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THE ECOLOGICAL AND ENVIRONMENTAL FUNCTIONS OF GRASS ECOSYSTEMS AND THEIR IMPORTANCE IN THE ELIMINATION OF DEGRADATION PROCESSES IN AGRICULTURAL LANDSCAPE

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Abstract: Grass ecosystems perform productive functions and significant non-productive functions – ecological and environmental. The sod (root biomass and tillering zone), with a dominant share of 80 % in primary grass swards production, ensures these functions. The production of root biomass and aboveground phytomass was examined on three grass swards types - permanent grass swards (PGS), over-sown grass swards (OGS), temporary grass swards (TGS) with four variants of mineral nutrition. The experiment was carried out in the research area of GMARI in Banská Bystrica (Slovak Republic). Root sampling was realized from the soil profile 0-100 mm by the method of monoliths. The lowest root biomass production was observed on TGS (7.3 $t.ha^{-1}$), the highest production on PGS (8.27 $t.ha^{-1}$). The root biomass production is highly influenced with mineral nutrition and with climate change. The significantly highest amount of root biomass (8.3 $t.ha^{-1}$) was produced on grass swards fertilized at highest doses of nutrients (180 kg N + 30 kg P + 60 kg $K.ha^{-1}$) and amount of root biomass was significantly higher during the dry years than climatically normal and wet years. Parameter for the evaluation of drought effect on the grass swards is the ratio of the root mass to the aboveground mass ratio (R/S). The results of R/S (4.02 - 5.16) demonstrate the significant ecological stability of the grass swards to the drought stress factor. The accumulation of biogenic elements in roots and in aboveground phytomass of grass swards was also determined. The total grass sward biomass accumulate: 362.7 $kg.ha^{-1}$ N, 41.8 $kg.ha^{-1}$ P, 252.1 $kg.ha^{-1}$ K, 115.5 $kg.ha^{-1}$ Ca, 49.7 $kg.ha^{-1}$ Mg on average. Root biomass has considerable importance in protection of the environment and food chain, because accumulates heavy metals from soil and prevents excessive release to the aboveground biomass using as forage for livestock.

Key words: biogenic elements, environment, grass ecosystem, heavy metals, root biomass, R/S ratio, sod.

1. INTRODUCTION

At present, when the warming of the Earth is becoming a serious global problem, grass swards perform a significant eco-stabilizing function in agricultural landscape. They dispose of homeostasis and adaptive mechanisms successfully react to several negative anthropogenic effects and factors of environment; they are also resistant to longer drought period or water logging, which are frequent global warming attendant phenomenon. Adapting to drought is a significant, after the drought, vegetation successfully regenerates from the storage resources of root biomass. The grass often preferred form of vegetative reproduction often helps the regeneration, but also more strategically important compensatory mechanisms. The species diversity belongs to the most important mechanisms; the semi-natural grass swards are normally composed of 30 – 70 vascular plants species (Ružičková & Kalivoda, 2007).

The permanent grass swards occupy 530,000 ha of agricultural soil fund in Slovakia, that represents 11 % of total land area. Their main cultivation importance is the creation of primary production consequently using as a volume source of fodder for livestock production. In addition to the primary importance, the grass swards perform also non-production functions - ecological and environmental, which are mainly implemented through the root system (root biomass) and tillering zone - grass sod. The root biomass and tillering zone with the share of up to 60–90 % in primary grass sward production ensures these functions (Titlyanova, 1991). Krajčovič & Ondrášek (2007) consider grass sod as a central component of semi-natural grass swards, which is physical, morphological, physiological and metabolic interface between aboveground and underground part of the biocenosis with important specific characteristics and functions for aboveground and underground biomass.

The grass swards significantly contribute to the protection of soil erosion by its massive root system, so they represent the important stability element in the rural landscape. The erosion is a serious ecological risk of agricultural soil degradation in sub-mountain and mountain conditions of Slovakia, but also in other Central European countries (Czech Republic, Austria). The potential water erosion represents 55 – 60 % and wind erosion represents 5 – 6 % share of the territory acreage in Slovakia. The grass swards and grass sod significantly alleviate this serious degradation phenomenon.

The importance of root system is assessed by Kutschera (1991). He states, that the roots contribute to the production of soil, to the protection of erosion and also help repair damaged soil structure. They are good testing elements to determine the effect of fertilizers, livestock manure and toxic substances, which were introduced into the environment due to environmental pollution.

The grass swards have significantly contributed to the creation and maintaining of ecological stability by relatively closed mass and energy flow circulation. Practically, the whole root biomass and tillering zone enter to the closed natural biomass circulation. We can rate meadow-pasture grass swards as highly stable and resistant to adverse negative environmental effects in comparison with the agro-ecosystem on arable land where a major part of the biomass is used beyond its border.

2. MATERIALS AND METHODS

In this article, we report the results which are a summary of scientific knowledge included the solutions of several research projects solved at Department of Research Institute of Grass Swards and Mountain Agriculture in Banská Bystrica - Slovak Republic.

Problems of acumulation and root system creation of grass ecosystems in various conditions of fertilization we monitored during the years 1992–1998 at three vegetation types: permanent grass swards (PGS), over-sown grass swards (OGS) and temporary grass swards (TGS). The experiment took place at Radvaň - by the Suchý vrch (Dry hill) at an altitude of 460 m above the sea, in Banská Bystrica, Central Slovakia. We chose the block method in four replications. The area belongs to the region Kremnické and Starohorské vrchy. Climatological characteristic: a slightly cool and a slightly wet area. Exposition to the northern slopes of 5°. Average annual precipitations are 746 mm, 422 mm per vegetation period. The average annual temperature is 7.7°C and 13.6°C for vegetation. The Lang's rain factor is equal to 106. The snow cover lasts for 80 days. The geological substrate of habitat consist weathering of andesite, a soil type is cambisol. Acid soil with pH/KCl = 4.34, C_{ox} = 35.1g.kg^{-1} and N_t = 2.74g.kg^{-1}.

The permanent grass swards belong to *Trisetetum flavescentis* coenosis. (*Arrhenatherion* Union). The grass determinate the coenosis physiognomy, especially the dominant species *Trisetum flavescens* and other valuable grass as *Poa pratensis, Dactylis glomerata* and *Arrhenatherum elatius.* Fabaceous plant types like *Trifolium repens, Trifolium pratense* and *Lotus corniculatus* improve the value of swards. The most significant species of herbs is *Taraxacum officinale*, which ranks among the subdominant of coenosis. The over-sown grass swards represent the original permanent grass swards improved by seeding the trifoil-grasses mixes consisting of *Dactylis glomerata* cv. Rela (2 kg seeding amount), *Festulolium* cv. Felina (6kg seeding amount), *Lolium perenne* cv. Metropol (4 kg seeding amount), *Trifolium pratense* cv. Sigord (1.5kg seeding amount), *Trifolium repens* cv. Huia (1kg seeding amount per ha^{-1}). The temporary grass swards consists the same composition mixes as the over-sown grass swards with the double seeding amount of the individual species. Each type of swards included four fertilizing types:

Variant 1 - a control - non-fertilized variant;
Variant 2 - 30 kg P.ha^{-1} and 60 kg K.ha^{-1} (fertilized once in spring);
Variant 3 - 90 kg N.ha^{-1}, 30 kg P.ha^{-1} and 60 kg K.ha^{-1} (dividing N 3x30 kg to mowing; fertilized with P and K once in spring);
Variant 4 - 180 kg N.ha^{-1}, 30 kg P.ha^{-1} and 60 kg K.ha^{-1} (dividing N 3x60 kg to mowing; fertilized with P and K once in spring).

The grass swards have been used in three mowing phases. Sampling of roots and tillering zone of grass swards was realized by method of monoliths sampling with the steel rollers. We took samples five times per year – at the beginning of vegetation season, just after mowing of swards and at the end of the vegetation season. In the article we present average results of five samples. The sampling was realized by using the steel roller (50 mm diameter) to a soil depth of 100 – 120 mm and was repeated for 20 times. We cut 20 mm top part from the monolith that forms the tilling zone. Sampled roots and tillering zone were washed out by a stream of warm water in sieves. The samples were dried at 60°C and determined the weight of dry mass. The samples were homogenized by milling and we defined the content of biogenic elements - N, P, K, Na, Ca and Mg.

The total content of N was determined by calculation of N substances (N = N substances: 6.25). Substances P and N were determined by SKALAR^{plus} SYSTEM automatic analyzer. Elements K, Na, and Ca were determined by using the flame photometry method of the model calibration curve. The atomic absorption spectrophotometrical method of the model calibration curve was applied to determine Mg.

Production of aboveground biomass was monitoring with aboveground biomass and tilling zone sampling. The data were applied to assess the R/S ratio (root biomass weight rate on aboveground swards mass). The standard statistical methods and PC technology were used to process the results (Statgraphics, version 5.0). The results of the root biomass production and R/S ratio were evaluated by multiple (multifactor) analysis of the variance at 99% level of LSD test, with the following variability: three types of grass swards (PGS, OGS, TGS), four mineral nutrition variants (0, PK, N 90 + PK, N 180 + PK) and seven years of monitoring (1992-1998).

Reaction of grass swards contamination by heavy metals is interesting from an environmental point of view. Monitoring of content of heavy metals in soil and in grass biomass we realized during the years 2002 and 2009 on semi-natural grass swards in region Starohorské vrchy (central Slovakia) within three locations at different altitudes (Fig. 1):

- Location Radvaň, the lowest altitude (480 m) had the northern exposure with a slope 12-15°; the soil type is humus carbonate (rendzinas) on limestone.
- Location Panský diel, the middle altitude (1000 m) had the south-western exposure with a slope more than 20°; the soil type is cambisol from weathered crystalline-acidic rocks.
- Location Kráľova studňa, the highest altitude (1300 m) had the south-eastern exposure with a slope 20-25°; the soil type is shallow humus carbonate on limestone.

The soil and grass biomass (including sod) samples were taken monthly (May–September), during the vegetation season and after modification in laboratory were analysed in the adsorption atomic analyser. The concentrations of nine heavy metals were determined in each sample (Cd, Co, Cr, Pb, Zn, Mn, Cu, Fe, Ni). The results were processed by mathematical-statistical methods with PC (Statgraphics sofware, version 5.0, multifactor variance analysis method).

3. RESULTS AND DISCUSSION

Root biomass of the grass swards is an important source of organic mass, which improves the soil structure and fertility. Its amount is much higher than the one-year crops on the arable soil.

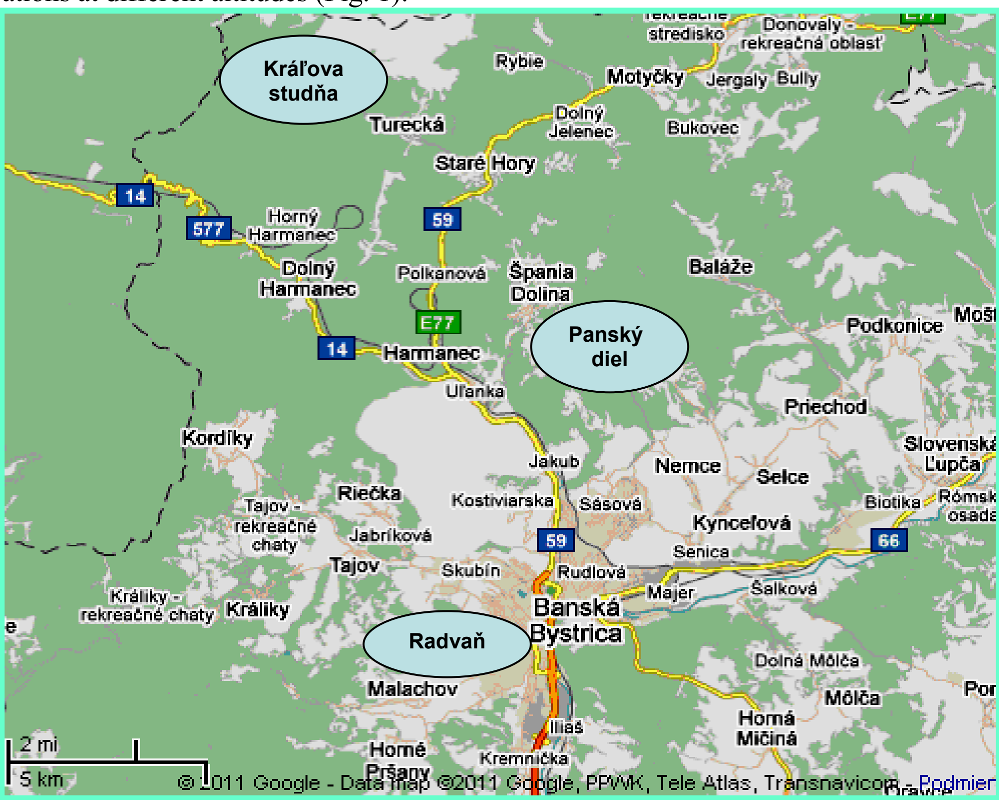

Figure 1. Situation map of sample sites in soil and plant samples in the surrounding of Banská Bystrica (Central Slovakia)

Table 1. Effect of grass swards and mineral nutrition on amount of root massa

Variants	Root biomass weight (t.ha^{-1})			Average	LSD α $_{0.01}$
	PGS	OGS	TGS		
1	7.75	7.24	6.68	7.22 a	
2	8.17	7.92	7.40	7.83 bc	
3	7.98	7.97	7.26	7.74 ab	
4	9.17	8.01	7.84	8.34 c	
Average	8.27 c	7.79 b	7.30 a		0.4648
LSD α $_{0.01}$				0.5367	

a, b, c - significant differences

The amount of root biomass also represents the highest percentage stand of total biomass per year in the same grass swards (roots – 40 %, tillering zone – 28 % and aboveground swards – total yield from whole mowing – 32 %). There has been 7.3 – 8.3 t.ha^{-1} of dry root mass in soil with grass swards depending on the grass swards cultivation type and mineral nutrition (Table 1).

Fiala & Jakrlová (1987) recorded the higher production. They state that the annual production of belowground biomass of different types of meadow swards in Českomoravská vrchovina is about 11 t. ha^{-1} (higher values were reached in fertilized swards) and is 2-3 times higher than aboveground primary production.

We recorded that there has been the lowest amount of root biomass on the temporary grass swards (TGS) - 7.30 t.ha^{-1}, significantly higher amounts on the over-sown grass swards (OGS) - 7.79 t.ha^{-1} and the highest amount on the permanent grass swards (PGS) - 8.27 t.ha^{-1} of dry mass in comparison with the three grass swards types during the years 1993-1998 within the research (Table 1).

Tesařová (1990) had also published the root biomass shortage on the renewed swards (TGS) in comparison with natural swards. She proves it by some soil physical properties improvement after grass swards renewal (reduction of moisture, temperature incensement, soil aeration improvement), which speeds up decomposition of herb waste and soil organic mass. On the other hand, herbs waste enters to soil decreases on the renewed grass swards in comparison with the semi-natural ones.

The unbalance between input and output of the organic substances can be one of the main reasons substantial decrease of humus in soils restored meadow swards and can even cause the smallest amount of root mass in our experiment. Gáborčík & Kohoutek (1999) also report root biomass decrease on the temporary grass swards in comparison with that on the permanent one. A lower quantities was recorded again in the production of tillering zone of OGS and TGS (5.0 or 5.3. t ha^{-1}), and higher on the permanent grass swards (PGS) - 5.6 t ha^{-1} of dry mass.

The application of mineral nutrition constitutes the additional factor affecting the root biomass amount along with grass swards cultivation in agriculture. The mineral nutrients often feature different effect. We reported the lowest root biomass amounts on the non-fertilized swards (7.22 t.ha^{-1} of dry mass), the balanced amounts on the swards fertilized with doses of 30 kg P + 60 kg K.ha^{-1} and 90 kg N + 30 kg P + 60 kg K.ha^{-1} (7.74-7.83 t.ha^{-1} of dry mass) in our experiment. Significantly the highest amount of root biomass was produced on the grass swards fertilized with higher doses - 180 kg N + 30 kg P + 60 kg K.ha^{-1} (8.3 t.ha^{-1} of dry mass). Some stimulatory effect of nitrogen on root biomass production has been proved.

The opinions on the production of grass swards root biomass with effect of fertilization are various. Úlehlová et al., (1981), Snyder & Cisar (2000), Velich (1986) and others quote an increase in the root biomass amount after the application of mineral nutrients. The higher production of the root biomass may be related to intensive nitrogen fertilization. Zeniščeva (1990) states that mineral nutrition, and nitrogen particularly stimulates root growth to a certain extent, but less intensively than aboveground biomass.

Positive effect of nitrogen fertilization on root production of natural grass swards was confirmed in experiments published by Úlehlová (1990). The author has explained the increase of root biomass weight from 1.9 to 3kg.m^{-2} after using 200 kg N.ha^{-1} by species changes of grass swards. Hejduk & Hrabě (2003) also observed the increase of underground biomass production as a result of higher fertilizer doses. They quote the production 989 g.m^{-2} on non-fertilized sites, that means 92 g.m^{-2} (8.6%) less than on fertilized ones (1081 g.m^{-2}). This difference is significant. On the contrary, Klapp (1971) states that nitrogen deficiency or its appropriate supply influences favourable the root system growth and development, while intensive nitrogen fertilization results in root weight reduction. Also Fiala (1985, 2007) and Mrkvička et al., (2004) quote the root biomass reduction on grass swards after the use of higher doses of nitrogen fertilization

(200kgN.ha^{-1}). The higher production of root biomass influenced by higher dose of nitrogen (180 kg.ha^{-1}) in our experiment is in agreement with the results published by Velich (1986), Hrabě et al., (1989), Tesařová (1990).

The root biomass and tillering zone together with organic mass are treated as the nitrogen source and more mineral elements. Table 2 shows the biogenic elements withdrawn by grass swards biomass.

They become potential nutrients for future vegetation crop in the mineralization process as the farmer's additional contribution. The sod significantly contributes to organic mass circulation and mineral nutrients in grass ecosystem. This fact appears more important if we realise that nutrients accumulated in aboveground vegetation often leak beyond the permanent grass ecosystem frontier in the form of livestock roughage, so they will not pass back into the mass natural circulation. The results achieved in our research with taking of mineral nutrients by the underground plant biomass are within the range published by Whitehead (2000) who studied taking of nutrients by the aboveground biomass in various types of grass swards. Extensive grass swards consumed 60 kg N, 6 kg P, 45 kg K, 15 kg Ca a 3 kg Mg. ha^{-1}, intensive ones 400 kg N, 60 kg P, 350 kg K, 120kg Ca a 30 kg Mg. ha^{-1}.

The year of cultivation has the additional influence on creation of root biomass. The agro-climate conditions constitute its influence, therefore more difficult to be manipulated by a farmer. We shall also focus on this aspect in the view of the fact that we encounter a threat of dry years. A lot of remarkable results related to weather-standard years and extreme seasons (Table 3) have been achieved during 7-years research (1992 – 1998).

The results achieved in 1992, when the total precipitation amounted only 287 mm and 724 mm during the whole year, document the drought negative effect on root system of grass swards. The air temperature was 15.8°C during the vegetation season and 9.0°C during the whole year. We can consider the year 1993 for climatically drier, when precipitation in the growing season was 336.5 mm.

Robust of the root system, the depth of penetration of roots into the soil profile and rooting density of the soil decide about the resistance of grass swards to droughts (except for the aboveground properties). In 1992, we observed weight of root system 10.2 t.ha^{-1} on the PGS and 9.5 t.ha^{-1}on the TGS. Similar production we observed in 1993 on all the three evaluated grass swards (10.3 – 11.5 t.ha^{-1}).

The production of root biomass is significantly higher during the climatically drier years like in years climatically normal and humid. We observed the considerable root biomass reduction during humid years 1995 and 1996, not only in comparison with the dry years but also with the standard climatic ones. The fact can be explained through the anatomical and morphological characteristics of the plant rooting adaptation to drought stress resulting in higher rooting creation – to the detriment of the aboveground vegetation parts, etc.

The soil moisture deficit inhibits growth of assimilative bodies resulting in distribution of the assimilative bodies into the roots in preference. On the one hand, the adaptations reduce water loss by transpiration; on the other hand, they are capable of gaining water from bigger depths, which enables growth under the soil moisture deficit conditions. Klapp (1971), Kolek et al., (1988) report that robust root system having the larger adsorption surface ensures better water uptake and more nutrients taken from the bigger soil volume and depths under the drought conditions. Gáborčík et al., (2007) also report that there is an increase in the grass swards root biomass under the precipitation deficit conditions. The results achieved document that there has been some rooting stability in response to the drought stress. The aboveground part of swards with significant growth reduction responds to drought stress in a more sensitive way.

The root biomass rate on the aboveground vegetation part (root/shoot - R/S) – genetically fixed – appears to be an important assessment parameter of drought impact on grass swards. The R/S ratio reflects the vegetation capability of avoiding the drought. The higher R/S values indicate that there has been the bigger vegetation drought resistance. Table 4 shows the R/S ratio during the individual years.

In 1993, we recorded maximum root production also documenting the broadest R/S ratio with the value of 8.79, evidently higher in comparison with the other years assessed. We also reported the R/S high value (5.43) in 1998, evidently higher as that during the period of 1994 – 1997.

Table 2. Nutrients accumulation by biomass in the grass swards in kg.ha^{-1}

Biomass/Accumulation	N	P	K	Ca	Mg
Roots	112.1	11.8	60.0	28.6	18.0
Tillering zone	97.2	10.5	40.0	29.8	13.6
Aboveground production	153.4	19.5	152.1	57.1	18.1
Total biomass	362.7	41.8	252.1	115.5	49.7

Table 3. The root biomass amount during the individual years ($t.ha^{-1}$)

Year	Total precipitation (mm)		Climatic year:	Root biomass weight ($t.ha^{-1}$)		
	IV-IX	I-XII		PGS	OGS	TGS
1992	287.0	724.1	dry	10.23 c	-	9.49 c
1993	336.5	794.7	dry	10.31 c	11.47 d	10.41 c
1994	564.7	917.3	standard	9.89 c	9.44 c	7.21 b
1995	568.3	935.7	muggy	7.16 ab	5.53 a	5.21 a
1996	630.9	971.3	muggy	6.69 a	6.28 a	5.83 a
1997	402.8	765.8	standard	7.65 ab	6.12 a	7.33 b
1998	494.8	829.7	standard	7.90 b	7.89 b	7.79 b
Average (50 years)	422.0	746.0				
LSD $\alpha_{0.01}$				1.1481	1.1337	1.2144

a, b, c, d - significant differences

Table 4. The root/shoot (R/S) ratio during the individual years

Year	1993	1994	1995	1996	1997	1998
R/S ratio	8.79 c	3.59 a	3.41 a	2.62 a	3.08 a	5.43 b

LSD $\alpha_{0.01}$ = 1. 5251; a, b, c, - significant differences

Table 5. The root/shoot (R/S) ratio on different grass ecosystem types

Vegetation	PGS	OGS	TGS
R/S ratio	5.16 b	4.02 a	4.27 ab

LSD $\alpha_{0.01}$ = 1. 0784; a, b, - significant differences

There has been approximately equal R/S ratio on the TGS and OGS, which amounts to 4.27 or 4.02. There has been the biggest R/S ratio on the PGV (5.16) and evidently higher one in comparison with the OGS (Table 5). The results have documented the higher permanent grass swards ecological resistance to the drought stress factor. Therefore, there has been good cause to believe that PGSs have been capable of tolerating global warming of the Earth and contribute to stability of the rural landscape.

The R/S ratio has also marked a substantial influence on grass swards mineral nutrition. There had been the R/S ratio (3.32 or 3.68) reaching evidently lower value in the variants fertilized by nitrogen in comparison with those not fertilized and those having $P_{30}K_{60}$ – 5.47 (Table 6). Rychnovská et al., (1985) publish the similar nitrogen fertilizing influence on the R/S ratio.

Table 6. The mineral nutrition influence over the root/shoot (R/S) ratio

Mineral nutrition	Var.1	Var. 2	Var. 3	Var. 4
R/S ratio	5.47 b	5.47 b	3.68 a	3.33 a

LSD $\alpha_{0.01}$ = 1. 2452; a, b, - significant differences

The mineral vegetation nutrition (nitrogen) has been considered the additional factor eliminating the drought influence on production richness. The swards fertilized applying the optimal (or higher) doses of nitrogen, phosphorus and potassium reached higher root biomass production in comparison with those not fertilized even during the dry, unfavourable years. We recorded root production amounting to 11 - 12 $t.ha^{-1}$ on the fertilized swards and 8 - 9 $t.ha^{-1}$ on the non-fertilized ones during the drought in 1992. The similar tendencies were recorded in the next years.

The grass sod has considerable importance in protection of environment. It serves as the anti-erosion factor and protects the grass swards against higher heavy metals concentration, which could otherwise break into the food chain. Documenting the results of the 2002 listed in table 7. The concentration of heavy metals underwent assessment within the four environment types – soil, roots, tillering zone and grass swards.

Soil has been the environment with a significant concentration of heavy metals. We have determined the highest concentrations of heavy metals in six cases: Cd - 2.11, Co - 8.23, Cr - 50.13, Pb - 36.26, Fe - 4552.27 and Ni - 44.94 $mg.kg^{-1}$. The average values have been determined for Mn - 258.91$mg.kg^{-1}$. There had been the lowest concentrations of Zn - 27.90 and Cu - 6.58 $mg.kg^{-1}$ in soil. The concentration of the elements Cd, Co, Cr, Pb, Fe and Ni was significantly higher in soil than in the biomass of grass vegetation. In the analyzed plant parts were significantly concentrated heavy metals in roots, followed by tillering zone and significantly the lowest content was recorded in the aboveground part of grass biomass.

Table 7. Concentration of the heavy metals in soil and grass swards biomass (mg.kg^{-1}) in 2002

Assessed environment	Heavy metals								
	Cd	Co	Cr	Pb	Zn	Mn	Cu	Fe	Ni
Soil	2.11 c	8.23 c	50.13 d	36.26 c	27.90 a	258.91 b	6.58 a	4552.27 d	44.94 d
Roots	1.85 c	6.12 b	28.48 b	35.40 c	130.31 b	291.79 bc	20.91 c	2013.73 c	16.29 c
Tillering zone	1.26 b	5.65 b	42.55 c	20.56 b	135.35 b	333.38 c	12.55 b	1644.84 b	10.72 b
Aboveg. Sward	0.79 a	2.11 a	8.95 a	5.62 a	34.72 a	78.18 a	4.67 a	183.06 a	2.53 a
LSD $\alpha_{0.05}$	0.296	0.589	2.698	5.445	10.587	52.159	1.926	283.739	4.644

a, b, c, d - significant differences

Table 8. Concentration of the heavy metals in soil and grass swards biomass (mg.kg^{-1}) in 2009

Assessed environment	Heavy metals					
	Cd	Co	Cr	Pb	Cu	Ni
Soil	0.83 b	5.34 b	25.14 b	22.98 b	4.54 a	6.81 a
Roots	0.66 ab	4.36 b	45.53 c	23.66 b	9.95 b	22.49 b
Sward	0.55 a	0.97 a	14.13 a	4.28 a	3.25 a	2.63 a
LSD $\alpha_{0.05}$	0.217	2.320	6.697	4.644	1.809	6.506

a, b, c - significant differences

The concentration of heavy metals in plant tissues also researched Andráš et al., (2007). They state that the highest content of metals is in the roots, then in the leafs and in the stalks. The flowers, seeds and fruits contain heavy metals at least. Determination of heavy metals in soil and biomass of grass vegetation was repeated in 2009 at the same locations (Table 8). Content of Cd, Co, Cr, Pb, Cu and Ni in soil and biomass of grass vegetation (roots and swards) was evaluated. The lowest content of heavy metals in the aboveground biomass of grass swards, a significant increase occurred in the soil, heavy metals are mostly concentrated in the biomass of roots was statistically recorded. There has been the highest concentration of heavy metals in roots and soil. The similar results have been included in the studies by Klobušický & Kopec (1997), Hecl et al., (2005).

The cultivated plants have different abilities to accept and accumulate risk elements. We can conclude that the grass species don't accumulate excessive amounts of heavy metals (in comparison with the soil and roots) in the aboveground part of biomass. It is considered that the transport of hazardous elements to the aboveground plant parts blocks Caspari's strips in endodermic cells of the root (Wenzel et al., 1999). Alloway (1990) notes that mobility of ions decides about the translocation of heavy metals elements and indicates that Cr and Pb belong to the least mobile elements. We recorded identical results in both years of evaluation. Content of Cr was 3 times higher and Pb 6 times higher in roots than in aboveground parts of grass.

4. CONCLUSIONS

The results confirm the importance of non-production functions of grass swards that bring enormous ecological, environmental and social effect even if the value of these functions can not be monetised.

- The lowest amounts of the root biomass were recorded on the temporary grass swards (TGS) - 7.30 t.ha^{-1}of dry mass, significantly higher amounts on the over-sown grass swards (OGS) - 7.79 t.ha^{-1} and the highest amounts on the permanent grass swards (PGS) - 8.27 t.ha^{-1} of dry mass.
- The specific nitrogen stimulating influence over root biomass production has been proven; a significantly the highest root biomass amount on the grass swards fertilized at higher doses - 180 kg N + 30 kg P + 60 kg K.ha^{-1} (8.3 t.ha^{-1} of dry mass).
- The total grass swards biomass accumulate 362.7 kg.ha^{-1} N, 41.8 kg.ha^{-1} P, 252.1 kg.ha^{-1} K, 115.5 kg.ha^{-1} Ca, 49.7 kg.ha^{-1} Mg average.
- The production of the root biomass was significantly higher in dry years than it in climatically normal and humid years.
- R/S ratio of the assessed grass swards achieved the values from 4.02 to 5.16.
- The highest concentration of heavy metals was in roots of grass swards and soil.

We recommend that the pasture cultivation system undergoes more intensive application on PGSs or OGSs. The permanent grass swards prove more ecological stability, better adaptation to the given locality as TGSs. They have been capable of providing adequate root biomass together with optimal mineral nutrition (8.3 t.ha^{-1}) and the aboveground biomass (6.3 t.ha^{-1}). The TGS cultivation system has been more economically demanding and has invaded the ecosystem balance. Both the aboveground and underground biomass amounts (7.3 t.ha^{-1} or 5.8 t.ha^{-1})

have been reduced on the TGS in comparison with the natural vegetation to a great extent.

From the point of view of the environmental functions, the grass swards root system constitutes some biological barrier for crop contamination by heavy metals concentrated in soil. There has been the highest concentration in soil and the reduced one in the tillering zone. The significantly lower heavy metals content has been determined in the aboveground part of vegetation. No heavy metals contamination risk was identified in the aboveground biomass, used as forage for livestock.

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