

**DRY MATTER YIELD AND CARBON PARTITIONING IN THE ABOVEGROUND PART
OF SWITCHGRASS (*PANICUM VIRGATUM* L.) GERMPLASM**

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Abstract

Carbon (C) accumulated in biomass can be converted into usable forms of energy like methane, bioethanol or solid fuel. Understanding the partitioning of aboveground biomass and C plays an important role in optimizing its pre-treatment technologies. Our objectives were to determine dry matter yield (DMY) and C partitioning in switchgrass germplasm. Plants were sampled at heading (HS) and seed filling (SFS) stages. The biomass of the SFS-sampled plants was separated into leaves (blades+sheaths), stems, and panicles. C content was determined by dry combustion. C yield per plant (CY) at HS ranged from 25.9 to 171 g (37.3 g on average for plants in the first harvest year, and 147 for those in the second harvest year), at SFS CY varied within a range of 79.8 – 295g and averaged 119 and 252g depending on the year of growth. DMY was a weighted factor for such results. At SFS, DMY of stems accounted on average for 46.3%, leaves for 40.5%, and panicles for 13.2% of the aboveground biomass of whole plant with respective C concentrations of 462, 439 and 459 g kg⁻¹ DM.

The keywords: bioenergy plant, carbon, biomass dry matter yield, aboveground plant part, *Panicum virgatum* L.

1. INTRODUCTION

Plants use sunlight to synthesize organic substances which serve as building materials or stores of energy. Bioenergy crop plants that function as solar energy collectors, fixing carbon from atmospheric CO₂ are the basis for biological systems that are expected to contribute to renewable energy production, help stabilize the rising levels of greenhouse gases, and mitigate the risk of global climate change (Jaradat 2010). Burning fossil fuels uses “old” biomass and converts it into “new” CO₂; which contributes to the “greenhouse” effect and depletes a non-renewable resource (McKendry 2002). Burning new biomass contributes no new carbon dioxide to the atmosphere, because replanting harvested biomass ensures that CO₂ is absorbed and returned for a cycle of new growth through photosynthesis. Concern over the increasing concentration of carbon dioxide in the atmosphere, caused mainly by burning fossil fuels, has intensified interest in developing biomass crops as resources for energy purposes as they are CO₂-neutral (Christian, Riche & Yates 2002). The most efficient photosynthetic organisms are land plants (Larkum 2010). An advantage of using perennial grasses as bioenergy source is that farmers are familiar with their management and already have the capacity to grow, harvest, store, and transport them (Sanderson & Adler 2008). C₄ perennial grasses are being considered for bioenergy because of their high productivity and low inputs (Dohleman, Heaton et al. 2009). In temperate and warm regions, C₄ grasses outyield C₃ grasses due to their more efficient photosynthetic pathway (Lewandowski, Scurlock et al. 2003). Switchgrass (*Panicum virgatum* L. – SWG) – the rhizomatous C₄ perennial grass is able to enhance biomass accumulation in a wide range of environmental conditions, which is the premise for considerable carbon (C) assimilation (Monti,

Barbanti et al. 2012). Oxygenic photosynthesis with C accumulation in the form of organic compounds (mostly carbohydrates and lignin) is the major route for solar energy conversion on the Earth today (Larkum 2010). The switchgrass is a more efficient collector of solar radiation (171.0 GJ of solar energy per ha) and has lower energy input requirements in its production cycle than other agricultural crops - from 37.1 (rye) to 116.3 GJ ha⁻¹ (grain maize) (Samson, Mani et al. 2005). This efficiency results in a net energy gain (163.8 GJ ha⁻¹) per ha which is approximately 60 per cent higher than that of grain maize (98.3 GJ ha⁻¹). C accumulated in biomass can be converted into usable forms of energy like methane, bioethanol or solid fuel. Not only biomass yield of plant accessions determines their energy value and use. For the anaerobic biomethane process to be optimal, carbon to nitrogen ratio (C:N) in DM is one of the main quality indicators. Literature sources indicate various ranges of C:N values: from 20 to 30 (Cotana & Giraldi 2007; Komatsu, Kudo et al. 2007), from 15 to 30 (Holliday, Chesshire & Mulliner 2005) or from 25 to 30 (Osman, Tinay & Mohamed 2006) and other C:N values. Combustion is the most important and mature technology available nowadays for biomass utilization (Nussbaumer 2003). Low C:N ratio, conditioned by low C and high N content in the burning biomass could lead up to pollutants such as NO_x. N, specifically protein, is good buffering agent in bioethanol production process (Dien, Jung et al. 2006). Knowledge of the partitioning of aboveground biomass, C deposit and peculiarity of C:N ratio fluctuation plays an important role for the choice of technologies of bioenergy feedstock use. The challenge in this study was to identify high yielding accessions of switchgrass as a multifunctional non-food energy crop with all the desirable characteristics, to determine dry matter yield (DMY) and C partitioning in the aboveground part of whole plant and morphological components of switchgrass germplasm and to clarify the peculiarities of the C:N ratio fluctuation.

2. MATERIAL AND METHODS

Plant material. Experimental collection was set up using the seedlings grown in a greenhouse. Seeds for the germplasm collections of switchgrass were obtained from the Plant Genetic Resources Conservation Unit (PGRCU) of the United States Department of Agriculture and Agricultural Research Service. The part of collection set up in 2011 was qualified as germplasm collection of the first harvest year and the part set up in 2010 - as germplasm collection of the second harvest year. The tested accessions included 8 cultivars and 32 wild ecotypes. Each accession consisted of 32 plants spaced 0.5 m apart with 8 plants per row, two rows per replication, and two replications per treatment. Reed canary grass variety Chiefton was established according to the same design.

The soil of the experimental site is *Endocalcari-Epihypogleyic Cambisol (CMg-p-w-can)* with the following characteristics of the plough layer (0–25 cm): pH 6.52, humus content 1.82. Simulating the species management under commercial cultivation conditions, the grass was cut twice per season at the beginning of anthesis (07.20) and after re-growth of aftermath (09.11) as feedstock for biogas in the first treatment. In the second treatment, the grass was cut once at seed ripening stage as feedstock for bioethanol of the second generation and for solid biofuel.

The weather conditions favoured herbage growth and development during the whole vegetation period in 2012. The winter conditions of 2011-2012 were similar to long term average and were conducive to overwintering of perennial grasses.

Plants were sampled at heading (HS) and seed filling (SFS) stages. Dry matter yield was measured in 500 g herbage samples dried to constant moisture. The biomass of the SFS-sampled plants was separated into leaves (blades+sheaths), stems, and panicles and the percentage of each fraction based on their dry mass, was determined. The data discussed in the paper concern only those accessions that proved to be promising by a complex agrobiological traits, i.e. five SWG accessions in the first harvest year and seven SWG accessions in the second harvest year (Table 1).

Table 1. The catalogue's numbers of the switchgrass accessions discussed in the paper

2010 yr collection (the second harvest year)		2011 yr collection (the first harvest year)	
PGRCU catalogue No	Lithuanian catalogue No	PGRCU catalogue No	Lithuanian catalogue No
642295	46	642198	67
642296	47	642200	69
642300	51	642208	74
642306	57	537588	77
642309	60	477003	79
642191	62		
642194	64		

Methods of sample preparation and chemical analyses. Fresh samples, chopped into particles of 3–5 cm, were fixed at 105°C for 15 min, dried at (65 ± 5) °C and ground in a cyclonic mill with a 1 mm sieve. The total C concentration in herbage samples was determined by dry combustion in an oxygen atmosphere at high temperature (about 1000°C) according to the Dumas principle. Analysis was performed with a Vario EL III analyzer (Elementar Analysensysteme, Hanau, Germany) detecting C as CO₂. The total nitrogen (N) content for C:N ratio calculation was carried out simultaneously with the C analysis. The nitrogen compounds in the test portion were converted into molecular nitrogen.

Statistical estimation of data. The experimental data were processed using statistical package ANOVA. Data variation and regressions-correlations were estimated using STAT software (Tarakanovas & Raudonius 2003).

3. RESULTS AND DISCUSSION

Knowledge of the distribution patterns of carbon in herbage biomass could be essential for harvest management and utilization of biomass for biofuels. Carbon concentration in DM of biomass, C ratio to N (C:N), as well as DM and C yields per plant (DMY, CY) depended both on plant development stage (heading stage – HS, seed filling stage – SFS) and harvest year (first – 1; second – 2) (Table 2). The DM yield (DMY) of energy plants is the most important trait and often could be a weighted factor for output of essential energy compounds in feedstock. The mean values recorded for DMY per plant were the lowest (83.6 g) for SWG accessions in the first harvest year when cut at heading stage (Table 2, HS1), 326 g, 258 and 549 for that of HS2, SFS1 and SFS2, respectively, i.e. according to the average DMY, SWG accessions were essentially more productive compared to reed canary grass (RCG) of the corresponding stage and age (Table 3), except for DMY of plants in the first harvest year when cut at seed filling stage (SFS1). A great DMY variation was observed within each group of SWG: 58.1–122 g in HS1, 172–355 g in SFS1, 251–345 g in HS2, and 423–639 g in SFS2.

Table 2. Pattern of the variation in carbon (C) concentration, dry matter and C yields (DMY, CY) and C:N ratio as influenced by different plant maturity stage and herbage age (HS1– at heading stage, 1st harvest year, HS2 – at heading stage, 2nd harvest year, SFS1 – at seed filling stage, 1st harvest year, SFS2– at seed filling stage, 2nd harvest year)

Trait		HS1	HS2	SFS1	SFS2
DMY g plant ⁻¹	Mean±SD	83.6±29.3	326±38.0	258±69.4	549±85.2
	Range	58.1–122	281–382	172–355	423–639
C g kg ⁻¹ DM	Mean±SD	446±6.75	452±2.69	460±4.65	458±3.43
	Range	436–452	450–457	454–464	452–462
CY g plant ⁻¹	Mean±SD	37.3±13.2	147±16.8	119±32.3	252±40.3
	Range	25.9–54.8	127–171	79.8–164	191–295
C:N	Mean±SD	22.8±2.42	40.2±3.03	34.9±5.01	73.5±5.83
	Range	19.6–25.6	36.5–45.5	30.0–42.1	61.4–77.6

C concentration in SWG biomass of HS1, HS2, SFS1 and SFS2 averaged 445, 452, 460 and 458 g kg⁻¹ DM respectively and varied within the relevant ranges: 436–452, 450–457, 454–464 and 452–462 g kg⁻¹ DM (Table 2). There is an evident impact of plant maturity (especially in the first harvest year of SWG) on the C concentration in biomass DM. Peculiarities in C output per SWG plant (CY) correspond to those observed for DMY. In the current study, SWG at heading stage was cut while simulating the biomass use as the feedstock for biogas production. While estimating SWG accessions' herbage as raw material for biogas it is critical to know the carbon to nitrogen ratio (C:N) in it.

The C:N values in SWG varied markedly between harvest years and between growth stages: from 19.6 to 77.6 (Table 2). Of the tested SWG samples only in those cut at heading stage in the first harvest year (HS1) the average value of this ratio was optimal 22.8 and its values varied in the range 19.6–25.6. Thus, according to this quality indicator, only this group of samples (HS1) proved to be suitable for biogas production. SWG biomass of plants advanced both in maturity and harvest years according to the C:N ratio is more suitable for other bioenergy needs; on the other hand, some N has important influence on ethanol production by *S. cerevisiae* under anaerobic conditions (Yue, Yu et al. 2012), however, when biomass is used for direct combustion high N values lead to NO_x emission because of partial oxidation of N present in the feedstock. Nevertheless El-Mashad (2013) reported that the methane yield of switchgrass was 126.69 and 166.71 ml/g VS at mesophilic and thermophilic temperatures, respectively, and it is noteworthy that in the study SWG was harvested in the late, i.e. post killing frost stage and air dried. To increase the yield of methane production from switchgrass, another N-rich feedstock, e.g., *Spirulina platensis* algae is needed to adjust the carbon to nitrogen ratio of switchgrass. Moreover, Massé, Gilbert et al. (2010) pointed out that methane yields from switchgrass grown under the cool humid climate of Eastern Canada suggest that this crop remains an interesting renewable alternative energy source and the specific methane yields decreased significantly with crop maturity from 0.266 to 0.309 NL CH₄ g⁻¹ VS in mid-summer to 0.191–0.250 NL CH₄ g⁻¹ VS in early fall. They also indicated (Massé, Gilbert et al. 2011) that the average specific methane yield from reed canarygrass-seeded plots (0.187 NL CH₄ g VS⁻¹) was less than from switchgrass-seeded plots (0.212 NL CH₄ g VS⁻¹). In our opinion, SWG cultivation for biogas production should be a relevant object for further complex studies and debates.

The high values of standard deviation (SD) and a wide range of DMY, C, CY and C:N variation showed that there were differences among SWG accessions (Table 2). To identify and select the most promising accessions, 5 SWG accessions in the first harvest year and 7 SWG accessions in the second harvest year were assessed for the aforesaid SWG traits in comparison with those of RCG variety Chiefton (Table 3). In terms of the annual DMY per plant, SWG 67 and SWG 69 were identified as the best in the SWG

germplasm collection in the first harvest year when cut both at heading and seed filling stages (Table 3). DMY of those SWG accessions was higher than that of RCG at the early phenological stage; however, RSG outstripped all SWG accessions of first year of herbage use cut at SFS. The accessions that stood out for this trait and showed higher DMY than average for SWG at HS in the group of the second harvest year were Nos 46, 60, 62. At SFS another two high-yielding SWG accessions joined them: Nos 47 and 51. As literature data suggest, SWG in the first year of growth does not reflect the true yield potential: as a small-seeded species that initially allocates a large amount of energy to developing a strong root system, switchgrass will typically attain only 33–66% of its maximum production capacity during the initial and second years before reaching its full capacity during the third year after planting (McLaughlin & Kszos 2005). This explains why rather scarce DMY of SWG was obtained in the first harvest year in our study. The magnitude of differences in C among SWG accessions in the group of the same maturity stage and age was not large. Like DMY, C yield and C:N were influenced by all three factors – SWG accession, plant maturity stage and harvest year (Table 3). Undoubtedly DMY was a weighted factor for CY variation among the germplasm in the sample group: the correlations between DMY and CY for individual sample group and in total were very strong with determination coefficient $R^2 \geq 0.996$. C concentration had only negligible positive impact on CY, which was increasing with advancing in plant age and maturity and determination coefficients varied from $R^2=0.0268$ (HS1) to $R^2=0.599$ (SFS2). With advancing maturity from heading until seed filling CY increased for all SWG accessions of the first year of grass use by 182 (SWG 67) – 290% (SWG 74). The SWG plants of the second harvest year were characterized by a slower increase in CY: by 44.6 (SWG 64) – 104 (SWG 51).

Although CY of RCG was often lower than that of SWG of the same maturity and age group (except for SFS1), CY increase with advancing maturity occurred more sharply than for SWG accessions. The C:N values in the biomass of all the tested SWG accessions at heading stage in the first harvest year were similar and were optimal for the biogas feedstock (Table 3). The lowest C:N values in the biomass were observed in the biomass of the SWG Nos 74 and 79 cut at both maturity stages. It has been scientifically validated and determined that grass quality, including nitrogen, is mostly dependent on maturity stage: protein/N concentration decreased while fiber fractions and lignin increased rapidly with advancing growth stages. Therefore with increasing maturity, the C:N ratio notably increased in the biomass of all SWG accessions tested independent of the year of grass use. The values of this quality attribute of the feedstock were much higher in the biomass of all SWG accessions in the second harvest year than those in the first harvest year; however, this regularity did not stand true for RCG. The variation among accessions in C:N value in the biomass depended not only on C concentration but also (probably much more) on nitrogen. Several authors stressed that both grass species and even separate genotypes of the same species exhibit different nitrogen use efficiency (Bregard, Belanger et al. 2001; Zemenchik & Albrecht 2002). Thus different C:N in the analysed SWG accessions grown in the same environment can be reasonably considered as their genetic singularity.

Table 3. Variation in the carbon concentration (C g kg⁻¹DM), dry matter and C yields per plant (DMY, CY) and carbon ratio to nitrogen (C:N) for SWG accessions in relation to plant maturity and age compared to the respective parameters of RCG

Sample ID	DMY	C	CY	C:N	DMY	C	CY	C:N	CY increase from HS to SFS	
	At heading stage (HS)				At seed filling stage (SFS)				g plant ⁻¹	%
	First harvest year									

SWG 67	107	449	47.9	23.6	291	464	135	37.5	87.3	182
SWG 69	122	448	54.8	25.6	355	461	164	34.4	109	199
SWG 74	58.1	447	25.9	20.1	223	454	101	30.0	75.3	290
SWG 77	59.2	452	26.7	24.1	172	463	79.8	42.1	53.0	198
SWG 79	71.5	436	31.2	21.0	249	455	113	30.7	82.0	263
RCG	62.6	452	28.3	19.6	387	453	175	51.3	147	520
Second harvest year										
SWG 46	382	447	171	38.7	639	462	295	76.1	124	72.9
SWG 47	312	450	140	42.4	572	461	264	77.6	123	87.7
SWG 51	281	452	127	43.9	565	457	258	61.4	132	104
SWG 57	303	455	138	48.2	445	456	203	77.0	65.4	47.5
SWG 60	349	455	159	35.7	638	458	292	74.5	133	83.7
SWG 62	361	450	163	34.0	558	462	258	70.7	95.1	58.5
SWG 64	294	450	132	40.1	423	452	191	77.0	59.1	44.6
RCG	230	440	101	20.8	471	464	252	29.6	118	116

In the study of Monti, Vingilio & Venturi (2008) it was clearly shown that the quality of biomass may drastically change with crop and biomass partition. Our (unpublished yet) and some data in literature (Monti, Vingilio & Venturi 2008; Burner, Tew et al. 2009; Shahandeh, Chou et al. 2011) revealed that leaves always showed the highest ash and minerals content than stems and reproductive organs. For direct combustion, SWG plants tissues with lower mineral concentrations (stems) are preferable, as high ash concentrations in leaves could be involved in reactions leading to ash fouling and slagging in biomass combustors (Demirbaş, 2005). Therefore not only the whole crop but also the biomass and its valuable components' partitioning should be considered. A two-way analysis of variance was carried out to determine if there was a significant effect of the aboveground plant part (Factor A: stem, leaves, panicles) and accession (Factor B) on both C concentration and C:N values, and the results of the analysis are summarized in Table 4. Seven SWG accessions cut at seed filling stage in second harvest year were used for the given part of study.

Table 4. Summary of the two-way analysis of variance (ANOVA) for significance of the effect of aboveground plant part and accession on C concentration and C:N values

Variance	DF	C concentration (C)		Carbon to nitrogen ratio (C:N)	
		Mean Square	F - act.	Mean Square	F - act.
Treatments	20	2.946	30.06**	8677.308	22.38**
Factor A	2	24.621	251.22**	82543.396	212.92**
Factor B	6	0.996	10.16**	476.970	1.23
Interaction AB	12	0.309	3.16*	466.462	1.2
Error	20	0.098		387.673	

Switchgrass plant part significantly ($P<0.01$) affected both C and C:N. Accession's main effect was significant at the $P<0.01$ level for C and statistically there was no significant difference for C:N among the seven SWG accessions. The accession $\times$ plant part interaction was statistically insignificant for C:N, and for C concentration it was significant at the $P<0.05$ level. Average C concentration was higher (at $P<0.01$) in stems ($462 \text{ g kg}^{-1} \text{ DM}$) and panicles ($459 \text{ g kg}^{-1} \text{ DM}$) than in leaves ($439 \text{ g kg}^{-1} \text{ DM}$) (Table 5). The C:N values in the stem tissue (150–193) were four – six-fold higher than in the leaves (29.1–38.9), and three – five-fold higher than in the panicles (39.6–47.1) suggesting a preferential accumulation of C in stems and of N in leaves and panicles, but primarily in seeds. The variation in chemical traits among the tested accessions was lower than that among plant parts (Table 5). This notwithstanding, one-way analysis of variance revealed significant differences ($P<0.05$ or <0.01) in C and C:N among the 7 SWG accessions within all aerial plant parts. SWG No 51 contained significantly greater ($P<0.01$) C content in stems compared with Nos 57, 62 and 64, while the rest of the accessions in panicles. The leaf portion of SWG No 64 contained higher C content than Nos 46 and 57 ($P<0.01$) and Nos 51 and 60 ($P<0.05$). The results also showed that the lowest C concentration in all plant parts was characteristic of SWG No 57.

Table 5. C concentration and C to N ratio in the biomass of aboveground plant parts of switchgrass germplasm in the second harvest year when cut at seed filling stage

Sample ID	C concentration in plant parts, g kg^{-1}			C to N ratio (C:N)		
	Stems	Leaves	Panicles	Stems	Leaves	Panicles
46	465	435	460	175	29.1	46.9
47	464	441	456	150	36.7	46.7
51	472	439	468	169	29.3	42.5
57	454	428	455	163	34.5	47.1
60	465	439	459	154	33.9	41.2
62	461	442	461	150	29.7	39.6
64	461	446	456	193	38.9	41.6
Average	462	439	459	165	33.1	43.7
LSD _{0.05/0.01}	5.14/7.79	5.49/8.32	4.20/6.36	50.1/75.9	5.23/7.92	6.39/9.68

The variation in the C:N among the germplasms often showed less reliable differences from average within biomass of any plant part. The statistically significant differences among ecotypes/varieties were more distinct when comparing respective biomass values among accessions themselves than those of an individual accession with average value. Statistically significant (at $P<0.01$ or $P<0.05$) differences from the mean were most frequently established for C:N value in stem and leaf portion of SWG No 64: it was the highest (193 and 38.9) among other germplasm within the respective plant part (Table 5). The SWG No 57 distinguished itself among others with greater C:N in panicles.

Solar energy, accumulated in C compounds in plants through atmospheric CO_2 capture can be used for bioenergy purposes. It is assumed that 1 g C is equivalent to 43.96 kJ, and 1 g dry matter of plant is equivalent to 16.76 kJ (Shiyomi, Takahashi & Kirita 2000). As a result, it is essential to establish not only the accumulated C output in whole aboveground biomass of energy crops, but also to reveal plant parts accumulating the highest CY. The particularity of CY partitioning among aboveground plant parts

was similar to that for DM biomass in respective plant portions (Table 6). Stems exhibited greater CY than other plant parts. Stems contained in average 119 g C per plant or 47.4 % C of the total CY per plant. An average CY share in panicles was the lowest among plant parts: it was 3.5 times lower than that in stems and 2.8 times lower than in leaf portions. The total CY in plant components varied between accessions: stems of SWG No 46 accumulated 175 g C per plant, while CY in stems of Nos 57 and 64 was twice as low (87.5 and 82.6 g C per plant). The variation in CY within leaf and panicle portions among germplasm was also wide: it ranged from 83.7 (No 64) to 111 (No 62) g C per plant in leaves, from 16.4 (No 62) to 73.6 (No 60) g C per plant in panicle fraction. Reconstituted C yield as the sum of CY in separate plant parts (Table 6) was well correlated ($r=0.997$) with CY per whole aboveground part of plant calculated as a product of DMY $\times$ C concentration (Table 3). There were evident correlations not only between SWG DMY and CY per whole plant ($r=0.998$), but also between DMY and CY in stem portion ($r=0.856$). C concentration in whole aerial plant part revealed a moderate impact on CY per whole plant ($r=0.697$).

Table 6. Dry matter and carbon output (g C plant⁻¹) partitioning in morphological fractions of switchgrass accessions

Sample ID	Morphological fractions, % per plant DM			Carbon yield from morphological fraction, g per plant			Reconstituted C yield, g per whole above-ground plant part
	Stems	Leaves	Panicles	Stems	Leaves	Panicles	
46	58.7	32.2	9.08	175	89.4	26.7	291
47	45.3	39.3	15.4	120	99.2	40.1	260
51	44.5	41.5	13.9	119	103.0	36.9	259
57	43.3	47.6	9.14	87.5	90.6	18.5	197
60	41.0	33.8	25.1	122	94.8	73.6	290
62	48.8	44.9	6.36	125	111	16.4	252
64	42.4	44.3	13.3	82.6	83.7	25.6	192
Average	46.3	40.5	13.2	119	95.9	34.0	249

Hence, based on the results of our study and literature data (Burner, Tew et al. 2009) it will be assumed that the partitioning and quality of aboveground biomass have important ramifications for crop management and for making decisions regarding appropriate energy conversion technologies. Therefore, agricultural strategies aimed at pursuing primary sources with a preponderant stem component should be recommended (Monti, Vingilio & Venturi 2008), when switchgrass is considered as a feedstock for combustion. Stems were much better than leaves and reproductive organs regarding to high values of C and C:N, lower mineral concentrations. Preferential nutrient partitioning within switchgrass may allow harvesting plant parts high in C for bioenergy, while leaving plant parts with higher mineral content in the field (Shahandeh, Chou et al. 2011). With this approach, depletion of soil nutrients and organic matter may be reduced. Moreover, when evaluating C accumulation in switchgrass biomass it should be borne in mind that perennial crops sequester yet more C in soil organic matter and contribute to atmospheric CO₂ mitigation strategies: the partitioning of C among components of plant biomass showed that aboveground vegetation contained only 18%, crown tissue 55%, and roots 27% of total biomass C (Frank, Berdahl et al. 2004).

4. CONCLUSIONS

1. The switchgrass plant maturity at biomass harvesting and grass harvest year are important factors affecting dry matter and carbon yields (DMY, CY), carbon concentration (C) and carbon to nitrogen ratio (C:N): all variables increased with advancing maturity and plants age, except for C in switchgrass biomass of the second harvest year, when average C concentration at heading was nearly-equal to that at seed filling (460 vs 458 g kg⁻¹ DM). CY per plant cut at heading stage ranged from 37.3 g on average for plants in the first harvest year to 147g for those in the second harvest year, at seed filling stage CY averaged 119 and 252g depending on the harvest year.
2. There were significant differences in DMY, C, CY and C:N among the accessions within same group of plants maturity and age. The accessions that showed higher DMY and CY than average for SWG at both stages in the groups were Nos 67, 69 (the first harvest year) and 46, 60 (the second harvest year).
3. Switchgrass plant part significantly ($P < 0.01$) affect both C and C:N. The C:N values in the stem tissue (150 – 193) were four – six-fold higher than in the leaves (29.1 - 38.9), and three – five-fold higher than in the panicles (39.6-47.1) C concentration in stems accounted on average for 462, leaves for 439, and panicles for 459 g kg⁻¹ DM.
4. Stems exhibit greater CY than other plant parts: their contained in average 119 g C per plant or 47.4 % C of the total CY per plant. An average CY share in panicles 3.5 times lower than that in stems and 2.8 times lower than in leaf portions.
5. DMY was a weighted factor for CY variation. DMY per whole plant showed a close correlation with CY ($r=0.998$) and CY per plant stem portion ($r=0.856$). C concentration had positive impact on CY, which was increasing with advancing in plant age and maturity.
6. The variation of DMY, CY, C concentration and C:N revealed in the switchgrass germplasm collection study showed some accessions to be a promising material to be used for renewable energy purposes under cool temperate climate conditions of Lithuania.

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