Effect of fertilization on the distribution of root phytomass and the yield of meadow stands

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ABSTRACT

In 1998–2000 the effect of fertilization on the quantity, stratification of root phytomass and yields of dry mass on mesophyte meadow stands was studied. The root dry matter in the soil depth of 0.0–0.25 m was oscillated and the extreme values in individual samplings were found in 1998 (402–702 g/m^2). In 1999 and 2000 the oscillating minimum and maximum values of dry root phytomass in all were 418–622 g/m^2, 423–678 g/m^2, respectively. The mean values of dry root mass in unfertilized treatments ranged from 484 to 540 g/m^2. PK increased the values insubstantially (507–565 g/m^2). The higher nitrogen dose (200 kg/ha) decreased predominantly the total quantity of dry root phytomass by 36–102% was found in the control treatments, compared in the yield of dry harvestable above-ground mass. In the systematic $P_{40}K_{100}$ fertilization the root weight in slightly moisten years (1998 and 2000) was by 18–70% higher in comparison with the dry year 1999 when the root mass was 24% less. In the fertilization 200 kg/ha N(+PK) in the first two years of studies the root phytomass was less by 12% and 38% compared with the yield of the dry meadow fodder. The mean representation of root phytomass in the soil layer 0.0–0.1 m was in 1999–2000 in the control and PK treatments nearly the same, and created 88% from the total quantity. N(+PK) fertilization caused the displacement of the root phytomass towards the surface.

Keywords: permanent meadow stands; fertilization; root phytomass; vertical distribution

Meadows stands consist of a large spectrum of plants of herbaceous character, where usually monocotyledonous species, mainly grasses prevail above the other dicotyledonous species. This species variability affects the morphological variability too (Rychnovská et al. 1985, Mrkvička and Veselá 2002a, b). The importance of root phytomass at the creation of the structural soil state is underlined by Dannowski and Werner (1997). These authors consider the root density as a factor effecting mechanical and mainly soil retention abilities and root length being the crucial factors effecting water and nutrient uptakes. The size of root systems in individual species is conditional or genetic, ecological conditions and pratotechnical face of activities. Data on root phytomass of grass growths range in very wide intervals due to the different floristic composition, water and nutrient regimen of the stand, exploitation etc. The most often given values range from 1 to 59 t/ha (Klapp 1971, Rychnovská et al. 1985, Kobes and Šimek 1998 etc.). According to Tomaškin and Čunderlík (2002) the meadow ecosystem type highly affects root phytomass production. The lowest production (7.3 t/ha) was reached at the temporary grass stand and the highest, statistically significant root quantity was found at the perennial grass stand. The quantity of root phytomass was affected by mineral nutrition due to the simulative nitrogen influence. Úlehlová et al. (1981), Gáborčík and Kohoutek (1999) agree on the same findings. Titlyanova et al. (1999) state that the pure primary production of perennial grass stands is very high and ranges from 1000 to 4000 g/m^2 per year according to the ecological conditions, when at least 70% of pure primary production is allocated in underground organs.

The creation of underground organs is affected by fertilization not only by direct nutrient activities on the species but also indirectly by the change of floristic stand composition, for the individual species strongly differ in the size and morphology of the root system. Klimeš (2000) studied the influence of differentiated nutrient levels on the dynamics of species variability and the total space composition. He used Shannon's diversity index for the species diversity evaluation. Nitrogen fertilization has usually the highest effect on the above ground organs and roots, compared with the other nutrients. According Klečka et al. (1938) the nitrogen nutrition does not support only the creation of above ground organs, but also roots of

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Table 1. The treatment used in experiment

Variants	Fertilizing (kg/ha)		
	N	P	K
1	0	0	0
2	0	40	100
3	100	40	100
4	200	40	100

meadow species, having larger resorption area for the nutrient and water uptake.

The sizable root phytomass of grass stands is a significant-stabilising element, as storage of acceptable nutrients and energy. Tomaškin and Čunderlík (2002) state that the root dry mass ranges on average meadows from 2 to 8–10 t/ha. More than 70–80% of roots are concentrated in the soil layer till 0.1 m and only 2–5% of roots get into lower than 0.2 m. Rychnovská et al. (1985) mentioned that the vertical root position is not equal in the soil, but missing from the surface to the depth. The influence of PK-fertilization on the root system is less significant than the effect of nitrogen fertilization (Adalsteinsson and Jensén 1988).

The main factor on the meadow stands with the regulated water regime is the fertilization affecting the fodder yields. The yield level is limited by the complex relatively constant, pratotechnically unmanageable ecological factors. The set of these factors represents the ecological upper level of potential yields, which can be reached by the optimal manageable factors (Velich et al. 1944). The main nutrient mostly affecting the fodder yields of grasslands, dominating at the yield increase, is nitrogen (Hopkins et al. 1990, Mrkvička and Veselá 1997, Jančovič et al. 1999).

MATERIAL AND METHODS

The experimental studies were accomplished from 1998 till 2000 on the permanent meadow stand of mesophyte character. The experiment was accomplished by the method of randomised blocks in four replicates. The plot area was 30 m^2 (6 × 5 m). Table 1 is from treatments that were observed.

Table 2. Amount of root phytomass (dry matter g/m^2), years 1998–2000

Years	Term of sampling	Treatments of fertilizing			
		$N_0P_0K_0$	$N_0P_{40}K_{100}$	$N_{100}P_{40}K_{100}$	$N_{200}P_{40}K_{100}$
1998	1.	501	663	693	671
	2.	542	687	702	690
	3.	405	402	491	458
	4.	488	509	614	496
	average	484	565	625	579
	relative %	100.0	116.7	129.1	119.6
1999	1.	521	474	571	509
	2.	581	611	582	622
	3.	422	430	418	451
	4.	498	511	500	479
	average	506	507	517	515
	relative %	100.0	100.2	102.1	101.8
2000	1.	581	622	628	678
	2.	601	589	600	584
	3.	437	423	447	442
	4.	542	587	550	642
	average	540	555	556	586
	relative %	100.0	102.7	103.0	108.5
Average weight of root phytomass (t/ha)		5.10	5.42	5.66	5.59

The characteristics of the experimental locality was described in the paper Mrkvička and Veselá (2002a, b). For the quantification of underground organs the method using the defined volume of soil samples was used. Soil monoliths were sampled by the helps of a steel cylinder 70 mm in diameter in the following terms April 3, June 4, July 19, October 25. The volume mass for the evaluation of the root phytomass per 1 m^2 was determined in the soil layers 0.0–0.25 m. Immediately after sampling the root phytomass was separated by washing up, including live and withered but not destroyed underground organs. For the elimination of stand heterogeneity the samples were taken from four randomised punctures in each basic plot, i.e. from 16 places of fertilization treatments in total. For the study of vertical distribution of root phytomass in individual soil profile layers the monoliths were divided into 5 parts by 50 mm. Before placing them into polyethylene bags the aboveground parts of plants were cut off (above the soil surface). For the washing up of soil monolites the silone net bags and sieves with 0.5 mm mash were used. The samples of root phytomass were dried up by a natural way to a constant weight and weighed.

For obtaining comparable results all the values were recounted and expressed in grams per 1 m^2. The method of fodder yield and dry mass determination were described in Mrkvička and Veselá (2002a, b). Results were processed by means of Statgraphic programme.

RESULTS AND DISCUSSION

In Table 2 there is presented the total quantity of root phytomass, i.e. live and withered, but not destroyed underground organs, which were determined in treatments with long lasting PK application and graded N(+PK) doses. Dry root phytomass in the soil depth 0.0–0.25 m in the years of studies were oscillating and the extreme values in individual samples were found in 1998 (402–702 g/m^2). In 1999 and 2000 the oscillating minimum and maximum values of dry root phytomass in all treatments of the experiment ranged from 418–622 g/m^2, 423–678 g/m^2, respectively. The mean values of dry root phytomass in unfertilized treatments ranged from 484 to 540 g/m^2. PK increased the values insubstantially (507–565 g/m^2). The higher nitrogen dose (200 kg/ha) decreased the total quantity of dry root phytomass predominantly. The results correspond to Rychnovská et al. (1985) etc. In return some authors mention that cutting and application of lower N doses caused the growth of total root phytomass (Lindow 1998 etc.).

In the plots with graded N fertilization the total quantity of dry root phytomass was in the first year of experiments by 4–28% lower in comparison with the yields of dry aboveground mass. This fact was not proved in 2000, when the yield of root phytomass was higher by 22 to 36%. In the experimental years the general conclusions were proved, i.e. the maximum production of root phytomass in all the treatments was in the period of first cuttings, i.e. at the end of May and the beginning of June. For example in the first experimental year the quantity of root phytomass oscillated in all treatments in the range 5.42 t/ha ($N_0P_0K_0$) till 7.02 t/ha ($N_{100}P_{40}K_{100}$), resp. 5.84 t/ha ($N_{200}P_{40}K_{100}$) – 6.01 t/ha ($N_0P_0K_0$). The quantity of root phytomass was influenced by seasonal changes, most often the decrease appeared in May and further increase in the autumn months. It was increasing in spring and maximum was reached in the beginning of

Table 3. Multiple range tests for yields of dry matter roots phytomass by fertilizing

Fertilizing	Count	*LS* Mean	Homogenous groups
$N_0P_0K_0$	12	509.917	*
$N_0P_{40}K_{100}$	12	542.333	**
$N_{200}P_{40}K_{100}$	12	560.167	**
$N_{100}P_{40}K_{100}$	12	566.333	*

Method: 95.0 percent Scheffe, $D_{min}\alpha$ = 54.665

Table 4. Multiple range tests for yields of dry matter roots phytomass by samplings

Sampling	Count	*LS* Mean	Homogenous groups
3.	12	435.5	*
4.	12	534.667	*
1.	12	592.667	*
2.	12	615.917	*

Method: 95.0 percent Scheffe, $D_{min}\alpha$ = 54.665

Table 5. Multiple range tests for yields of dry matter roots phytomass by years

Year	Count	*LS* Mean	Homogenous groups
1999	16	511.25	*
2000	16	559.563	*
1998	16	563.25	*

Method: 95.0 percent Scheffe, $D_{min}\alpha$ = 41.237

Table 6. Yields of roots phytomass and dry matter (t/ha dry matter) by different level of fertilizing, years 1998–2000

Years	Fertilizing			
	$N_0P_0K_0$	$N_0P_{40}K_{100}$	$N_{100}P_{40}K_{100}$	$N_{200}P_{40}K_{100}$
1998 roots phytomass	4.84	5.65	6.25	5.79
Dry matter	2.52	4.80	6.46	6.54
Relatively (dry matter = 100%)	192.1	117.7	96.7	88.5
1999 roots phytomass	5.06	5.07	5.17	5.15
Dry matter	3.72	6.61	7.22	8.26
Relatively (dry matter = 100%)	136.0	76.2	71.6	62.3
2000 roots phytomass	5.40	5.55	5.56	5.86
Dry matter	2.67	3.25	4.08	4.81
Relatively (dry matter = 100%)	201.5	170.8	136.3	121.8

the period of creating ears in prevailing grassed (according to Klapp 1971). Andrezejewska (1991) and others present the dry root phytomass in the range 5–20 t/ha in the stands placed in the middle of hygroserie row (H_3). In the experimental years statistically significant effects of fertilization, years and sampling term on the production of dry root phytomass was found. The third treatments (N_{100}PK) showed statistically significant difference in the yield of dry root phytomass compared with the treatments without fertilization (Table 2). The quantity of dry root phytomass in the first and second samplings was statistically not significant. In the following samplings statistically significant yield decrease appeared. The sample No. 3 was significantly the lowest one (Tables 3 and 4). In 1999 statistically significant decrease of dry root phytomass was quite evident, compared with the years 1998 and 2000 (Table 5).

The control treatments showed, during the experimental years, a higher quantity of dry root phytomass by 32–102% in comparison with the yield of dry harvestable aboveground mass (Table 6). At the systematic $P_{40}K_{100}$ fertilization the root weight in slightly humid years (1998 and 2000) was 18–70% higher in comparison with the dry year 1999, when the root mass was 24% less. At the fertilization 200 kg/ha N(+PK) in the first two experimental years the root phytomass was less by 12% and 38% compared with the yield of the dry meadow fodder. These results were not proved in the year 2000.

It is evident (Table 7) that the quantity of dry root phytomass during 1998–2000 was higher than the non fertilized treatments (by 72%) and the plots with PK fertilization by 11%, compared with the production of dry aboveground mass. A slight decrease of root phytomass (by 5–14%) was evident in the plots with the graded nitrogen doses. Nitrogen nutrition increased the growth of aboveground biomass by 21% and 34%, in comparison with the PK fertilized plot.

Table 7. Production of root phytomass and dry matter (dry matter t/ha), years 1998–2000

Treatments	Years	Production (t/ha)	
		root phytomass	dry matter
$N_0K_0P_0$	1998	4.84	2.52
	1999	5.06	3.72
	2000	5.40	2.67
	total	15.3	8.91
	average	5.10	2.97
$N_0P_{40}K_{100}$	1998	5.65	4.80
	1999	5.07	6.61
	2000	5.55	3.25
	total	15.27	14.66
	average	5.42	4.89
$N_{100}P_{40}K_{100}$	1998	6.25	6.46
	1999	5.17	7.22
	2000	5.56	4.08
	total	16.98	17.76
	average	5.66	5.92
$N_{200}P_{40}K_{100}$	1998	5.79	6.54
	1999	5.15	8.26
	2000	5.86	4.81
	total	16.80	19.61
	average	5.60	6.54

Table 8. Vertical distribution of root phytomass in depth of soil 0.0–0.25 m; term of samples 4.6.1999 and 4.6.2000

Depth of soil (m)	Fertilizing							
	$N_0P_0K_0$		$N_0P_{40}K_{100}$		$N_{100}P_{40}K_{100}$		$N_{200}P_{40}K_{100}$	
	g/m^2	relative	g/m^2	relative	g/m^2	relative	g/m^2	relative
1999								
Total	581.3	100.0	611.2	100.0	582.2	100.0	622.1	100.0
0.0–0.05	396.4	68.2	415.6	68.0	397.1	68.2	436.1	70.1
0.05–0.10	111.0	19.1	121.0	19.8	124.0	21.3	133.8	21.5
0.10–0.15	40.7	7.0	41.0	6.7	37.3	6.4	28.6	4.6
0.15–0.20	26.2	4.5	26.3	4.3	18.0	3.1	18.7	3.0
0.20–0.25	7.0	1.2	7.3	1.2	5.8	1.0	5.0	0.8
2000								
Total	601.2	100.0	588.9	100.0	600.4	100.0	584.1	100.0
0.0–0.05	404.6	67.3	389.9	66.2	411.9	68.6	402.4	68.9
0.05–0.10	122.6	20.4	127.8	21.7	133.9	22.3	144.3	24.7
0.10–0.15	38.5	6.4	41.2	7.0	39.0	6.5	24.5	4.2
0.15–0.20	27.1	4.5	23.0	3.9	10.2	1.7	8.8	1.5
0.20–0.25	8.4	1.4	7.1	1.2	5.4	0.9	4.1	0.7

Mineral fertilization influenced, except seasonal changes and quantity of root phytomass, and its stratification too (vertical distribution). The data on vertical distribution of root phytomass in the soil depth 0.0–0.25 m are presented in Table 8. The highest quantity of dry root phytomass was in the soil layer 0.0–0.1 m in all the studied treatments. In 1999 it ranged from 87.3% to 91.6% and in 2000 from 87.7% to 93.6% from the total dry root phytomass. In 1999–2000 the mean portion of root phytomass, in upper soil layer 0.0–0.1 m, was 87.5% in the control treatments and 87.9% in PK fertilized one. Phosphoric potassium fertilization did not affect the vertical distribution of root phytomass. N(+PK) fertilization caused a displacement of the root phytomass towards the surface. In the presented experimental years the mean of root phytomass reached at the 100 kg N(+PK) treatments 90.2% and in the plot fertilized by 200 kg N(+PK) 92.6%.

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ABSTRAKT

Vliv hnojení na množství a distribuci kořenové fytomasy a výnosy lučního porostu

V letech 1998 až 2000 byl studován vliv hnojení na množství a stratifikaci kořenové fytomasy a na výnosy suché hmoty na mezofytním lučním stanovišti. Hmotnost sušiny kořenové hmoty v hloubce půdy 0.0–0.25 m za sledované roky kolísala, přičemž krajní hodnoty u jednotlivých odběrů jsme zaznamenali v roce 1998 (402–702 g/m^2). V letech 1999 a 2000 jsme zjistili kolísání minimálních a maximálních hodnot suché podzemní hmoty u všech variant v rozmezí 418–622, resp. 423–678 g/m^2. Průměrné hodnoty sušiny kořenové hmoty u nehnojených variant se pohybovaly v rozmezí 484–540 g/m^2, PK-hnojení zvýšilo hodnoty pouze nepatrně (507–565 g/m^2). Vyšší dávka dusíku (200 kg/ha) převážně snížila celkové množství suché podzemní biomasy. U kontrolní varianty jsme zaznamenali vyšší množství suché podzemní biomasy o 36 až 102 % v porovnání s výnosem suché skliditelné nadzemní hmoty. Při soustavném hnojení $P_{40}K_{100}$ byla hmotnost kořenů v mírně vlhčích ročnících (1998 a 2000) o 18 až 70 % vyšší než v sušším roce 1999, kde jsme zjistili o 24 % kořenové hmoty méně. Při hnojení N(+PK) 200 kg/ha v prvních dvou letech sledování bylo v průměru o 12 a 38 % méně kořenové hmoty, než byl výnos suché hmoty luční píce. V průměru let 1999 až 2000 bylo zastoupení podzemní fytomasy ve vrstvě půdy 0.0 až 0.10 m u kontrolní a u PK-hnojené varianty shodné a činilo 88 % z celkového množství. Poněkud výraznější posun podzemní kořenové hmoty k povrchu způsobovalo N(+PK) hnojení.

Klíčová slova: trvalý luční porost; hnojení; kořenová fytomasa; vertikální distribuce

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