THE ASSESSMENT OF LINSEED VARIETY 'SCORPION' FOR SUITABILITY FOR BIOFUEL PRODUCTION

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Abstract
In the research, possibilities of linseed as a fuel constituent were evaluated by the following indicators: carbon content, sulphur content, and gross calorific value. The object of the research was the linseed variety 'Scorpion'. The trials were carried out in humi–podzolic gley soil during the period 2008-2010. Complex fertilizer was applied before sowing; N fertilizer rates – N0 kg ha^{-1} as control, N60, N80, and N100 kg ha^{-1}. The research shows ($p<0.001$) that the sulphur and carbon content and the highest calorific yield are influenced by the agrometeorological conditions of the growth year and by the N fertilizer. Various plant sections (stems, shives, and the chaff) were observed to have differing carbon and sulphur contents. Regarding the data of calorific yield results from one hectare, the year 2009 was more favourable than 2010. Taking all factors into consideration, for solid fuel output it is best to use linseed residue material.
Key words: *Linum usitatissimum* L., carbon, sulphur, gross calorific value.

Introduction

Worldwide, linseed is mainly grown for the seed. From the stems technical fibre is obtained, but from the residue material – the shives and chaff – it is possible to obtain solid fuel. The shives are obtained from the woody part of the flax. The shives can be used for insulation material production, also there exist other uses, for instance, adding them to chipboards or as shives for animal bedding. Also the question of using the shives as a fuel is an interesting possibility, as from 2 kg of shives it is possible to obtain the same amount of calorific yield as from 1 litre of heavy fuel oil. The flax shives are characterized by a high lignin (23-31%) content, as well as cellulose (53%) and hemicellulose (24%) content (Tamaki and Mazza, 2010; Ross and Mazza, 2010). In Lithuania (Груздевене et al., 2009) and also in Latvia at the present moment the residue from linseed is ploughed back into the soil or burnt on the field.

The aim of the research was to evaluate the possibilities of linseed variety 'Scorpion' for biofuel production.

Materials and Methods

Annual crop – linseed (*Linum usitatissimum* L.) from *Linacea* family – was tested in the locations and under the conditions described in Table 1. The nitrogen supplementary fertilizer and agrochemicals were given to the linseed in the fir-tree phase (GS 4) (Growth Stages by Turner), and insecticide – at GS 1 and GS 4.

The meteorological conditions for the growth of linseed are shown in Figure 1. In all three growth years the hydrothermal coefficient (HTC) of Selianinov was slightly above 1.5, but the plant germination conditions were not favourable in 2008-2009.

HTC calculated by formula (Čirkovs, 1978):

$$\text{HTK}=\frac{\sum N}{\sum t_{>10^0C}}\times 10\,; \qquad (1)$$

where

$\sum N$ – sum of precipations for a month, mm;

$\sum t_{>10}$ – sum of temperature above 10°.

Criteria:

HTK ≤ 0.5 – strong, very strong drought;
HTK = 0.6 – weak drought;
HTK ≤ 0.7 – dry conditions;
HTK ≥ 1.0 – characterizes the sufficient moistening.

The linseed samples were harvested by hand in the growth stage of the early yellow ripeness. The plants were tied up in bundles and left to dry in the field for 5-8 days. When flax was dry, it was crushed with the machine Eddi, and after that the pods were cleaned through a shive. The seeds were cleaned with a sample cleaner MLN, weighed (accuracy ± 0.001 g) and the seed yield was established taking 100% purity and 9% moisture content. The sample of 10 g of stems was weighed (accuracy ± 0.0001 g), then scutched with the tool ЛМ-3, broken and shaken until the shives were withdrawn, and weighed again. The result was calculated by the formulae according to the Practicum of crop (Freimanis et al., 1980).

The following parameters were tested: 1) the carbon content in shives, according to standard ISO 625; 2) the sulphur content, according to standard ISO 334; 3) the gross calorific value ($Q_{gr.d}$) with V (volume)=constant for dried fuel at 105°C, according to standard LVS CEN/TS 14918.

Table 1

Trial methods of the linseed variety 'Scorpion'

Parameters		Trial year		
		2008	2009	2010
Soil type		Humi-podzolic gley soil		
Soil composition	pH	7.3		7.0
	OM, %	3.8 (Tyurin's method)		6.5 (Tyurin's method)
	P, mg kg^{-1}	36 (DL method)		63 (DL method)
	K, mg kg^{-1}	54 (DL method)		98 (DL method)
Pre-crops		Spring rape		Winter wheat
Complex fertilizers	N:P:K, kg ha^{-1}	6:11.3:24.9, total 300 (N=29.03; P=54.9; K=120.5)		
Sowing time		9th May	4th May	6th May
Sowing rate	kg ha^{-1}	70		
N fertilizer rate	kg ha^{-1}	N0, N60, N80, N100		
Picking dates		29th August	28th August	10th August
Threshing dates		23rd September	21st September	20th September
Trial plots	m^2	7.5		
Replication		4		
Agro-chemicals	Insecticide	Fastaks 50 e.c. (alfa- cipermetrin, 50 g L^{-1}) 0.3 L ha^{-1}		
	Herbicide	Glins 75 d.g. (hlorsulfuron, 750 g kg^{-1}) 10 g ha^{-1}		
		Lontrels 300 s.c. (klopiralid, 300 g L^{-1}) 0.3 L ha^{-1}		MCPA Super 500 s.c. (MCPA, 500 g L^{-1}) 1.0 L ha^{-1}

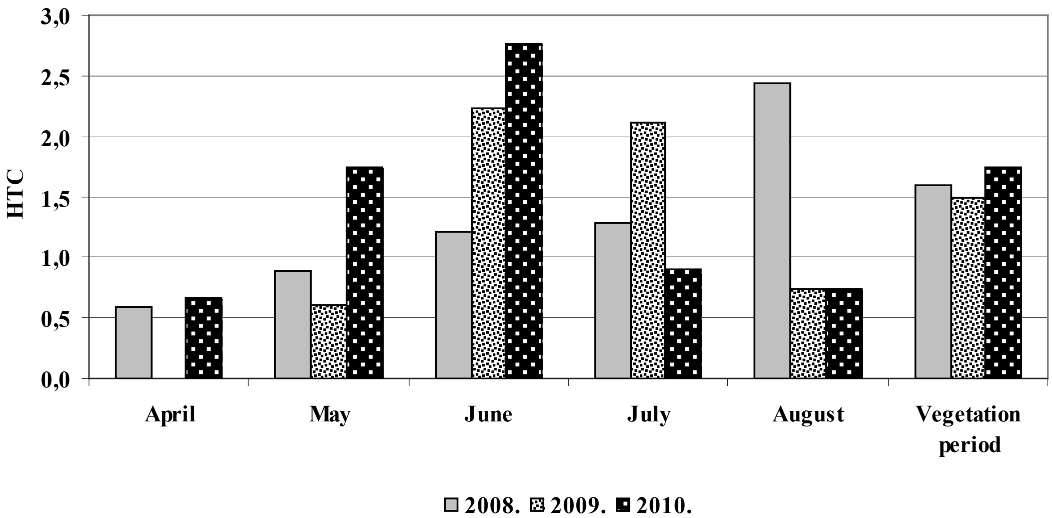

Figure 1. **Water stress expressed as hydrothermal coefficient (HTC) in Viļāni in 2008-2010.**

The MS Excel programme was used for data statistical processing. The statistical evaluation of data was carried out by using methods of correlation and regression, as well as dispersion analysis, and descriptive statistics (Доспехов, 1985; Arhipova and Bāliņa, 2003).

Results and Discussion

Carbon is the main burning element in fuel. The carbon content (min – average – max) was established for the linseed stems (0.39 – 0.43 – 0.47 g kg^{-1}), shives (0.38 – 0.40 – 0.44 g kg^{-1}) and chaff (0.40 – 0.43 – 0.48 g kg^{-1}) (Fig. 2). In 2008 and 2010, the greatest carbon content was in the flax stems (0.45 g kg^{-1} and 0.44 g kg^{-1}), in 2009 - in the chaff (0.44 g kg^{-1}). Analysis of the influence of N fertilizer on the content of carbon showed that highest C content in stem and shaff was obtained after applying N0 and N60 kg ha^{-1}, but in shives – after application of N60 kg ha^{-1}.

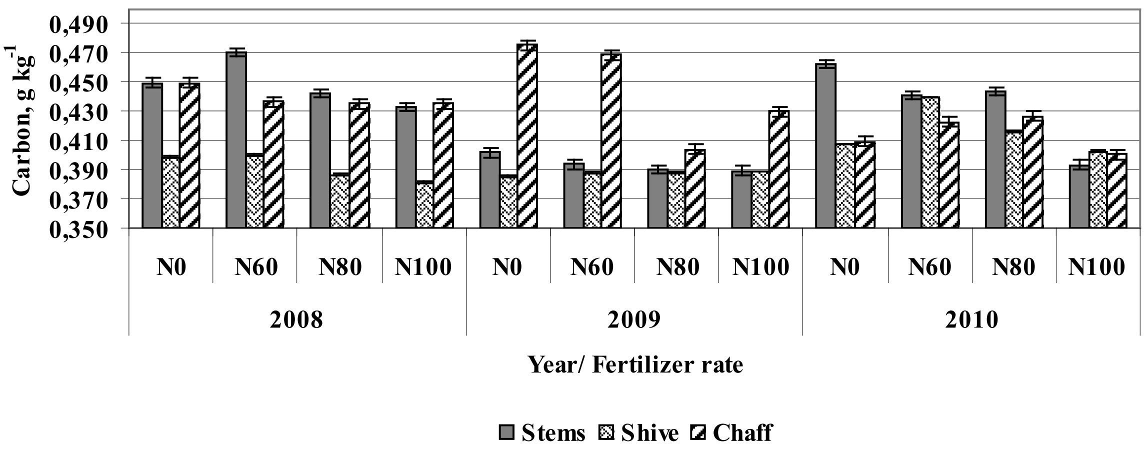

Figure 2. **Carbon content depending on the linseed growing year, and N fertilizer rates**

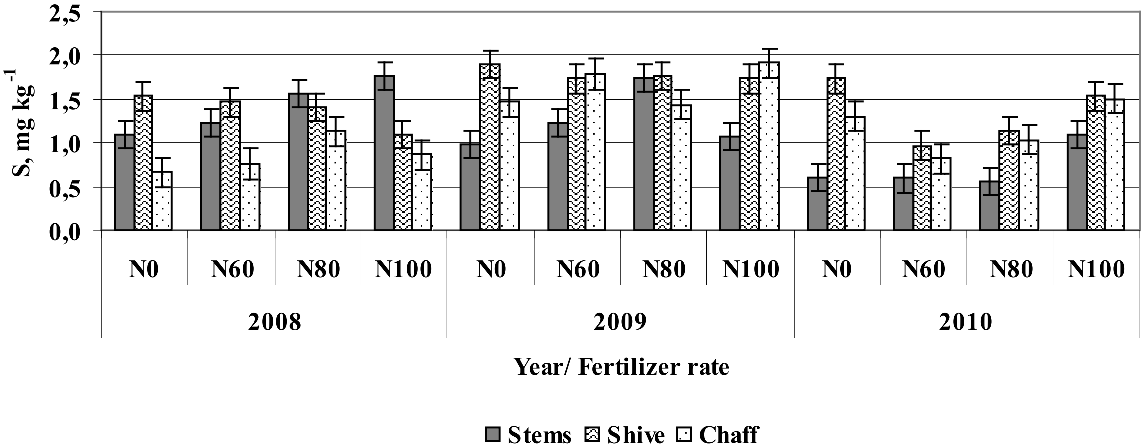

Figure 3. **Sulphur (S) content depending on the linseed growing year, and N fertilizer rates**

The calorific value from sulphur burning is low – 9300 kJ kg^{-1}, therefore the value for it as a burning element is low, and sulphur is an unwanted and harmful component in fuel, as it produces in the boiler surface heat and other energy equipment corrosion (Cars, 2008). The sulphur content (min – average – max) was established for the linseed stems (0.56 – 1.13 – 1.77 mg kg^{-1}), shives (0.97 – 1.50 – 1.90 mg kg^{-1}) and chaff (0.66 – 1.22 – 1.91 mg kg^{-1}) (Fig. 3). In 2008, the greatest S content was in the flax stems (1.42 mg kg^{-1}), in 2009, in the chaff (1.78 mg kg^{-1}), and in 2010 - in the shives (1.34 mg kg^{-1}). It can be seen that for flax stems and chaff the greatest S content was found after application of N 100 kg ha^{-1}, for the shives – N0 kg ha^{-1}. Linseed hybrids grown in Latvia have up to 1.0 mg kg^{-1} sulphur content in the shives using the fertilizer rate of N60 kg ha^{-1} (Komlajeva et al., 2011), which means that the sulphur content can be determined by the chosen variety.

For the linseed variety 'Scorpion', the sulphur and carbon content and the gross calorific yield in various plant sections were dependent on the growth year and N fertilizer rate (Table 2).

In our research the influence of N fertilizer is not unequivocal. In other research (Vucāns, 1996) it has been found that the fertilizer can increase the productivity and can reduce the energy indicators. In 2010, HTC variances were observed in the flowering stage of linseed - due to excessive rainfall in June, and rainfall deficit and temperatures above 30 °C in July (Fig. 1). Scientists Ivanovs and Stramkale (2001) have observed that precipitation requirements for flax are relatively great and temperature requirements are modest.

Our research showed a significant negative correlation ($p<0.05$) between sulphur (y) and carbon (x) content in the shives of linseed (Fig. 4). In the shives and stems of the linseed, a weak correlation ($p>0.05$) was observed between sulphur and carbon. That confirms that each part of a plant has a different chemical composition. The feed availability in plant is dependent on the soil quality, the fertilizer usage, and weather conditions (Hiltunen et al., 2008).

Table 2

The influencing factor proportion ($p<0.001$) on the carbon and sulphur content and gross calorific value of the linseed variety 'Scorpion', η, %

Plant part	Factor	Carbon content	Sulphur content	Gross calorific value
Stems	Growth year (A)	65.7	51.8	95.4
	Nitrogen fertilizer (B)	19.3	18.8	1.1
	Interaction (A x B)	14.8	25.4	3.1
Shive	Growth year (A)	64.6	45.7	47.0
	Nitrogen fertilizer (B)	17.3	19.3	12.8
	Interaction (A x B)	18.1	28.1	38.6
Chaff	Growth year (A)	33.4	66.8	–
	Nitrogen fertilizer (B)	23.5	9.1	–
	Interaction (A x B)	42.5	19.9	–

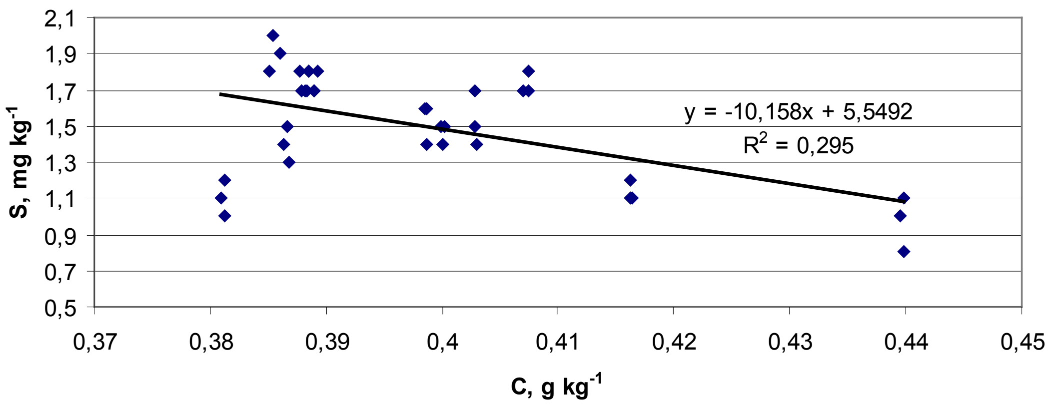

Figure 4. **Sulphur (S) content depending on carbon (C) content in shives of the linseed variety 'Scorpion', 2008-2009 ($p<0.05$; n=36: r=0.54)**

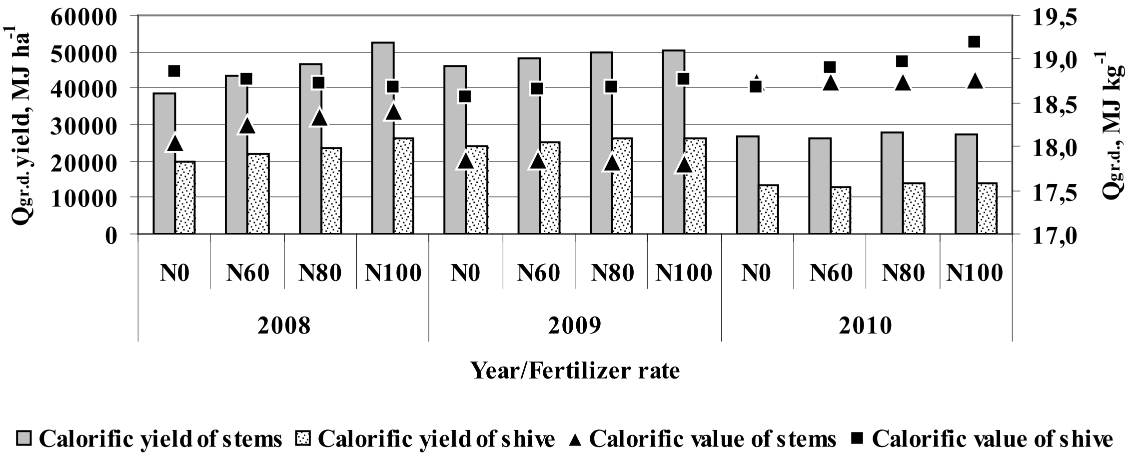

Figure 5. **Calorific yield and value depending on the linseed growing year, and N fertilizer rates**

The heat from fuel burning is a basic quality indicator. The German standard DIN 51731 indicates that the calorific value would reach at least 17.5 MJ kg^{-1} (Tardenaka, Spince, 2006), but in 2010 the gross calorific value for the linseed shives varied from 18.2 to 19.4 MJ kg^{-1} (Poiša, Adamovičs, 2011a) and 18.7–20.2 MJ kg^{-1} (Komlajeva et al., 2011). The gross calorific value (min – average – max) of linseed variety' 'Scorpion' is shown in Figure 5: for the linseed stems (17.75 – 18.28 – 18.79 MJ kg^{-1}), for the shives (18.56 – 18.78 – 19.23 MJ kg^{-1}). In all research years the highest calorific value was observed for the linseed shives. In 2009 the calorific value was lower than in 2008 and 2010, but the productivity was greater.

The research showed a significant positive correlation ($p<0.05$) between the gross calorific value and the carbon content in the linseed 'Scorpion' stems ($p<0.05$; $n=36$; $r=0.52$) and shives ($p<0.05$; $n=36$; $r=0.56$).

The linseed gross calorific value in our research was found to be similar to that of other plants: 1) in winter crops (triticale, winter rye, winter wheat) the straw has a higher calorific value than the grain, for example, for straw the highest calorific value has been determined – 16.39 MJ kg^{-1}, the net calorific value – 14.75 MJ kg^{-1} (Kaķītis et al., 2009), 2) for hemp variety 'Bialobrzeskie' the gross calorific value has been determined 17.76–18.98 MJ kg^{-1}, and net calorific value – 15.03–16.14 MJ kg^{-1} (Poiša, Adamovičs, 2011b), 3) for the dry matter of sunflower briquette – 17.07–17.37 MJ kg^{-1}, but for briquettes from dioecious and monoecious hemp a slightly lower calorific value was determined 16.60–16.74 MJ kg^{-1} and 16.56–16.64 MJ kg^{-1} respectively (Alaru et al., 2011). Linseed residue material can be used for the production of solid fuel, even though the stem crop, compared to other energy-producing plants, is small.

Conclusions

For the linseed variety 'Scorpion', the sulphur and carbon content and the highest calorific value in various plant parts was dependent on the growth year and the nitrogen fertilizer rate. Carbon content (min – average – max) in various was similar – stems (0.39 – 0.43 – 0.47 g kg^{-1}), shives (0.38 – 0.40 – 0.44 g kg^{-1}) and chaff (0.40 – 0.43 – 0.48 g kg^{-1}).

Sulphur content (min – average – max) in linseed production differed – stems (0.56 – 1.13 – 1.77 mg kg^{-1}), shives (0.97 – 1.50 – 1.90 mg kg^{-1}) and chaff (0.66 – 1.22 – 1.91 mg kg^{-1}).

The gross calorific value (min – average – max) was observed in the linseed stems (17.75 – 18.28 – 18.79 MJ kg^{-1}) and shives (18.56 – 18.78 – 19.23 MJ kg^{-1}).

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