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THE ENVIRONMENTAL ASPECTS OF ENERGY CROPS GROWING IN THE CONDITION OF THE CZECH REPUBLIC

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Abstract
Renewable energy resources have been developing very fast due to negative effects and finite reserves of the fossil fuels. Biomass is ranked among the most promising renewable energy resources within the Central Europe. Corn (*Zea mays* L.) is currently the most widely grown crop in the Czech Republic; nevertheless, the cultivation of corn provokes soil erosion by water. Perennial energy grass called tall wheatgrass (*Elymus elongatus* subsp. Ponticus cv. Szarvasi-1) is supposed to be a good and environment-friendly alternative to corn. Field trials including these two crops were established in the experimental locality of South Bohemia. Their yield potential was monitored during spring harvest periods (use for combustion). Dry phytomass was fundamentally analysed (N, C, H, S) and higher heating value was determined too. Universal Soil Loss Equation was calculated for both crop species. Corn provided much higher average yield in a three-year interval; corn phytomass reached higher heating value as well. The area of *Elymus elongatus* should enlarge considerably, if we wanted to get the identical amount of energy from corn and *Elymus elongatus*. However, we found that, compared to *Zea mays* L., water erosion theoretical land losses would be several times less serious for *Elymus elongatus*.
Key words: energy crops, erosion, yield.

Introduction

Fast world population growth (Schau & Fet, 2008) provokes a higher demand for energy (Ho & Show, 2015). A considerable demand for energy is met by fossil fuels (Sakuragi, Kuroda, & Ueda, 2011). Burning of fossil fuels pollutes the environment (Nicoletti *et al*., 2015) and produces greenhouse gas emissions (Moutinho, Madaleno, & Silva, 2016). Global reserves of fossil fuels are strictly limited. Therefore, renewable energy resources (RER) have become a key issue to be raised (Bernas *et al*., 2014). RER may help change the climate (Cherubini & Strømman, 2011).

Biomass is one of the most significant RER (Bernas *et al*., 2016b). It is used for direct combustion or biogas production (Jasinskas, Zaltauskas, & Kryzeviciene, 2008). Demirbas (2004) considers the near future promising – biomass can be burnt. Low water content in biomass is crucial. Therefore, the right harvest time is necessary and important there. It also determines a proportion and composition of chemical elements in phytomass. If we harvest plants later, the proportion of unwanted chemical elements decreases (N, S, K, Na and Cl are not good for burning, they slow it down) (Hadders & Olsson, 1996). The amount of ash which is produced by biomass burning is important. Csete *et al*. (2011) state that there is about 5% of ash in tall wheatgrass (*Elymus elongatus* subsp. ponticus cv. Szarvasi-1). Almost the same percentage of ash is indicated in corn (*Zea mays* L.) straw (Durda *et al*., 2016).

Energy crops have become more popular and the area of energy crops has been extending in the Czech Republic (Kopecky *et al*., 2015). Nowadays, corn is very popular there (Mast *et al*., 2014). It is, nevertheless, considered an environmentally unfriendly crop (Vogel, Deumlich, & Kaupenjohann, 2016). It contaminates ground water with nitrates (Glavan, Zorcic, & Pintar, 2016). There is a competition between energy crops and food production as well (Emmann, Schaper, & Theuvsen, 2012). A high risk of water erosion is another negative aspect of corn growing (Vogel, Deumlich, & Kaupenjohann, 2016). Soil erosion is a common problem that complicates watershed management around the world (Karas, 2016).

As the erosion damages the upper and most fertile soil layer the most, it causes the production and non-production potential of the soil to decrease (Blanco-Canqui & Lal, 2008). There are specific conditions for water erosion in the Czech Republic – because of the area of land blocs; they are the largest land blocs amongst all the European countries. Former land management system caused many hydrographical or landscape features to be removed from the countryside; such features, nevertheless, protected the soil against erosion very well. Nowadays, more than one half of arable land is endangered by water erosion in the Czech Republic (Novotny *et al*., 2014).

Grasslands and grass growing seem to be environment-friendly measures; they provide a sufficient amount of phytomass which is used in the eco energy sector (Kopecky *et al*., 2017). Compared to an annual crop, perennial grass protects the land against torrential rains and wind more and all year long (Mrkvicka, Vesela, & Ninaj, 2007). Therefore, it is highly recommended to grow grass in regions and localities facing water erosion (Dumbrovsky *et al*., 2014). Growth is the only arable land management factor we can influence directly – it is important to adopt anti-erosion measures at the same time in order

Table 1

Annual and seasonal climate of the years 2013 – 2015 at the experimental site of České Budejovice

Year	Average temperature (°C)		Precipitation (mm)	
	year	season	year	season
2013	9.1	15.3	685.4	469.5
2014	10.2	15.1	595.9	428.7
2015	10.5	16.9	487.7	233.8
Long-term average (1961 – 1990)	8.3	14.2	520.0	366.2

Table 2

Habitat characteristics

Altitude (MSL)	400
Agricultural production region	grain-growing
Soil texture class	medium heavy-textured soil
Soil type	pseudogley cambisoil
pH H_2O	6.1
pH KCl	5.6
GPS coordinates	48°97’44.13” N, 14°44’88.37” E

to protect the land against erosion (Novotny *et al.*, 2014). Grasslands play an important ecological and environmental role in the landscape (Nitsch *et al.*, 2012). Compared to annual crops, they require fewer fertilizers (Lewandowski *et al.*, 2003).

Bernas *et al.* (2016a) also consider *Phalaris arundinacea* L. and *Elymus elongatus* to be suitable energy grass species. Csete *et al.* (2011) recommend *Elymus elongatus* subsp. ponticus cv. Szarvasi-1 too; they highly appreciate its yield potential and drought-resistance properties. Water deficiency is supposed to be the major agricultural threat (Konvalina *et al.*, 2014).

This article intends to compare the conventionally grown corn and the alternative tall wheatgrass from the point of view of their yield potential and energy gain. It also intends to determine water erosion threat the soil faces – crop stands of these energy crops were monitored at the experimental locality of the University of South Bohemia in *České* Budějovice. The trial was conducted between 2013 and 2016.

Materials and Methods

Small-plot trials with *Elymus elongatus* subsp. ponticus (cv. Szarvasi-1) and *Zea mays* L. (hybrid Simao) were established in South Bohemia, at an experimental station of the University of South Bohemia in *České* Budějovice. Characteristics of the test habitats are described in Tables 1 and 2.

The experimental plot had been fertilized with mineral fertilizers before perennial grass of *Elymus elongatus* was seeded there. The following amounts of fertilizer were used: 200 kg of ammonium sulphate per hectare, 100 kg of ammonium nitrate with dolomite per hectare, 300 kg of triple superphosphate per hectare and 60 kg of potassium chloride per hectare. Grass was seeded on the experimental plot on 17 April 2013. Four small experimental plots were established there – each of them having an area of 10 square metres (8 times 1.25 m). The phytomass was harvested every spring of 2014, 2015 and 2016 (on 1 April 2014, on 17 March 2015 and on 21 March 2016) – the phytomass plants contained little water then. The harvest of 2014 represents the yield for 2013 growing season, and so on. The crop stands were cut with a grass mower having a mowing bar. They were left 6 cm long. After mowing the crop stand, mineral fertilizers were applied – 300 kg of ammonium sulphate per hectare, 150 kg of ammonium nitrate with dolomite per hectare, 60 kg of triple superphosphate per hectare and 60 kg of potassium chloride per hectare.

Corn crop stand (an area of 100 square meters) was established every spring of 2013, 2014 and 2015 (17 May 2013, 15 May 2014 and 17 April 2015). After the crop stand was seeded, fertilizers were applied there – 220 kg of ureastabil per hectare, 190 kg of triple superphosphate per hectare and 100 kg of potassium chloride. Another 115 kg of ureastabil per hectare were added into the crop stand during the stage of growth. *Zea mays* L. was harvested in the same period of time as *Elymus elongatus*.

Afterwards, the harvested fresh matter yield was determined and processed for drying. Dry matter (DM) content was determined by drying the biomass at 60 °C until constant weight. Based on water content, the yield of the fresh matter was converted to the dry matter hectare yield.

Dried samples of both plants were homogenized and they were subjected to the elementary analysis in the Central Laboratories of the Czech Technical University in Prague. Elementary elements (N, C, H, and S) were detected in the phytomass with the Vario EL CUBE equipment, which is based on a purge&trap chromatography and separates gasses emerging from a sample burning; it provides the maximum working extent possible – greater extent than the other analyzers provide. Then percentage of oxygen was calculated (O = 100 - N - C - H - S - ash); in this equation, ash was replaced by a common figure of 5% which is very often mentioned in special literature sources. Higher heating value (HHV) was calculated afterwards. A pattern recommended by Sheng & Azvedo (2005) was used there (Sheng & Azvedo considered the pattern the most exact):

$$HHV = -1.3675 + 0.3137 \times C + 0.7009 \times H + 0.0318 \times O \; (MJ \cdot kg^{-1}) \quad (1)$$

HHV… higher heating value
C, O, H… weight percentage of elements in a dry sample

Based on the data acquired, energy gain was calculated for both crops afterwards.

$$E = HHV \times Y \; (GJ \cdot ha^{-1}) \quad (2)$$

E… energy gain
HHV… higher heating value
Y… average yield of DM

A long-time loss of the soil caused by water erosion was also calculated via Universal Soil Loss Equation (Wischmeier & Smith, 1978):

$$G = R \times K \times L \times S \times C \times \times P \; (t \cdot ha^{-1} \cdot year^{-1}) \quad (3)$$

G… the computed soil loss per unit area, expressed in the units selected for K and for the period selected for R
R… the rainfall and runoff factor
K… the soil erodibility factor
L… the slope-length factor
S… the slope-steepness factor
C… the cover and management factor
P… the support practice factor

We used a substitution and substituted R-factor with 40 which was recommended for the region of the Czech Republic. Other factors were derived from relevant plants and calculated for every single experimental plot (local geographical and land conditions). K-factor of 0.38 and S-factor of 0.47 were the same for both crops. *Zea mays* L. reached the L-factor of 1.62 and C-factor of 0.32. *Elymus elongates* reached the L-factor of 1.35 and C-factor of 0.005. We used another substitution and substituted P-factor with 1 in the equation (no anti-erosion measures). Figures of the factors had been derived from Janecek *et al.* (2012) and their methodology. Multiplying G-value by an area generating 1 TJ of energy, we got the total amount of soil theoretically washed away by the water erosion (if we grow the above-mentioned and assessed energy crops).

Results and Discussion

Yield produced by grass and corn between 2014 and 2016 is shown in Figure 1. As far as *Elymus elongatus* is concerned, there is an average of four micro plots. In 2014, *Elymus elongatus* produced a low yield which was caused by slow growth in the initial stage of growth. On the other hand, in 2015 (harvest in 2016), its great potential for growth and yield potential showed. In spite of the extreme weather conditions – long dry periods that could even reduce yield to its one half (Csete *et al.*, 2011), this grass species produced the yield of 9.6 $t \cdot ha^{-1}$ DM. On the other hand, *Zea mays* L. could not cope with the atypical weather conditions and it produced very low yield.

Zea mays L. reached the 2014/2016 average yield of 12.7 $t \cdot ha^{-1}$ of DM and *Elymus elongatus* reached the 2014/2016 average yield of 7.1 $t \cdot ha^{-1}$ of DM. Compared to available data, corn and grass reached yield figures are relatively low. For example, Mast *et al.* (2014) show *Elymus elongatus* yield of 8.9 $t \cdot ha^{-1}$ – 13.4 $t \cdot ha^{-1}$ DM (they largely depend on harvest time). Other authors show *Elymus elongatus* yield of up to 20 $t \cdot ha^{-1}$ DM. *Zea mays* L. did not produce any high

Table 3

Elementary analysis

Plant species	% N	C %	H %	S %
Zea mays L.	1.238	43.37	7.04	0.07
Elymus elongatus	0.64	43.73	6.29	0.07

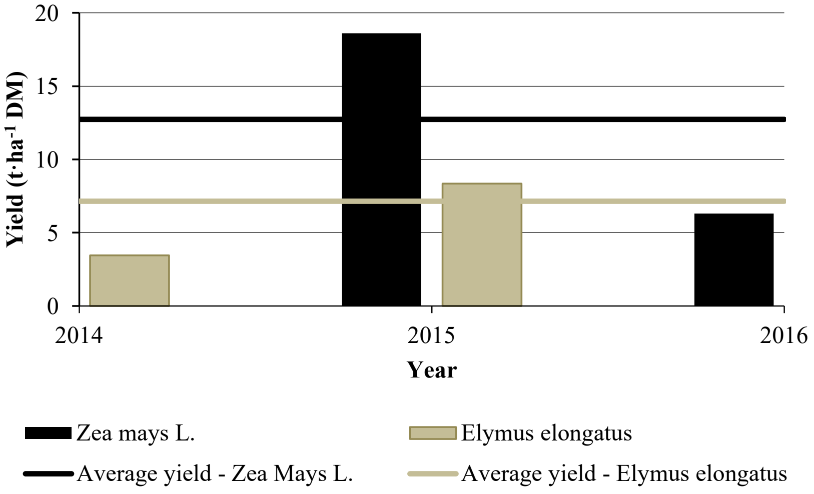

Figure 1. Yield of energy crops.

yield at the same station either (12.7 t·ha^{-1} DM). For example, Badalikova, & Bartlova (2011) showed the yield of 20.26 t·ha^{-1} DM (usual farming technology, ploughing).

Based on the elementary analysis results (Table 3), HHV was calculated for both crops. *Zea mays* L. reached the figure of 18.6 MJ·kg^{-1} and *Elymus elongatus* reached the figure of 18.2 MJ·kg^{-1}. Such figures correspond to commonly accepted figures. For example, Demirbas (2001) states the figure of 18.27 MJ·kg^{-1} for corn straw.

Zea mays L. crop stand reached the average energy gain figure of 236.2 GJ·ha^{-1} and *Elymus elongates* crop stand reached the average energy gain figure of 129.8 GJ ha^{-1}. Re-calculating the above-mentioned figures, we found that we need 4.23 ha of *Zea mays* L. or 7.70 ha of *Elymus elongates,* so that we get 1 TJ of energy from the phytomass. The amount of soil theoretically washed away due to water erosion is very different – it is 29.8 t in the case of *Zea mays* L. cultivation and 0.4 t in the case of *Elymus elongatus* cultivation. According to Vogel, Deumlich & Kaupenjohann (2016), crop stands do not effectively protect land or the soil against water erosion. According to a lot of authors (e.g. Prochnow *et al*., 2009), grassland successfully protects land and soil against water erosion (much better than wide-row crops).

Conclusions

Corn produced the average yield of 12.7 t·ha^{-1} DM. Tall wheatgrass produced the average yield of 7.1 t·ha^{-1} DM. Pursuant the results of elementary analysis of phytomass samples, corn HHV attained 18.6 MJ·kg^{-1} and tall wheatgrass HHV attained 18.2 MJ·kg^{-1}. Corn produced twice as high hectare energy (236.2 GJ·ha^{-1}) yield as tall wheatgrass (129.8 GJ·ha^{-1}). Corn area needed for 1 TJ of energy was much larger than tall wheatgrass area. On the other hand, tall wheatgrass is an efficient method of land and soil protection against water erosion. It perfectly protects land and soil. Universal Soil Loss Equation calculation confirmed this fact as well. If we produced the amount of phytomass needed for 1 TJ of energy on a certain parcel, only 0.4 tons of the soil would be washed away by water erosion for tall wheatgrass and 29.8 tons for corn. Perennial energy grass species are good alternatives to corn; they effectively protect land and soil against water erosion and they also provide us with other services and are ecosystem-friendly.

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