Chapter 2
Features of Carbon Stock in the Biomass of Industrial Hemp and Stinging Nettle

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Abstract Recently, researchers have drawn their attention to industrial hemp (*Canabis sativa* L.) and stinging nettle (*Urtica dioica* L.), as feedstocks, potentially having a wide nonfood application. The aim of the present work was to compare dry matter (DM) and carbon (C) yields as well as C concentration in the above-ground biomass, stems and shives of the mentioned crops. In this chapter, extra attention has been paid to the C accumulation in stems and shives, since stems are a more environmentally friendly resource for solid biofuel compared to the whole above-ground part of the plant, and shives are an agricultural waste.

Field experiments with industrial hemp (eight varieties) and stinging nettle (one wild nettle and two treatments of fibre nettle clone) were carried out during 2010–2012. Dew retting and water retting were used to extract the fibre. C concentration in the samples of hemp and nettle was determined by wet oxidation with dichromate.

DM yield of the above-ground biomass of hemp amounted to an average of 10607 kg ha^{-1}, of stems 9063 kg ha^{-1} with high C concentrations of 555 and 568 g kg^{-1} DM, respectively. DM yield of the nettle declined along with a harvest year and ranged from 11604 kg ha^{-1} (2010) to 5596 kg ha^{-1} (2012) averaging

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A. Sayigh (ed.), *Renewable Energy in the Service of Mankind Vol I*,
DOI 10.1007/978-3-319-17777-9_2

7589 kg ha^{-1} per trial. DM yield of wild nettle was more than twice as low as that of fibre nettle clone (on average 3945 kg ha^{-1} vs 9411 kg ha^{-1}).

C stock in stems of hemp and nettle amounted to an average of 5149 and 3719 kg ha^{-1}, respectively. DM yield was a weighted factor for C yield.

Shives, which are the woody residue left over from the processing of hemp and nettle straw appeared very rich in C the concentration of which in hemp shives varied in the range of 564–602 g kg^{-1} DM and in nettle shives 543–596 g kg^{-1} DM. The retting method (R) significantly ($P<0.01$) affected the C concentration in nettle shives.

The high heating value (HHV) of biomass, stems and shives of hemp and nettle was determined, and the theoretical accumulation of CO_2 in biomass per ha was calculated.

Results of this study showed that the hemp and fibre clones of stinging nettle could be promising candidates for bioenergy production. The CO_2 content fixed into the biomass of the studied crops might contribute towards the reduction of climate warming.

Keywords Bioenergy plant · Shives · Carbon · Dry matter yield (DMY) · *Canabis sativa* L · *Urtica dioica* L

2.1 Introduction

Today, it is clear that the development of Europe's renewable energy resources is a crucial element in the battle against climate change [1]. The fight against climate change and the depletion of fossil fuels has forced humanity to "decarbonising" the economy [2]. Burning fossil fuels uses "old" biomass and converts it into "new" CO_2, which contributes to the "greenhouse" effect and depletes a non-renewable resource [3]. The need for CO_2 management, in particular capture and storage, is currently an important technological, economical and global political issue and will continue to be so until alternative energy sources and energy carriers diminish the need for fossil fuels [4]. A plant used for biomass energy grows by removing CO_2 from the air through photosynthesis [5]. Carbon (C) accumulated in biomass through CO_2 fixation can be easily converted into usable energy [2]. Biofuel from energy plants is considered at least as "C neutral": CO_2 that is released in burning is returned to the biomass from the atmosphere during photosynthesis and returned for a cycle of new growth [3, 5].

Currently, researchers are focusing attention on hemp (*Canabis sativa* L.) and stinging nettle (*Urtica dioica* L.), as high yielding multipurpose feedstocks. Growing well in Central Europe, both hemp and stinging nettle are promising candidates for nonfood market production: textile, paper, building industries as well as bioenergy [6–11]. Hemp is an annual monoecious or dioecious plant and it is considered as being a crop that requires no pesticides, since it outcompetes weeds, uses little fertiliser or irrigation in temperate areas and potentially causes little land use change since it can be grown on marginal land (though it will require more inputs if not grown on cropland) [12]. Industrial hemp (variety Futura 75) grown in Northern Europe, yielded an average of 14.4 Mg DM ha^{-1} and exhibited satisfactory net energy yields per hectare [9, 13]. The stinging nettle is a common dioecious herbaceous perennial plant that grows on ruderal sites, in gardens, at the edges of forests and in wooded areas of the riverine floodplains [6]. Nettle is practically not grown commercially in Europe [14]. The existing areas cover experimental plots. Several new nettle clones have been selected and characterised by high fibre content and strong tillering [15]. The trials with the clones of fibre nettle have been conducted in Austria, Germany and Italy [8, 16, 17]. The annual dry matter yield (DMY) of nettle in boreal growing conditions ranged from 6–10 Mg ha^{-1} [18] and DMY of stalks of five clones fluctuated from 2.3–9.7 Mg ha^{-1} [16]. Clones of fibre nettle were successfully tested as bioenergy crop, mainly for the purpose of anaerobic digestion [18, 19].

Shives are the woody residue left over after the processing of stalks (hemp, nettle, flax or other fibrous crop) on target for fibre extraction. This agricultural waste could be used as a renewable source for composites, combustion or other forms of bioenergy [20,21].

Since C containing compounds from the biomass generate a principal amount of biomass energy, we devoted our attention to the features of C stock in the above-ground biomass of hemp and stinging nettle and its fractions—stems and shives.

2.2 Material and Methods

A field experiment was carried out in the Central Lowland of Lithuania (55°39′11″N 24°13′59″E) at the Upytė Research Station of the Lithuanian Research Centre for Agriculture and Forestry on an *Eutri-Endohypogleyic Cambisol* (*CMg-n-w-eu*) [22]. The study involving eight monoecious varieties of industrial hemp and three treatments of stinging nettle (one wild nettle and two treatments of fibre nettle clone) was carried out during 2010–2012 in three replications. The hemp variety (V) "USO 31" (of Ukrainian origin) is known as a very early variety. Polish varieties "Beniko" and "Bialobrzeskie" are considered as medium-early in the country of their origin. The other five hemp varieties are French in origin and differ in earliness: "Fedora 17" is early-maturing, "Felina 32" and "Santhica 27" are medium-late maturing, "Epsilon 68" is late-maturing and "Futura 75" is a very late-maturing variety. The seed rate of hemp was 50 kg ha^{-1}, interrow spacing was 10 cm. Hemp was sown at the beginning of May, and harvested when the first mature seeds appeared (in September or October, depending on the year and variety ripening). In all experimental years, the V "USO 31" was harvested 0.5–1 month earlier than the other varieties: on September 9 in 2010, September 13 in 2011 and September 19 in 2012. The rest of the hemp varieties were harvested on October 4, September 22–23 and October 15–16, respectively.

The current study on stinging nettle was a follow-up of the experiment where nettle has been cultivated since 2008. The wild stinging nettle was planted at a density of 60 × 60 cm and clones of fibre nettle—at two densities: 60 × 60 and 60 × 100 cm. Stinging nettle was cut at the end of May—beginning of June for testing biomass of young plants as food ingredient. After regrowth, stinging nettle was harvested when seeds were mature in the lower part of the inflorescence: at the end of August in 2010, on September 12 and 4 in 2011 and 2012, leaving stubble of up to 15 cm height. The biomass harvested at this time was studied as a feedstock for industry (textile and bioenergy).

Since we investigated stinging nettle and hemp as multifunctional plants, the dew retting and water retting were used to extract fibre. Shives obtained after retting were evaluated as a feedstock for solid biofuel.

The growing seasons were abundant in precipitation, whose amount was distributed unevenly over the period, but generally the weather conditions were favourable for hemp and stinging nettle growing.

C concentration in the samples of hemp and nettle was determined by a spectrophotometric procedure after wet oxidation of plant material with dichromate [23, 24]. In this chapter, extra attention has been paid to the C accumulation in stems and shives, since stems are a more environmentally friendly resource for solid biofuel compared to the whole above-ground plant part, and shives are an agricultural waste. Samples of hemp ant nettle stems were analysed for C every year. C in shives was established in the samples of 2010 and 2011 harvest years and in the samples of above-ground mass of 2010 harvest year. C concentration in above-ground biomass of 2011, 2012 harvests was calculated from C concentration in stems using coefficients 0.9774 for hemp and 0.9664 for nettle. These coefficients were obtained from the data of 2010 harvest as a ratio of C in the respective samples of plant above-ground biomass and stems. Samples for the total nitrogen (N) concentration were analysed by the Kjeldahl method. The ash content was determined by the method consistent with LST EN 14775 [25] with mass incineration at (550 ± 10) °C. Klason lignin was analysed using the procedure NREL LAP 003 [26]. Gross calorific value (GCV) or high heating value (HHV) was measured using an IKA bomb calorimeter (C 200, Germany) following the LST EN 14918 [27]. Around 1 g of biomass was pelletised and introduced in the bomb, which was charged with pure oxygen (> 99.99 %) to a pressure of 3.0 ± 0.2 MPa. The bomb had previously been calibrated with benzoic acid.

Two- and three-way ANOVA [28] with a three-replication design was performed on the data to determine the significance of the following factors: hemp varieties/nettle treatment V/T: (V/T; for above ground biomass, stems and shives), harvest year Yr: (Yr; for above ground biomass, stems and shives), retting method (R; for shives) on dry matter (DM) yield, C concentration and yield.

2.3 Results and Discussion

According to the data of two-way ANOVA, the DMY both of hemp above-ground biomass (further biomass) and stems, as well as C output in biomass and stems significantly ($P<0.01$ or $P<0.05$) depended on V and did not depend on the growing year (Yr; Table 2.1). Conversely, the effect of the Yr was significant ($P<0.01$), and statistically insignificant varietal impact on C concentration (C) in the biomass and stems was revealed. The effect of interaction of the V and Yr on DMY, C yield (CY) as well C in biomass was negligible. Factors' interaction was significant for C in stems (at $P<0.05$) only.

Mean biomass DMY per trial amounted to 10607 kg ha^{-1} and stems DMY to 9065 kg ha^{-1}. DMY both of stems and biomass of early-maturing varieties USO 31 and Fedora 17 were significantly lower than mean per trial. One of the most productive varieties was the latest-maturing variety Futura 75. Polish hemp varieties Beniko and Bialobrzeskie were also high yielding though they are ranked as medium early-maturing. The same patterns were obtained regarding CY accumulated in biomass and stems. As C concentration variation with variety was inappreciable DMY was a weighted factor for calculated CY. With regard to the Yr, which is an entireness of environmental conditions of the hemp growth period, lower than average per trial DMY and CY were obtained in 2010 and 2012, in contrast to 2011 where it was higher yielding, though differences from the mean were statistically insignificant. It was observed that hemp biomass, and particularly stems, contained high C concentration (on average 552 and 568 g kg^{-1} DM). The highest (at $P<0.01$) C was found in biomass and stems (558 and 573 g kg^{-1} DM) of the 2012 yield, when the lowest average DMY was recorded and vice versa. Some differences in temperature and precipitation distribution during the growing seasons of hemp and plant biomass maturity at harvesting could have an impact on C concentration: The majority of hemp varieties were harvested 2–3 weeks earlier in 2011 than in 2010 and 2012.

All the parameters of the stinging nettle presented in Table 2.2 were significantly ($P<0.01$) impacted by Yr. Nettle treatment (T; at $P<0.01$) and T × Yr interaction (at $P<0.05$ mostly) were weighty factors for DMY both of biomass and stems as well as for the respective CY. However, C in both biomass and stems was T and T × Yr independent parameter. Biomass DMY of wild nettle was more than twice as low as that of the clone of fibre nettle (on average 3945 kg ha^{-1} vs 9194 and 9629 kg ha^{-1}). Such large distinction between clones of fibre nettle and wild ecotype was observed in each year of the study and not only in DMY of biomass, but in DMY of stems as well as in CY from biomass and stems. Differences in both DM and CY between treatments of fibre nettle grown in plots of diverse density were inappreciable with a trend of higher values in the sparser plots (60 × 100 cm). Biomass and stems of nettle plants had high C (528 and 546 g kg^{-1} DM, respectively) and CY (4125 and 3719 kg ha^{-1}); although these values were lower in the respective fractions of hemp. C stock of clones of fibre nettle amounted to 4882–5389 kg ha^{-1} in biomass and to 4579–4810 kg ha^{-1} in stems. DMY of the nettle declined along with a harvest year and ranged from 11,604 kg ha^{-1} (2010)–5596 kg ha^{-1} (2012)

Table 2.1 Summary of two-way ANOVA for dry matter yields (DMY), C concentration (C) and C yield (CY) in above-ground biomass and stems of industrial hemp

Variable	Biomass DMY kg ha^{-1}	Stems DMY kg ha^{-1}	C in biomass g kg^{-1} DM	C in stems g kg^{-1} DM	CY with biomass kg ha^{-1}	CY with stems kg ha^{-1}
	Significance of the factor					
Variety (V)	*	**	Ns	ns	*	**
Growing year (Yr)	ns	ns	**	**	ns	ns
V × Yr	ns	ns	Ns	*	ns	ns
Mean value per trial	10607	9065	552	568	5866	5149
Variety	*Average value for variety*					
Beniko	11848*	10471**	551	566	6533*	5926**
Bialobrzeskie	11435	9953	555	570	6356	5673
Epsilon 68	9994	8534	548	563	5483	4803
Fedora 17	9272*	7777	554	569	5148*	4430*
Felina 32	10498	8956	554	569	5816	5089
Futura 75	11627	10193*	555	570	6457	5809*
Santhica 27	10877	9085	550	565	5993	5135
USO 31	9303*	7548**	552	573	5142*	4329**
P_{05}	*1110*	*950*	*5.93*	*6.12*	*623*	*549*
P_{01}	*1482*	*1268*	*7.92*	*8.17*	*832*	*733*
Growing year	*Average value for year*					
2010	10479	8991	553	570	5814	5122
2011	11164	9491	546**	561**	6100	5328
2012	10178	8712	558**	573**	5683	4998
P_{05}	*593*	*508*	*3.17*	*3.27*	*333*	*293*
P_{01}	*792*	*678*	*4.23*	*4.37*	*444*	*392*

ns not statistically significant, significance of differences evaluated from mean
* significant at $P < 0.05$ ** significant at $P < 0.01$

Table 2.2 Summary of two-way ANOVA for dry matter yield (DMY), C concentration (C) and C yield (CY) in above-ground biomass and stems of stinging nettle

Variable	Biomass DMY kg ha^{-1}	Stems DMY kg ha^{-1}	C in biomass g kg^{-1} DM	C in stems g kg^{-1} DM	CY in biomass kg ha^{-1}	CY in stems kg ha^{-1}
	Significance of the factor					
Treatment (T)	**	**	ns	ns	**	**
Growing year (Yr)	**	**	**	**	**	**
T × Yr	*	*	ns	ns	*	**
Mean value per trial	7589	6715	528	546	4125	3719
Nettle treatment	*Average value for treatment*					
Wild nettle	3945**	3194**	524	542	2103**	1767**
Fibre nettle, 60 × 60 cm	9194**	8305**	526	545	4882**	4579**
Fibre nettle, 60 × 100 cm	9629**	8646**	533	552	5389**	4810**
P_{05}	*982*	*898*	*8.09*	*8.37*	*473*	*487*
P_{01}	*1353*	*1237*	*11.14*	*11.54*	*652*	*671*
Growing year	*Average value for year*					
2010	11604**	10979**	550**	569**	6584**	6234**
2011	5567**	4633**	528	546	2945**	2537**
2012	5597**	4533**	505**	523*	2845**	2385**
P_{05}	*982*	*898*	*8.09*	*8.37*	*473*	*487*
P_{01}	*1353*	*1237*	*11.14*	*11.54*	*652*	*671*

ns not statistically significant, significance of differences evaluated from mean
* significant at $P < 0.05$ ** significant at $P < 0.01$

averaging 7589 kg ha^{-1} per trial and 9412 kg ha^{-1} per clones of fibre nettle (Table 2.2). As reported by Vogl and Hartl [6] as well as Harwood and Edom [29] stinging nettle can be cultivated for 4 and more years. It is likely that in our study a sharp decrease in DMY and other related parameters in 2011 occurred due to the fact that after harvesting in 2010 before winter (November 15) the aftermath was cut. On the other hand, yielding potential of plants could fall with the harvesting year: 2011 was a third harvesting year of nettle.

Although, according to the most discussed features, stinging nettle conceded to industrial hemp, our results showed nevertheless that the annual C production per above-ground biomass and stems was distinctly higher for clones of fibre stinging nettle (5135 and 4695 C ha^{-1} yr^{-1} on average) than that of the mature forests [30]. Gower et al. [30] reported that the above-ground net primary C production of the mature forests in Canada ranged from 3490–3520 kg C ha^{-1} yr^{-1} for aspen stands to 1170–1220 kg C ha^{-1} yr^{-1} for jack pine stands. Consequently C stocks in the biomass and stems of wild nettle (2103 and 1767 C ha^{-1} yr^{-1}) were lower than annual C accumulated per ha for aspen stands; however exceeded those for jack pine stands. Our results also showed that C production per above-ground biomass and stems of hemp (5866 and 5149 kg C ha^{-1} yr^{-1} on average) noticeably exceeded that of mature forests. To accumulate these C quantities in above-ground biomasses, plants of hemp and clones of fibre nettle had utilised from atmosphere on average 21,509 and 18,828 kg CO_2 ha^{-1} yr^{-1}, respectively, (CO_2 content needed for stubble and roots biomass not included). So theoretical calculation shows, that fixation of CO_2 into biomasses of industrial hemp and clone of fibre nettle might contribute towards reducing its accumulation in the atmosphere. Our results support the conclusion of Finnan and Styles [31] that hemp could considerably reduce greenhouse gas emission. The same is true for stinging nettle. This chapter discusses the C stock in a part of the annual yield of nettle above-ground biomass and stems only, that is, in biomass accumulated during the short summer period of approximately 3 months. Therefore in order to calculate the total annual C stock, one should sum the above described C yield with C stock in biomass, cut at the end of May–beginning of June and aftermath for stinging nettle as food ingredient, as well in stubbles and roots. It is noteworthy that, first, nettle is a perennial crop with root biomass exceeding that of annuals [32] and second, nettle fields could be expected to remain productive for several years with low labour costs which will positively influence the economic viability of nettle biomass production [29].

Three-way analysis of variance (ANOVA), applied to reveal the significance of factors for shives percentage from stems, shives DMY, C and CY in shives was carried out according to the following scheme: A factor R, B factor V or nettle treatment (T), C factor harvest year (Yr; Table 2.3). ANOVA was used for hemp and stinging nettle separately. The R was significant at $P<0.01$ for shives output from stems and C concentration in nettle shives only. Yr and V or nettle treatment were factors that impacted output, DMY, CY of shives both of hemp and stinging nettle. All the tested factors and Yr interaction with both R and T were significant ($P<0.01$) for nettle shives output. Average per trial output of shives from nettle stems (60.5 %) was markedly higher than that from hemp stems (45.7 %). Water-retted stems provided lower percentage of shives (45.7 and 57.0 %, respectively for hemp and nettle), than dew-retted stems (46.2 and 64.0 %, respectively). Output of shives had a direct impact on DMY and CY in shives: DMY and CY for nettle shives were higher than for hemp shives, likewise DMY and CY for dew-retted shives were higher than for water-retted shives. The contribution of DMY of stems in combination with shives output for DMY and C stock in shives it cannot be disregarded.

As for C stock, it should be noted that C accumulated in shives of clones of fibre nettle was equal to that of the mature forests for aspen stands, CY in shives of wild nettle was close to annual C production per jack pine stands and CY in shives of hemp varieties took up an intermediate position (Table 2.3) and [30]. So, for C stock that was found in the discussed agricultural waste, the target plants consumed large quantities of atmospheric CO_2: 9068 and 9739 kg ha^{-1} on an average for hemp and stinging nettle shives, respectively.

Average HHV, concentration of components, which are important to characterise hemp and nettle biomass, stems and shives as a source for solid biofuel are presented in Table 2.4.

Table 2.3 Summary of three-way ANOVA for shives output from stems and DMY, C concentration (C) and C yield (CY) of hemp and nettle shives

Variable	Shives output % from stems		Shives DMY kg ha^{-1}		C in shives g kg^{-1}		CY in shives kg ha^{-1}	
	Hemp	Nettle	Hemp	Nettle	Hemp	Nettle	Hemp	Nettle
Factor	*Significance of the factor*							
Retting method (R)	ns	**	ns	ns	ns	**	ns	ns
Hemp variety (V)/Nettle treatment (T)	**	**	**	**	ns	ns	**	**
Growing year (Yr)	**	**	**	**	ns	**	**	**
R × V/T	ns	ns	ns	ns	*	ns	ns	ns
R × Yr	ns	**	ns	ns	ns	**	ns	ns
V/T x Yr	**	**	**	**	ns	ns	**	**
R × V/T × Yr	ns	ns	ns	ns	*	ns	ns	ns
Mean value per trial	45.7	60.5	4222	4595	586	579	2473	2656
Retting method	*Average value for retting method*							
Dew retting	46.2	64.0**	4245	4830	588	566**	2494	2741
Water retting	45.2	57.0**	4198	4360	584	591**	2452	2571
P_{05}	*0.960*	*1.11*	*158*	*353*	*2.37*	*5.02*	*92.6*	*212*
P_{01}	*1.28*	*1.51*	*210*	*479*	*3.15*	*6.82*	*123*	*289*
V/Nettle treatment	*Average value for* V*/nettle treatment*							
Beniko	37.5**		3861		584		2250	
Bialobrzeskie	44.9		4494		587		2634	
Epsilon 68	47.9		4259		585		2486	
Fedora 17	44.9		3247**		585		1898*	
Felina 32	46.8		4670		584		2720*	
Futura 75	44.4		4655		583		2715	
Santhica 27	45.1		4266		593*		2535	
USO 31	53.9**		4323		589		2546	
P_{05}	*2.54*		*418*		*6.27*		*245*	

Table 2.3 (continued)

Variable	Shives output % from stems		Shives DMY kg ha^{-1}		C in shives g kg^{-1}		CY in shives kg ha^{-1}	
	Hemp	Nettle	Hemp	Nettle	Hemp	Nettle	Hemp	Nettle
P_{01}	*3.38*		*555*		*8.33*		*326*	
Wild nettle		62.8**		2056**		579		1200**
Fibre nettle, 60 × 60 cm		57.4**		5429**		579		3162**
Fibre nettle, 60 × 100 cm		61.3		6299**		578		3606**
P_{05}		*1.57*		*499*		*7.10*		*300*
P_{01}		*2.14*		*678*		*9.65*		*408*
Growing year	*Average value for* V/*nettle treatment*							
2010	35.8**	56.6**	3208**	6245**	588	586**	1886**	3657**
2011	55.5**	64.4**	5235**	2945**	585	571**	3060**	1654**
P_{05}	*0.960*	*1.11*	*158*	*353*	*2.37*	*5.02*	*92.6*	*212*
P_{01}	*1.28*	*1.51*	*210*	*479*	*3.15*	*6.82*	*123*	*289*

ns not statistically significant, significance of differences evaluated from mean
* significant at $P < 0.05$ ** significant at $P < 0.01$

Table 2.4 Averaged data for solid fuel quality-related components in biomass and it fractions of hemp and stinging nettle

Biomass fraction	Hemp				Stinging nettle			
	HHV	Ash	Lignin	N	HHV	Ash	Lignin	N
	MJ kg−1 DM	g kg−1 DM			MJ kg−1 DM	g kg−1 DM		
Whole above ground plant part	18.1	67.1	175	5.70	18.2	99.8	165	15.6
Stems	18.5	37.1	177	4.59	18.3	74.3	171	9.70
Shives, dew retting	19.5	21.2	207	3.09	18.7	53.2	208	6.68
Shives, water retting	19.5	12.8	204	3.13	19.1	20.5	217	5.06

A problem that herbaceous energy crops pose during combustion is the ash content: high ash amounts can cause slagging. High concentration of N in combusting biomass can promote greenhouse gas NO_x emissions, and lignin is associated with HHV [33]. All fractions of hemp and nettle showed good results of HHV: from 8.1–18.2 MJ kg^{-1} DM of whole above-ground plant part biomass to 19.1–19.5 MJ kg^{-1} DM of shives. Ash, N contents in both hemp and nettle declined, whereas HHV and lignin increased in the following order: above-ground plant part—stems—shives. From the data presented in Table 2.4, one can see that combustion properties (lower ash and N contents and higher HHV) of hemp fractions seem to be more valuable for solid biofuel than those of nettle. Therefore, our results corroborate an argument of Finnan and Styles [31] that hemp is a sustainable annual crop for climate and energy policy.

Figure 2.1 shows the linear relationships between averaged for fractions HHV and C as well as lignin concentration values. Both parameters of biomass quality positively at $P<0.01$ correlated with the HHV. Demirbaş [33] showed also that the HHV of lignocellulosic fuels is highly correlated with lignin content.

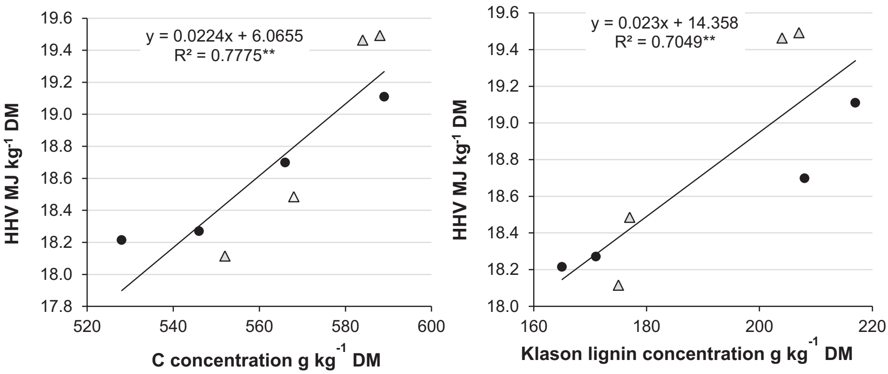

Fig. 2.1 The impact of C and Klason lignin concentration on high heating value (HHV) of biomass. Data averaged for fractions over all hemp varieties/nettle treatments, growing year (Yr) and replications, but separately for hemp (▲) and stinging nettle (●) as well as for water- and dew-retted shives

2.4 Conclusions

Hemp and clones of fibre stinging nettle could be promising candidates for bioenergy production. Annual C production per above-ground biomass and stems was distinctly higher for hemp (5866 and 5149 kg C ha^{-1} yr^{-1} on an average) and clones of fibre stinging nettle (5135 and 4695 kg C ha^{-1} yr^{-1} on an average) compared with mature forests. According to HHV, C, lignin concentration and other solid biofuel-related parameters shives were revealed to be the most valuable fraction of both crops—hemp and stinging nettle. When comparing the two crops, hemp fractions showed better properties for solid biofuel purpose than nettle. The CO_2 content fixed into biomass of studied crops might contribute towards reduction of climate warming.

Acknowledgements The article presents research findings obtained through the long-term programme "Biopotential and Quality of Plants for Multifunctional Use" implemented by Lithuanian Research Centre for Agriculture and Forestry.

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http://www.springer.com/978-3-319-17776-2

Renewable Energy in the Service of Mankind Vol I
Selected Topics from the World Renewable Energy Congress WREC 2014
Sayigh, A. (Ed.)
2015, XXIX, 985 p. 514 illus., 401 illus. in color., Hardcover
ISBN: 978-3-319-17776-2