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ROLE OF NON-PRODUCTIONAL FUNCTIONS OF GRASSLAND IN SOIL PROTECTION AND ENVIRONMENT

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Abstract. There is more than 800 000 ha of grassland in Slovakia. Besides its primary productional-function, grassland has also non-productional functions, which are performed mainly by its root biomass. The amount of roots in grassland soils is several times higher in comparison with annual crops on arable land. In grassland soil there is about 7.3 – 8.3 t DM (dry matter).ha^{-1} of root biomass depending on grassland type, its management and mineral nutrition.

The root biomass of grassland is an important resource of organic matter, which improves soil structure and fertility. A dense rooting of turf layer and a higher humus content are important for better utilisation of soil humidity and cause the high ability to protect soil against nutrient leaching into water resources.

The root biomass is also a resource of nitrogen and other mineral substances. Their accumulation in the root biomass is following: N - 112, P - 11.8, K - 60, Ca - 28 and Mg - 18 kg.ha^{-1}. In the process of mineralisation they become the potential nutrients for the further grassland production. Thus the root system contributes to an organic matter cycle and to the cycle of mineral nutrients in grassland ecosystem.

The root system has also an important role in the environment protection. Besides its erosion-controlling role it also protects the aboveground biomass against the increased concentration of heavy metals, which could penetrate otherwise the food-chain. The roots work as a certain biological barrier of the first contact of the sward plants with heavy metals elements in the soil. There is concentrated the highest level of heavy metals, it decreases in the tillering zone and their substantially lower level was found in the tissues of the above-ground parts of the sward which serve as a feed-food-chain resource.

Key-words: environment, grassland ecosystem, heavy metals, root biomass, R/S ratio.

1. INTRODUCTION

Grasslands occupy more than 800,000 ha of agricultural land in Slovakia. Their main agricultural function is the primary production, which form the source for livestock feeding.

In mountain and submontane regions grassland has besides its production function also a non-production and stabilizing functions. It forms an important part of country' s ecological stability, with a root system playing a big role. The root system having its physiological functions, also influences the physical state of soil, enriches soil by organic matter, increases soil retention capacity and protect soil against erosion. The dense root system forms a biological filter in soil, supports its nutrients balance, protection of ground water and accumulation of heavy metals and toxic substances.

The root production of plants represents 50-80 % of total plant biomass. Our aim was to study the formation of root system, root production and accumulation in two different grassland types.

2. MATERIAL AND METHODS

This contribution is a compilation (synthesis) of the research results of several studies at Grassland and Mountain Agriculture Research Institute (GMARI), Banská Bystrica.

Root accumulation and production were studied at two different grassland systems and under four different fertilization regimes in 1992 -1998. A field trial was established in Banská Bystrica (central Slovakia) at the site Suchý vrch – Radvaň (altitude: 460 m a.s.l., average annual temperature 6.3°C, during the growing season 13.6; average annual rainfall 848 mm, during the growing season 451 mm), the snow cover lies 80 days. The Soil is a cambisol with $pH_{KCl} = 4.3$, $C_{OX} = 35.0$ g.kg^{-1} and $N_t =$ 2.74 g.kg^{-1}.

The two types of grassland, PG-permanent (seminatural) grassland and TG – temporary (sown) grassland were treated in four ways:

1. untreated control
2. 30 kg P + 60 kg K . ha^{-1}. yr^{-1} (fertilized in spring in one dose)
3. 90 kg N + 30 kg P + 60 kg K . ha^{-1}. yr^{-1}(3x30 kg N to each cut, PK in spring)
4. 180 kg N + 30 kg P + 60 kg K . ha^{-1}. yr^{-1}(3x60 kg N to each cut, PK in spring)

Both grassland types were under 3 cut regime.

The permanent grassland belongs to association *Trisetum flavescentis* (union *Arrhenatherion*). The temporary grassland was established in spring 1991 by sowing the following amounts of seeds per hectare: *Dactylis glomerata* cv. Rela (4 kg), *Festulolium* cv. Felina (12 kg), *Lolium perenne* cv. Metropol (8 kg), *Trifolium pratense* cv. Sigord (3 kg) a *Trifolium repens* cv. Huia (2 kg. ha^{-1}).

Root sampling was conducted at the beginning of growing season, at three cuts and in autumn at the end of growing period. Roots were sampled by steel cylinder (Ø = 50 mm) into the soil depth of 100-120 mm in 20 replicates. The increase in root growth was measured by means of small containers of metal net, which were put into the soil profile at the beginning of the growing season to a depth of 100 mm. At the end of growing season, containers were pulled out of the soil and the amount of roots intergrown in the nets was measured. This measurement represented the annual root growth increase. Sampled roots were washed by a stream of lukewarm water, dried at 60 °C and weighed.

In 1997-1999 heavy metal concentrations were monitored on seminatural grasslands of Starohorské vrchy region at the three different sites of different altitudes:

- Radvaň (480 m a.s.l.), north-inclined slope of 12-15°; soil type: rendzina soil on line-stone
- Panský diel (1000 m a.s.l.), south-west inclination, slope of > 20 °, cambisol
- Kráľova studňa (1300 m a.s.l.), south-east inclination, slope of 20-25°, shallow rendzina soil on lime-stone.

Soil and plant samples were taken five times during the growing season: once a month (May - September) from undistorted sward and analysed in laboratory by atomic absorption analyser to assess concentrations of Cd, Co, Cr, Pb, Zn, Mn, Cu, Fe and Ni.

The results were treated by multifactorial analysis of variance at 95% level of statistical significance.

3. RESULTS AND DISCUSSION

Root biomass of grassland is an important resource of organic matter, which improves soil structure and fertility. Its amount is several times higher than that of annual plants on arable land. The amount of root biomass in the same grassland represents the highest percentage of total grassland biomass per year (roots – 40 %, tillering zone – 28 % and above-ground sward – sum of yields of all cuts – 32 %). The root biomass forms 7.3 – 8.3 t of DM. ha^{-1} depending on grassland type and management and on mineral fertilisation.

In comparison of the two grassland types during six years (1993-1998) the lowest amount of root biomass was found on sown grassland (DTP) – 7.3 t DM . ha^{-1} and the highest one on permanent grassland (TTP) – 8.3 t DM . ha^{-1} (Tomaškin, 2000). The similar results were published also in the other scientific articles: Tesařová (1990), Gáborčík, Kohoutek (1999). Because of their limited life existence and more slow decomposition grasses belong to the crops which the most enrich the soil with organic matter. This organic matter is typical of wider ratio C:N (30-50:1), its mineralisation is slow and thus a more stable humus is developed which improve soil structure for a longer time. The matted roots of turf layer and increased humus content cause the better utilisation of soil moisture and soil ability to control nutrients' leaching into water resources. The amount of root biomass is influenced also by mineral fertilisation. Effect of mineral nutrients often varies. Our results confirm the lowest root production at unfertilised swards (7.3 t DM. ha^{-1}); balanced root production at swards with P - 30 + K - 60 kg. ha^{-1} and N - 90 + P - 30 + K - 60 kg.ha^{-1} (7.7 – 7.8 t DM. ha^{-1}); the highest root production being at application of N - 180 + P - 30 + K - 60 kg. ha^{-1} (8.3 t DM. ha^{-1}). The certain stimulating effect of nitrogen on root production was confirmed (Tomaškin, 2000, Jančovič, 1985, Gregorová et al. 1989). The root biomass also supplies the soil with nitrogen and several other minerals. Their accumulation in root biomass is following: N - 112, P - 11.8, K - 60, Ca - 28 and Mg - 18 kg.ha^{-1} (Tomaškin, 2000). These nutrients are available for further forage production and thus the root system forms a part of the cycle of organic matter and mineral nutrients in grassland ecosystem.

Root production is also influenced by climatic and weather conditions in different years. In recent years a menace of dry years became very real. Impact of dry weather on grassland root system can be seen in the 1992 results, when rainfall during growing period was only 287 mm (annual rainfall was 724 mm) and average temperature during growing period 15.8 °C (annual temperature was 9°C). Also years 1993 and 1997 were quite dry when rainfall during growing season achieved only 336.5 and 502.8 mm, respectively.

The drought resistance of grassland depends (besides the above-ground cover) on size of root system, its depth and density. In 1992 the root biomass on permanent and sown grassland was 10.2 and 9.5 t DM. ha^{-1}, respectively This amount of root production is in accordance with the root production in normal climatic years or even exceeds it. The anatomical and morphological characteristics can explain the root adaptation to drought stress and the increased root production – also at the expense of lower aboveground plant production. The root adaptation to drought stress decreases the water loss by transpiration and root is also able to take water from the deeper soil layers, which enables it to grow also in conditions of water shortage. In normal climatic years (1995, 1996 and 1998) the root production varied from 6.0 – 8.00 t DM.ha^{-1}. The amount of roots in total biomass yield decreased because of increased water access in soil (Tomaškin, 2000).

Root/short (R/S) ratio is the next important parameter that influences the drought resistance of grass sward. Its higher values indicate the higher drought resistance. In 1992 R/S was at permanent and sown grassland 7.7 and 4.6, respectively. The results confirm the higher ecological stability of permanent grassland to resist the drought. This tendency was confirmed also in other dry years (Tomaškin, 2000).

The negative effect of drought on forage production can be also eliminated by mineral fertilisation, mainly by nitrogen. The highest yields of root biomass were achieved on swards that received optimal (or higher) doses of nitrogen, phosphorus and potassium. In 1992 root production on fertilised and unfertilised sward was 11-12 and 8-9 t DM. ha^{-1}, respectively. Similar results were found in other years, too (Tomaškin, 2000).

The root system of grass sward is also important in the protection of environment. It has an anti-erosion effect and controls the heavy metal concentration in aboveground cover and thus protects the food chain (Tab. 1).

Tab. 1. Average heavy metal concentrations in soil and biomass of grass sward from three sites of Central Slovakia (mg . kg^{-1})

Material tested	Heavy metals								
	Cd	Co	Cr	Pb	Zn	Mn	Cu	Fe	Ni
Soil	2.35	13.17	5.99	151.09	48.70	589.27	11.42	2192.90	11.24
Roots	2.27	6.92	7.62	24.45	208.21	353.83	39.25	3569.37	12.52
Sward	1.61	5.93	3.93	12.38	103.93	330.28	11.49	1351.44	8.18

Comparison of different media (soil, roots, and above-ground biomass) confirmed the highest concentrations of Cd, Co, Pb and Mn in soils (2.35, 13.17, 151.09, 589.27 mg.kg^{-1}, respectively). Soil concentration of Cr, Fe and Ni (5.99, 21.92, 11.24 mg.kg^{-}1 respectively) was medium and those of Zn and Cu the minimum level

(48.71, 11.42 mg.kg^{-1} respectively).

Of plant biomass the roots are medium where the heavy metals concentrate considerably. The highest concentration was found with Cr (7.62 mg.kg^{-1}), Zn (208.21 mg.kg^{-1}), Cu (39.25 mg.kg^{-1}), Fe (35.69 mg.kg^{-1}) and Ni (12.52 mg.kg^{-1}). The other elements occurred at medium level and the lowest values were not determined.

The above-ground biomass showed the different pattern of heavy metal concentrations: their lowest values were assessed with seven elements: Cd (1.61 mg.kg^{-1}), Co (5.93 mg.kg $^{-1}$), Cr (3.93 mg.kg $^{-1}$), Pb (12.38 mg.kg^{-1}), Mn (330.28 mg.kg^{-1}) and Ni (8.18 mg.kg^{-1}). The concentrations of Zn 103.93 mg.kg^{-1} and Cu 11.49 mg.kg^{-1} were of average value.

The roots function as a biological barrier of the first contact of grassland with heavy metals in the soil. There is the highest concentration of heavy metals, it declines in the tillering zone and far lower heavy metals' concentration was found in plant tissues in the aboveground cover. The content of heavy metals in forage production is thus not so dangerous in case of feed-food-chain because root system can accumulate them. The similar results were published also in the other scientific articles: Klobušický, Balcar (1997), Klobušický, Kopec (1997), Petříková (1990), Hecl et al. (2005).

4. CONCLUSIONS

Our results confirm the need to utilise the system of forage production on permanent grassland more intensively. The permanent grassland is ecologically more stable and more adapted to the site conditions and combined with optimal mineral fertilisation it can give the appropriate root and above-ground plant production: 8.3 and 6.3 t DM. ha^{-1}, respectively. The system of sown grassland is economically demanding and changes the dynamic balance of ecosystem: in comparison with permanent grassland the amount of under-ground and aboveground biomass has essentially declined (7.3 and 5.8 t DM. ha^{-1}).

The heavy metal concentrations in soil and plant biomass in the three years (1997-1999) varied considerably. Evaluation of these concentrations in the three different media confirmed their highest levels in soil and roots. These media serve as a stock of elements for the aboveground biomass, which, however, doesn't intake such an amount to balance the heavy metal concentrations in the whole plant. The values of heavy metal concentrations of the aboveground part of the sward are constantly the lowest and considerably different when comparing with roots and soil values.

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