Influence of different systems of grazing, type of swards and fertilizing on underground phytomass of pastures

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ABSTRACT

Problems concerning total dry weight and distribution of underground phytomass were studied in a pasture trial at Rapotin near Šumperk, the Czech Republic in the period 1995–1999. The total weight of dry underground pasture phytomass (DUP) was 976 g/m^2 (5-year average) in a soil layer of 0–200 mm (both live and dead roots). The DUP was significantly increased by mineral fertilizers (90 kg N/ha, 30 kg P/ha a 90 kg K/ha). The weight of DUP was not significantly influenced by a grazing system, renewal or resowing of the original grassland. In unfertilized plots, DUP weight amounted to 989 g/m^2, i.e. 92 g/m^2 (8.6%) less than in fertilized plots in the period 1996–1999. In the same period, under the grassland exploited by rotational grazing 1142 and under continuous grazing 1082 g/m^2 DUP were determined, i.e. by 60 g/m^2 (5.5%) less. The highest DUP weight in the period 1996–1999 was found in autumn 1997 (1222 g/m^2) immediately before achieving the maximum forage yield in May 1998. In a layer of 0–20 mm, 54.6% of the total DUP was found. In this surface layer, significant increase in the DUP weight was found in fertilized plots. In 1999, some 88.5 and 90.2% of DUP were concentrated in unfertilized (903 g/m^2) and fertilized (952 g/m^2) plots, respectively in a layer of 0–100 mm.

Keywords: underground phytomass; pasture; fertilizing; grazing systems; roots distribution

The underground phytomass of grasslands is created primarily by fascicled grass roots, their projections and also roots and rhizomes of various herb species. The vertical distribution of plant underground organs is not uniform but roots decrease from the soil surface towards lower soil layers. In the subsurface layer, the most intensive activity occurs of microorganisms, gas exchange between soil and atmosphere, reserve storage, vegetative propagation and the largest sorption of water and nutrients. The lower layer is insignificant from the viewpoint of quantity but to a great extent participates in nutrient and water withdrawal from lower layers and in biogeochemical cycles (Rychnovská et al. 1985).

The root/shoot ratio reaches the highest value (even over 10) both on dry and waterlogged sites due to slow decomposition and larger accumulation of disintegrated dead roots. Decomposed dead roots of grasslands enrich soil with organic matter and markedly affect soil properties. Fiala et al. (1999, 2001) found favourable effects of grass roots on soil properties in clear-cut induced by air pollution. Formation of the larger amount of active roots results also in the higher resistance of stands to changes of outside conditions. The underground biomass of grasslands is a source of assimilates and there is an extraordinarily active biological surface, the effectiveness of which in the ecological balance of landscape was not yet fully recognized and appreciated (Fiala 1996).

If grasslands are grazed then (according to Greenwood and Hutchinson 1998) the growth of roots is affected not only by defoliation and soil trampling but also by changes in the botanical composition of stands. Decreasing the root weight after frequent defoliation is ascribed to the translocation of storage substances from underground to above-ground plant organs. Turnover of roots under grasslands takes 2–3 years extending to 4 years during dry years (Fiala 1993).

MATERIAL AND METHODS

Determination of the underground biomass weight and distribution was carried out in a pasture at the Rapotín locality at an altitude of 400 m a.s.l., from geomorphologic point of view belonging to Hrubý Jeseník. Long-term total precipitation amounts to 727 mm, long-term mean annual temperature 6.9°C. Soil texture class and type is represented by sandy-loam Cambisol developed on the mica schist deluvium. Original pasture stand belongs to the *Lolio-Cynosuretum* Tüxen 1937 association.

Fertilization variants since 1996

1) H0 – unfertilized, without mineral fertilizers, animal excrements only
2) H1 – fertilized in spring 30 kg N, 30 kg P, 90 kg K and further after the 1st and the 2nd harvest 30 kg N/ha, in total 90 kg mineral N/ha per year. In 1995, stands H1 were fertilized by a dose of 60 kg N/ha only.

Results achieved were obtained and processed under the financial support of the MSM Research Plan No. 432100001.

Stand variants

1) PG – original (permanent) grassland established on arable land in 1985.
2) RG – resown grassland (May 1995), no-tillage resowing by an SE-2-024 machine – the mixture of *Lolium perenne* L. (cv. Bača, 6.0 kg/ha), *Poa pratensis* L. (cv. Slezanka, 8.0 kg/ha) and *Trifolium repens* L. (cv. Ovčák, 6.0 kg/ha).
3) NEG – newly established sward, the mixture of *Lolium perenne* L. (cv. Mustang, 6.0 kg/ha), *Poa pratensis* L. (cv. Slezanka, 4.0 kg/ha), *Phleum pratense* L. (cv. Sobol, 3.0 kg/ha), *Festulolium* (cv. Felina, 6.0 kg/ha), *Trifolium repens* L. (cv. Jura, 4.0 kg/ha) and *T. pratense* L. (cv. Radegast, 2.0 kg/ha).
4) NEG-2 – newly established grassland consisting of 12 varieties of 8 following species: *Lolium perenne* L. (cv. Mustang, 2.4 kg/ha and cv. Tarpan, 2.1 kg/ha), *Poa pratensis* L. (cv. Slezanka, 2.0 kg/ha), *Phleum pratense* L. (cv. Sobol, 3.0 kg/ha), *Festulolium* (cv. Felina, 6.0 kg/ha and cv. Hykor, 4.0 kg/ha), *Trifolium repens* L. (cv. Jura, 2.0 kg/ha and cv. Hájek, 2.0 kg/ha), *T. pratense* L. (cv. Radegast, 2.0 kg/ha and cv. Start, 1.0 kg/ha), *Festuca rubra* ssp. *rubra* L. (cv. Táborská, 2.0 kg/ha) and *Trisetum flavescens* (L.) Beauv. (cv. Rožnovský, 1.5 kg/ha).

Variants of exploitation (grazing)

The grassland was used alternately in such a way that in the first grazing cycle it was mowed and forage was conserved and next three growths were grazed. The stands were grazed by beef breeds and their crossbreeds at a loading of 1.7–2.0 cattle units/ha. In the year of the experiment establishment (1995), the stands were harvested by mowing only.

Rotational grazing (A) – the first growth of forage was mowed for conservation purposes and in next three grazing cycles the stand was grazed in grazing maturity by the system of rotation grazing.
Continuous grazing (B) – after harvesting and evaluation of the first cut the newly growing stand was continually grazed until mid-November.

Underground biomass samples were taken by the method of monoliths according to Fiala (Rychnovská et al. 1987) always in autumn after the growing season. The soil monolith was taken by means of a hollow steel cylinder of an inner diameter of 50 mm. The soil sample with underground phytomass was taken from four repetitions of two samples from the soil profile to a depth of 200 mm. Immediately after sampling the soil monolith, the soil sample was divided into two parts. In 1995–1998, it was 0–20 mm and 20–200 mm and in 1999, 0–100 mm and 100–200 mm.

After plant biomass separation from soil particles, washing by water was carried out on screens of 1.0mm mesh diameter and the biomass was then naturally dried. Results were processed by the ANOVA method with the multiple range test according to Tukey through Statgraphics 7.0 program. After determining the effect of the grazing system the DUP weight correction was carried out for soil imbalance (Chloupek 1996) because in 1995, higher values of DUP weight were found in block B. A more detailed description of the experiment is given in a PhD Thesis of Hejduk (2000b).

Table 1. Effects of fertilization on the total DUP weight of pastures (g/m^2) in 1996–1999

Fertilized (H1)	1 081
Unfertilized (H0)	989
Difference |H1–H0|	92*
$D_{T0.05}$	81.7

RESULTS AND DISCUSSION

Total weight of dry underground phytomass

The total weight of dry underground phytomass of pasture stands (hereafter DUP) amounted to on average 976 g/m^2 in a soil layer of 0–200 mm for a period of five years (1995–1999).

Highly significant differences (p = 0.01) were found between particular years. If the initial year 1995 (when H1 variants were fertilized by 60 kg N/ha only) was not taken into account the DUP weight was also significantly affected by fertilization (p = 0.05) (Figure 1 and Table 1). In fertilized plots, DUP was 9.3% higher than in unfertilized plots.

It is generally given in the literature that NPK fertilization decreases the weight of underground phytomass of grasslands. Straka (1999) states for *Polygono-Cirsietum palustris* the DUP weight from 1929 (without fertilization) to 1470 g/m^2 (180 kg N + PK). Úlehlová (1993) found the DUP weight amounting to 2780 g/m^2 in an unfertilized

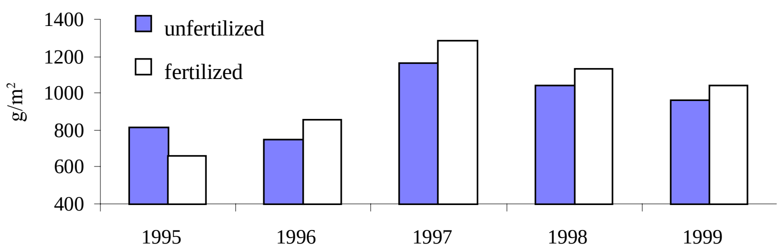

Figure 1. Effects of fertilization on the weight of dry underground phytomass in particular years

Table 2. Effects of the grazing system on the total DUP weight (g/m^2) in 1996–1999 (values corrected for soil imbalance)

Rotational grazing (A)	1 142
Continuous grazing (B)	1 082
Difference |B–A|	60.1
$D_{T0.05}$	89.5

Table 3. The rate of white clover in dry matter yield of pasture herbage (% in 1st cut)

Fertilizing level	1996	1997	1998	1999
Unfertilized	14.2	55.3	35.6	26.4
Fertilized	5.7	40.6	31.0	20.7

meadow community on a mesohygrophytic site at Kameničky in a soil layer of 0–160 mm. These results correspond also to the opinions of some authors that optimum conditions for the maximum growth of roots differ from those for the high production of aboveground biomass. Straka and Hrabě (2000), however, found the highest annual increment of underground biomass on a meadow site at Kameničky (measured in particular cuts) in a fertilized variant with 90 kg N + PK. Higher doses of nutrients no longer increased the DUP weight. On a grazing site at Rapotín (Hejduk 2000a, b), mineral fertilization with 90 kg N + PK significantly increased both forage production and DUP weight as against a variant unfertilized with mineral fertilizers. The highest DUP weight was found in autumn 1997, i.e. before reaching the maximum forage production in spring 1998. According to Straka (1999), there is a positive correlation between these parameters in the course of years in the same stand.

In the rotational system of grazing, significantly lower DUP weight was found according to Table 1. However, the fact was given by soil properties because already in 1995 when the area was not grazed higher values of DUP weight were found there. For the correction of values according to the year 1995, it was found that owing to continuous grazing the DUP weight was inconclusively decreased (4-year average) by 5.3% as compared with rotational grazing (Table 2). Results of Fiala and Zelená (1994) who found that after intensive defoliation the DUP weight was decreased by 67% as compared with a non-mowed grassland were confirmed. According to Rieder (1983), the lowest DUP values within grasslands are found under intensive pastures. Greenwood and Hutchinson (1998) investigated the total length of roots in a soil layer of 0–750 mm. In an area of 1 m^2, they found 196 km in a non-grazed grassland and 169 or 161 km in a pasture with low or high load. On the other hand, Straková and Hrabě (2001) mention that the total DUP under intensive swards (mowed annually 15–20 × to a height of 35 mm) reach 1255.5 g/m^2 in a layer of 0–200 mm during autumn sampling, i.e. more than in pastures at Rapotín harvested 4 times a year. It is evidently given by the different botanical composition of grasslands and higher variation of plants and root mineralization after their damage by grazing animals.

Between particular types of grassland, significant differences were not found. The highest weight of underground phytomass was found in newly established grasslands (NEG = 1001 g/m^2, NEG-2 = 992 g/m^2), lower one under original grasslands (PG = 976 g/m^2) and oversown grasslands (RG = 934 g/m^2).

The rate of white clover in pasture swards reached its maximum in 1997, in the same year as the maximum DUP weight (Table 3). Biologically fixed N can as the low level of fertilising support DUP weight. The succession of individual types of sward was published by Hejduk (2000a).

The larger amount of roots does not provide automatically preconditions for a higher yield potential. They have shown that optimum conditions for the maximum growth of roots do not identify with suitable conditions for the high production of aboveground biomass. Sobotik (1996) found that the underground phytomass of grasslands at alpine locations was usually much larger than in valleys. An alpine pasture in Austria at an altitude of 1700 m showed 1890–4850 g/m^2 DUP whereas otherwise under the same conditions at an altitude of 1100 m it reached only 490–940 g/m^2.

Vertical distribution of underground phytomass

In 1996–1998, the DUP weight in all variants of pastures amounted to a mean value of 546 g/m^2 at a depth of 0–20 mm (Table 4). The quantity represented 54.6% of the total underground phytomass weight (0–200 mm). A year-class, fertilization and grazing system showed sig-

Table 4. Effects of the grazing system and fertilizing on the total weight and stratification of DUP in pastures, 1996–1998 (g/m^2)

Grazing system	Fertilization variant	Soil layer (mm) and DUP proportion (%)				
		0–20	%	20–200	%	0–200
Continuous grazing	H0	5.77	54.2	4.88	45.8	10.65
	H1	6.16	56.1	4.82	43.9	10.98
Rotational grazing	H0	4.90	54.4	4.11	45.6	9.01
	H1	5.80	53.4	5.07	46.6	10.87

Table 5. Effects of fertilization on the DUP weight (g/m^2) at a depth of 0–20 and 20–200 mm in 1996–1998

	0–20 mm	20–200 mm
Fertilized (H1)	597	495
Unfertilized (H0)	534	449
Difference |H1–H0|	63.0*	46.0
$D_{T0.05}$	54.5	61.3

Table 6. Effects of the grazing system on the DUP weight (g/m^2) at a depth of 0–20 and 20–200 mm in 1996–1998 (values corrected for soil imbalance)

	0–20 mm	20–200 mm
Rotational grazing (A)	627	546
Continuous grazing (B)	596	485
Difference |A–B|	30.3	60.5
$D_{T0.05}$	61.3	69.2

Table 7. Weight and stratification of DUP in pastures in 1999 (g/m^2)

Grazing system	Fertilization variant	Soil layer (mm) and DUP proportion (%)				
		0–100	%	100–200	%	0–200
Continuous grazing	H0	9.50	89.5	1.12	10.5	10.62
	H1	10.04	91.0	0.99	9.0	11.03
Rotational grazing	H0	8.55	89.9	0.96	10.1	9.51
	H1	9.00	91.2	0.88	8.8	9.87

nificant effects on differences in the underground biomass weight at a depth of 0–20 mm ($p = 0.05$). In the surface layer, significantly higher values of the DUP weight occurred in fertilized variants (Table 5). After correction for soil imbalance, significant differences between grazing systems were not found in the layer. Straková and Hrabě (2001) found 69.4% DUP in intensive lawns in a layer of 0–20 mm in the course of autumn sampling, which confirmed that the depth of rooting decreased with the intensity of exploitation.

In the lower 20–200 mm layer under investigation, differences between particular variants were insignificant (Tables 5 and 6). Greenwood and Hutchinson (1998) found that a non-grazed grassland showed lower proportion of roots in a subsurface layer of 0–50 mm than an intensively grazed pasture, however, it exhibited higher proportion of roots in the lower layer of soil.

In evaluating soil layers of 0–100 and 100–200 mm in 1999 (Table 8) the underground phytomass mean weight reached the value of 922 g/m^2 in the upper layer representing 89.3% of the total underground phytomass (0–200 mm) in the given year (88.5 in unfertilized and 90.2% in fertilized grasslands). With respect to the limited number of data (one-year results), results were not significantly different (Table 8). In meadows on a mesophytic site, Velich (1986) concluded that 82–88% of root biomass was concentrated at a depth of 0–100 mm and 96–98% at a depth of 0–200 mm. In intensive pastures, Rieder (1983) mentions 95% in a layer of 0–100 mm and 3.6% of the total DUP weight in a layer of 100–200 mm.

Results obtained in 1999 show that more underground phytomass is formed in fertilized variants in the subsurface layer whereas in unfertilized variants, non-significantly more roots penetrates also to a deeper layer of 100–200 mm. The deeper root system, the better its capacity to uptake moisture and to resist stress induced by draught (Straková and Hrabě 2001).

Determination of the underground organ weight in grasslands is considerably difficult and work demanding. Table 9 shows that with respect to the high variability of values it is necessary to carry out a considerable number of measurements in order to determine conclusions. According to Fiala (Rychnovská 1993), increment and root decomposition heterogeneity under grasslands is enormous and, therefore, all calculations are qualified estimates only. Rieder (1983) demonstrates the fact by data indicating that short-lived roots of a 2–8 week life span form 80% roots originating in the course of a year.

It is necessary to evaluate the DUP weight variability from more aspects such as grassland type, ecological conditions of a site, the course of succession in newly sown communities and resulting changes in species composition.

In the future, in the study of roots of grasslands it will be necessary to use image analysis technology making possible to determine the length, surface and volume of roots (Greenwood and Hutchinson 1998). Precise evaluation of the parameters can provide valuable data for better understanding the ecological role of roots.

Table 8. Effects of fertilization on the DUP weight (t/ha) in layers 0–100 and 100–200 mm in 1999

	0–100 mm	100–200 mm
Fertilized (H1)	952	93
Unfertilized (H0)	903	104
Difference |H1–H0|	49	11
$D_{T0.05}$	180.6	21.6

Table 9. Values of the mean DUP weight (g/m^2) variability, standard deviation, coefficient of variation (%) and variation range (g/m^2) in particular years

Year	Mean	s	V_k	Maximum	Minimum	Variation range
1995	740	314	42.4	1 488	278	1 210
1996	801	212	26.5	1 451	407	1 044
1997	1 224	359	29.3	2 313	586	1 727
1998	1 088	352	32.4	2 198	548	1 651
1999	1 026	371	36.2	1 992	453	1 538

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Received on July 2, 2002

ABSTRAKT

Vliv rozdílných systémů spásání, typu porostu a hnojení na podzemní fytomasu pastevních porostů

Problematika celkové hmotnosti a distribuce podzemní fytomasy pastevních porostů byla exaktně studována v období 1995–1999 v pastevním pokuse v Rapotíně u Šumperka v asociaci *Lolio-Cynosuretum* Tx. 1937. Celková hmotnost suché podzemní fytomasy pastviny (SPF) byla ve vrstvě půdy 0–200 mm v průměru pěti let 976 g/m^2 (živé i mrtvé kořeny). Hmotnost SPF byla průkazně zvýšena vlivem minerálního hnojení (90 kg N/ha, 30 kg P/ha a 90 kg K/ha). Na plochách bez minerálního hnojení byla zjištěna hmotnost SPF v průměru sledovaných let 989 g/m^2, což je o 92 g/m^2 (8,6 %) méně než na parcelách minerálně hnojených. Při rotačním systému spásání (oplůtková pastva) byla zaznamenána neprůkazně vyšší hmotnost SPF oproti kontinuálnímu systému spásání o 60 g/m^2 (5,5 %). Nejvyšší hmotnost SPF byla v období 1995–1999 zjištěna na podzim 1997 (1222 g/m^2) bezprostředně před dosažením maximálního výnosu píce (květen 1998), v roce kulminace jetele plazivého v porostech. Ve vrstvě 0–20 mm bylo za období let 1996–1999 stanoveno 54,6 % celkové SPF do hloubky 200 mm. V této vrstvě byla na hnojených variantách průkazně zvýšená hmotnost SPF o 63 g/m^2 (11,8 %). Ve vrstvě 20–200 mm nebyly nalezeny průkazné rozdíly mezi variantami. Ve vrstvě 0–100 mm bylo v roce 1999 soustředěno 88,5 % SPF na nehnojených a 90,2 % SPF na hnojených variantách (903, resp. 952 g/m^2).

Klíčová slova: podzemní fytomasa; pastvina; hnojení; pastevní systémy; distribuce kořenů

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