2.07	**2.01**
N:S* (15-16:1)	16.4	15.7	15.5	**15.6**	17.0	15.2	**16.1**	16.2	16.5	**16.3**

* optimum values according to MAJCHERCZAK et al. (2006)

of double doses of mineral fertilisers resulted in the expansion of the K:Mg ratio towards the optimal value in comparison with single doses, by 2.89%, 1.95% and 7.48%, respectively. The optimal ionic ratio K:Mg (6.03) was obtained in perennial ryegrass under the influence of a double dose of In 4 with urea. A slightly narrower K:Mg ratio was obtained by doubling the doses of SP 25 and SF 20 with the addition of urea (5.74 and 5.69, respectively). Both single and double doses of mineral fertilisers and urea applied with the use of compost have expanded the K:Mg ionic proportions in the perennial ryegrass compared to the series in which it was not used. It was found that the applied double doses of mineral fertilisers and urea with the participation of compost resulted in broadening the K:Mg ionic ratio in the test plant in comparison with single doses, by 2.13%, 6.45% and 1.00%, respectively. Under the influence of double doses of mineral fertilisers and urea applied with the use of compost, close to the optimal K:Mg ionic ratio in perennial ryegrass was obtained under the influence of SP 25 and In 4 6.11 and 6.05, respectively, as well as 5.99 in response to a single dose In 4 (Table 6). The results concerning ionic proportions in plants indicate that the mineral fertilisers used in the experiment with and without the use of compost as well as exclusive organic fertilisation resulted in the K:Mg ratio being expanded towards the optimal value.

The K:Ca ionic ratio in perennial ryegrass in all objects of the experiment was wider than the optimal value. The narrowest K:Ca ratio in the test plant was obtained from the control variant (2.50). Multi-component mineral fertilisers with the addition of urea and compost resulted in the expansion of the K:Ca ionic ratio in perennial ryegrass compared to the control by 16.4%, 20.0%, and 23.6% (Table 7), 20.4%, 24.4% and 22.4% (Table 6), respectively.

Mineral fertilisers (SF 20 and SP 25) used with compost resulted in a slight expansion of the K:Ca ratio in perennial ryegrass compared to the object in which only organic fertiliser was applied, by 10.2% and 13.9 and 12.1%, respectively (Table 6). Introducing the first and second dose of mineral fertilisers including urea, with and without the participation of compost, had little effect on the differentiation of the K:Ca ionic ratio. The narrowest K:Ca ratio in the test plant in series without organic fertilisation was obtained under the single dose of SF 20 with the addition of urea. In the objects with compost, the narrowest K:Ca ionic ratio in perennial ryegrass was obtained due to the single dose of SF 20, SP 25 and In 4 with the addition of urea.

In both years of the research (2007 and 2008), the optimal K:(Ca+Mg) ionic ratio in perennial ryegrass was obtained in all fertiliser objects. On average, during the two years of the experiment, the K:(Ca+Mg) ratio in the test plant in the object fertilised only with compost was 1.80, and when using multi-component mineral fertilisers and urea, irrespective of the size of doses and their application with or without compost, it ranged from 1.91 (Table 7) to 2.09 (Table 6).

Single doses of mineral fertilisers and urea increased the K:(Ca+Mg) ionic ratio in perennial ryegrass compared to the control by 17.9%, 20.4% and 21.0%, respectively. The use of double doses of mineral fertilisers and urea had no significant effect on the extension of K:(Ca+Mg) ratio in the test plant as compared to single doses. Single and double doses of mineral fertilisers applied with compost contributed to the increase in the K:(Ca+Mg) proportion by 8.33%, 8.90% and 12.2%, respectively, in comparison to the object fertilised exclusively with compost. On the other hand, they did not affect variation of the average ratio in the examined grass in comparison to the series in which organic fertiliser was not used. The K:(Ca+Mg)ratio was within the range of optimal values. These data indicate that it is possible to increase the dose of compost and mineral fertilisers in appropriate proportions without negatively affecting the optimal values of the K:Mg and K:(Ca+Mg) ratios. The K:Ca ionic proportions under the influence of mineral fertilisers used with and without the participation of compost were wider than the optimal value. Similar results were obtained by Krzywy-Gawrońska (2006). These data indicate that calcium should be introduced into the soil in order to obtain the optimal K:Ca ratio. The introduction of calcium fertilisers would be expedient because the pH_{KCl} of the soil decreased under the influence of multi-component mineral fertilisers and urea used in the experiment (Krzywy, Krzywy 2001, Krzywy et al. 2002).

Schung, Haneklaus (2000), Podleśna, Kocoń (2009), Barczak et al. (2016, 2017), based on research, indicate significant interaction of sulfur and nitrogen as nutrients necessary for the synthesis of amino acids included in proteins. The quantitative N:S ratio is a measure of the interaction of these components. The widest N:S ionic ratio in perennial ryegrass was recorded in the plants fertilised without using compost (18.9), where it was higher than the ionic ratio in spring oilseed rape seeds (9.3:1- Šiaudnis 2010) or in the biomass of grasslands (9.2-12.6:1– Grygierzec et. al 2015). The N:S ratio ranged from 15.7 to 17.0 under the influence of single doses of mineral fertilisers and urea without compost (Table 7). Doubling the doses of mineral fertilisers and urea narrowed the N:S ionic ratio in the object with SF 20 fertilisers and SP 25, and the N:S ratio in the In 4 object expanded by 1.85% compared to single doses. The N:S ionic ratio under the influence of single doses of mineral fertilisers and urea applied with compost ranged from 16.4 to 16.8. Doubling the doses of fertilisers slightly narrowed the N:S ionic ratio in the object with SF 20 and In 4, but the N:S ratio broadened by 2.38% in reponse to SP 25 compared to single doses. In the series of experiments without compost fertilisation, the optimal N:S ionic ratio was obtained in the objects where a single and double dose of SF 20 with urea were applied. In other fertiliser objects, the N:S ionic proportions were slightly wider than optimal. The high value of the N:S ionic ratio is most likely due to the high nitrogen content in ryegrass, which is a consequence of larger uptake of this element compared to the needs of oil plants or cereals. These data indicate that it is possible to increase the contribution of mineral fertilisers containing nitrogen and sulfur in appropriate proportions, and it is necessary to introduce proportional amounts of nitrogen and sulfur in the form of mineral fertilisers to the composted object. The research results confirm the data obtained by other authors, according to which an increase in the sulfur content in plants is related to the availability of this element originating from the soil solution (Jamal et al. 2010).

Proportions of nutrients in plants are varied due to their diversity. There are significant differences between the content of macronutrients, their proportions and requirements for products intended for fodder. Jarnuszewski, Meller (2013) report that the ionic proportions they found in the research oscillated at the level of 3.13 for K:Mg; 5.65 for K:Ca, and 1.15 for K:(Mg+Ca). The ionic ratios obtained in our research are wider for K:Mg and K:(Mg+Ca) but narrower for K:Ca compared to those given by the above authors. The ratios obtained in the test plant slightly differed from values that are considered optimal in fodder crops.

CONCLUSIONS

1. Multi-component mineral fertilisers and urea used in single doses caused an increase in the average content of nitrogen, potassium and sulfur in perennial ryegrass compared to the control object. The average content of calcium and magnesium under the influence of single doses of mineral fertilisers did not diverge considerably from the content obtained in the control.

2. Double doses of mineral fertilisers with the addition of urea increased significantly the content of K, Ca and S in perennial ryegrass compared to single doses.

3. Multi-component mineral fertilisers and urea applied with the use of compost increased significantly the content of N, K, Ca and S in perennial ryegrass compared to the object, in which organic fertiliser was excluded.

4. The applied mineral fertilisers used with and without compost have resulted in an expansion of the K:Mg ionic ratio towards the optimal value in perennial ryegrass.

5. The research indicated that the applied mineral fertilisation with and without the use of organic fertilisation contributed to the optimal value of K:(Ca+Mg) and K:Ca ratios to be expanded above the optimal value in perennial ryegrass.

6. The applied mineral fertilisation with and without compost modified the N:S ratio in the perennial ryegrass within the limits of optimal values.

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