THE EFFECT OF ORGANIC FERTILIZERS ON MINERAL COMPONENT CONTENT IN TALL OAT GRASS

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ABSTRACT

Studies on mineral component contents in tall oat grass were conducted as a pot experiment in 2005. Mineral fertilization, farmayard manure, compost, municipal and industrial sludge were use and two levels of NPK fertilization were considered: 1 level -0.30g N, O.11g P, 0.26g K $\cdot pot^{-1}$, and 0.60g N, 0.22g P and 0.52g K $\cdot pot^{-1}$. Doses of farmyard manure, compost, municipal and industrial sludge were established on the basis of nitrogen fertilization level and were applied in the first year of the experiment under maize. The study results show that P, K, Mg, Ca, Fe and Mn contents in tall oat grass depended on the dose and kind of organic fertilizers applied, date of harvest and on the plant part. Higher concentrations of P, K, Ca, Mg were observed in plants fertilized by farmyard manure, compost, while Fe and Mn on municipal and industrial sludge. The contents of the analyzed macro- and microelements in individual plant parts looked as follows: I cut > II cut > root for P and K; II cut > I cut > root for Mg and Ca, and root >II cut > I cut for Fe and Mn. P (II cut) and Mg (I cut) concentrations in dry matter of tall oat grass were considered optimal, while Ca content was too low. The values of Ca: P, Ca: Mg, K: Mg, and Fe :Mn ratios in the grass did not fall within the limits assumed as safe for fodder. Only the value of K (Ca+Mg) ratio in plant was optimal on both sludges, farmyard manure$_1$ and compost$_1$. The highest uptake of P, K, Mg ands ca was noted on farmyard manure$_2$, whereas Fe and Mn on industrial sludge.

Keywords: macroelements, microelements, farmyard manure, compost, sludge, elements ratios, uptake

INTRODUCTION

It has been commonly considered that plant chemical composition is one of important elements determining fodder quality. Fertilization, which supplies adequate amounts of mineral components to soils considerably influences plant nutritive value and therefore the health and productivity of animals [UNDERWOOD 1971, CZUBA, MAZUR 1988, MAZUR 1999]. It has been assumed that 12 elements are crucial for the proper growth and development of plants: N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn, B and Mo and their effect on growth and development of grasses is diversified [FALKOWSKI et al 2000]. The quality of obtained fodder is determined not only by the above mentioned element abundance, but also by their proportions. The source of mineral components may be organic fertilizers, composts from urban wastes and sewage sludges used for soil treatment. Utilization of the above mentioned chemically unpolluted organic fertilizers for agronomic purposes is of great biological and ecological importance and is the most rational way of their management [MAZUR 2002, ANTONKIEWICZ et al 2003]. A manifold effect is the advantage of organic fertilizers and wastes, since they play an important role both in plant nutrition and forming soil fertility [JANKOWSKA-HUFLEJT 2001].The experiment was conducted to assess the consequent effect of organic fertilizers on the content of selected mineral components (P, K, Ca, Mg, Mn and Fe) and their ratios in tall oat grass.

MATERIAL AND METHODS

Studies on mineral component content in tall oat grass were conducted as a pot experiment in the second year of vegetation (2005). The soil used for the experiment had weakly loamy sand texture, pH_{KCL} 4.66, organic C content 11.2g $\cdot kg^{-1}$, nitrogen 1.0 g $\cdot kg^{-1}$ and very low concentrations of available phosphorus (7.2mg P_2O_5 $\cdot kg^{-1}$) and potassium (17.3 mg K_2O $\cdot kg^{-1}$). According to limit numbers of heavy metals the soil revealed natural contents of: Zn, Cu, Ni, Pb and Cd [KABATA-PENDIAS et al 1995]. The experimental design comprised 11 objects differing with the kind and dose of supplied fertilizers. The following were used for the experiment: mineral salts, farmyard manure, compost, municipal and industrial sludge and two NPK fertilization levels were considered. The dose for the first level was 0.30g N, 0.11g P and 0.26g K per pot^{-1}, while for the second level respectively: 0.60g N, 0.22g P and 0.52g K per pot^{-1}. Doses of nitrogen and potassium were divided in two and applied for individual tall oat grass cuts. Phosphorus was supplied once before tall oat grass sowing. Fertilizer components were supplied as solutions of NH_4NO_3, KH_2PO_4 and KCl. Organic fertilizers were used in the first year of the experiment under maize and their doses were based on nitrogen fertilization level [JASIEWICZ, ANTONKIEWICZ 2005]. Chemical composition of the above mentioned fertilizers was shown in Table 2. The fertilizer doses were respectively for 1 and 2 level of treatment: farmyard manure 181 and 362 g, compost 38 and 76 g, municipal sludge 73 and 146g, industrial sludge 87.45 and 174 g fresh mass $\cdot pot^{-1}$. After harvesting I and II cut the plants were dried in a dryer at 75°C and subsequently the amount of the aboveground parts and roots was assessed [JASIEWICZ et al 2006]. The contents of P, K, Ca, Mg, Mn and Fe were assessed using ICP-AES method after dry mineralization [OSTROWSKA et al 1991]. This work, apart from mineral component concentrations, presents also the their ratios them and uptake. Ratios of K:Mg, K:Ca, K:(Mg+Ca), Fe:Mn were computed as equivalents, whereas Ca:P and Ca:Mg were weight ratios. Pearson correlation coefficients were calculated in order to determine the interrelations between mineral components [STANISZ 1998].

Table 1 Chemical composition of fertilizers

Fertilizers	Dry mass	Org. matter	C-org	N/P/K
	%	$g \cdot kg^{-1}$ s.m.		
Farmyard manure	14,56	855,3	-	20,9 / 4,5 / 19,7
Compost	54,72	437,3	253,6	26,4 / 5,1 / 13,4
Municipal sludge	18,81	640,4	371,4	40,1 / 16,0 / 3,5
Industrial sludge	21,84	482,8	280,0	28,8 / 8,6 / 2,3

RESULTS AND DISCUSSION

The content of mineral components in tall oat grass was changing depending on the dose and kind of applied fertilizer, date of harvesting and analyzed plant part (Tab. 2).

According to literature data the optimal amount which satisfies animal demand for individual elements has been assumed as follows: 3.0g P, 1 7-20g K, 2.0g Mg,7.0g Ca, 40-70mg Fe and 40-60g Mn $\cdot kg^{-1}$d.m.of fodder [ed. ROGALSKI 2004, FALKOWSKI et al 2000]. P concentrations in tall oat grass ranged between 2.02 and 6.64 g $\cdot kg^{-1}$d.m. and arranged as follows: I cut > II cut > root (Tab.2). The most diversified P concentrations under the influence of fertilizers applied were detected in I cut (v=23%), then in root (v=15%) and II cut (v= 12%).The highest P concentration was registered on single compost dose treatment (I cut), NPK_2 (II cut) and on double dose of municipal sludge treatment (root). Increase in phosphorus content in plant from these treatments in relation to the control was respectively by 152%, 25% and 47%. The smallest quantities of this element were found in II cut yield from single dose of compost. In result of this fertilizer activity P contents in yields declined by 19% as compared with the control. NPK, farmyard manure, compost and industrial sludge fertilization used in single doses caused a slight decline in P concentration in roots (Tab.2). According to FALKOWSKI et al [2000] a positive relationship between P and N has been noted in grasses, while N and protein content may increase under the influence of phosphorus. A similar dependency was observed in the presented experiment –correlation coefficient between these elements was respectively: r=0.3 (I cut), r= 0.9 (II cut) at p=0.01. Nitrogen content in the discussed grass was presented by JASIEWICZ et al [2006]. On all organic treatments an approximate to normal phosphorus concentration as observed in II cut, whereas I cut revealed considerably elevated content of this macroelement as compared with the optimal amount (Tab.2).

The tall oat grass K abundance ranged between 6.18 and 30.48 g $\cdot kg^{-1}$d.m.and as in the case of P its amount was decreasing in subsequent cuts (Tab.2). NOWAK and DRASZEWSKA-BOŁZAN [2001] observed similar dependencies. In roots potassium content was 2-3 times lower than in the aboveground parts. Definitely the highest amounts of potassium were found in I cut yield from treatments where double doses of compost and farmyard manure were used. K concentration in effect of these fertilizers activity increased respectively by 69% and 70%. In II cut potassium concentration was less diversified (v=11%) in comparison with I cut (v=16%). In this cut, applied organic fertilizers, except a double dose of compost, did not affect increase in K content in tall oat grass yield (Tab.2). The lowest K concentrations were assessed in yield from industrial sludge treatment. The applied sludge caused a decrease in potassium level in relation to the control, both in case of single and double dose application by 21% and 13%. Only double dose of NPK and compost led to an increase in K, respectively by 21% and 2% (II cut) and 4% (roots). Roots were characterized by the least diversified K contents (v=9%). Potassium concentrations most approximating the standard occurred in II cut, particularly in organic treatments (17.32-22.32 g $\cdot kg^{-1}$d.m.). Research of various authors revealed this component excessive presence in plants so generally, no noticeable K deficiencies are found in green fodder [GORLACH et al 1985, GRZEGORCZYK et al 1992, SZPUNAR-KROK, BOBRECKA-JAMRO 2001, ROGALSKI et al 2004]. High K concentrations and deficiency of Mg and Ca most often change the quality of plants intended for ruminants [MARECIK 1991]. In the presented investigations K level exceeded the desired values, particularly in the I cut yield.

Table 2 Element contents in tall oat grass

Element		Control	NPK		Farmyard manure		Compos		Sludge sewage		Sludge industry	
		I	II*	III**	IV*	V**	VI*	VII**	VIII*	IX**	X*	XI**
		g · kg^{-1} s.m.										
P	I cut	2,64	3,74	4,89	3,97	4,39	6,64	4,19	3,61	4,47	4,18	4,24
	II cut	3,22	2,93	4,07	2,83	3,27	2,62	2,95	2,82	3,31	2,97	3,29
	Root	2,21	2,02	2,31	2,14	2,74	2,11	2,63	2,42	3,24	2,19	2,84
K	I cut	16,0	22,2	26,9	23,8	27,2	24,2	30,5	22,4	23,9	20,5	21,1
	II cut	21,8	21,9	26,4	19,4	21,7	20,3	22,3	19,7	20,3	17,3	19,0
	Root	7,60	6,61	7,87	6,64	7,49	6,88	7,91	6,49	6,96	6,18	6,56
Mg	I cut	2,19	2,10	1,90	2,45	2,50	2,41	1,84	2,36	2,27	2,20	2,26
	II cut	3,41	3,05	2,89	3,67	4,47	3,54	3,34	3,32	2,76	2,7	2,95
	Root	0,64	0,60	0,70	0,69	0,86	0,78	0,84	0,69	0,72	0,54	0,55
Ca	I cut	3,20	3,31	2,53	2,34	1,98	2,57	1,24	2,84	2,42	1,90	1,89
	II cut	3,81	5,16	4,60	5,55	4,13	4,23	3,88	4,35	3,50	3,32	3,68
	Root	1,10	1,22	1,63	1,31	1,39	1,42	1,48	1,04	1,14	0,93	0,93
mg · kg^{-1} s.m.												
Fe	I cut	97,6	92,2	103	96,5	102	97,3	105,5	99,7	91,5	92,0	98,4
	II cut	150,5	88,7	96,0	89,6	89,6	72,7	84,5	78,1	78,7	76,8	67,0
	Root	4175	1560	1730	1565	1290	1805	1620	2605	2965	2565	3450
Mn	I cut	63,4	272	597	91,9	118	100	117	132	245	278	572
	II cut	478	499	906	270	244	241	236	267	296	279	859
	Root	214	233	490	166	178	156	169	159	242	221	363

*1 doses : 0,30 g N, 0,11 g P, 0,26 g K · pot^{-1} **2 doses: 0,60 g N, 0,22 g P, 0,52 g K · pot^{-1}

Mg concentrations in grass ranged between 0.54 and 4.47 g $\cdot kg^{-1}$d.m. and placed as follows: II cut > I cut > root. A higher Mg content assessed in subsequent cut corroborates the opinion that as vegetation period progresses plant abundance in this component increases [FALKOWSKI et al 1993, 2000].High Mg concentrations were registered in tall oat grass on a double dose of farmyard manure. The growth in comparison with the control was respectively: by 14% (I cut), 31% (II cut) and 34% (root). The lowest amount of Mg was determined on a double dose of compost treatment (I cut), municipal sludge (II cut) and both doses of industrial sludge (II cut). The applied fertilizers caused a decline in Mg content in relation to the control by respectively 16%, 19% , 21% and 13%. Mg content was the most diversified under in effect of the applied fertilizers in root (v=16%), then in II cut (v=15%) and I cut (v=10%). Mg content most approximate to optimal was registered in I cut, whereas II cut revealed highly elevated content of this macroelement in relation to standard.

The structure of Ca content in tall oat grass was similar to Mg: II cut > I cut > root and ranged between 0.93 and 5.55 g $\cdot kg^{-1}$ d.m. Applied organic fertilizers caused a decline in Ca content in I cut. Ca concentrations in yields from this cut were always higher at a single dose of fertilizer (Tab.2). The lowest concentration of this macroelement was registered in grass fertilized with a double dose of compost (I cut), the content dropped by 61% in comparison with the control (Tab. 2). The highest Ca concentrations were found in tall oat grass treated with a single dose of farmyard manure (II cut). In comparison with the control Ca level raised by 46% under the influence of this fertilizer. In roots a pronounced decline in Ca content was observed under the influence of both doses of industrial sludge (Tab.2). On these treatments a decrease in Ca level was respectively by 15% in relation to the control. The greatest diversification of Ca content was characteristic for I cut (v=26%), then for root (v=19%) and II cut (v=16%). Calcium proved the most deficient element in these studies. Contents of Ca in both cuts was on a low level in comparison with the calcium amount desired in fodder plants. NOWAK and DRASZAWSKA-BOŁZAN [2001] registered similarly deficient Ca concentrations in their studies.

Fe and Mn contents in the test plant fluctuated respectively from 67 and 4175 mg Fe and from 63 to 906 mg Mn $\cdot kg^{-1}$d.m. The level of the above mentioned elements in tall oat grass under the influence of applied organic fertilizers looked as follows: root > II cut > I cut. The highest Fe concentration was assessed in effect of double dose of compost (I cut) and on the control (II cut and root). In the case of manganese, NPK - fertilized tall oat grass revealed the highest concentration of this element (Tab.2). Fertilizer variants used in the experiment obviously affected the diversification in both elements contents. Fe concentrations were most diversified in the root (v=40%), then II cut (v=25%) and I cut (v=5%).A reverse dependency was registered for Mn, I cut revealed the highest diversification in this element content (v=80%), then II cut (v=6%) and root (v=44%). Levels of both elements assessed in the presented experiment were very high and exceeded the values optimal for fodder plants.

Apparent correlations were present between mineral component contents. P concentration in yields were positively correlated with K level (r=0.5), Mn (r=0.31), while K content with Mg level (r=0.03) and Mn (r=0.12). Mg level was positively correlated with Ca and Fe content, whereas Ca content with Fe and Mn concentrations. No visible antagonism was observed between the elements in fodder because the correlations between them were statistically insignificant, despite forming negative tendencies.

The ratios between mineral components are also important and a good indicator of fodder nutritive quality. Good quality fodder should reveal optimal proportions of **Ca : P** -2:1, **Ca: Mg** -3:1, **K: (Ca+M**g) - 1.6-2.2, **K : Mg** – 6:1, **K : Ca** – 2:1 [CZUBA, MAZUR 1988, FALKOWSKI et al 2000]. In the tall oat grass the ratios of the above mentioned components were fluctuating widely, which points to changes occurring in the plant chemical composition under the influence of the fertilizer application (Tab.3). The above mentioned ratios were changing also in the subsequent regrowths.

Table 3 Element ratios in tall oat grass

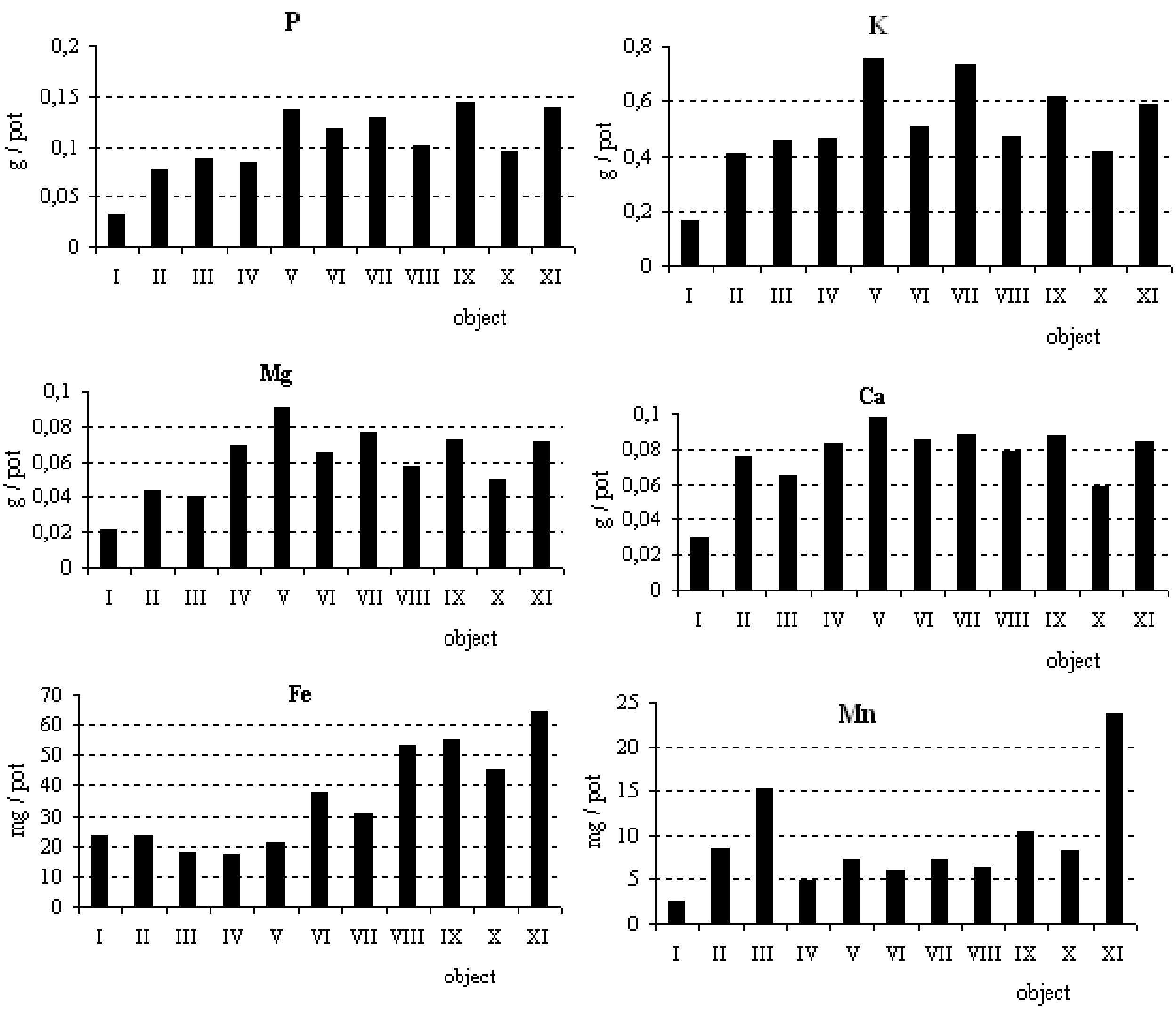
Elements ratio		Treatments										
		I	II*	III**	IV*	V**	VI*	VII**	VIII*	IX**	X*	X**
Ca : P	I cut	1,21	0,89	0,52	0,59	0,45	0,39	0,30	0,79	0,54	0,45	0,45
	II cut	1,18	1,76	1,13	1,96	1,26	1,61	1,32	1,54	1,06	1,12	1,12
Ca : Mg	I cut	1,46	1,58	1,33	0,96	0,79	1,07	0,67	1,20	1,07	0,89	0,84
	II cut	1,12	1,69	1,59	1,51	0,92	1,19	1,16	1,31	1,27	1,23	1,25
K:(Mg+Ca)	I cut	1,20	1,71	2,44	1,91	2,29	1,90	3,66	1,71	2,00	1,90	1,93
	II cut	1,19	1,10	1,45	0,86	0,97	1,04	1,22	1,03	1,30	1,14	1,15
K : Mg	I cut	2,28	3,35	4,41	3,02	3,39	3,13	5,16	2,96	3,29	2,90	2,91
	II cut	1,99	2,24	2,84	1,64	1,51	1,79	2,08	1,85	2,29	2,00	2,01
K : Ca	I cut	2,57	3,50	5,46	5,22	7,06	4,85	12,6	4,06	5,09	5,53	5,74
	II cut	2,94	2,18	2,95	1,79	2,70	2,47	2,96	2,33	2,98	2,68	2,66
Fe : Mn	I cut	1,51	0,33	0,17	1,03	0,85	0,96	0,88	0,74	0,37	0,33	0,17
	II cut	0,31	0,17	0,10	0,33	0,36	0,30	0,35	0,29	0,26	0,27	0,08

Irrespectively of the fertilizer variant, the Ca : P weight ratio in tall oat grass dry matter assumed values lower than optimal, only on a double farmyard manure dose, Ca : P ratio was 1.96 (II cut) and approximated values considered the right ones. However, it should be emphasized that the value of Ca: P ratio in II cut oscillated within the permissible range because UNDERWOOD [1971] beside the optimal stated also value 2:1, 1:1 and 7:1 ratios as permissible. The value of Ca : Mg ratio in the test plant was lower than the stated optimum (Tab.3). The compost applied as a single dose, farmyard manure and industrial sludge in both doses affected an apparent narrowing of the above mentioned ratio, particularly in I cut as compared with the control. K: (Ca+Mg) relationship is an important criterion of fodder quality and its value should not exceed 2.2. At higher values pasture tetanus symptoms may appear [KASPERCZYK, FILIPEK 983, FALKOWSKI et al 2000, UNDERWOOD 1971, BOBRECKA-JAMRO 2002, NOWAK, DRASZAWSKA-BOŁZAN 2001, CZUBA,MAZUR 1988]. The ratio in the test plant should be considered as safe in I cut on sludge treatments, on single dose of compost and on NPK treatment (Tba.30.With subsequent regrowths the proportion was narrowing (Tab.3). Irrespective of treatment the equivalent ratio K : Mg assumed values lower than optimal and in II cut even greater narrowing of the above mentioned ratio was observed. The values of this proportion most approximate to the standard occurred in I cut on double dose of compost. Data compiled in Table 3 show that K : Ca ratio in the analyzed plant were above the assumed optimum. A very clear widening of K : Ca ratio happened in I cut under the influence of compost and double doses of farmyard manure, which might have resulted from high K content in these fertilizers. In II cut values of this ratio were apparently lower and oscillated towards the proper value (Tab.3). Fe : Mn ratio an all fertilizer treatments was lower than the optimal – 1.5- 2.5 stated by WARDE et al [1996].

Only on the control (I cut) the value of the analyzed proportion ranged within the optimum (Table 3). The fertilizers applied caused considerable narrowing of the above mentioned ratio, particularly in II cut yields.

The amount of elements removed with the plant depended on the amount of yield [JASIEWICZ et al 2006] and individual element concentration. The mineral element uptake by tall oat grass were greatly diversified depending on fertilizer applied (Fig.1).

Fig. 1 Uptake of elements by tall oat grass



The largest element uptake (P, K, Mg, and Ca) was registered for tall oat grass cultivated on double doses of farmyard manure and on industrial sludge (Fe and Mn). The lowest removal P, K, Mg, Ca and Mn as detected on the control, whereas Fe on single dose of farmyard manure treatment. From among the analyzed elements the highest uptake of Mn was noted (866% on double dose of industrial sludge) whereas the lowest absorption of Fe (33% on double compost dose).Only for Fe a decline in this metal removal by tall oat grass as compared with the control was detected on NPK_2 treatments and on farmyard manure. Irrespective of the treatment, far larger quantities of P, K, Mg and Ca were removed by tall oat grass green part than by the roots. The structure of the above mentioned elements uptake by the plant reveals that tall oat grass aboveground parts were absorbing respectively 52-75%P, 73-86%K, 76-90%Mg, 66-85%Ca, 47-72%Mn. Only the removal Fe by roots was larger than by the aboveground parts (90-97%).

CONCLUSIONS

1. From among tested fertilizers and organic wastes the consequent effect of farmyard manure and compost apparently increased the tall oat grass concentrations of P, K, C and Mg, whereas sludge effect raised Fe and Mn.
2. The level of the above mentioned elements shaped as follows: I cut > II cut > root for P and K; II cut > I cut > root for Mg and Ca, and root >II cut > I cut for Fe and Mn.
3. Concentrations of P (II cut) and Mg (I cut) fell within the ranges considered optimal in fodder, whereas K, Mn and Fe concentrations in both cuts exceeded the desired values. Ca proved the most deficit element.
4. Values of Ca : P, Ca : Mg, K : Mg and Fe : Mg ratios in the tested plant were lower whereas K : Ca higher than the optimal values. In I cut K : (Ca +Mg) ratio was considered safe on sludge treatments and on single dose of farmyard manure and compost.
5. Organic fertilizers caused a narrowing of the above mentioned ratios in tall oat grass yields, whereas K: Ca proportion was widened under the influence of these fertilizers.
6. The greatest amounts of P, K, Mg and Ca were harvested with tall oat grass fertilized with a double dose of farmyard manure and Fe, Mn from industrial sludge treatment.
7. Tall oat grass aboveground parts absorbed respectively: 52-75% P, 73-86%K, 76-90% Mg, 66-85% Ca and 47-72% Mn. Only Fe removal with roots was greater than by the aboveground parts.

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