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# COMPARISON OF ENERGY SOURCES GROWN ON AGRICULTURAL LAND

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The aim of the paper is to compare biomass production of energy plants and selected crops grown on arable land in the south-western Slovakia in 2007–2014, its energy value and the influence of decisive climatic factors on the size of the production. The data on yields of dominant crops grown in the agricultural farm were obtained from the statistical data of the farm. Aboveground biomass of willows and poplars was harvested at the end of the harvest cycle. Aboveground biomass of *Miscanthus sinensis* was harvested in 2010–2014, always in early spring period of the following year. Winter wheat, spring barley and maize grown for silage during the period 2007–2014 provided the lowest yields in 2010 and the highest in 2011 and 2014. The highest energy value was obtained from maize in 2014 (400.66 GJ $ha^{-1}$). The short rotation coppice poplars of Italian provenance yielded biomass with energy value of 951.68 GJ $ha^{-1}$ $year^{-1}$ at the end of the first three-year harvest cycle in 2012. The analysis of variance confirmed that there are highly significant statistical differences in the poplar biomass yield among the varieties and individual experimental years. The fast growing willows of Swedish provenance provided aboveground biomass energy value of 868.88 GJ $ha^{-1}$ $year^{-1}$ at the end of the first four-year harvest cycle in 2011. The biomass production of the perennial grass *Miscanthus sinensis*, depending on the growing period, can be expressed by a polynomial trend function. The highest biomass production was obtained in the third growing period (2012). At the end of the fifth growing period (2014), the yield amounted to 28.60 t $ha^{-1}$ of the dry aboveground biomass. The energy value of the aboveground biomass of *Miscanthus* reached 486.20 GJ $ha^{-1}$ in 2014. Differences in the biomass yield of the *Miscanthus* genotypes are statistically highly significant in each of the monitored growing periods. The growth and production process of the selected energy species reflect the specificities of soil and climatic conditions of the individual growing periods, as well as the ability of individual species and varieties to provide biomass production in the given conditions. Regression analysis of the produced aboveground biomass of the crops grown in the Kolíňany cadastre has not confirmed a statistical dependence in selected climatic parameterss.

**Keywords:** energy plants, arable crops, energy value, biomass

Energy production is a key sector of the Slovak national economy. Its main objectives and priorities are listed in the strategic document called "The Action Plan for Energy Policy up to 2035 with a perspective to 2050". Slovakia increases its energy security and sovereignty by introducing low carbon technologies, including renewable energy sources (RES). The greatest technical potential of renewable sources is attributed to biomass. Biomass has a great perspective for heat production in central heating systems, local establishments and households. Biomass can be produced locally and thus it is of great importance for rural development, maintaining agricultural production and hence employment opportunities in rural areas (Brozio et al., 2007). Growing arable crops and energy crops on agricultural land is influenced by geographical, ecological and climatic conditions, growing technologies and intensification factors (Grundman et al., 2013). In recent years, the production is also affected by increasingly occurring weather extremes (Mikó et al., 2014).

Establishing plantations of energy crops and their acceptance by population is often controversial and leads to conflicts of interests among food manufacturers and producers of biomass for energy purposes. Managers often ask how much and what commodities they should produce, who would be the buyer and what will be the profit. Economists are able to express the cost-effectiveness of production costs (Grausová and Čižmárik, 2007), but they need analyses of production from the biological perspective that predict certain natural values of yields.

The aim of the paper is to compare biomass production of energy plants and selected crops grown on arable land in the south-western Slovakia in 2007–2014, its energy value and the influence of decisive climatic factors on the size of the production.

The paper is a part of an interdisciplinary study of a project aiming at restoring an agricultural farm in order to promote and develop business in a given area.

## Material and methods

The site characteristics, data on climatic conditions, biological material, rotation cycles of the fast-growing trees and plants, inputs and outputs in the form of energy value of the aboveground biomass are shown in Table 1.

In the first part of the analysis, the paper evaluates biomass yield of the fast-growing trees, plants and agricultural crops grown on arable land. The biomass yields

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**Table 1** Characteristics of the studied area and the plant material

| **Area description** | | |
|---|---|---|
| GPS localization | 48° 21′ 20.7″ N 18° 12′ 24.5″E | Literary sources |
| Altitude | 180 m a.s.l. | |
| Soil | moderate, loam | Demo et al. (2013) |
| Ø annual air temperature during the last five years | 11.02 °C | SHMI (2015) |
| Ø air temperature during the growing period | 15.51 °C | SHMI (2015) |
| Annual precipitation | 607.78 mm | SHMI (2015) |
| **Inputs** | | |
| Fertilization | 100 kg N, 60 kg K, 30 kg P ha$^{-1}$ before establishment of the experimental plantation | |
| Irrigation | not applied | |
| Chemical plant protection | not applied | |
| **Biological material** | | |
| *Salix* | varieties INGER, TORA, SVEN, TORDIS and GUDRUN | Demo et al. (2013) |
| *Populus* | varieties Monviso, Pegaso, AF-2 and Sirio | |
| *Miscanthus* | genotypes *Miscanthus* × *giganteus* and *Miscanthus sinensis* TATAI | Jureková et al. (2012, 2013) |
| **Rotation cycles / age of the stand** | | |
| *Salix* | four-year rotation cycle / 7-year old stand | |
| *Populus* | three-year rotation cycle / 5-year old stand | |
| *Miscanthus* | One-year rotation cycle / 5-year old stand | |
| **Outputs, energy value of the biomass** | | |
| *Salix (willow)* | 18.38 MJ kg$^{-1}$ | Demo et al. (2013) |
| *Populus (poplar)* | Monviso 18.63 MJ kg$^{-1}$<br>Pegaso 18.27 MJ kg$^{-1}$<br>AF-2 18.17 MJ kg$^{-1}$<br>Sirio 18.90 MJ kg$^{-1}$ | Demo et al. (2013) |
| *Miscanthus (silver grass)* | 17 MJ kg$^{-1}$ | McKervey et al. (2008) |
| *Triticum aestivum* (winter wheat)<br>*Hordeum vulgare* L. (spring barley)<br>*Zea mays* ssp. *mays* (silage maize) | 16.76 MJ kg$^{-1}$<br>16.16 MJ kg$^{-1}$<br>16.13 MJ kg$^{-1}$ | Váňa (2006) |

are expressed in the form of biological yield and its potential energy – gross energy.

The data on yields of the dominant crops grown in the farm in Kolíňany during 2007–2014 were obtained from the internal statistics of the company.

Measurements of growth parameters of the fast-growing trees and plants were taken in the years 2007–2014 (willows), 2011–2014 (poplars), 2010–2014 (*miscanthus*). The aboveground biomass of willows was harvested in 2011 after the first (four-year) harvest cycle, and poplars in 2013 after the first (three-year) harvest cycle. The aboveground biomass of *miscanthus* genotypes was harvested during 2010–2014, always in the early spring period of the following year. The biomass harvesting was done manually, using a brush cutter, pruning shears and/or hand saws. The biomass yield (*BY*) was calculated based on the following formula (Brozio et al., 1984):

$$BY = Dw \ / \ \text{the size of the experimental site}$$

where:
*BY* – biomass yield
*Dw* – dry weight of the aboveground biomass
the value of *BY* is expressed in t ha$^{-1}$.

The biomass production is understood as a photosynthetic activity of plants (vegetation stand), which is expressed by the amount of the total dry matter, its accumulation and the production of biological yield. The term potential yield and/or potential energy expresses yield (created energy) that corresponds to the maximum utilization of environmental factors.

The energy value of the biomass yield is expressed by gross energy (calorific value) of dry matter unit, the value of which is relatively stable (depending on the content of fat and carbohydrates in the dry matter). The unit was expressed in GJ ha$^{-1}$ and/or GJ t$^{-1}$.

The major growing period is defined according to Minďaš et al. (2011) by the average daily air temperature T +10 °C, as a period of biomass production of crops demanding higher air temperatures. The large growing period (the period of the year-round biomass production of perennial crops) is defined by biological temperature minimum, average daily air temperature T +5 °C.

## Results and discussion

The research of the fast-growing energy tree species of the genus *Salix* and *Populus* began by establishing a willow plantation in 2007, later in 2009 a poplar plantation was established and in 2010 a plantation of perennial grass *Miscanthus sinensis* was established at the research site in Kolíňany. In the early years, the research focused on the cultivation technologies, density and structure of the stands, planting methods and comparison of the production potential of the species and varieties (Jureková et al., 2011; Demo et al., 2011; Demo et al., 2013a; Milovanović et al., 2012; Kotrla and Prčík, 2013, Demo et al., 2014).

The paper compares biological yields of the so-called first generation energy resources represented by the dominant agricultural crops (Table 2). The yields of the cereals reached the average value of 10.72 t ha$^{-1}$ (*Tritticum aestivum*), 10.97 t ha$^{-1}$ (*Hordeum vulgare*) and 20.75 t ha$^{-1}$ (silage corn) in 2007–2014. Compared with that, the second generation of energy resources (biomass of the woody crops and *miscanthus*) provided significantly higher average values during the studied period (Table 2). The energy crops can be grown on a low-value agricultural soils with the perspective of 20 years.

The willow stand established in 2007 maintained strong growth activity throughout the entire studied period. A cutback (technical cut) was made in the winter of 2007. The highest production of dry matter was 47.11 t ha$^{-1}$ at the end of the first four-year harvest cycle (2011) (Table 2). Similar results of Swedish willow varieties (Inger, Tordis and Sven) reported Mikó et al. (2014) with an average dry biomass yield of 38.6 t ha$^{-1}$ year$^{-1}$ in the control treatment and 50.8 t ha$^{-1}$ year$^{-1}$ in the fertilized treatment in a two-year harvest cycle.

The first year of the second harvest cycle (2012) was characterized by high productivity of the stand. The biomass yield reached 29.65 t ha$^{-1}$ year$^{-1}$. In the third year (2014), the average biomass yield of the studied willow varieties was 53.17 t ha$^{-1}$ year$^{-1}$. In order to evaluate differences in biomass quality of the grown crops, it is important to know their energy values. It is expressed as gross energy of a dry matter unit. The results are shown in Table 3.

In order to compare gross energy values of the studied species, we will focus on the results obtained in 2008, when the stands of willows began to grow after the cutback. In this period, the energy value was higher in the arable crops, mainly winter wheat and silage maize. In the second and subsequent years, higher values were obtained from the silage maize.

Italian varieties of poplars showed rapid growth and good adaptability to the environment. They reached the maximum value of biomass in 2012 (the last year of the first rotation cycle) (Table 2). The energy value of the biomass was 951.68 GJ ha$^{-1}$ year$^{-1}$ Analysis of variance confirmed that the biomass yield of poplars is highly significant between the varieties and the experimental year (Table 5).

Based on these results and other findings published in a number of papers (Demo et al., 2013b and 2014; Prčík et al., 2014; Prčík and Kotrla, 2015) it can be noted that the

**Table 2** Yields of dry aboveground biomass of individual arable crops and energy species (t ha$^{-1}$ year$^{-1}$) grown in the research site in Kolíňany

| Crop | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | Average |
|---|---|---|---|---|---|---|---|---|---|
| ***Triticum aestivum*** | 10.37 | 13.37 | 10.22 | 7.35 | 12.86 | 8.69 | 10.58 | 12.39 | 10.72 |
| ***Hordeum vulgare*** | 10.22 | 11.31 | 9.80 | 7.17 | 14.42 | 9.95 | 11.22 | 13.73 | 10.97 |
| ***Zea mays* ssp. *mays*** | 22.22 | 22.74 | 31.85 | 8.31 | 20.10 | 16.10 | 15.08 | 24.84 | 20.15 |
| ***Salix*** | 3.48 | 7.66 | 36.96 | 20.89 | 47.11 | 29.65 | 22.85 | 53.17 | 27.72 |
| ***Populus*** | – | – | – | – | 26.05 | 51.47 | 15.97 | 34.48 | 31.99 |
| ***Miscanthus*** | – | – | – | 10.95 | 17.50 | 24.85 | 27.20 | 28.60 | 21.82 |

**Table 3** Potential energy value of biomass of arable crops and energy plants (GJ ha$^{-1}$ year$^{-1}$) grown in the research site in Kolíňany

| Crop | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | Average |
|---|---|---|---|---|---|---|---|---|---|
| ***Triticum aestivum*** | 179.39 | 231.29 | 176.76 | 127.87 | 222.64 | 150.43 | 183.15 | 214.37 | 185.74 |
| ***Hordeum vulgare*** | 164.58 | 182.11 | 157.78 | 107.33 | 148.84 | 157.42 | 193.20 | 195.35 | 163.33 |
| ***Zea mays* ssp. *mays*** | 380.18 | 389.08 | 544.95 | 142.18 | 343.91 | 275.47 | 258.02 | 425.01 | 344.85 |
| ***Salix*** | 63.96 | 140.79 | 679.32 | 383.96 | 865.88 | 544.97 | 419.98 | 977.26 | 509.52 |
| ***Populus*** | – | – | – | – | 485.31 | 951.68 | 294.81 | 637.54 | 592.34 |
| ***Miscanthus*** | – | – | – | 186.15 | 297.50 | 422.45 | 462.40 | 486.20 | 370.94 |

**Table 4** Potential energy value of biomass of poplar genotypes (GJ ha-1) grown in the research site in Kolíňany

| Genotype | 2011 | 2012 | 2013 | 2014 | Average |
|---|---|---|---|---|---|
| **Monviso** | 537.12 | 1087.85 | 408.81 | 370.39 | 601.04 |
| **Pegaso** | 339.64 | 1065.32 | 257.42 | 781.96 | 611.09 |
| **AF-2** | 484.96 | 740.06 | 224.22 | 793.30 | 560.64 |
| **Sirio** | 569.08 | 917.22 | 293.14 | 597.24 | 594.17 |

**Table 5** Single-factor analysis of variance (ANOVA) of the biomass yields between the *miscanthus* genotypes and each experimental year (2010–2014), between the poplar varieties and each experimental year (2011–2014)

| Analysed parameter | F | P-value | F critical | Significance |
|---|---|---|---|---|
| **Miscanthus and years** | 158.0191 | 9.28E-69 | 1.947348 | +++ |
| **Poplar and years** | 10.71837 | 1.51E-08 | 1.99199 | +++ |

Level of significance is defined as: n: non-significant impact, +: significant impact in $P \leq 0.05$, ++: $P \leq 0.01$ and +++: $P \leq 0.001$

production process of the fast-growing trees grown in the conditions of south-western Slovakia is conditioned to species and genotype heterogenity.

In terms of biomass production, the *miscanthus* stand was studied in 2010–2014 (Table 2). The highest biomass increases recorded both *miscanthus* genotypes in the third growing period (2012), when the average production reached 24.85 t ha-1, which was an increase by almost 60% compared with 2011. After the fifth growing year (2014), the average production of the stand was 28.60 t ha-1 of dry matter.

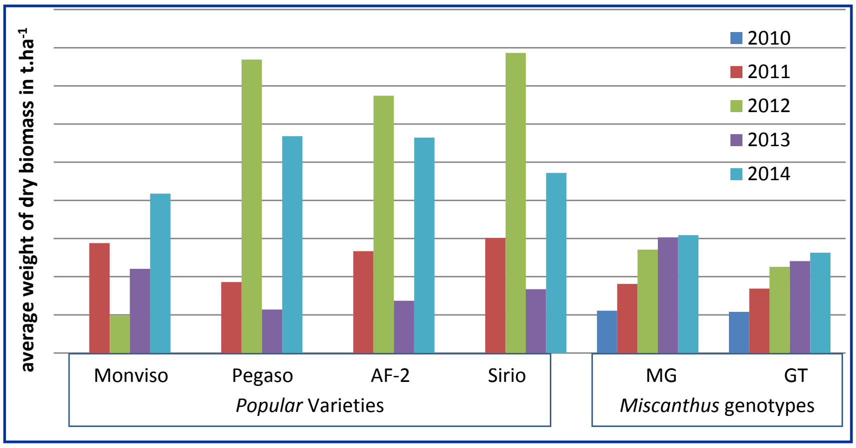


**Figure 1** Differences in the production of dry aboveground biomass of *Populus* varieties and *Miscanthus* genotypes at the site in Kolíňany in the studied years (2010–2014)
MG *Miscanthus* × *giganteus*, MT Misscanthus sinensis TATAla

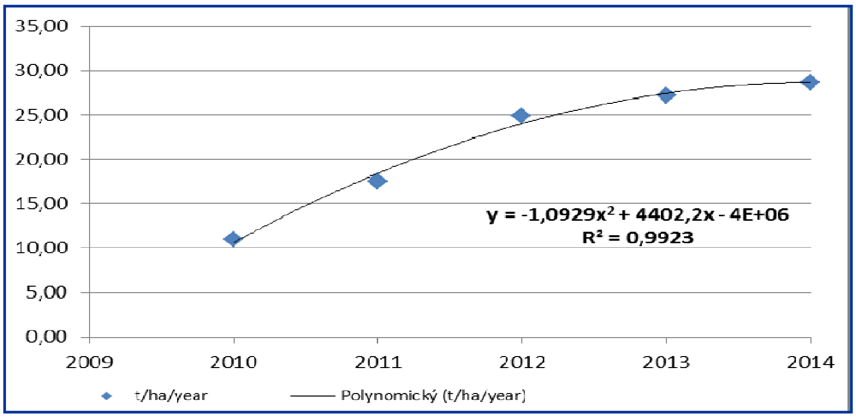


**Figure 2** Polynomial trend function of *miscanthus* biomass growth in the studied years

During the years 2011–2014 (Table 4), we studied a production of aboveground dry matter of Italian poplar genotypes. The production value was converted into its energy value. We compared the energy values of the produced biomass (dry matter) of the individual poplar genotypes. The studied genotypes may be divided into two groups, based on the average values. The first group includes genotypes Monviso (601.04 GJ ha-1) and Pegaso (611.09 GJ ha-1). They provided an approximately even production of 600 GJ ha-1. The second group that include genotypes AF-2 (560.64 GJ ha-1) and Sirio (594.17 GJ ha-1) provided a production that is below 600 GJ ha-1. The difference between the highest (Pegaso) and the lowest average energy value (AF-2) is 9.3% (50.43 GJ ha-1).

Differences in biomass production of the *miscanthus* genotypes were statistically highly significant in each studied growing period (Table 5).

Figure 2 shows a high statistical correlation ($R^2 = 0.9923$) between the growing years and the production of the total *miscanthus* aboveground biomass.

The statistical significance of the total above-ground biomass production of *Miscanthus* in the growing seasons is shown in Figure 2. It can be stated that the statistical significance ($R^2 = 0.9923$) is high. Each year the tillering circle of the individuals increases, thus creating space for an increase of the biomass production.

**Table 6** Regression analysis of willow biomass production in dependence of selected climatic indicators

| Regression Statistics | | | | |
|---|---|---|---|---|
| **Multiple R** | 0.173571 | | | |
| **R Square** | 0.030127 | | | |
| **Adjusted R Square** | -0.35782 | | | |
| **Standard Error** | 20.53122 | | | |
| **Observations** | 8 | | | |
| **ANOVA** | | | | |
| | **df** | **SS** | **MS** | **F** |
| **Regression** | 2 | 65.46942 | 32.73471 | 0.077657 |
| **Residual** | 5 | 2107.655 | 421.5309 | |
| **Total** | 7 | 2173.124 | | |
| | **Coefficients** | **Standard Error** | **t Stat** | **P-value** |
| **Intercept** | -12.3405 | 167.5001 | -0.07367 | 0.944126 |
| **X1 (mm)** | -0.00848 | 0.062938 | -0.13481 | 0.898019 |
| **X2 (°C)** | 4.069561 | 13.59681 | 0.299303 | 0.776751 |

At the same time, growth parameters such as height and thickness of the stems increase as well. Subsequently, the growth culmination and the stand production will be monitored.

The energy value of the *miscanthus* aboveground biomass (Table 3) achieved on average 486.20 GJ ha$^{-1}$ year$^{-1}$. A *miscanthus* stand in conditions of Northern Ireland reached 12–25 t ha$^{-1}$ with the total energy of 260 GJ ha$^{-1}$ yr$^{-1}$ (McKervey et al., 2008).

In the second stage, the analysis focused on selected climatic factors (annual rainfall and average annual air temperature) that are supposed to have crucial impacts on vegetation. Regression analysis (Table 6) of the created aboveground biomass of the studied crops in the cadastre of Kolíňany unconfirmed statistical dependence on annual precipitation and annual average air temperatures in each growing period. Regression coefficient of the willow stand was 0.0301. The coefficient of other species had similar trend.

## Conclusion

Comparison of the production and energy values of biomass of arable crops and energy plants grown on agricultural land of the selected farm (SUA farm) showed significant differences in productivity and energy value of the product.

The paper compares biological yields of the so-called first generation energy resources represented by the dominant agricultural crops (Table 2). The yields of the cereals reached the average value of 10.72 t ha$^{-1}$ (*Tritticum aestivum*), 10.97 t ha$^{-1}$ (*Hordeum vulgare*) and 20.75 t ha$^{-1}$ (silage corn) in 2007–2014. Compared with that, the second generation of energy resources (biomass of the woody crops and *miscanthus*) provided significantly higher average values during the studied period (Table 2). The energy crops can be grown on a low-value agricultural soils with the perspective of 20 years.

The fast-growing Italian poplars produced 51.47 t ha$^{-1}$ of aboveground biomass with average energy value of 951.68 GJ ha$^{-1}$ year$^{-1}$ at the end of the first three-year harvest cycle in 2012. In 2014, in the second year of the three-year harvest cycle, the average biomass yield was 34.40 t ha$^{-1}$, with energy value of 637.53 GJ ha$^{-1}$ year$^{-1}$.

The fast growing Swedish willows created 47.11 t ha$^{-1}$ of dry matter with energy value of 868.88 GJ ha$^{-1}$ year$^{-1}$ at the end of the first four-year harvest cycle (2011). In 2014, the biomass yield was 53.17 t ha$^{-1}$ with energy value of 997.26 GJ ha$^{-1}$ year$^{-1}$. The productivity of the species and its energy value is conditioned by genotype.

The highest increases of aboveground biomass of the perennial grass *Miscanthus sinensis* were in the third growing year (2012) (in both *miscanthus* genotypes), when the average production reached 24.85 t ha$^{-1}$. It is an increase by almost 60% compared to 2011. After the fifth growing year (2014), the stand reached 28.60 t ha$^{-1}$ of dry matter. The energy value of the *miscanthus* biomass was 486.20 GJ ha$^{-1}$ year$^{-1}$ in 2014.

The growth and production process of the selected energy tree and plant species reflect the specificities of soil and climatic conditions of individual growing periods and the ability to produce biomass in the specific conditions affected by both species and variety heterogeneity.

The comparison of the productivity of agricultural crops and energy trees and plants grown on agricultural land confirmed that the fast-growing trees and plants provide high biomass yields and have high values of gross energy with minimum inputs. They represent renewable resources with long-term perspective and can be grown on unused soils.

The results will be used for the energy assessment of the arable crops and energy plants that will help to make decisions on economic advantages of growing different plant species for energy purposes.

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## References

BROZIO, S. – LAUFER, S. – PIORR, H.P. – ZEIDLER, M. – ZELLER, H. – LORENZ, K. – BROWER, J.E. – ZAR, J.H. 1984. Field and Laboratory Methods for General Ecology. W. C. Brown Company Publishers, Dubuque, Iowa

DEMO, M. et al. 2011. Produkčný a energetický potenciál švédskych odrôd rýchlorastúcej energetickej dreviny rodu *Salix* pestovanej v suchších pôdno-klimatických podmienkach juhozápadného Slovenska. Nitra : SPU, 110 s. ISBN 978-80-552-0577-9.

DEMO, M. et al. 2013a. Biomass production potential of different willow varieties (*Salix* spp.) grown in soil-climatic conditions of South-Western Slovakia. In: Wood research, vol. 58, no. 4, pp. 651–662. ISSN 1336-4561.

DEMO, M. – PRČÍK, M. – TÓTHOVÁ, D. – HÚSKA, D. 2013b. Production and energy potential of different hybrids of poplar in the soil and climatic conditions of south-western Slovakia. In: Wood Research, vol. 58, no. 3, pp. 439–450. ISSN 1336-4561.

DEMO, M. – HÚSKA, D. – TÓTHOVÁ, M. 2013. Vŕba (*Salix* L.) ako zdroj biomasy pre energetické účely : pestovateľské technológie. Nitra : SPU, 59 s. ISBN 978-80-552-1021-6.

DEMO, M. et al. 2014. Comparison of production parameters of willow (*Salix* spp.) and poplar (*Populus* spp.) varieties in the last year of the first four-year harvest cycle. In: Wood research, vol. 59, no. 4, pp. 705–715. ISSN 1336-4561.

GRAUSOVÁ, G. – ČIŽMÁRIK, L. 2007. Význam využitia poľnohospodárskej pôdy na nepotravinárske účely vo vidieckej ekonomike. Bratislava : VÚEPaP. 41 s. ISBN 978-80-8058-460-3.

GRUNDMAN, P. – KLAUSS, H. – PIORR, H.P. – BROZIO, S. – ZEIDLER, M. 2013 Regional potential analysis-biomass as energy feedstock in regional economic cycles in region Havelland-Flaeming. Report: Rural Biological Resources in Regions. 71 pp. [online][cit. 2015-23-06]. Dostupné na internete: http://www.central2013.eu/fileadmin/user_upload/Downloads/outputlib/ Rubires_wp3_regional_analysis_Haveland_uploaded.pdf

JUREKOVÁ, Z. – DRAŽIĆ, G. – KOTRLA, M., – MARIŠOVÁ, E. – MILOVANOVIĆ, J. – TÓTHOVÁ, M. – KONČEKOVÁ, L. 2011. Biological factors influencing the growth and biomass production of willows planted in Southern Slovakia 2011. In Acta regionalia et environmentalica, vol 8, no. 2, pp. 47–5. ISSN 1336-5452.

JUREKOVÁ, Z. – KOTRLA, M. – PAUKOVÁ, Ź. – PRČÍK, M. 2012. The growth and yield of different *miscanthus* genotypes in the conditions of South-Western Slovakia. In Acta regionalia et environmentalica, vol. 9, no. 2, pp. 29–34. ISSN 1336-5452.

JUREKOVÁ, Z. – KOTRLA, M. – PAUKOVÁ, Ž. 2013. Life cycle of *Miscanthus* × *giganteus* (Greef et Deu) grown in Southwestern Slovakia. In Acta regionalia et environmentalica, vol. 10, no. 2, pp. 40–43. ISSN 1336-5452.

KOTRLA, M. – PRČÍK, M. 2013. Environmental and socio-economic aspect of growing *Miscanthus* genotypes. In: Scientific papers, vol, 13, no. 1, pp. 201–204. ISSN 2247-3527.

McKERVEY, Z. – WOODS, V. B. – EASSON, D. L. 2008. *Miscanthus* as an energy crop and its potential for Northern Ireland. A review of current knowledge. AFBI Occasional publication, no. 8, 80 p.

MIKÓ, P. – KOVÁCS, G.P. – ALEXA, L. – BALLA, I. – PÓTI, P. – GYURICZA, Cs. 2014. Biomass production of energy willow under unfarouble field conditions. In Applied Ecology and Environmental research, vol. 12, no. 1, pp. 1–11. ISSN 1589 1623.

MILOVANOVIĆ, J. – DRAŽIĆ, G. – IKANOVIĆ, J. – JUREKOVÁ, Z. – RAJKOVIĆ, S. 2012. Sustainable production of biomass through *Miscanthus giganteus* plantation development. Annals of Faculty Engineering Hunedoara In International Journal of Engineering, vol. 10, no. 1, pp 79–82. ISSN 1584-2665.

MINĎAS, J. – PÁLENÍK, V. – NEJEDLÍK, P. (Eds). 2011. Dôsledky klimatickej zmeny a možné adaptačné opatrenia v jednotlivých sektoroch. Záverečná správa. Zvolen, Bratislava : EFRA – Vedecká agentúra pre lesníctvo a ekológiu, 253 s.

PRČÍK, M. – KOTRLA, M. – HAUPTVOGL, M. 2014. Changes in production parameters of fast-growing energy grey poplar varietes (*Populus* x Canescens) in Slovakia. In: SGEM 2014. 1st ed. Sofia : STEP92 Technology, pp. 93–100.

PRČÍK, M. – KOTRLA, M. 2015. Targeted cultivation of the energy plants in conditions of the Slovak regions In Scientific papers. Management, economic engineering in agriculture and rural development, vol. 15, no. 1, pp. 399–404. ISSN 2284-7995.

VÁŇA, J. 2006. Strategie v biomase – situace, cíle, činnost.