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ROOT MASS AND ROOT TO SHOOT RATIO OF DIFFERENT PERENNIAL FORAGE PLANTS UNDER WESTERN LITHUANIA CLIMATIC CONDITIONS

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ABSTRACT

In the Vezaiciai Branch of the Lithuanian Research Centre for Agriculture and Forestry – Albi-Endohypogleyic Luvisol soil experiments were performed to determine perennial forages *Trifolium pratense* L., *Trifolium repens* L., *Medicago sativa* L., *Phleum pratense* L. root mass and root to shoot ratio in differently managed temporary grasslands. Lithuania's Western region‘s specific edaphic and climatic conditions are suitable for perennial grass development and growth, ensuring a stable biological productivity. Research showed that, for all assessed indicators, perennial grass species and the meteorological conditions in many cases had substantial (P≤0.01, P≤0.05) influence. Biomass of different forage types (roots and shoots) were distributed differently in separate stages of age. Strong (r=0.708-0.888) correlation was determined between legumes root and shoot mass. Substantial increase in root mass of timothy and alfalfa of second year of usage influenced the increase of coefficient of biological productivity (respectively: from 0.93 to 4.54 and from 0.75 to 1.71). The proportional annual increase of red and white clover shoots and roots mass had inconsiderable impact on biological productivity coefficient (from 0.34 to 0.66). The amount of precipitation during the year and vegetation period had a significant impact on the shoot and root mass of red clover (r=0.674* to 0.736*). For the timothy and white clover roots biomass, the precipitation during vegetation period (r=0.671* and 0.704*) had significant influence. Correlation was not found between alfalfa phytomass and rainfall indicators.

Key words: perennial forage plants, root mass, root to shoot ratio, rainfall.

INTRODUCTION

In Lithuania the most important perennial forage plants grown in arable lands are red and white clover, alfalfa, timothy and others. Legumes differ from grasses by their root system. Legume family perennials’ root system consists of the main root and branching secondary roots. Grasses roots are fibrous highly branching, and distributed shallower than legumes.

Roots are an integral part of plants, playing important functions in regulating whole-plant growth. The primary function of roots is absorption of water, and other nutrients from the soil, and anchoring the plant (Gregory, 2008). Above ground part and roots of perennial grasses stabilize natural and anthropogenic processes, and retain balance in nature (Van Eekeren et al., 2010). Shoot to root ratios at peak standing crop are commonly used to estimate the annual crop residue C inputs to the soil from the root-oriented depreciation time left in the soil at harvest (Bolinder et al., 2002).

Root plasticity plays an important role in plant adaptation to heterogeneous environments. Plants showing rapid and highly plastic responses in root growth and development have a selective advantage because they can rapidly utilize the available resources. Many plant species are capable of rapidly adjusting both their morphology and physiology in the acquisition of limiting essential resources that become available in a localized patch of soil (Huang and Eissenstat, 2013).

Grasses with deeper and denser rooting better assimilate food elements and water, and therefore improve the quality of grassland productivity and reduce nutrient leaching. The selection of particular perennial grasses species or variety may be an effective mean in increasing root penetration and density (Deru

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et al., 2012). The ability of roots to follow moisture into deeper layers of the soil profile improve the ability of a plant to tolerate or avoid short and long periods of drought.

Literature states, that most of perennial forage plants roots (70-95%) assemble at 0-20 cm layer. Lapinskiene (1986) writes that 46-60% of third-year red clover and timothy mixture roots are located at 0-5 cm depth, and in arable layer – up to 76-92%. Ma et al. (2000) stated that the majority of plant roots are located at 35 cm depth. Hakl et al. indicated that 50% of alfalfa roots are at 15 cm depth, and their mass per unit of area strongly depends on crop density (Hakl et al., 2009). The findings of other researchers show that it is difficult to establish roots mass precisely and objectively, and the largest proportion of the roots weight locates at 0-45 cm layer of the top soil (Rasse et al., 2005). *Lolium perenne*, *Festuca arundinacea*, *Dactylis glomerata* main roots mass (respectively: 83, 65 and 76%) assemble in 0-8 cm top soil layer (Deru et al., 2012). Distribution of roots in soil profile is determined by the plant type and soil characteristics (Garten and Wullschleger, 2000).

Western Lithuania predominant soils (59.4%) are naturally acidic Dystric Albeluvisols and Gleyic Luvisols (Karcauskiene and Repsiene, 2009). In soil where air, water and nutrient resources available are meagre and fragmented with a large variation through the soil profile, for plant roots, micro-organisms and soil fauna is often difficult to move. And even when the soil is rich in these elements, they are often hardly accessible to organisms, due to their incorporation in soil mineral part. Therefore, plant roots need to adapt and influence their environment (Hinsinger et al., 2005), optimize their functional architecture, access the resources throughout the heterogeneous soils (Pierret et al., 2007). Climate influences aboveground biomass growth (Ionescu et al., 2012; Stavarache et al., 2012), but most of perennial grasses can survive unfavourable conditions because of nutrients accumulated in root system (Ingram and Fernandes, 2001). Annual root biomass differences reflect environmental conditions variability (Hayes and Seastedt, 1987). Root growth in spring is dependent on soil temperature, root longevity - from annual temperature (Gill and Jackson, 2000). Perennial plants allocate proportionately more biomass to roots and rhizome in comparison to annual grasses. Increased resource allocation to roots is a stress resistance trait, since roots (and particularly tubers and rhizomes, as perennial storage organs) provide the safety to resume growth when environmental constraints such as water or nutrient availability have passed (Munné-Bosch, 2014). At unfavourable growth conditions, i.e. on the retardation of the organic matter mineralisation, the slowdown of the activity of the micro-organisms, the increase of concentration of non-viable roots mass decreases the productivity of grassland aboveground phythomass; however the underground phythomass increases (Lapinskiene, 1986).

The purpose of this research was to evaluate different perennial forage plants aboveground and root phythomass and their ratio changes in natural Western Lithuania climate conditions.

MATERIAL AND METHODS

Description of the experimental site

The field experiments were conducted in Western Lithuania at the Vezaiciai Branch of the Lithuanian Research Centre for Agriculture and Forestry (55º43'24 N, 21º27'24 E). Experiments were repeated in time. Duration of 1st experiment was two years. Duration of 2nd experiment was three years. Experiments were set up in 2002 and 2003. The field experiments were conducted using a multi–factorial method. The soil of the experimental site was Albi – Edohypogleyic Luvisol, light loam on medium heavy loam. Agrochemical characteristics of the plough layer were as follows: pH_{KCl} – 6.0-6.1, mobile P_2O_5 and K_2O – 104-199 and 120-166 mg kg^{-1} soil, respectively, N_{total} 0.08-0.11 %, C_{org} 0.90-1.05 %.

Treatments and analysis

In the first experiment (2002 and 2003), spring barley (*Hordeum vulgare* L.) cv. 'Ula' was undersown with perennial grasses in compliance with the experimental design.

Perennial plants were sowed: red clover (*Trifolium pratense* L.) cv. 'Vyliai', white clover (*Trifolium repens* L.) cv. 'Suduviai', alfalfa (*Medicago sativa* L.) cv. 'Birute', timothy (*Phleum pratense* L.) cv. 'Gintaras II'. Development of the perennial plants varied: In the first experiment perennial plants of the second year were ploughed as a green manure, in the second experiment perennial plants of the third year were ploughed as a green manure. Seeking to determine the ecological value of different preceding crops no mineral fertilisers and plant protection products were used.

In the first experiment root mass was measured in second decade of September of the sowing year, and in the second year - before ploughing under as green manure, in third decade of July. In the second experiment root mass was measured three times: at the sowing year, second year in second decade of September, and before ploughing in third decade of July.

Root mass was determined by the Katchinski monolith washing method (Lapinskiene, 1986). For each treatment monoliths were dug up to a depth of 10 cm from two locations. Roots were washed out from the soil, dried and their dry-matter weight was measured.

Aboveground phythomass was evaluated at the time of the taking root samples from the same locations. Shoots were dried and their dry-matter weight was measured.

Root to shoot ratio as coefficient of biological productivity was determined by assessing the ratio of the root mass to aboveground mass. When the difference between the root and shoot mass of the plant is small grassland is potentially productive (Lapinskiene, 1986).

Soil samples were collected before experiment establishment and after perennials ploughing from the 0-20 cm depth. Available P_2O_5 and K_2O were determined by the A–L method, total nitrogen by Kjeldahl, organic carbon by a mineraliser 'Heraeus' (Germany).

Meteorological conditions

In spring of 2002 warm and dry weather prevailed. At the beginning of summer there was sufficient warmth and moisture for the development of perennial grasses, and in August with prevailing dry weather and declining moisture reserves, the conditions for grass growth were only satisfactory (Table 1). The drought lasted until the second decade period of September. In spring and summer of 2003, except for July, hydrothermal conditions were favourable for the development of perennial forage plants. During the spring-summer period of 2004 agro-meteorological conditions for the development of cereals and perennial forage plants were satisfactory, since the amount of rainfall was by 20% lower than the long-term mean. The autumn was warm and wet, which might have intensified biochemical processes in soil and partly leaching of released nitrogen. In 2005 the spring and beginning of summer were drier (rainfall only 80%) compared with the long-term mean.

Table 1. Meteorological conditions for the years 2002-2007, according to Vezaiciai weather station

Year	Month							Per vegetation period	Per year
	04	05	06	07	08	09	10		
Mean air temperature, °C									
2002	7.1	15.3	15.8	18.6	20.0	12.9	4.7	13.5	7.8
2003	4.9	11.6	14.6	19.4	16.7	13.1	5.4	12.2	7.0
2004	7.2	10.7	13.4	15.8	18.1	13.3	8.3	12.4	7.0
2005	6.2	11.1	14.4	18.6	16.1	14.2	8.1	12.7	7.0
Sum of rainfall, mm									
2002	14.1	20.3	63.5	132.4	0.3	100.1	102.3	433.0	865.0
2003	47.2	42.5	72.7	47.9	116.8	65.8	144.0	536.9	767.8
2004	15.8	36.8	68.9	52.5	64.4	194.8	116.5	549.7	904.1
2005	14.5	37.3	45.5	193.4	267.0	16.2	34.8	608.7	990.5

Statistical analysis

The data were statistically estimated using analysis of variance method from software *ANOVA*. The significant differences between the means were established by the least significant difference at significance levels of P≤0.05 and P≤0.01 (Tarakanovas and Raudonius, 2003).

The symbols used in the paper are: *significant at P<0.05, and **significant at P<0.01.

RESULTS AND DISCUSSION

Root and shoot mass of perennial forage plants

Each herb is different from other species by distinctive growth stages rhythm and their duration. One of the key determinants of perennial crop productive age is plant development in sowing year, especially in acidic soil (Kryževičienė and Žemaitis, 1997; Daugėlienė, 2000), because sown cover crop and undercrop are competing for moisture, light, nutrients (Kadžiulienė et al., 2005). Perennials mass is determined by many factors: genotype, growth technology, agro-meteorological conditions, harvest time, age (Butkutė and Paplauskienė, 2006; Harkot, 2005).

Evaluation of the data of the first experiment using analysis of variance shows that in the first year of perennials age (at the year of sowing) the species of plants (F_{act}=21.01** $LSD_{0.5}$=116.36), and the meteorological conditions of experimental years (F_{act}=6.24* $LSD_{0.5}$=95.01) had significant influence on shoot mass (Table 2).

Assessing perennial species studied by shoot mass showed that timothy weight was 191.72 g m^{-2} or 54.4% less than the red clover‘s and 65.7% less than white clover‘s. Red clover mass compared to the mass of white clover was also substantially (by 24.9%) lower.

Table 2. Dry matter mass of roots and shoots in the first experiment, g m^{-2}

Year (Factor A)	Species (Factor B)			Mean for A factor
	Timothy	Red clover	White clover	
Shoot mass in the first year of age				
2002	184.39	345.54	466.56**	332.17
2003	199.04	495.22**	652.87**	449.04*
Mean for B factor	191.72	420.38**	559.71**	
$LSD_{0.5A}$ = 95.008 $LSD_{0.5B}$ = 116.36 $LSD_{0.5A\times B}$ = 164.558				
Root mass in the first year of age				
2002	194.27	151.27	136.94	160.83
2003	331.21*	189.49	245.22	255.31**
Mean for B factor	262.74	170.38*	191.08	
$LSD_{0.5A}$ = 59.616 $LSD_{0.5B}$ = 73.015 $LSD_{0.5A\times B}$ = 103.258				
Shoot mass in the second year of age				
2003	501.59	1789.81**	853.50	1048.30
2004	305.73	2019.11**	944.27*	1089.70
Mean for B factor	403.66	1904.46**	898.89**	
$LSD_{0.5A}$ = 225,792 $LSD_{0.5B}$ = 276.538 $LSD_{0.5A\times B}$ = 391.084				
Root mass in the second year of age				
2003	694.27	492.04*	324.84**	503.72
2004	748.41	828.03	423.57**	666.67**
Mean for B factor	721.34	660.03	374.20**	
$LSD_{0.5A}$ = 101.001 $LSD_{0.5B}$ = 123.701 $LSD_{0.5A\times B}$ = 174.939				

Perennials vegetation period is long, so they need high humidity levels. The influence of weather conditions was evident in the very first year of vegetation. In 2002, the weather conditions were satisfactory for plants to grow. In April and May it was dry; rainfall was 30 and 47% of average rates. In 2003, the spring – summer period, optimum quantity of rainfall fell, and perennials grew and developed well. On average in 2003, regardless of the species, shoot mass was higher by 35.2%, and root mass by 58.7% in comparison with 2002. Similar findings were reported by other authors (Strakova et al., 2010), while investigating ryegrass.

Investigated plant root mass variation was essentially influenced by the plant species (F_{act}=3.63* $LSD_{0.5}$=73.02) and the weather conditions (F_{act}=10.35** $LSD_{0.5}$=59.62). Assessing the perennial species showed that the lowest shoot mass was developed by timothy, which also formed the highest (262.74 g m^{-2}) root mass. Timothy root mass was substantially higher (by 35.2%) than red clover‘s and by 27.2% higher than white clover‘s. In 2003, the root mass was 58.7% higher when compared with 2002 data. The literature indicates that the rainfall during the growing season and the mass of the roots have strong (r=0.797) positive correlation (Jancovic et al., 2002).

Similar tendencies of shoot and root mass variation was determined at the second year of usage. In mid-summer (July third decade), shoot and root mass was determined 2.4-3.2 times higher than in the first year of usage. At perennials favourable development in 2003, shoot and root mass was 3.2-3.1 times higher, and in 2004, when the spring and summer rainfall was missing – only 2.4-2.6 times higher. Shoot mass was largely influenced by plant species (F_{act}=63.03** $LSD_{0.5}$=276.538). Timothy shoot mass weight was 403.66 g m^{-2} or 78.8% less than the red clover‘s and 55.1% than white clover‘s. Red clover phytomass, compared to the mass of white clover was substantially (52.8%) higher. Shoot mass measured before ploughing down the perennials as green manure, ranked in the following order: red clover > white clover > timothy.

Roots mass variation was essentially influenced by the plant species (F_{act}=18.49* $LSD_{0.5}$=123.70) and the weather conditions (F_{act}=10.73** $LSD_{0.5}$=101.00). As in the first year of usage, the lowest shoot mass was grown by timothy, which also formed the largest root mass. Timothy‘s root weight was 725.34 g m^{-2} or by 92.8% (substantially) higher than white clover‘s and 9.3% higher than red clover‘s. Compared with the first year of usage, timothy‘s and white clover‘s root mass increased 2.7 and 2.0 times, and red clover‘s – even 3.9 times. This temporal variation was explained mainly by the increase of root biomass in the 0 to 15 cm layer (Bolinder et al., 2002). Each member of agrocenosis is seen as a pre-plant under the accumulated levels of organic and nutrient elements and created conditions for subsequent growing plants (Nemeikštienė et al., 2010). Analysed root mass can be ranked in the following order: timothy > red clover > white clover.

The second experiment data showed that in the first year of usage (at year of sowing) plant species (F_{act}=11.79** $LSD_{0.5}$=87.28) and weather conditions (F_{act}=11.98** $LSD_{0.5}$=61.72) had a significant influence on the mass of shoots (Table 3).

Alfalfa and timothy shoot mass was 277.87 and 177.55 g m^{-2} or 31.6% and 56.3% lower than the red clover‘s, and 27.7% and 53.8% than white clover‘s. Similar data for the development of alfalfa is known from other researchers. Šarūnaitė et al. (2008) reported that in the first half of growing season alfalfa growth is slow. In addition their yield depends on the age: in the first growing year yield is lower than that of the subsequent years. Yield of alfalfa grown on heavy loamy soil was substantially (by 17.7%) lower compared with red clover‘s yield (Nemeikšienė et al., 2010). Timothy shoot mass compared with that of alfalfa was also substantially (by 36.1%) lower. Regardless of the species, shoot mass in 2003 was found by 41.1% higher, compared with 2002 data.

Table 3. Dry matter mass of roots and shoots of the second experiment, g m^{-2}

Year (Factor A)	Species (Factor B)				Mean for A factor
	Timothy	Red clover	White clover	Alfalfa	
Shoot mass in the first year of age					
2002	186.31	304.14	351.91**	191.08	258.36
2003	168.79	507.96**	417.20**	364.65**	364.65**
Mean for B factor	177.55	406.05**	384.55**	277.87*	
$LSD_{0.5A}$ = 61.716 $LSD_{0.5B}$ = 87.280 $LSD_{0.5A\times B}$ = 123.432					
Root mass in the first year of age					
2002	140.13	170.38	132.17	248.41**	172.77
2003	191.08	191.08	191.08	170.38	185.91
Mean for B factor	165.61	180.73	161.62	209.39	
$LSD_{0.5A}$ = 33.379 $LSD_{0.5B}$ = 47.205 $LSD_{0.5A\times B}$ = 66.758					
Shoot mass in the second year of age					
2003	363.06	1041.40**	417.20	555.73	594.35
2004	630.57	1984.08**	684.71*	1479.30**	1194.67**
Mean for B factor	496.82	1512.74**	550.96	1017.52**	
$LSD_{0.5A}$ = 149.152 $LSD_{0.5B}$ = 210.932 $LSD_{0.5A\times B}$ = 298.303					
Root mass in the second year of age					
2003	941.08	770.70	321.66**	880.57	728.50
2004	1144.90	1218.15	410.83	1670.38**	1111.07**
Mean for B factor	1042.99	994.43	366.24**	1275.48	
$LSD_{0.5A}$ = 186.727 $LSD_{0.5B}$ = 264.071 $LSD_{0.5A\times B}$ = 373.453					
Shoot mass in the third year of age					
2004	259.55	1659.24**	507.96	732.48	789.81
2005	187.90	1769.11**	699.04	1369.43**	1006.37
Mean for B factor	223.73	1714.17**	603.50*	1050.96**	
$LSD_{0.5A}$ = 239.968 $LSD_{0.5B}$ = 339.366 $LSD_{0.5A\times B}$ = 479,936					
Root mass in the third year of age					
2004	1156.05	942.68	331.21*	1625.80	1013.93
2005	877.39	1335.99	291.4*	1972.93*	1119.43
Mean for B factor	1016.72	1139.33	311.31**	1799.36**	
$LSD_{0.5A}$ = 330.592 $LSD_{0.5B}$ = 467.527 $LSD_{0.5A\times B}$ = 661.184					

The largest mass of roots was formed by alfalfa, but significant differences between plant species were not identified. Comparison of the root mass data showed that in 2003, the root mass was 7.1% higher, but the difference was within the range of error.

According to the average data of the second year, shoot mass (at the end of growing season) was 2.3-3.3 times greater and mass of the roots was 1.4-1.7 times greater than the mass of the first year.

Shoot mass was largely influenced by plant species (F_{act}=40.76** $LSD_{0.5}$=210.93) and the weather conditions (F_{act}=65.42** $LSD_{0.5}$=149.15). The data show that essentially the largest shoot mass (1512.74 g m^{-2}) was grown by red clover. Alfalfa‘s shoot mass was by 32.7% lower and of white clover’s and timothy’s respectively: 63.6% and 67.2% lower compared with red clover‘s.

For good development of plants, not only the total amount of rainfall is important, but also its even distribution during the growing season, especially during the rapid growth phase. In 2003, due to the uneven distribution of rainfall in summer - autumn period, shoot mass was substantially (by 50.2%) lower than in 2004.

Investigated grasses root development at the second year was essentially influenced by plant species (F_{act}=17.52** $LSD_{0.5}$=264.07) and the weather conditions (F_{act}=16.95** $LSD_{0.5}$=186.73). Alfalfa root mass was by 71.3% (substantially) greater than white clover‘s, by 22.0% (substantially) greater than red clover‘s and by 18.2% than timothy‘s.

According to the average data, at the third year of growing, before ploughing under as green manure in July‘s third decade, the shoot and root mass was similar to that of the second year in the autumn, with the exception of timothy shoot mass, which accounted for only 0.4 part. Shoot mass was essentially influenced by the plant species (F_{act}=28.77** $LSD_{0.5}$=339.37). Substantially, the highest (1714.17 g m^{-2}) shoot mass originated from red clover. Timothy‘s mass was by 86.9% lower than the red clover‘s, by 78.7% lower than alfalfa‘s, and by 62.9% than white clover‘s. Essential differences between the shoot mass were determined among investigated legumes plants.

By comparing the data on shoot mass one can see that in 2005, when June and July precipitation was 158.3% of the norm, the shoot mass was by 21.5% greater, the difference is not significant. Perennials shoot mass before ploughing under as green manure, ranked in the following order: red clover > alfalfa > white clover > timothy.

Perennials root mass development was essentially influenced by the plant species (F_{act}=13.74** $LSD_{0.5}$=467.53). Root mass difference between timothy and red clover was within the error range. White clover‘s root mass was substantially lower (from 69.4 to 82.7%) when compared with the other investigated plants. Alfalfa formed the greatest amount (1799.36 g m^{-2}) of root mass. Root mass ranked in the following order: red clover > alfalfa > timothy > white clover.

Phytomass and precipitation interdependencies

Correlation and regression analysis showed a significant influence of the growing season‘s and annual rainfall on the red clover‘s root and shoot mass (Table 4).

Table 4. The relationship of phytomass with precipitation, during 2002-2005

Phythomass indicators (y)	Rainfall amount indicators (x)	Coefficients of regression equation y = a + bx		r
		a	b	
Timothy				
Soot mass	Vegetation period rainfall total, mm	-91.074	0.739	0.255n
	Annual rainfall total, mm	387.515	-0.104	-0.052n
Root mass	Vegetation period rainfall total, mm	-1963.91	4.943	0.671*l
	Annual rainfall total, mm	-1079.29	2.024	0.401n
Red clover				
Shoot mass	Vegetation period rainfall total, mm	-3788.03	9.446	0.706*l
	Annual rainfall total, mm	-2524.46	4.37	0.477n
Root mass	Vegetation period rainfall total, mm	-2622.96	6.169	0.736*l
	Annual rainfall total, mm	-2660.95	3.869	0.674*l
White clover				
Shoot mass	Vegetation period rainfall total, mm	-423.653	1.941	0.527n
	Annual rainfall total, mm	124.312	0.559	0.221n
Root mass	Vegetation period rainfall total, mm	-426.99	1.343	0.704*l
	Annual rainfall total, mm	8.927	0.320	0.245n
Alfalfa				
Shoot mass	Vegetation period rainfall total, mm	-2901.72	6.875	0.739n
	Annual rainfall total, mm	-2933.62	4.288	0.701n
Root mass	Vegetation period rainfall total, mm	-4343.86	10.150	0.747n
	Annual rainfall total, mm	-4978.60	7.009	0.785n

Statistically significant linear correlation (r=0.706*) was found between the red clover‘s shoot mass (y) and the growing season‘s precipitation (x) over the study period. During the growing season, an increase of 100 mm precipitation (at the range of 433.0-608.7 mm) increased shoot mass by 944.6 g m^{-2}. Red clover root mass also correlated with growing season‘s precipitation, With a statistically significant linear correlation (r=0.736*). Growing season‘s amount of precipitation determined red clover‘s shoot and root mass by 50-54%.

Annual amount of precipitation was important for red clover growth and development. When annual rainfall varied in 767.8-990.5 mm range, a strong linear correlation (r=0.674*) was found with root mass. Annual amount of rainfall determined red clover‘s root mass by 45%.

Timothy and white clover root mass (y) was also dependent on the growing season rainfall (x), showing strong correlation, statistically significant (r=0.671* and 0.704*). Growing season‘s amount of rainfall determined the root mass of timothy and white clover by 45 and 50% respectively. According to the regression equation, 100 mm of rainfall (at 433.0-608.7 mm range) increased timothy‘s and white clover‘s root mass by 494.3 and 134.3 g m^{-2} respectively.

No correlation between the phytomass of alfalfa and amount of rainfall was found. It is considered that plants with long roots take moisture from the deeper layers, resulting in the fact that uneven distribution of rainfall or arid periods do not affect growth of alfalfa essentially.

Shoot and root mass correlation

Legumes shoot and root mass closely correlated with each other. Among the shoot and root mass of red clover we found a strong linear (r=0.848**) correlation. Summarized dependence of red clover‘s shoot on the root mass is expressed in regression equation: y = 340.335 + 1.353x. Root biomass determined 72% of shoot mass variation.

A similar tendency was found by analysing alfalfa shoot and root mass dependency, which was described by a strong linear (r=0.848*) correlation. Alfalfa shoot mass dependence on the root mass was expressed by the regression equation: y = 116.287 + 0.608x. Root mass determined 79% of shoot biomass variation.

White clover‘s shoot mass dependence on mass of roots also had a strong linear correlation (r=0.708*). White clover‘s shoot mass dependence on the root mass was expressed by the regression equation: y = 215.248 + 1.368x. Root mass determined 50% of shoot biomass variation.

No correlation was observed between timothy phytomass indicators. It is considered that this is due to poor timothy re-growth.

Shoot to root ratio

Partial aging is typical for perennial plants, because every year they are losing aboveground part, while the root system remains viable, Phytomass accumulation patterns are well reflected by biological productivity coefficient – the root to shoot ratio. The literature indicates that the root to shoot ratio may vary within locations and climatic conditions (Bolinder et al., 2002). Water deficit provokes decrease in root dry matter and influences relations between roots and shoot (Barbosa et al., 2013). Already in the sowing year (at the first growing year) there were differences between legumes and grasses in total phytomass and root to shoot ratios (Table 5). This was caused by specific biological characteristics (growth and development pattern during sowing year and subsequent years). According the average data, both types of clover shoot mass was 2.25-2.93, alfalfa’s – 1.33 (Tables 2 and 3) times the mass of roots and root to shoot ratios were determined respectively: 0.34-0.45 and 0.75 (Table 5). Timothy‘s shoot and root mass during the first year of growing were similar, and therefore the root to shoot ratio was close to one (average 1.15).

Western Lithuania‘s specific edaphic and climatic conditions are suitable for growth and development of perennials, and the stability of their biological productivity is ensured. At the second year age grasses, even though the lack of rainfall in 2004 led to an insufficient growth during the vegetation season, but averaged data shows that the obtained total phytomass was good. The evaluation of perennials phytomass during summer (July‘s third decade) shows that both types of clover shoot mass was 2.88-2.40 times greater than of the roots (Table 2). Root to shoot ratios determined similar to the first year, respectively: 0.35 to 0.42 (Table 5).

Table 5. Root to shoot ratios of perennials

Year	Experiment	Time of determination	Species			
			Timothy	Red clover	White clover	Alfalfa
1st year of age	Experiment I	End of September	1.37	0.41	0.34	-
	Experiment II	End of September	0.93	0.45	0.42	0.75
2nd year of age	Experiment I	End of July	1.79	0.35	0.42	-
	Experiment II	End of September	2.10	0.66	0.66	1.25
3rd year of age	Experiment I	-	-	-	-	-
	Experiment II	End of July	4.54	0.66	0.52	1.71

Evaluation of phytomass at the beginning of autumn, when plants had reached greater stage of development indicates that roots had formed a larger mass. Both types of clover shoot mass was only 1.50 to 1.52 times greater than the root mass; root to shoot ratios were higher (0.66) compared with ratios in summer. Consequently, the grasses roots grow more intensively in the autumn. Alfalfa and timothy root mass was 20.2 and 52.4% lower than the mass of roots and their root to shoot ratios was 1.25 and 2.10 respectively. Similar data have been obtained by other researchers (Bolinder et al., 2002).

At the third year, when plants were aging, red and white clover shoot mass was 1.50-1.94 times greater than the root mass. Root to shoot ratios remained similar (0.66-0.52) as at the second year. Alfalfa and timothy shoot mass was by 41.6 and 78.0% lower than the root mass. Alfalfa and timothy root to shoot ratios increased up to 1.71 and 4.54. Though these species have a different root system, they produced the largest amount of phytomass compared to the other investigated species. The difference is that, timothy with high (4.54) root to shoot ratio indicates a potential decline in the productivity, while the low (1.71) biological productivity ratio of alfalfa shows that the species is potentially productive. An increase in root to shoot ratio could be an indication of a healthy, well developed plant, provided the increase came from greater root size and not from a decrease in shoot weight (Watt et al., 2013).

CONCLUSIONS

Perennials shoot and root mass and the rate of formation at different stages varied due to plant species and climatic conditions.

During the first year (sowing year), under favourable weather conditions during vegetation period, timothy, red and white clover shoot mass was 29.9-35.2%, and root mass was 29.5-58.7% higher compared with droughty vegetation period. Weather conditions influence on alfalfa‘s shoot and root mass formation was not observed. The lowest (184.64 g m^{-2}) shoot mass was formed by timothy, which formed the greatest (214.18 g m-2) root mass.

During the second year, the largest (1708.6 and 1017.52 g m^{-2}) shoot mass originated from red clover and alfalfa. However, the highest (1275.48 and 882.16 g m^{-2}) root mass was formed by alfalfa and timothy. Higher annual rainfall substantially increased root mass (from 32.5% in mid-summer to 52.5 in early autumn). An essential influence of the year for shoot mass formation was determined at its evaluation in autumn.

In the third year, the largest shoot and root mass was obtained from red clover and alfalfa, respectively: from red clover 1714.17 and 1139.33 g m^{-2}, from alfalfa 1050.96 and 1799.36 g m^{-2}. Due to favorable weather conditions for growth and development, essential differences between the year to year data were not observed.

Annual and the vegetation period amount of precipitation significantly influenced red clover shoot and root mass (r=0.674* to 0.736*). Timothy and white clover root mass was significantly influenced by vegetation period rainfall level (r=0.671* and 0.704*). No correlation was found between the mass of alfalfa and amount of precipitation. A strong (r=0.708-0.888) correlation was determined between legumes root and shoot mass.

Root to shoot ratio consistently increased each year and it was determined to be the highest in the third year of growth. Red and white clover roots and shoot mass proportional increment changed the annual root to shoot ratio insignificantly. Considerable annual timothy and alfalfa root mass increase had significant effect on the above species root to shoot ratio.

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