External and internal factors influencing the growth and biomass production of short rotation woods genus *Salix* and perennial grass *Miscanthus*

Zuzana Jureková, Gordana Dražić
Editors

External and internal factors influencing the growth and biomass production of short rotation woods genus *Salix* and perennial grass *Miscanthus*

Spoljašnji i unutrašnji faktori koji utiču na rast i proizvodnju biomase drvenastih vrsta roda *Salix* i višegodišnjih trava roda *Miscanthus*

Editors: ZUZANA JUREKOVÁ, GORDANA DRAŽIĆ

Authors: JELENA MILOVANOVIĆ
NADA BABOVIĆ
ANA ĐORĐEVIĆ
SLOBODAN SPASIĆ
ELEONÓRA MARIŠOVÁ
LÝDIA KONČEKOVÁ
MARIÁN KOTRLA
MONIKA TÓTHOVÁ

Publisher: Faculty of Applied Ecology FUTURA
Singidunum University Belgrade

For publisher: Prof. Jordan Aleksić, PhD

Technical editors: Jelena Milovanović, Nada Babović, Ana Đorđević, Slobodan Spasić

Reviewers:

MIRJANA ŠIJAČIĆ – NIKOLIĆ, PhD
Professor of the Faculty of Forestry University of Belgrade, Serbia

DRAGANA DRAŽIĆ, PhD
Scientific advisor of the Institute of Forestry Belgrade, Serbia

ELECTRONIC EDITION
Belgrade, 2011 C (Copyright)

CIP – Katalogizacija u publikaciji Narodna biblioteka Srbije, Beograd

630*286/287(0.034.2)
EXTERNAL and internal factors influencing the growth and biomass production of short rotation woods genus *Salix* and perennial grass *Miscanthus* [Elektronski izvor] / [authors Jelena Milovanović ... *et al*.]
Editors: Zuzana Jureková, Gordana Dražić – Beograd: Fakultet za primenjenu ekologiju Futura, 2011 (Beograd:Damnjanović i sinovi). – 1 elektronski optički disk (CD-ROM): tekst; 12cm. Sistemski zahtevi: nisu navedeni. Nasl. Sa naslovnog ekrana. – Podaci o autorima – preuzeti iz kolofona.
Tiraž 150. – Bibliografija uz svako poglavlje.
ISBN 978-86-86859-26-6
a)Vrba – Gajenje b) Miskantus - Gajenje
COBISS.SR-ID 188489484

Contents

PREFACE

The monograph you are just starting to read was written by the team of authors from Slovak University of Agriculture and the Singidunum University in Belgrade, who cooperated on a bilateral Slovak-Serbian project "Comparative studies of the adaptability and productivity of energy crops and plants grown on agricultural land of southern Slovakia and Serbia." The project ran in 2010-2011. The main objective was to gather knowledge in the cultivation of the so-called fast-growing energy trees and plants grown in different ecological conditions of Slovakia and Serbia and to get to know their physiological reactions which enable the production potential and adaptability.

The publication contains the results of the experimental research of the five fast-growing Swedish varieties of genus *Salix* and perennial grass *Miscanthus x giganteus*. The following chapters summarize the own observations of the ecophysiological characteristics of the studied trees and plants and practical experiences in the production, treatment and maintenance of plantations of the energy trees and plants in the conditions of southern Slovakia and Serbia. In addition to the above, the book also includes the results of our previous research of the energy trees and plants.

Individual chapters are addressed to biological and ecological characteristics of the studied genus, external factors influencing the biomass production and establishment of plantations, their structures and practical management. Special sections focus on biotic interactions (internal factors) in crop stands and the impact of competition, diseases and pests. The final chapter describes the European and national legislation of Slovakia and Serbia, which interalia discusses sustainable agriculture, renewable energy sources and their obtaining in relation to nature conservation.

The book provides an overview of current knowledge and trends in the world with a number of literature sources and their comparison with own results. We recommend it to scientific and professional community, students, graduates and practical growers.

This work was supported by the Slovak Research and Development Agency and by the Ministry of Education and Science of the Republic of Serbia under the contract SK-SRB-0029-09 and by the Ministry of Education and Science of the Republic of Serbia through the project TR 31078 "Ecoremediation of degraded areas through agri-energy crops production".

Zuzana Jureková, Gordana Dražić

1 Importance of energy crops growing

Status of fuel and energy base in the world requires a radical intervention in the energy sector, notably by changing the fuel base and the use of additional resources in the form of renewable energy. Renewable energy sources are based on sophisticated and environmentally friendly technologies and contribute to strengthening and diversifying the structure of industry, agriculture and forestry. Biomass energy use has a multifaceted meaning.

Energy crops offer clear ecological advantages over fossil fuels, such as a positive carbon balance (due to the photosynthesis of the biomass used as raw material) which contributes to the reduction of greenhouse gases emissions and the low sulphur content, which contributes to the reduction of acidifying gases emissions (Gosse, 1995). The main encouragement to bio-energy crop production and development was the acceptance of Kyoto protocol (1997) related to climate changes and reduction of greenhouse gases emissions. High interest in bio fuels on global level could be explained with following facts: bio fuel is a potential which can make a country less dependant of fuel oil import; bio fuel usage contributes to CO_2 emissions reduction; bio fuel usage can significantly improve quality of life in rural areas (Oljaca *et al.*, 2007).

The ideal energy crop has to have good capacity for energy transformation from solar to harvestable biomass with maximum efficiency, minimal input requirements and favorable environmental influence. Energy biomass systems must be characterized with very positive energy balance, which means lower energy inputs than energy yield, especially because energy inputs are related to fossil fuels and carbon emissions to the atmosphere. Cultivation, harvest and nitrogen fertilization require high financial and fossil fuel inputs (Heaton *et al*., 2004; Drazic and Milovanovic, 2010).

Traditional bio-energy sources are woody biomass and agricultural residues. Forests and woody crops are a source of energy through the conversion of woody biomass into convenient solid, liquid or gaseous fuels to provide energy for industrial, commercial or domestic use. Already biomass provides about 11% of the world's primary energy supplies. About 55% of the 4 billion m^3 of wood used annually by the world's population is used directly as fuel wood or charcoal to meet daily energy needs for heating and cooking, mainly in developing countries. In addition, large quantities of industrial wood waste are used to generate heat, steam and electric power in developed countries. Bioenergy systems often use biomass that would otherwise be unmerchantable and the conversion of biomass may involve biochemical, thermochemical, or physical/chemical processes (IEA Bioenergy Contacts, 2003).

In Serbia, around 7% of households use wood for heating. Promotion of high density tree plantation establishing with short rotation is very effective, because it provides uniform, locally available raw material from fast growing deciduous forest species. Plantations usually contain high density planted willow and poplar individuals, harvested every third year. Roots stay in the soil after harvesting and provide new outgrowths next spring. Large amount of heat energy can be yield using wood biomass (including bark and branches) for pellets and briquettes production and direct combustion. In agro-environmental conditions of Serbia, the best results are reached with American black poplar clones (*Populus deltoides* Marsh.), because of their relatively high wood volume and increment comparing with Euro-American poplar clones (Klasnja *et al*., 2006). However, willow plantations establishment and biomass production improvement are of particular significance during last decades. Combination of adequate selection of energy crop, planting density and necessary biological measures of sylviculture and protection, can provide very good preconditions for long-term development of plantations for renewable energy production.

Fruit trees and grape vine residues can be used as energy source as well. Main factors of success in this case are the species and variety/grade (Zivkovic *et al*., 2007). However, collecting, preparation, processing and use of fruit tree and grape vine residues do not have wider application in Serbia because of high moisture content, variability of raw material and large volume, which leads to lower quantity, low rationality in transport requirements, hard manipulation, storage and usage in burners.

Wheat can be very interesting as solid energy source because of its high productivity and high potential for CO_2 substitution. The whole crop and some fractions of seed and reed can be used for combustion. However, high concentrations of Cl, K and N in the biomass have negative influence during the combustion process (Kauter *et al*., 2002). Biomass can be significantly improved through adding of coal and additives and as such can be used for particular types of burners with low level of pollutant emission, especially SO_2 (Sedláček *et al.,* 2007).

Corn is the main raw material for ethanol production, and its consumption as alternative fuel raising on global level. Serbia is one of important corn producers in Europe, and it has very good preconditions for ethanol production (Radosavljevic, 2007). The most important quality parameter for usual farming crops is starch content in kernel, which has to be over 70% to reach 37-40 liters of ethanol from 100 kilograms of corn. Beside corn, ethanol can be produced economically from potato and sugar beet. The ethanol price, for example produced from corn, varies between 30 and 60 USD and it depends on corn market price (Agamuthu, 2007).

Oilseed rape is the main raw material for biodiesel production in Serbia. On the global market, beside oilseed rape, the most presented biodiesel sources are sunflower, soya and palms. Biodiesel has two main advantages in comparison with mineral fuels: biodegradability in short period and significantly lower emission of pollutants while combustion.

There are numerous research activities in the world, especially on grass species, for potentially energy production. Annual or multiannual species of grass with high biomass yield, high efficiency in nutrients and water consuming and good quality of biomass combustion are very perspective as energy crops. Perennial grasses can often produce higher yield of biomass than forest trees, while existing mechanization of forest management units are at disposal (Heaton *et al*., 2004). The most interesting for cultivation and with the highest bioenergy potential are (Dzeletovic *et al*., 2007): Switch grass (*Panicum virgatum* L.), Red canary grass (*Phalaris arundinacea* L.), Giant cane (*Arundo donax* L.) and Miscanthus (*Miscanthus*×*giganteus* Greef et

Deu.). Perennial grasses require only one cultivation activity, preparation for planting, and during 10-20 years of cultivation nitrogen inputs are low. Energy ratio (energy input/energy yield) can be less than 0,2 in this production (McLaughlin and Walsh, 1998), while this ratio for ethanol production from corn or biodiesel production from oilseed rape is usually higher than 0,8 (Ulgiati, 2001). Perspective and further development of perennial grasses cultivation will mostly depend on market prices of fossil fuels and wheat, as well as availability of state subsidies for biomass production and specific agro-technical measures of cultivation.

Slovakia, in terms of landscape, is a predominantly rural country. Rural regions occupy 86% of the territory and are home to more than 40% of the population. Spatially, the most extensive economic activity is agriculture, which is devoted to the area of more than 49% of the territory. Slovakia is a country of forests. It has the second largest forest coverage in Europe following Finland. Forest area represented 2.004 million ha in 2003, which is 43% of Slovakia (according to the Concept of Using Agricultural and Forestry Biomass, approved by Slovak government decree in 2003). Slovakia is thus a country with large energy potential stored in biomass. Biomass is obtained intentionally, as a result of agricultural or forest production or as a biomass from wastes produced by wood and food industries and agriculture. Plant biomass originates by conversion of solar energy and its use in the photosynthetic processes of plants. Biomass production depends on the genetic potential of a species and environmental factors that influence the course of physiological processes (mostly photosynthesis and respiration). These are integrated in the production process and the final harvest. The value of annual biomass production in Slovakia merely from agriculture amounted to 20 685 388 t in 1990. Since then, it was decreasing (Kanianska *et al*., 2009). Part of this biomass is harvested in the form of field crops; another is used for feeding of livestock and as bedding. Quite a large part remains in the fields and is ploughed in order to maintain soil fertility and natural regulating processes. It has been discussed for several years what amount of biomass waste should be ploughed into the soil. Víglaský (2000) states that 65% of straw (from the cultivation of cereals, maize, rape seed, etc.), could be used for energy purposes. On the other hand, Bédi (2001) recommends to use only 35% of waste biomass for energy purposes and to plough the rest in order to restore soil organic matter and microbial life.

The document "Strategy of Higher Use of Renewable Energy Sources in Slovakia" (2007) shows that Slovak agriculture can produce up to 46.5 PJ of energy from agricultural biomass, without adverse affect to livestock production or soil nutrition. Nevertheless, the use of biomass is still insufficient. In 2005 it was only 17 PJ, which is about 2% of total energy consumption. Purpose-grown biomass for energy production reached 4 million tons (57 PJ) in 2010, while annual production in terms of energy could be much higher (up to 160 PJ).

A similar situation is also in the use of biomass derived from forest production. These sources could provide for energy purposes part of the timber unprocessed in the wood industry and also waste from the wood industry, greenery from urban and rural areas, windbreaks, tree alleys, municipal waste wood, alluvium wood and so on.

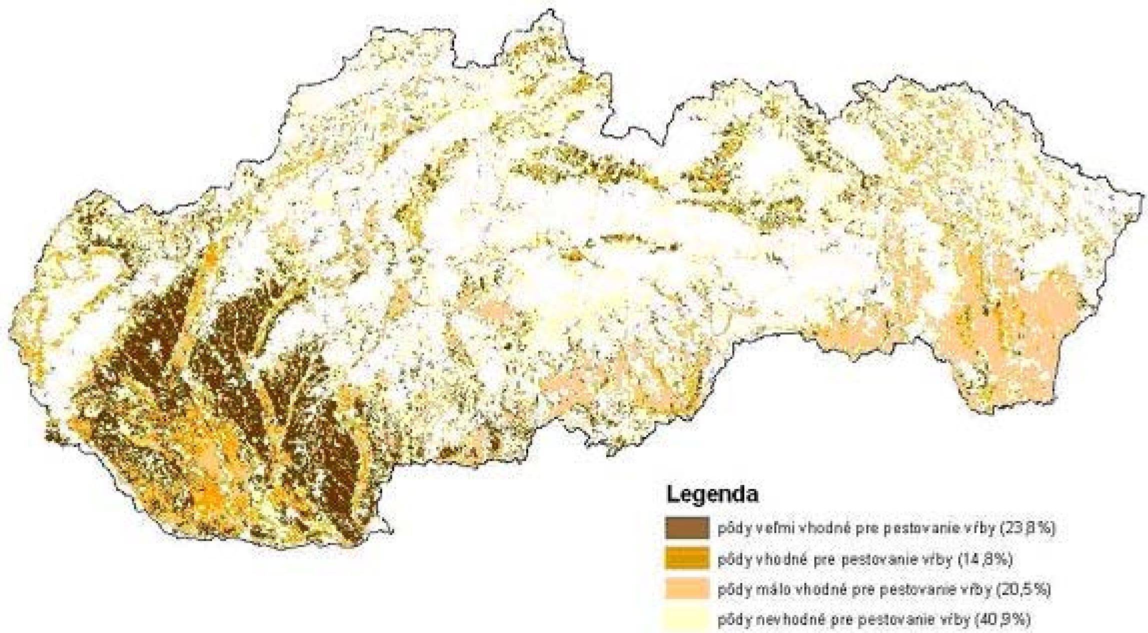
Currently, the total amount of forest biomass (dendromass) is 2.43 million tons (26.8 PJ energy), but only about 42% of this potential is used.

Even a brief assessment of agricultural biomass sources shows that the energy potential of the produced biomass is much higher than its share on energy consumption. These values, however, are not entirely accurate because the evidence of the quantity of waste biomass and purpose-grown biomass is non-uniform and there is a lack of standard methodology for the balance analysis.

In 2008, Slovak government approved the Biomass Action Plan, which identifies barriers to implementation of biomass for energy purposes. These are technical (lack of technical, machine and technological equipment), economic (unstable business environment, lack of capital in agricultural and forest organizations, lack of state aid, unprofitable energy price, etc.) and legislative barriers.

Increasing the share of renewable energy sources and control of production technologies is in accordance with the "Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources, as amended". It is part of measures to reduce greenhouse gas emissions and observance of the Kyoto Protocol to the United Nations Convention on Climate Change and other obligations and international commitments to reduce greenhouse gas emissions after 2012. Except of the mutual problems of atmosphere protection, ozone layer, aridization and advancing climate change also other problems have been discussed, like abandoned and fallow arable land that is temporarily excluded from agricultural production, as well as contaminated and devastated land in former industrial sites (brownfields). A valuable perspective in addressing these problems is establishment of the so-called energy plantations of fast-growing trees and annual and perennial plants that are the basis of fuel biomass. Well localized plantations of energy trees (*Salix*) may provide a number of local environmental benefits and can perform different ecological services, such as shelters for animals and nesting places for birds, as well as a role in soil-conservation and soil-protection from erosion and phytoremediation. On the other hand, energy plantations cannot be established in any protected areas (national parks and protected landscape areas), or forest land. Therefore, the fast-growing trees should be planted on soils that had already been used for production purposes. An important aspect is also the requirement that plantations do not interfere with the landscape scenery.

In Slovakia, currently much discussed is the promotion of carbon sequestration in the soil as one of the measures to mitigate the effects of climate change. At present, the loss of soil carbon into the atmosphere is supported by land conversion, improper use of grassland areas, excessive drainage, destruction of wetlands and deforestation (Pichler *et al.,* 2011). Part of the carbon losses can be replaced by change in the management system that would prefer a higher storage of carbon in the soil, reducing its emissions into the atmosphere, change of the land use and improved land management. Jolánkai (2007) considers, as one of the main areas of the carbon sequestration, growing of energy crops and use of their biomass for energy purposes.



Zdroj: VÚPOP

Legend

soils highly suitable for willow cultivation (23.8%)
soils suitable for willow cultivation (14.8%)
soils less suitable for willow cultivation (20.5%)
soils not suitable for willow cultivation (40.9%)

Fig. 1.1 Suitability of agricultural land for growing willow and poplar in Slovakia (SSCRI, 2009)

This requirement is satisfied by fast growing tree species of genus *Salix* and *Populus*. In particular, willows have a perennial habitus with rapid growth, rapid biomass production, deeply penetrating powerful root system and high transpiration rates. Species of both genera have also significant phytoextraction characteristics affirmed in particular in relation to cadmium and zinc (Greger and Landberg, 1999, Šotníková *et al.,* 2003, Lunáčková *et al.,* 2003/4).

In Slovakia, experimental willow plantations of common osier (basket) willow (*Salix viminalis*) have been planted in Krivá in the Orava region since 1994 and since 2005 also in a farm of Slovak University of Agriculture in Kolíňany where Swedish willow and poplar varieties of different provenance are grown. The research of energy crops also includes growing perennial grass *Miscanthus* (*Miscanthus sinensis* x *giganteus* GreefetDeu and *Miscanthus sinensis* TATAI). Total area of land in Slovakia suitable for energy plantations of trees and plants, according to the *Soil Science and Conservation Research Institute (SSCRI)* is 355 830 ha (Figure 1.1).

The above listed advantages of growing energy crops (trees) and their practical use will require an ongoing theoretical research and experimental verification of production technologies in specific climatic conditions.

Interests and attitudes of different stakeholders in bio fuels production are variable and controversial and external factors can have significant influence in the process of national programming of bio fuels production (Lakner, 2008). Bio energy can contribute significantly to climate change struggle and rural development, but also can cause further degradation of soil and water resources, ecosystem instability, food safety problems and increasing of greenhouse gasses emissions, if human resources do not respect rules of sustainability during the production development (Sagar and Kartha, 2008). Having in mind this problems, main goals of national policies in energy management have to be energy consuming reduction, introduction of renewable energy sources, increasing of quality and quantity of agricultural production and environmental pollution reduction, followed with decreasing of production costs (Janic *et al*., 2009).

Intensive researches have to support policy framework development and provide baseline for decision making and modeling of scenarios of future environmental and socio-economic influences of biomass production. Economic efficiency of bio energy sources is still questionable and it has to be supported with exact measurements conducted within multiannual field and laboratory experiments, as a baseline for further cost-benefit analyzes (Milovanovic *et al*., 2011; Drazic *et al*., 2010). The price of bio fuel on global market is still high and this type of energy is not available to wider population, while the producers have competitiveness problems with conventional plants production.

European Union provides subsidies for bio energy production which is the only way for profitability in this area. Production of energy crops will not reduce production of food, but it can have significant influence on increasing of agricultural products prices (Dolensek *et al.,* 2006). Commercialization of bio fuels requires developed methodologies and processes, accessible market, especially for rural areas, and equality of trade conditions. On the other hand, highly efficient agricultural systems combined with geographical optimization of soil resources use can lead to decreasing of arable land necessary for food production for 72% until 2050 (Smeets *et al.,* 2007).

Supportive governmental measures for bio fuels production in every country have to be planned and documentary by experimental research results from the field, because of many assets of this type of energy production: oil import decreasing, greenhouse gasses emission reduction, new employment offers and sustainable use of degraded lands.

From the above it follows that only intensive use of existed and newly bio energy crops can lead to multifunctional agriculture, as well as to price stability of agricultural products. These improvements will contribute to sustainable rural development of every country.

In this monograph, we review the role of perennial woody and herbaceous crops in meeting the need for sustainable land use and development. Research results from field sample plots of willows and *Miscanthus* are explained with the aim of closer recognizing of environmental contribution and influences, energy and economic efficiency of these energy crops.

References:

AGAMUTHU, P. 2007. *Sustainable fuel from biomass: clamour or glamour?* In Waste Management and Research, 25 (4), 2007, p. 305-306.

BÉDI, E. 2001. *Obnoviteľné zdroje energie*. Bratislava : Fond pre alternatívne energie, SZOPK. 2001, 143 p. ISBN 80-85369-12-6.

DOLENŠEK M. - OLJAČA, S.I. - OLJAČA, M.V. 2006. *Upotreba biljaka za proizvodnju energije*. Poljoprivredna tehnika, 31 (3), 2006, p. 93-101.

DRAŽIĆ, G. - MILOVANOVIĆ, J. 2010. *Forest lands valorization possibility through fast growing energy crop Miscanthus giganteus cultivation.* International scientific conference »Forest ecosystems and climate changes«, Institute of Forestry Belgrade, IUFRO, EFI. Belgrade. 9-10 March. Proceedings, Vol. 2, p. 303-308.

DRAŽIĆ, G. - SEKULIĆ, S. - MILOVANOVIĆ, J. - ALEKSIĆ, J. 2010. *Master plan plantaže energetskog useva Miscanthus x giganteus*. Međunarodno savetovanje „Energetika 2010“. Zlatibor. 23-26.03. Zbornik radova. p. 96-99.

DŽELETOVIĆ, Ž.S. - DRAŽIĆ, GD. - GLAMOČLIJA, Đ. - MIHAILOVIĆ, N.LJ. 2007. *Perspektive upotrebe biljaka kao bioenergetskih useva.* Poljoprivredna tehnika, 32 (3), 2007, p. 59-67.

GOSSE, G. 1995. *Environmental Issues and Biomass, Biomass for Energy, Environment, Agriculture and Industry.* Proceedings of the 8th European Conference, Vol. 1, Ed. P. Chartier, A.A.C.M. Beenackers, G. Grassi, Pergamon Press, p. 52 - 62.

GREGER, M. - LANDBERG, T. 1999. *Use of willow in phytoextraction*. In Int. J. Phytorem., Vol. 2, 1999, p.1-10.

HEATON, E.A. - CLIFTON-BROWN, J. - VOIGT, T.B. – JONES, M.B. - LONG, S.P. 2004. *Miscanthus for renewable energy generation: European Union experience and projections for Illinois***.** In Mitigation and Adaptation Strategies for Global Change, 9 (4), 2004, p. 433-451.

IEA BIOENERGY CONTACTS. 2003. *Sustainable production of woody biomass for energy – A position paper prepared by IEA Bioenergy*. New Zealand. 2003. 12 pp.

JANIĆ, T. - BRKIĆ, M. - IGIĆ, S. - DEDOVIĆ, N. 2009. *Gazdovanje energijom u poljoprivrednim preduzećima i gazdinstvima*. Savremena poljoprivredna tehnika, 35 (1-2), 2009, p. 127-133.

JOLÁNKAI, M. - NYÁRAI, F.H. - FARKAS, I. - SZENTPÉTERI, Z. 2007. *Agronomic impact on energy crop performance*. In Cereal Research Communications, Vol.35 (2), 2007, p. 537-541.

KANIANSKA, R. - KIZEKOVÁ, M. - MAKOVNÍKOVÁ, J. 2009. *Poľnohospodárstvo ako zdroj biomasy na energetické účely na Slovensku*. In Enviromagazín, No. 4, 2009, p.7-9.

KAUTER, D. - LEWANDOWSKI, I. - CLAUPEIN, W. 2002. *Quality management during production of triticale for solid fuel use*. In: *Contribution to the 12th European Biomass*

Conference (Ed. A Faaij), Utrecht University/Copernicus Institute/Science Technology and Society, Utrecht, 2002, p. 52-55.
KLAŠNJA, B. - ORLOVIĆ, S. - GALIĆ, Z. - PAP, P. - KATANIĆ, M. 2006. *Gusti zasadi topola kao sirovina za proizvodnju energije.* Glasnik Šumarskog fakulteta, 94, 2006, p. 159-170.
LAKNER, Z. - KAJARI, K. - SOMOGYI, S. 2008. *Rise and fall of a national bio-fuel programme – a case study from Hungary*. In PTEP – časopis za procesnu tehniku i energetiku u poljoprivredi, 12 (3), 2008, p. 118-124.
LUNÁČKOVÁ, L. - ŠOTTNÍKOVÁ, A. - MASAROVIČOVÁ, E. - LUX, A. - STREŠKO, V. 2003/4. *Comparison of cadmium effect on willow and poplar in response to different cultivation conditions*. In Biologia Plantarum Vol. 47 (3), 2003/4, p. 403-411.
McLAUGHLIN, S.B. - WALSH, M.E. 1998. *Evaluating environmental consequences of producing herbaceous crops for bioenergy*. In Biomass and Bioenergy*,* 14 (4), 1998, p. 317–324.
MILOVANOVIĆ, J. - DRAŽIĆ, G. - IKANOVIĆ, J. - JUREKOVA, Z. - RAJKOVIĆ, S. 2011. *Sustainable production of biomass through Miscanthus giganteus plantation development*. 3rd International Scientific Conference Management of Technology-Step to Sustainable Production. June 8-10, Bol, Island Brac, Croatia. Conference Proceedings. 2011, p. 440-444.
OLJAČA, S. - OLJAČA, M.V. - KOVAČEVIĆ, D. - GLAMOČLIJA, Đ. 2007. *Ekološke posledice upotrebe biljaka za dobijanje energije*. Poljoprivredna tehnika, 32 (4), 2007, p. 91-97.
PICHLER, V. - AHMED, Y. A. R. 2011 *Ovplyvňovanie sekvestrácie a zásob pôdneho uhlíka rôznymi typmi krajinnej pokrývky* [online]. Dostupné na internete: <www.tuzvo.sk/files/3_3/katedry_lf/kpp/kolokvium-umb-sj.ppt>.
RADOSAVLJEVIĆ, M. 2007. *Kukuruz – obnovljiv izvor energije i proizvoda*. PTEP – časopis za procesnu tehniku i energetiku u poljoprivredi*,* 11 (1-2), 2007, p. 6-8.
SAGAR, A.D. - KARTHA, S. 2007. *Bioenergy and Sustainable Development*? In Annual Review of Environment and Resources, Vol. 32, 2007, p. 131-167.
SEDLÁČEK, P. - MUCHA, N. - PEČTOVÁ, I. - FEČKO, P. 2007. *Ekologické pelety z hnědého uhlí a biomasy*. In Acta Montanistica Slovaca, 12 (2), 2007. p. 274-277.
SMEETS, E.M.W. - FAAIJ, A.P.C. - LEWANDOWSKI, I.M. - TURKENBURG, W.C. 2007. *A bottom-up assessment and review of global bio-energy potentials to 2050*. In Progress in Energy and Combustion Science, 33 (1), 2007, p. 56-106.
SMERNICA EURÓPSKEHO PARLAMENTU A RADY 2009/28/ES o podpore využívania energie z obnoviteľných zdrojov energie.
SSCRI 2009. Dlhodobá stratégia využitia poľnohospodárskych a nepoľnohospodárskych plodín na priemyselné účely [online]. Schválené dňa 4. 2. 2009 uznesením vlády SR č. 108/2009, mapové podklady Výskumný ústav pôdoznalectva a ochrany pôdy Bratislava, 2009, p. 46. Dostupné na internete: <http://www.abe.sk/dokumenty/Dlhodoba_strategia.pdf>.
ŠOTNÍKOVÁ, A. - LUNÁČKOVÁ, L. - MASAROVIČOVÁ, E. - LUX, A. - STREŠKO, V. 2003. Changes in the rooting and growth of willows and poplars induced by cadmium. In *Biologia Plantarum*, Vol. 46 (1), 2003, p. 129-131.

VÍGLASKÝ, J. 2000. Biomasa a jej možnosti uplatnenia v komunálnej energetike. In Zborník prednášok zo seminára konaného v rámci projektu „Fénix“, Liptovský Mikuláš, 68 p.
ZACHARDA, F. 2007. Potenciál poľnohospodárskej a lesníckej biomasy, ekonomické a legislatívne predpoklady rozvoja bioenergetiky. In Predpoklady využívania poľnohospodárskej a lesníckej biomasy na energetické a biotechnické využitie. Nitra : SAPV, 2007, č.58, p. 7-15.
ULGIATI, S. 2001. *A comprehensive energy and economic assessment of biofuels: When 'green' is not enough*. In Critical Reviews in Plant Sciences, 20 (1), 2001, p. 71–106.
ŽIVKOVIĆ, M. - RADOJEVIĆ, R. - UROŠEVIĆ, M. 2007. *Priprema i potencijal ostataka rezidbe u vođnjacima i vinogradima, kao energetskog materijala*. Poljoprivredna tehnika, 32 (3), 2007, p. 51-58.

2 Biological characteristics of short rotation coppice

2.1 Biological characteristics of genus Salix

Plants belonging to the genus *Salix* were among the first recorded as flowering plants in the interglacial period (Newsholme, 2002). Genus *Salix* originated in the subtropical area and later spread slightly into the tropical area expanding to the temperate zone and later to the Arctic zone. Species of the genus *Salix* are currently widespread mainly in northern temperate regions (Europe, Asia and North America). Species diversity is highest in China (270 species) and Russia (120 species). About 65 species grow in Europe and 160 species can be found in North America (Kuzovkina and Quigley, 2005). Only three species originated in Central and South America (Argus, 1986). About 12 species grow in Africa, most of which are endemic of local occurrence (Newsholme, 2002). Linné (1763) described and divided two genera within this family *Populus* and *Salix*. Nakai (1920 In Dickmann and Kuzovkina, 2008) described a new genus *Chosenia*, which bears mean values of the features of the preceding genera.

The genus *Salix* is very heterogeneous and includes 400-500 species, which differ in the size structure and growth forms (Stott, 1984). The most accepted is classification according to Skvorstov (1968), which distinguishes three main subgenera:

Representatives of the subgenus *Salix* - so called "real" willows are trees or high shrubs with narrow or pointed leaves. Flowers usually appear together with or after leaves. Male flowers are characterized by the presence of two and/or several stamens. These features are considered developmentally initial. Typical representatives include crack willow (*Salix fragilis* L.) and white willow (*Salix alba* L.) (Newsholme, 1992). The subgenus *Vetrix* includes mostly shrubs or small trees with a wide variety of leaf shapes (from narrow to round leaves). Leaves may have entire or distinctly serrated margins. Catkins emerge before leaves. Female flowers have only one nectary. The representatives of this subgenus have two stamens and buds are enveloped by a single scale. This subgenus includes, for example *Salix caprea* – goat willow (sallow) and eared willow (*Salix aurita*).

Subgenus *Chamaetia* represents a group of willows adapted to arctic and alpine conditions by their low or procumbent growth habit (Azuma *et al.*, 2000). The leaves are small and round, catkins bloom after leaves. Representatives of this subgenus include for example *Salix reticulata* L. *S. herbacea* L., *S. retusa* L. (Newsholme, 1992).

Willows are considered as plants with very difficult determination. High degree of hybridization, a large genetic variability and its impact on morphological variability, possibility of apomixy and reduction of morphological traits on flowers are phenomena that are largely involved in the complicated classification and determination of the willows.

Genus *Salix* is species-abundant and taxonomically complicated species of willow family (*Salicaceae*). *Salicaceae* family is a widespread group of dicotyledonous plants belonging to the order *Malphigiales* Martinus. In a narrow division, the family *Salicaceae* consists of 2-4 genera. The family is widespread, especially in temperate northern hemisphere (Figure 2.1). It does not occur in New Zealand and Australia. In Europe are only two naturally existing genera – poplar (*Populus* L.) and willow (*Salix* L.) (Chmelař and Koblížek, 1990). The family *Salicaceae* includes dioecious deciduous tree species with shrub or tree-like growth, soft wood, usually simple leaves, short petioles, lanceolate-linear, mostly entire margins and the arrangement of the leaves is typically alternate. Flowers are grouped in slender catkins, which are unisexual without flower envelopes. Male flowers have usually 2 (2-12) yellow stamens. Female flowers are less tawdry with gray-green colour. Fruits are capsules. Seeds are small and usually have a short germination. Detailed botanical characteristics provide Dickmann and Kuzovkina (2008) (Table 2.1). Willows have typically large, well-developed root system (Chmelař and Koblížek, 1990; Stevens, 2001).

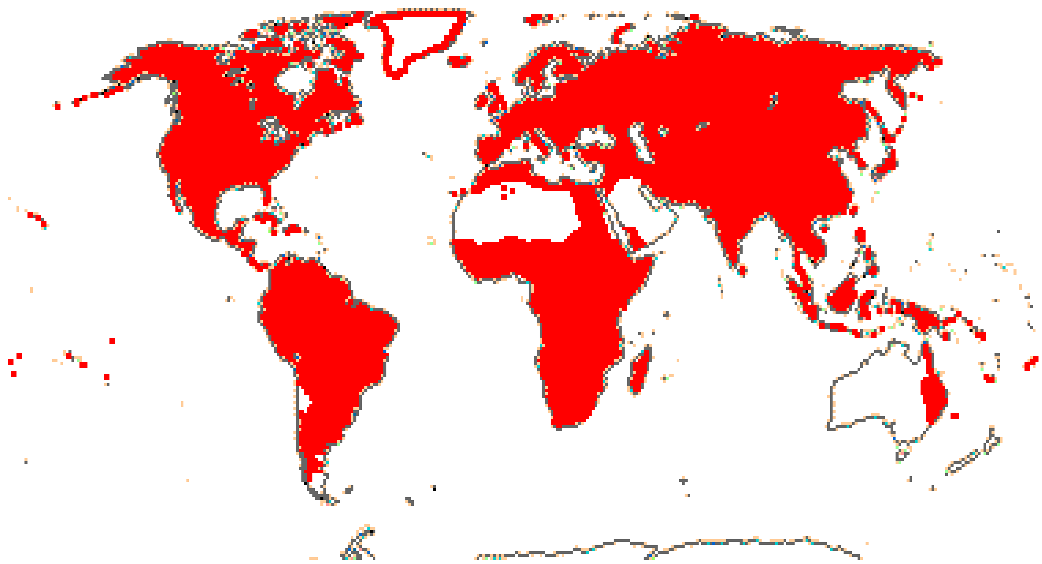


Fig. 2.1 Distribution of *Salicaceae* family in the world (Stevens, 2001)

Salix dasyclados Wimmer (synonym *Salix burjatica* Nasarov, *S. aquatica* Smith) is a species of Russian willow, which is approximately equally widespread as *Salix viminalis*. It is a tree or shrub up to 10 m high. Its shoots can reach 80-90 cm in diameter and is characterized by dense straight gray-brown branches. It grows on suitable sites in northern Russia along river valleys, roadside ditches and on well-drained, moist and aerated substrates can reach up to 20 m of height (Dickmann and Kuzovkina, 2008). In Western Europe, are common hybrids similar to *Salix dasyclados* and therefore several authors consider this species a hybrid (cf. Newsholme, 1992). However, under normal seed production, absence of hybrid segregation, specific ecological niche and the huge distribution of the species, this assumption appears to be inaccurate. *S. dasyclados* can be used for basket-making, as a protection of stream banks and for biomass production (Kopp *et al.*, 2001).

Salix viminalis Linaeus – tall shrub or multi-stem tree growing up to 6-8 m of height, with long flexible shoots with olive and/or gray-brown colour. Osier willow is widespread in Eurasia regions except for the Far East. It grows on alluvial substrates along the stream banks, in ditches and on sandy soils with sufficient moisture content. It has long narrow leaves (up to 20 cm) with conspicuously revolute or undulate margins. Leaves have a dark green colour with a pubescence on lower leaf surface. Catkins are densely sericeous containing flowers with brown bracts.

S. viminalis is more persistent, resistant and robust species creating straight and long flexible shoots up to 4 m long with high production of pulp. For these reasons, it is considered as the most suitable species for reinforcement of banks and ditches and is used also as a building

material and for afforestation. *Salix viminalis* can freely cross with many species: eg. *S.* × *smithiana* (*S. cinerea* × *S. viminalis*), *S.* × *hirtei* (*S. viminalis* × *S. cinerea* × *S. aurita*), *S.* × *sericans* Tausch (*S. caprea* × *S. viminalis*), *S.* x *fruticosa* Doell (*S. aurita* x *S. viminalis*), *S.* x *friesiana* Andersson (*S. repens* x *S. viminalis*), *S.* × *mollissima* Hoffman (*S. triandra* × *S. viminalis*), *S.* × *rubra* Hudson (*S. purpurea* x *S. viminalis*), and *S.* × *forbyana* Smith (*S. cinerea* × *S. viminalis* × *S. purpurea*). Combinations with *Salix dasyclados* dominate in European hybridization programs. Many clones of this species and some of its hybrids are grown as fast-growing trees for biomass production (Verwijst 2001). It is the most important species in Europe for commercial use (Kopp *et al*. 2001).
Registered varieties of Swedish provenance bred by intentional crossing of mainly *Salix viminalis,* as well as other species of shrub willows are Tora, Tordis, Inger, Sven and Gudrun. These varieties and varieties of Hungarian provenance are also included in the trials of the experimental research site in Kolíňany.

Tab. 2.1 Botanical characteristics of *Salix* (Dickmann and Kuzovkina, 2008)

Character	**genus *Salix***
Genome	2n = 38 chromosomes; diploid to dodecaploid (12x); genome has not been sequenced
Flowers	Appear before, with, or after leaves; catkins mostly erect; insect or wind pollinated. Perianth and disk usually absent but with 1 or 2 nectaries; bracts entire, pubescent, usually persistent; stamens few – 2 to 12 - usually with yellow anthers; pollen thick-walled and tricolpate; stigmas two-lobed; ovaries with 2 carpels
Fruit	2-valved capsule
Leaves	Never lobed or deltoid. Almost always elongate in shape – obovate, oval, ovate-lanceolate, lanceolate, or lanceolate-linear; venation pinnate; margins finely serrate or entire, occasionally glandular.
Stipules	Sometimes persistent and prominent
Petioles	Short, round in cross-section
Buds	Enveloped by a single scale; closely appressed to twig; mostly sympodial and lacking a true terminal bud
Shoots	Slender; green, brown, yellow,, orange, purple, or red in colour; circular in cross-section; pith circular in cross-section; homophyllous (does not form brachyblasts). Rarely develop root suckers.
Wood	Light (specific gravity 0,30-0,42), uniform, straight-grained, soft, pale, not durable, tough and shock resistant, odourless; rays heterocellular
Habit	Extremely variable; can be procumbent plants, multi-stemmed shrubs, and medium to large trees
Habitat	Mostly cold temperate regions; common in wetlands, peatlands, riparian corridors, but uncommon in uplands; abundant in tundra and alpine zones
Number of taxa	330-500

2.2 Biological characteristics of genus Miscanthus

2.2.1 Origin and taxonomy characteristic

The natural habitat from which giant grasses from the genus *Miscanthus* originate is primarily Asia (Jeżowski, 1994; Deuter and Jeżowski, 1998; Xi and Jeżowski, 2004). These plants are frequently referred to as elephant grass or Chinese grass, but the name *Miscanthus* is also used. The genus *Miscanthus* has its origins in the tropics and subtropics, but different species are found throughout a wide climatic range in East Asia (Greef and Deuter, 1993) (Figure 2.2). Its occurs within the orthoseral (tall) grasslands of East Asia, from the tropics and subtropics to the Pacific Islands, the warm temperate regions and the subarctic (Lewandowski *et al.,* 2000). Miscanthus belongs to family of *Poaceae*, subfamily of *Panicoidae*, tribe of *Andropogoneae*, subtribe of *Conservation*. Under *Saccharineae,* there are 5 genera, namely Imperata, Erianthus, Saccharum, Miscanthidium and Miscanthus (Greef and Deuter, 1993).
The remarkable adaptability of miscanthus to different environments makes this novel crop suitable for establishment and distribution under a range of European and North American climatic conditions. In Europe these grasses started to be cultivated, initially as ornamental plants, about 80 years ago, when it was introduced from Japan. The high adaptability of *Miscanthus* to varying environmental conditions is linked to a variety of growth types, which are characteristic for the heterogeneity between the species and also within the same species. (Greef *et al*., 1997). A number of ornamental varieties of miscanthus are known to exist under various common names. According to Deuter (2000) genus *Miscanthus* include 17 species with high biomass production potential. The best-known European *Miscanthus* is a triploid (2n=3×=57/58) (Linde-Laursen, 1993) hybrid *Miscanthus×giganteus*[1], generated by crossing *Miscanthus sinensis* (sin. *Miscanthus purpurascens* Anderss) (2×) ×*Miscanthus sacchariflorus (Maxim.) Benth. et Hook* (4×)[2] (Jeżovski, 2008). A sterile hybrid horticultural genotype, *Miscanthus x giganteus* Greef et Deu. was brought back to Denmark by Aksel Olsen in 1935, and was observed to have exceptionally vigorous growth (Linde-Laursen, 1993). The genotype *Miscanthus×giganteus* Greef et Deu. has several synonyms like *Miscanthus sinensis* var. *`Giganteus'* (Schwarz *et al*., 1994), *Miscanthus* x *ogiformis Honda `Giganteus'* (Hansen and Kristiansen, 1997) and *Miscanthus `Giganteus'* (Linde-Laursen, 1993).
At present giant grasses from the genus *Miscanthus* are considered to be key renewable raw materials for industry and energy production (Jeżovski, 2008). *Miscanthus giganteus* high level biomass production (20 t/ha/year) and possibility of cultivation on less quality soil (HEATON *et al.* 2004) make this crop very suitable as annual renewable raw material for bio-fuel production

[1] German scientists Greef and Deuter introduced *Miscanthus spp*. into Europe and made a hibryd called *Miscanthus x giganteus* (Chou, 2009)

[2] Miscanthus sinesis (2n = 38) and Miscanthus sacchariflorus (2n = 76) (linde- Laursen IB, 1993)

(Dražić *et al.*, 2010). Biomass crops can provide renewable sourses of fuel for heat energy and electricity generation, whilst making gainful use of excess agricultural land (Beale *et al.*, 1999). It has been shown that this plant has extremely high potential for storage, exclusion from bio-geo-chemical carbon cycle, which makes it significant in combat against global warming (Clifton-Brown *et al.*, 2007).

Fig. 2.2 Miscanthus in a semi-natural habitat in Japan (DEFRA publications, 2001)

2.2.2 Crop biology

Miscanthus is a perennial rhizomatous grass with the C4 photosynthetic pathway. Its sterile hybrid witch cannot form fertile seeds as a consequence of its triploidy. (Lewandowski *et al.*, 2000). As sterile hybrid *Miscanthus* spears naturally by means of underground storage organs (rhizomes) (Clifton-Brown and Lewandowski, 2000; Lewandowski *et al.*, 1999). However, their spread is slow and there will not be any uncontrolled invasion of hedges or fields. These rhizomes can be split and the pieces re-planted to produce new plants. Due to their photosynthesis properties (C4 plant), *Miscanthus* species have a potential for very high growth rates. The key biological characteristics are i) reproduction is possible only through vegetation way, ii) it is sensitive to low temperatures, iii) its development requires high insolation and relatively large quantity of water (Dražić *et al.*, 2009).

Plants with C4 photosynthesis have the potential to out-yield plants with C3 photosynthesis because of higher radiation-, water- and nitrogen-use-efficiencies, but they require warmer conditions than C3 plants to initiate growth in spring time. In Europe it begins growth in April and continues until halted by frost in November (Ercoli *et al.*, 1999). *Miscanthus* is planted in spring and canes produced during the summer are harvested in winter. This growth pattern is repeated every year for the lifetime of the crop, which will be at least 15 years. Typically, M. x giganteus stands require between 3–5 years for full establishment depending on the quality of the planting site, after which economically viable cropping commences (Price *et al*., 2004). Literature data show that *Miscanthus* biomass increases by third year and remains constant for several following years (Cristian *et al.*, 2008).

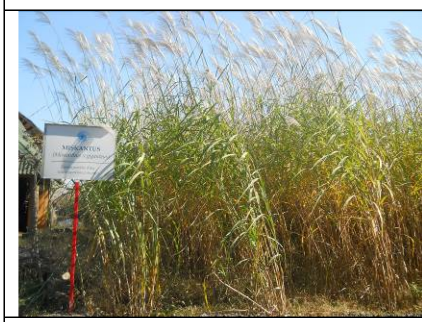
Draying and nutrient recycling		Harvest
	January 2011	
		
October 2011		April 2011
Senescence		Growth
	July 2011	

Fig. 2.3 Growth cycle of Miscantus (photo by Nenad Mitic)

During the interval of intensive growth and development (since the beginning of April till the end of October) miscanthus plants were characterized with high water content (50-65%) and high nitrogen content (≥1%). At the end of September maximal biomass of the miscanthus aboveground parts was achieved. With the shift to the stage of winter dormancy (since the end of October till the beginning of April) water content in the crop was gradually decreased by stem and leaf drying. N, P and K contents in the crop were also decreased, partly due to defoliation and falling off of stem tops, and partly due to nutrients transport from aboveground parts to the rhizomes (Dželetović *et al*., 2009). For an example, it has been shown that *Miscanthus x giganteus* begins growth from the dormant winter rhizome when soil temperatures reach 10 to 12ºC (Clifton–Brown, 1997). The plant has an extensive root system that responds quickly to a rapid demand for nutrients during spring growth, thus reducing the risk of nitrate leaching (Himken *et al*., 1997). The threshold temperature for leaf expansion of plants which have begun to grow ranges between 5 and 10°C, and considerable variation exists in the thermal response of leaf expansion for different genotypes (Lewandowski *et al*., 2000). The growth pattern of the crop is simple (Figure 2.3). It produces new shoots annually and these usually emerge from the soil during April. In late spring, new shoots grow from the crown, with rapid growth during May–July, producing cane-like stems up to 4 m in height. Shoot growth continues through September and even into October, whilst full senescence occurs following the first frosts of the autumn (Price *et al*., 2004). These shoots develop into erect, robust stems, which reach 1 - 2 m in height by late August of the year of planting, with a diameter of 10 mm. The stems, which have an appearance similar to bamboo canes, are usually unbranched and contain solid core. From late July the lower leaves start to dry. Crop drying accelerates during autumn, as nutrients move back to the rhizome. Leaves then fall and a deep leaf litter develops. Any remaining foliage dies following the first air frost and the stems dry to relatively low moisture content (30-50%) during winter. By February, free standing, almost leafless canes remain and it is these which are harvested mechanically. This growth cycle is repeated once spring-time temperatures increase again. From the second season onwards the crop can be expected to achieve a maximum height of 2.5 - 3.5 m[3] Field experiments have shown that freezing in winter time in Serbia (Table 2.2) amounts to 10%, but damages caused by late frosts have also been noticed (after vegetation starts). Watering needs depend mostly on weather conditions and soil properties, it is mostly done in first vegetation year and it significantly increases production price (Dražić *et al*., 2009).

Tab. 2.2 Losses of miskantus plants in 1st year. Date represents averages of 3 samples by 100 plants in field experiments; in parenthesis was done interval of experimental data. * damaged but survive plants.

Experimental site	Degree of emergency %	Summer damage %	Winter freezing damage* %	Late frost damage* %
Chernozem	92 (72-96)	5 (2-10)	5 (3-7)	14 (5-20)
Eutric cambisol	90 (85-95)	5 (2-9)	10 (5-12)	12 (5- 15)
Degraded vertisol	86 (70-90)	7 (3-11)	2 (0-3)	3 (1-5)
Humosol Zasavica	84 (80-92)	5 (3-12)	2 (0-3)	5 (0-11)
Deposol Kolubara	82 (76-88)	6 (1-12)	-	-

[3] BEST PRACTICE GUIDELINES – For applicants to DEFRA'S Energy Crops Scheme, DEFRA PUBLICATIONS, 2001

It should be stressed that the above ground part of *Miscanthus* is composed of several stems without branches which are developed from the same rhizome and leaves. Basic process, photosynthesis, happens in leaves during vegetation period. This means that for accumulation of organic substance (development of biomass) number of leaves per offset and number of offsets per rhizome (tillering) is significant. Since biosynthetic processes happen in leaf mostly, green leaves accumulate biogenic elements while in function. Older leaves are lower on the stem than newer ones, they are developed earlier and their functions stop earlier. That is why one of important parameters of biomass development is the moment when leaves start to die. (Dražić *et al*., 2009).

Photosynthesis process itself is characterized with its energy efficiency. It is therefore shown that photosynthesis in *Miscanthus* leaf is more efficient than that in maze and sorghum leaves and also that manipulations are possible at genetic and physiological level aimed at its increase. In the first side-by-side large-scale trials of these two C_4 crops in the U.S. Corn Belt, *Miscanthus* (*Miscanthus* x *giganteus*) was 59% more productive than grain maize (*Zea mays*). Total productivity is the product of the total solar radiation incident per unit land area and the efficiencies of light interception (ϵ_i) and its conversion into aboveground biomass (ϵ_{ca}). The average leaf area of *Miscanthus* was double that of maize, with the result that calculated canopy photosynthesis was 44% higher in *Miscanthus*, corresponding closely to the biomass differences (Dohleman and Long, 2009). Improvements in photosynthetic solar energy conversion efficiency and productivity can be achieved upon minimizing, or truncating, the chlorophyll antenna size of the photosystems (Melis, 2009).

Another physiological process is important for consideration: translocation of biogenic elements N, P, K, Ca, and Mg throughout annual cycle. The mineral concentration of aerial biomass is at its highest during spring and early summer and then declines, probably as a result of remobilization (Beale and Long, 1997, Christian *et al.*, 1998). It was measured the transfer of minerals from leaves and stem to rhizomes to be 21–46% of N, 36–50% of P and 14–30% of K (Himken *et al*., 1997). The greatest part of root mass is comprised of rhizome mass, and the nitrogen content in the root system rises with the increase of nitrogen rate applied. Nitrogen content in above-ground parts is highest at the moment of emergence. During elongation, the contents of nitrogen, phosphorus and potassium are gradually decreased in above-ground parts (Dželetović, 2010).

After the end of active growth, when all leaves are dry, biogenic elements, particularly nitrogen, are returned to rhizomes in order to provide reserve which may be easily activated as soon as favorable conditions occur for spring growth.

References

ARGUS, G.W. 1986. *The genus Salix (Salicaceae) in the Southeastern United States*. In Systematic Botany Monographs, Vol. 9, 1986, p. 1-170.

AZUMA, T. – KAJITA, T. – Y KOYAMA, J. – O ASHI, H. 2000. *Phylogenetic relationships of Salix (Salicaceae) based on rbcL sequence data*. In American Journal of Botany, Vol. 8, 2000, No.1, p. 67-75.

BEALE, C.V.- LONG, SP. 1997. *Seasonal dynamics of nutrient accumulation and partitioning in the perennial C4-grasses Miscanthus giganteus and Spartina cynosuroides.* In Biomass and Bioenergy, Vol.12(6), 1997, p. 419–428.

BEALE, C.V. – MORISON, J.I.L. - LONG, S.P. 1999. *Water use efficiency of C_4 perennial grasses in temperate climate.* In Agricultural and Forest Meteorology, Vol. 96(1-3), 1999,p. 103-115.

CHMELAŘ J. – KOBLÍŽEK J. 1990. 65. *Salicaceae* Mirbel – vrbovité. In Hejný S. -Slavík B. [eds.]: *Kvetena České republiky 2.* Academia, Praha, p. 458-495.

CHRISTIAN, D.G. - RICHE, A.B. 1998**.** *Nitrate leaching losses under Miscanthus grass planted on a silty clay loam soil*. In Soil Use and Management, Vol. 14(3), 1998, p. 131-135.

CHRISTIAN, D.G. - RICHE, A.B. – YATES, N.E. 2008. *Growth, yield and mineral content of Miscanthus × giganteus grown as a biofuel for 14 successive harvests*. In Industrial Crops and Products, Vol. 28(1), 2008, 320-327.

CLIFTON-BROWN, J.C. – BREWER, J. - JONES, M.B. 2007. *Carbon mitigation by the energy crop Miscanthus.* In Global Change Biology, Vol. 13 (11), 2007, 2296–2307.

DEFRA : Planting and growing Miscanthus, Defra Publications, PB No 5424, 2001

DEUTER, M. - JEŻOVSKI, S. - 1998. *Szanse i problemy hodowli traw z rodzaju Miscanthus jako ro´slin alternatywnych*. Hodowla i Nasiennictwo, Vol 4, 1998, p.45–48.

DEUTER. M. 2000. Breeding *approaches to improvement of yield and quality in Miscanthus grown in Europe*. In: *European miscanthus improvement—final Report September 2000*. (Eds. Lewandowski I, Clifton-Brown JC), Institute of Crop Production and Grassland Research / University of Hohenheim, Stuttgart, 2000, p. 28–52.

DIDKMANN, D.I. – KUZOVKINA, Y. A. 2008. *Poplars and Willows of the World, with Emphasis on Silviculturally Important Species* [online]. Rome, Italy: FAO Forest Management Division Working Paper IPC/9-2, 134 p. Dostupné na internete: <http://www.fao.org/forestry/32608/en>

DOHLEMAN, F.D. – LONG, S.P. 2009. *More Productive Than Maize in the Midwest*: *How Does Miscanthus Do It?* In Plant Physiology, Vol 150,2009, p.2104-2115.

DRAŽIĆ, G. - DŽELETOVIĆ, Ž. - ĐORĐEVIĆ, A. .2009. *Environmental impact on Miscanthus giganteus biomass quality measured as ecosystem processor activity*. Abstract Book. The Second International Environmental Best Practice Conference, Krakow, Poland, Septembar 14-18, 2009, p. 44

DRAŽIĆ, G. - MITIĆ, M.- MIHAILOVIĆ, N. - ĐORĐEVIĆ, A. - MARKOVIĆ, S. 2009. *Produkcija biomase Miscanthus giganteus sa aspekta energetske i ekološke efikasnosti ekosistemskog procesora*. 14. Simpozijum Termičara Srbije, 13.-16. oktobar, Soko Banja, Zbornik radova, 2009, p. 450-456.

DŽELETOVIĆ, Ž. - MIHAILOVIĆ, N. - GLAMOČLIJA, Đ. - DRAŽIĆ, G. 2009. *Odložena žetva Miscanthus × giganteus – uticaj na kvalitet i količinu obrazovane biomase*. U PTEP – časopisu za procesnu tehniku i energetiku u poljoprivredi, Novi Sad, Vol. 13(2), 2009, p. 170-173.

DRAŽIĆ, G. - MILOVANOVIĆ, J. - IKANOVIĆ, J. - GLAMOČLIJA, Đ. 2010. *Miscanthus giganteus increment parameters in the early stage of development*. International Conference »Structural changes in agrosector«. Nitra, Slovakia. 19.11. 2010, p. 33-36.

DŽELETOVIĆ, Ž. 2010. *Uticaj azota i gustine zasada na morfološke osobine i prinos biomase vrste Miscanthus x giganteus Greef et Deu*. Doktorska disertacija, Poljoprivredni fakultet Beograd, 2010, p. 122.

ERCOLI, L. – MARIOTTI, M. – MASONI, A. – BONARI, E. 1999. *Effect of irrigation and nitrogen fertilization on biomass yield and efficiency of energy use in crop production of Miscanthus.* In Field Crop Research, Vol. 63(1), 1999, p. 3-11.

GREEF, J.M. – DEUTER, M. 1993. *Syntaxonomy of Miscanthus × giganteus Greef et Deu*. In Angewandte Botanik*,* Vol. 67, 1993, p. 87–90.

GREEF, J.M. – DEUTER, M. – JUNG, C. – SCHONDELMAIER, J. 1997. *Genetic diversity of European Miscanthus species revealed by AFLP fingerprinting*. In Genetic Resources and Crop Evolution, Vol. 44(2), 1997,p. 185-195.

HANSEN, J. – KRISTIANSEN, K. 1997. *Short-term in vitro storage of Miscanthus × ogiformis Honda 'Giganteus' as affected by medium composition, temperature, and photon flux density*. In Plant Cell, Tissue and Organ Culture*,* Vol. 49(3), 1997, p. 161-169.

HEATON, E.A. – CLIFTON-BROWN, J. – VOIGT, T.B. – JONES, M.B. – LONG, S.P. 2004. *Miscanthus for renewable energy generation: European Union experience and projections for Illinois*, In Mitigation and Adaptation Strategies for Global Change, Vol. 9, 2004, p. 433–451

HIMKEN, M. – LAMMEL, J. – NEUKIRCHEN, D. – CZYPIONKA-KRAUSE, U. – OLFS, H-W. 1997. *Cultivation of Miscanthus under West European conditions: Seasonal changes in dry matter production, nutrient uptake and remobilization*. In Plant and Soil, Vol. 189, 1997, p. 117-126.

JEŻOWSKI, S. 1994. Miscanthus sinensis "Giganteus"- a grass for industrial and energetic purpose. In Genet. Pol. Vol. 35A, 1994, p. 372–379.

JEŻOVSKI, S. 2008. *Yield traits of six clones of Miscanthus in the first 3 years following planting in Poland*. In Industrial Crops and Products, Vol.27, 2008, p. 65–68.

KOPP, R.F. – SMART, L.B. – MAYNARD, C.A. – ISEBRANDS, J.G. – TUSKAN, G.A. - ABRAHAMSON L.P. 2001. The development of improved willow clones for eastern North America. In *Forestry Chronicle*, Vol. 77, 2001, No. 2, p. 287-292.

KUZOVKINA, Y.A. – QUIGLEY, M.F. 2005. Willows beyond wetlands: uses of *Salix* L. species for environmental projects. In *Water, Air and Soil Pollution,* 162, 2005, p. 183-204.

LEWANDOWSKI, I. – CLIFTON – BROWN, J.C. – DEUTER, M. 1999. *Potential of Miscanthus genotypes in Europe: over-wintering and yields*. In: Alternative crops for sustainable agriculture (Eds. Mela T, Christiansen J, Kontturi M, Pahkala K, Partala A, Sahramaa M, Sankari H, Topi-Hulmi M and Pithan K), European Commission, BioCity, Turku, Finland,1999, p. 46-52.

LEWANDOWSKI, I. – CLIFTON-BROWN, J.C. – SCURLOCK, J.M.O. – HUISMAN, W. 2000. *Miscanthus: European experience with a novel energy crop*. In Biomass and Bioenergy, Vol. 19, 2000, p. 209-227.

LINDE – LAURSEN, I.B. 1993. *Cytogenetic analysis of Miscanthus 'Giganteus', an interspecific hybrid*. In Hereditas, Vol. 119(3), 1993, p. 297–300.

MELIS, A. 2009. *Solar energy conversion efficiencies in photosynthesis: Minimizing the chlorophyll antennae to maximize efficiency*. In Plant Science, Vol 177(4), 2009, p. 272-280.

NAKAI, T. 1920 *Chosenia,* a new genus of *Salicaceae*. In *Botanical Magazine (Tokyo),* Vol. 34, 1920, p. 66–69. In Dickmann, D.I. - Kuzovkina Y. A. 2008. *Poplars and Willows of the World, with Emphasis on Silviculturally Important Species* [online]. Rome, Italy: FAO Forest Management Division Working Paper IPC/9-2, 134 p. Dostupné na internete: <http://www.fao.org/forestry/32608/en>

NEWSHOLME, C. 1992. *Willows, the genus Salix*. London : B.T. Batsford Ltd., 1992, 224 p. ISBN 0713468815.

NEWSHOLME, C. 2002. *Willows: the genus Salix*. Portland, Or Timber Press, 2002, 224 p. ISBN 0881925659.

PRICE, L. – BULLARD, M. – LYONS, H. – ANTHONY, S. – NIXON, P. 2004. Identifying the yield potential of Miscanthus×giganteus: an assessment of the spatial and temporal variability of M.×giganteus biomass productivity across England and Wales. In Biomass and Bioenergy, Vol. 26(1), 2004, p. 3-13.

SKVORTSOV, A. K. 1968. Ivy SSSR. Sistematicheskiy i geograficheskiy obzor [Willows of the USSR. Taxonomic and geographic revision.] Nauka, Moscow. 262 pp. In Skvortsov A.K. 1999. *Willows of Russia and Adjacent Countries: Taxonomical and Geographical Revision* (transl.)from: Skvortsov. Joensuu: Joensuu University.

STEVENS, P. F. 2001. Angiosperm Phylogeny Website [online]. Version 9, Missouri : Botanical Garden < http:// www.mobot.org/MOBOT/research/APweb>.

STOTT, K.G. 1992. Willows in the service of man. In *Proceedings of the Royal Society of Edinburgh*, 98B: 169-182.

VERWIJST, T. 2001. Willows: an underestimated resource for environment and society. In *Forestry Chronicle*, Vol. 77, 2001, No. 2, p. 281–285.

3 Ecological characteristics of short rotation coppice

3.1 Ecological characteristics of genus Salix

The ecological amplitude of genus *Salix* is broad. Natural range of willows stretches from Europe to Asia and North America. Willow spreads from the high mountains at the upper limit of vegetation and beyond the Arctic Circle and on the other side back to tropical forests. The upper limit of productive plantations of fast-growing tree species of genus *Salix* is estimated to about 600 m above sea level in our conditions. Willows are representatives of the population r-strategy with rapid growth, particularly at a young age. In terms of life forms they belong into the shrub and/or tree fanerophytes. The flowering phenophase occurs in early spring. The spread of diaspores is realized by trichometeorochory. They belong to pioneer plants, which are able to fill the newly created or vacated soil. They grow quickly on locations with water-logged soils. In the natural succession process, they are gradually pushed away by shade trees, which overgrow and overshadow them.

Ecological demands of willows to light are high. They have maximum requirements for sun exposure; they are so called heliophytes (light-demanding species). Shade restricts their growth. From an economic and production point of view, all *Salix* species demand year-round available soil moisture. Lack of water during the growing season reduces their height increases, but also resistance to biological impacts. Requirements for soil moisture are specific to particular willow species.

Life cycle of fast-growing tree species is around 20 to 30 years in Slovak conditions. Selection of a suitable site, based on knowledge of ecological requirements of *Salix* is an essential step to ensuring optimal production and economic use of this woody crop. The system of willow biomass production should be implemented in order to achieve maximum biomass production while maintaining good soil quality and ensuring nutrient cycle.

In natural conditions, the plant production process is realized in the soil-plant-atmosphere system in a defined space and time. Production process affects the interaction of environmental factors. These factors (also for fast-growing woody crops) include sunlight, water, mineral nutrition, growth hormones, carbon dioxide, pests, weeds and regulation technologies (Kostrej *et al.*, 1998).

In terms of ecological requirements, following factors are important for selection of a suitable habitat for establishment of plantations of fast-growing *Salix* species:

1. topographical and geographical aspects,
2. the quality of soil, its physical and chemical characteristics,
3. climatic conditions, especially temperature and rainfall,
4. water availability (high groundwater level).

We conducted a basic research of production performance of fast-growing tree species of genus *Salix* in the research base in Kolíňany, cadastral area of Kolíňany village, Nitra district. GPS coordinates of the location are 48° 21' 21" N and 18° 12' 23" E. The area is situated at an altitude of 180 m above sea level, near the creek Bocegaj. The land is tenanted by Slovak University of Agriculture in Nitra. The research area is approximately 1.29 hectares.

3.1.1 Soil Properties

The main regulation of the European Union COM (2006) 231 on the strategy for soil protection is to prevent further soil degradation, conservation of its natural functions and restoration of degraded soils.
One possible alternative use of agricultural land, which is not profitable to use for food production, is the production of biomass for energy production. The main types of biomass resources are fast-growing woody crops. Determination of the appropriate location of fast-growing trees on agricultural land in Slovakia is based on an analysis of production potential of bonited soil-ecological units (BSEU) and typological-production categories of agricultural land. At the same time, the requirement of protection of the primary agricultural land is respected, which is essential to ensure agricultural production in Slovakia. On this basis, SSCRI developed a map of Slovakia with possible locations for fast-growing tree plantations. Promotion of fast-growing woody crops is also embodied in the Rural Development Programme for 2007-2013 under the provisions 5.3.2.2.1. Within Slovakia, SSCRI identifies a land that meet the criteria for fast-growing tree cultivation (area of approximately 355 830 ha) and a land where it is possible to get subsidies for the establishment of plantations of fast-growing woody crops under RDP (Rural Development Program) SR 2007-2013 (area of approximately 57 190 ha). The maps are prepared on the basis of orthomaps with accuracy of one production unit. The maps are available in the map server of SSCRI:
http://www.podnemapy.sk/portal/verejnost/rr_dreviny/rr_dreviny.aspx.

The most suitable soils for SRC (short rotation coppice) woody crops are soils rich in nutrients and organic material in a flat terrain. *Salix* species terms prefer neutral soil reaction (pH). Suitable soil types are loam-sandy to clay-loam with good water retention. In environmental terms, one of the advantages of the SRC plantations, in addition to their rapid growth is also the ability to take up excess nitrogen and phosphorus, which usually tend to be washed away from agricultural land. Part of the nutrients is removed during the harvesting of the biomass. This may be however supplemented by application of wastewater and sludge (Stupavský, 2009).

Fig. 3.1 Bonited soil-ecological unit on the research site in Kolíňany (2011)

The soil at the research site in Kolíňany (Figure 3.1) is in terms of BSEU classified by the code 0111002. Climatic region is warm, very dry and plain, with an average temperature of 15 to 17 °C during the growing season. Main soil unit is gleyic fluvisol, moderate soil located mostly in the alluvial plains of rivers with high level of groundwater. Terrain steepness and exposure: a plain without signs of surface erosion (0° to 1). The soil is deep (60 cm or more) and without skeleton. In terms of particle size, the soil belongs to moderate soils.
Demo *et al.* (2011), based on an analysis of the soil substrate at the beginning of the research period (2007), state that the average soil pH in the research site was 7.26, the average content of nitrogen, phosphorus and potassium was 900.77 mg kg^{-1}, 114.33 mg kg^{-1} and 213.88 mg kg^{-1} respectively. The average percentage of humus content was 1.8%.

3.1.2 Climatic requirements

Salix species belong to woody crops with great ecological tolerance in relation to climatic conditions of Central Europe.
Methods used in analyzing the climate situation on the research site in Kolíňany are as follows.
Data on the average air temperatures and average rainfall for the years 2007 to 2010 were analyzed based on measurements of SHI Bratislava from the meteorological station located in Nitra – Veľké Janíkovce and evapotranspiration values were taken from the meteorological station in Jaslovské Bohunice.
Based on information received from SHI, climadiagrams were compiled according to Walter and Leith (1967). Climadiagrams express the relationship between the annual average of monthly precipitations and annual trend of average monthly air temperatures. On the y-axis scale, 2 mm of precipitation corresponds to 1 °C. This diagram illustrates that the temperature curve is an indicator of gradual changes in evaporating power of the atmosphere during the year.

When assessing the growing period of the corresponding years by the amount of precipitation and average air temperature, we used a scale according to Demeterová (2002) (Table 3.1).

Tab. 3.1 Characteristics growing season according to rainfall and temperature from the average [% LTN]

Rainfall / Average air temperature	< 60	60-79	80-89	90-110	111-120	121-140	> 140
Period characteristics	Extremely dry	Very dry	Dry	Normal	Wet	Very wet	Extremely wet

% LTN – the percentage of long-term climate normal

Hydrothermal coefficient according to Seljaninov is used to classify moisture conditions of an area in a certain period. It is defined (in Juva, 1959) by following formula:

$$C_{HT} = \frac{\sum H_R}{0{,}1\sum t_{10}}$$

where C_{HT} - hydrothermal coefficient
ΣH_R - the amount of rainfall for the observed period (t>10 °C) in mm
Σt_{10} - the amount of average daily temperatures for that period in °C

Then, we evaluated the observed period based on data that are shown in the table 3.2.

Tab. 3.2 Characteristics of the period by hydrothermal coefficient

Hydrothermal coefficient	below 0.3	0.31-0.50	0.51-0.99	1.00	1.01-2.00	over 2.00
Characteristics of the period	catastrophic drought	drought	water shortage	rainfall equals evaporation	enough water	water surplus

Growing season is the number of days that limits the beginning and termination of days with average daily temperatures T ≥ 10 °C (Vereš, 1980). Length of growing period for the reference years was determined as follows: for the year 2007 – 242 days, year 2008 – 224 days, year 2009 – 215 days and year 2010 – 241 days. This is a period of intense growth and development of vegetation from the beginning of the foliation stage to the stage of their abscission.

In terms of water balance of the site, it is important whether the vegetation has enough water during the growing season. Therefore, we expressed the relationship between the trend of monthly precipitation and average monthly air temperatures by climadiagrams (Figure 3.4). The part where the curve reaches lower levels of precipitation than the temperature curve is called a period of physiological drought.

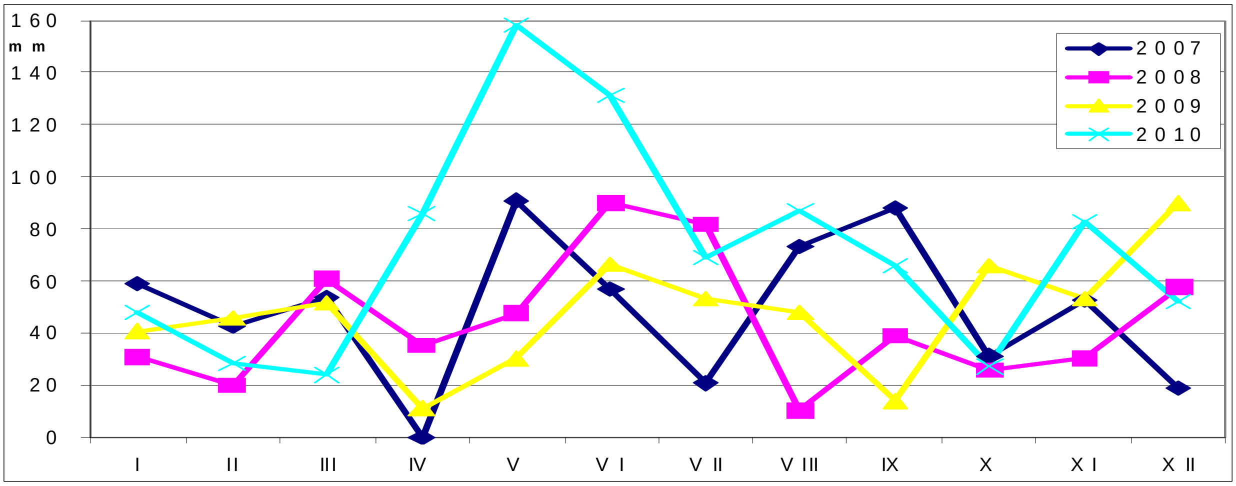


Fig. 3.2 Total monthly rainfall for the years 2007 to 2010 in a research site in Kolíňany (according to measurements by SHI, 2011)

In the conditions of Central Europe, it is expected that evaporation of the fallen precipitation returns 60% of the water to the air, 45% of which is accounted for by transpiration, 14% represents evaporation from a bare soil and 1% is the evaporation from a water surface. Total monthly values of evapotranspiration (ET_0) for the years 2007-2010 (from April to October) are shown in Figure 3.3. The highest values of evapotranspiration were measured in 2007 (total 705.2 mm), while the lowest amount of monthly evapotranspiration values were in 2010 (total 528.0 mm).

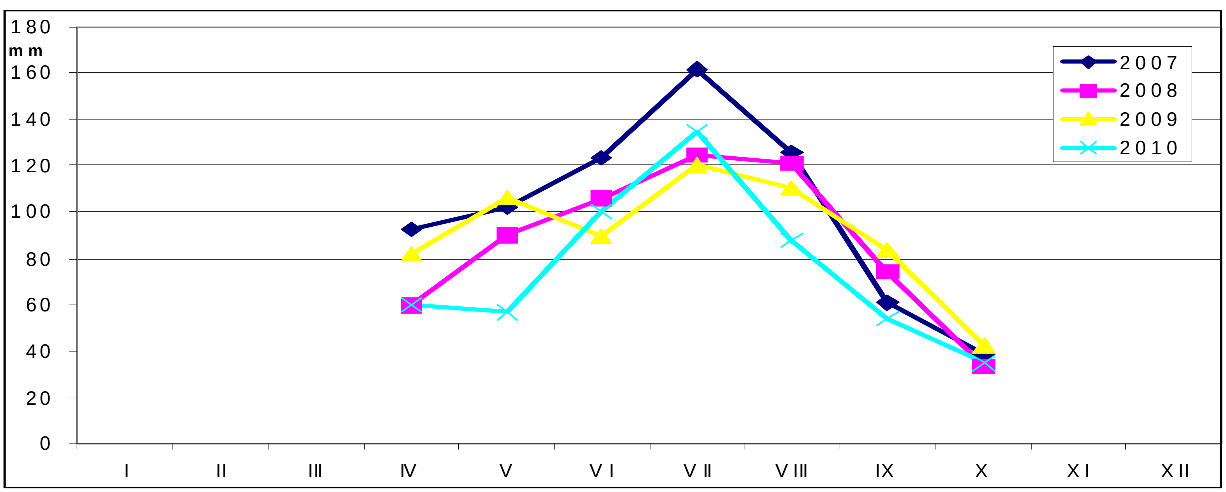


Fig. 3.3 Total monthly evapotranspiration values for the years 2007-2010 in the research site in Kolíňany (according to measurements by SHI, 2011)

The temperature curve is an indicator of changes, so called evaporating power of the atmosphere. If the rainfall curve reaches lower values than the temperature curve it indicates dry season for most plants that cannot use a groundwater.

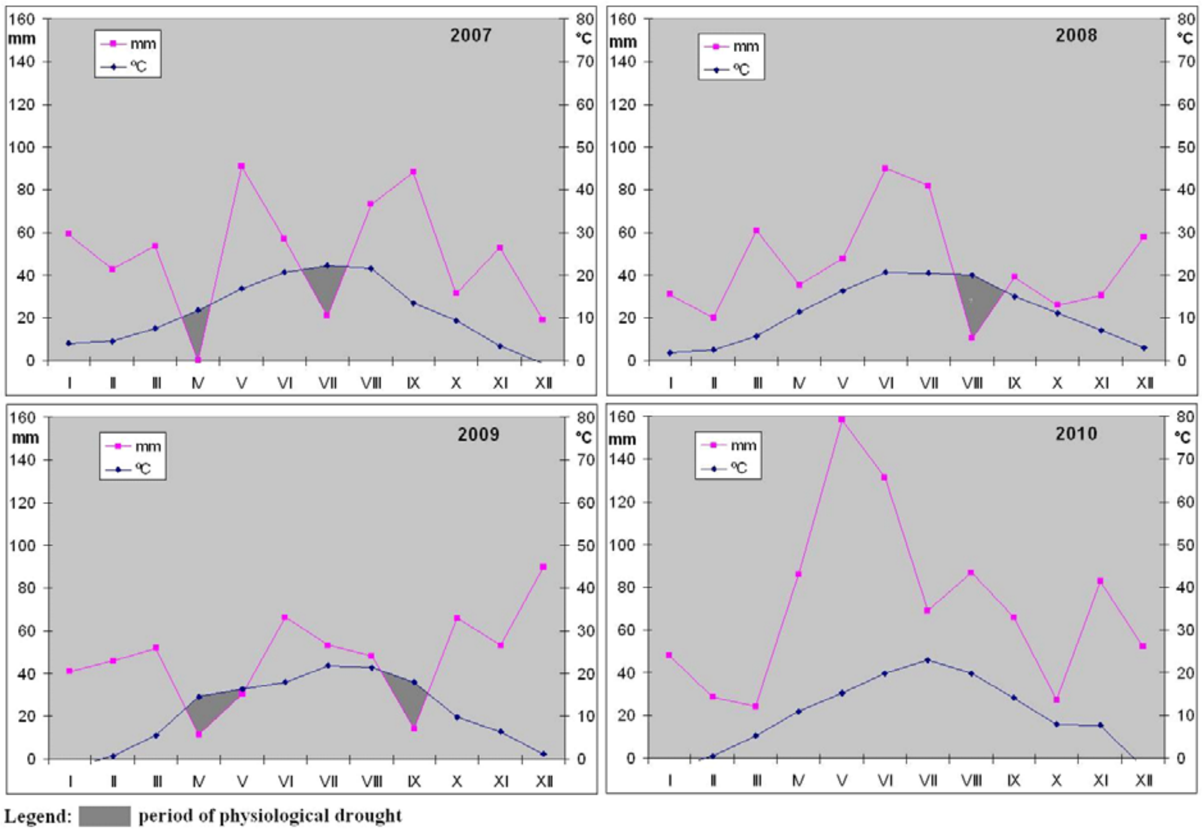


Fig. 3.4 Climadiagrams for the period 2007-2010 in the research site in Kolíňany

Monthly precipitation totals for the years 2007-2010 in the research site in Kolíňany are shown in Figure 3.2. In terms of rainfall, the year 2008 was the driest (in the observed 4 years-period) with 529.4 mm of precipitation. These relations, expressed from 2007, indicate that the physiological drought in can by observed in 2007 (April-June), 2008 (August-September) and 2009 (April-May, August-September). The highest amount of precipitation was in 2010: 860.2 mm and the physiological drought did not occur during the growing season of this year. We concluded that significant period of drought during the growing season of the reference years did not occurred, with the exception of the beginning of the growing season in 2007 (April). On the contrary, the most moisture available for plants was recorded in July and August of the reference years, ergo at the time when the growing season culminates.

Evaluation of moisture conditions of growing period by means of rainfall, as reported by Šútor *et al.* (2005), however, cannot be applied to assess the state of water in the soil aeration zone in relation to soil drought and water shortage for plants in the soil. From our assessment results, that the growing season 2009, can be considered according to the percentage of long-term precipitation as dry season (80.00% LTN), so a growing season characteristic by long physiological drought. Years 2007 and 2008 can be evaluated according to the percentage of long-term rainfall rate as normal in relation to soil drought (value of 99.28 and 90.78% LTN). Year 2010 is characterized according to the percentage of long-term precipitation as extremely wet (171.72% LTN). The assessment of the growing periods 2007-2010 according to the percentage of average air temperature shows normal characteristics of the growing season in the observed years (value of 100.18% LTN in 2007, 99.62% LTN in 2008, 103.93% LTN in 2009 and 95,84% LTN in 2010) (Jureková *et al.*, 2011.

Tab. 3.3 Characteristics of growing periods 2007-2010 by means of hydrothermal coefficient in the research site in Kolíňany

Year	C_{HT}	period characteristics
2007	1.12	enough water
2008	0.91	water shortage
2009	0.79	water shortage
2010	1.83	enough water

Legend: C_{HT} hydrothermal coefficient

Evaluation of moisture conditions in growing periods 2007-2010 for the research site in Kolíňany by means of hydrothermal coefficient is given in Table 3.3. Based on this analysis we can conclude that between years 2007 and 2010, according to the hydrothermal coefficient, there was enough water for willow growth and biomass production.

3.1.3 Hydrological requirements

Salix species have high demands on water. Water shortages cause low biomass production and low resistance to disease, pests and weeds.

Localization of willow plantations in relation to water requirements and/or willow tolerance to flooding, takes place in areas with high levels of groundwater (floodplain and alluvial areas). However, Hofmann-Shiele *et al.* (1999) argue that long-term flooded soils, as well as long-term ground water level in the root zone is one of the most important factors which affect the above-ground biomass production of *Salix viminalis*. The reason is reduction of the physiological activity of roots. On the other hand, fast-growing *Salix* species have a poor drought resistance (Wikberg and Ögren, 2004).

Soil moisture required for willow growth is secured by amount of precipitation falling on the crops during the growing season, as well as the height of groundwater level.

Hydrological situation of the research site in Kolíňany analyzed Hauptvogl (2011) by monitoring volumetric soil moisture content in 2008 and 2009. He found that the lowest value of volumetric soil moisture was at a depth of 0.1 meters and the highest average value was recorded at a depth of 1.0 m. During the observed period, soil water was more accessible for willows in the research site, possibly because of higher groundwater levels.

3.2 Ecological characteristics of genus Miscanthus

The main ecological characteristics of genus *Miscanthus* that affect plant growth include soil properties, high or low temperatures, water availability, drought and frost tolerance. Depending on when these environmental factors occur, their intensity and duration can reduce plant vitality and cause damage. Annual variability in these factors results in annual yield variations.

Although the crop prefers warmer climates it has been shown that miscanthus can be grown with favourable results throughout Europe. Harvestable yields in England vary on average between about 12 t/ha to around 16 t/ha (Defra, 2007). Applications for the Energy Crops Scheme (ECS) in England must be linked to an energy end use (either on or off-farm) that is within reasonable distance of the crop. Since the miscanthus will exist on the site for at least 15 years and can reach up to 3.5m in height, its impact on the local landscape (particularly if the site is close to a footpath or a favorite view) or an adjacent landowner or homeowner needs to be considered. Impacts on wildlife, archaeology and public access must also be addressed prior to cropping. In addition, the impact of harvesting machinery on the soil should be considered.

3.2.1 Soil Properties

Miscanthus usually takes between three and five years to reach its full yield potential but full yield can be reached earlier on soils where establishment is quicker. *Miscanthus* has been reported growing, and producing high or reasonable yields on a range of soils, from sands to high organic matter soils. It is also tolerant of a wide range of pH, but the optimum is between pH 5.5 and 7.5. From experience gained in the establishment and growing of the crop in Ireland since 2006, it is clear that the more productive and fertile soils are more suitable in terms of growth vigour and ease of establishment than the more marginal sites. *Miscanthus* is harvested in the winter or early spring and therefore traffic ability of the site at this time of year is an important factor to consider. It is essential that the site does not get excessively waterlogged during this period, as this may limit accessibility for harvesting machinery and cause damage to the soil structure. The fallen leaf material and the rhizome mat below the soil surface provide very stable ground conditions for harvesting. Soil diffuse pollution should be controlled by ensuring soils retain good structure and compaction is minimized. Further guidance can be found in Cross Compliance Guidance for Soil Management. Growing *miscanthus* on heavy clay, poorly drained or peaty soils in most circumstances should be avoided.

Overall soil erosion risks are highest within the first two years of growth, however once the stands have established they have a stabilizing effect. Initial losses may be comparable to row crops, but on average biomass crops will only produce up to 4 Mg ha^{-1} yr^{-1} erosion compared to 18.1 Mg ha^{-1} yr^{-1} for agricultural crops. Due to the lower erosion potential, biomass crops have been used in a number of conservation projects to restore land and as a buffer strip to reduce run-off of nitrogen and sediment (Börjesson, 1999). So far studies looking at erosion losses associated with biomass crops have been short term. The average erosion loss remains an estimate until longer term studies have been carried out. Also it is needed to study losses associated with plantation removal. The soil type used in the studies is not always provided in the literature, which is an issue, as soil type can have a large effect. Experimentation looking at the effect of soil type in relation to establishment and removal would be useful.

3.2.2 Climatic requirements

Since irrigation of biomass crops is unlikely to be economic, it is important to identify genotypes that optimize the use of water in different climatic regions, and those which are tolerant of water stress.

Climatic factors may need to be considered in conjunction with the soil type, i.e. sandy soils may suffer higher losses due to wind erosion, whereas heavier clay soils will be more affected by rain. Miscanthus has the C4 photosynthetic pathway (generally found in tropical or semi-tropical grasses) but it can grow more efficiently at low temperatures than most other C4 plants. Miscanthus does not grow at temperatures below a threshold of 6°C. This is considerably lower than for corn and therefore the potential growing season is longer. Late spring frosts which destroy early spring foliage and effectively reduce the duration of the growing season are the major constraint to long season growth in *M.* × *giganteus*.

The climate of a location is an important consideration in determining the yield. The average temperature has an effect through both the length of the growing season and the efficiency of photosynthesis. Thus higher latitude and topographic height may limit the yield. This is likely to have a greater impact on the yields of miscanthus, due to its use of the C4 photosynthetic pathway, that SRC willow.

Future climate change may have an impact on the choice of where biomass crops are planted, although there is a complex interplay of a number of factors so it is difficult to reach any specific conclusions currently. There is evidence, although not conclusive, that increasing levels of atmospheric CO_2 act to "fertilise" the crops so that higher yields are obtained, implying that the same yield could be obtained from a smaller land area. However, increased concentrations of ozone in the lower atmosphere may mitigate this to some extent. Generally, the simulations for the future climate of England suggest an increase in the average summer and winter temperatures and an increase in winter rainfall balanced by a decrease in summer rainfall. The increase in temperatures will increase yields by extending the growing season. It may also allow the crops to be grown in areas which were previously too cold. However, these "gains" may be offset by the reduction in summer rainfall resulting in growth being limited by water availability. Research is ongoing to produce numerical models of crop yield that incorporate the impact of climate change.

Frost tolerance

Since C4 grasses are of tropical origin, much research effort has focused on the influence of low temperatures (including frost and chilling) on growth. Frost tolerance can be divided into two categories: (i) frost tolerance associated with the overwintering rhizome in winter, and (ii) frost tolerance of newly emerging shoots in spring. Late frosts during the spring may damage young plantings in Northern Europe and constitute an obstacle to crop establishment; in cooler areas, late frosts can damage newly expanded leaves during the first year of the crop or just after the regrowth of older plantings.

Clifton-Brown and Lewandowski (2000b) quantified significant genotypic variation in the temperatures at which young rhizomes were killed and discovered that *M. ×giganteus* was more susceptible to low temperatures than a *M. sinensis* hybrid. The temperatures required to initiate growth from the overwintering rhizome and the effects of frost on the newly emerged leaves in spring were reported by Farrell *et al*. (2006).

Once planted, survival of first-year *M.* x *giganteus* is highly dependent on the environment. In addition to competition from weeds and pests, cold tolerance and over-winter survival of first-year stands is also a concern in temperate areas with cold winters and little snow cover. Clifton-Brown and Lewandowski (2000b) and Clifton-Brown *et al.* (2001) examined first-year cold tolerance, and their results indicate a major risk to viability when winter soil temperatures drop below -3°C at the 5-cm soil level, with lethal rates of up to 50%. First-year plantings at the University of Illinois (USA) were severely damaged by a cold winter in 2008–2009. However, this appears to be primarily a problem with first-year plants, as Pyter *et al*. (2009) reported good survival of established *M.* x *giganteus* with winter air temperatures dropping as low as -29°C.

3.2.3 Hydrological requirements

Although water use efficiencies of C4 crops are often higher than for C3 crops, availability of water will often dictate the maximum yield achievable by miscanthus at a site. Long periods of drought are serious since they limit the amount of biomass that can be produced and in very extreme cases can lead to plant death when soils are shallow or sandy. Water limitation is relevant especially in Southern Europe where, due to high temperature and irradiation, there are potentially high productive sites for C4 crops. Increased productivity will result in higher water demand, so that water may become a limiting factor to both crop productivity and the economic viability of the crop.

Because of the climatic differences between Northern and Southern Europe, it is therefore necessary to select potential energy crops from species with a high water-use efficiency (Jones and Walsh, 2007), particularly when adapting the species to water-limited areas. The identification of drought-tolerant genotypes that can produce more biomass under water stress conditions remains an essential component in the improvement of miscanthus (Clifton-Brown and Lewandowski, 2000a).

Annual rainfall and soil water retention will strongly influence the yield of miscanthus at any site. *Miscanthus* possesses good water use efficiency when considered on the basis of the amount of water required per unit of biomass and miscanthus roots can penetrate and extract water to a depth of around 2m. However, to achieve high yields miscanthus may need more water. In addition, a dense canopy means that 20-30 % of rainfall is intercepted by, and evaporates off, the leaves and never reaches and infiltrates into the soil. Limited soil water availability during a growing season will prevent the crop from reaching full potential yield in that year; a loss of 90 kg of biomass per ha for each millimetre of soil water deficiency has been calculated. Irrigation is not justified due to the cost and the current value of the biomass obtained. In times of severe drought, the foliage of miscanthus will first show leaf rolling and then die back from the leaf tip. This will reduce yield in the year of drought but in all cases experienced in the UK to date the crop will survive and re-grow the following year (Defra, 2007).

Table 3.4 *Miscanthus* yields reported for Europe, by latitude (North to South), adopted from Lewandowski *et al*., 2000

Location and latitude	**Mean annual temperature/ precipitation**	**Age of Stand**	**Stand density (plants m^{-2})**	**Harvest period**	**Yield (t ha^{-1} year^{-1}, dry matter)**	**Notes on fertilization, irrigation**	**Reference**
Denmark, 56ºN	7.3ºC 693 mm	4-6 5		April	7-15, 7-9 (farmers trials)	70-100 kg N had no yield effect	Jørgensen, 1996
Northern Germany 53-54ºN	8.0-8.8ºC 700-720 mm	3-4	1-3	December	15-24	80 kg N ha^{-1} a^{-1}	Schwarz et al., 1995
Northern Germany, 53ºN	7.9-8.8ºC 547-600 mm	4-5	1-3	February/March	8-14	0-100 kg N had no yield effect	Beuch, 1998
Southern Britain, 51-52ºN	500-700 mm	3	1	Spring	10-15	No response to fertilizer N, drought occurred	Bullard et al., 1996
Central Germany, 52ºN	8.7ºC 617 mm	3-4	1-4	February/March	15-22	navodnjavanje, 0-240 kg N (60 kg N optim.)	Jacks-Sterrenberg, 1995
Central Germany, 50-52ºN	6.3-9.0ºC 680-760 mm	3-4	2	December	4-20	80 kg N ha^{-1} a^{-1}	Schwarz et al., 1995
Central Germany, 51ºN	9.3ºC 715 mm	3	1	Spring	15-18	Low fertilizer requirements: 60 kg N, 8 kg P, 80 kg K, 15 kg Mg ha^{-1}	Himken et al., 1997
Central Germany, 50ºN	9.1ºC 606 mm	6	1-2	February/March	6-20	0-100 kg N had no yield effect	Beuch, 1998
Central Germany, 50ºN	9.1ºC 606 mm	3-8	1		5-10 poor soil 15-24 good soil		Hotz et al., 1996

Table 3.4 (continued)

Location and latitude	Mean annual temperature/ precipitation	Age of Stand	Stand density (plants m^{-2})	Harvest period	Yield (t ha^{-1} $year^{-1}$, dry matter)	Notes on fertilization, irrigation	Reference
Southern Germany, 49ºN	7.4-8.5ºC 520-810 mm	3-4	1-3	December	9-19	80 kg N ha^{-1} a^{-1}	Schwarz et al., 1995
Southern Germany, 48-49ºN	7.5-9.8ºC 691-850 mm	2-4	2	February	8-30	0-150 kg N, 100 kg N highest yield, no irrigation	Lewandowski and Kicherer, 1997
Austria, 48ºN	8.8ºC 700 mm	3	1		22	No response to N fertilizer above 90 kg N ha^{-1}	Schwarz et al., 1994
Northern Switzerland, 47ºN	7.5ºC 944-1066 mm	1-2	3-5	January	13-19	0-80 kg N	Mediavilla et al., 1997
North–west Spain, 43ºN	12.1-14.7ºC 1866-1945 mm	4	4		14-34	0-120 kg N had no yield effect	Bao Iglesias et al., 1996
Northern Greece, 41ºN		2	1	September	44	fertilized and frequently irrigated	Danalatos et al., 1996
Central Greece, 38ºN		2-3	5	End of growing season	26	little effect of added N, 40-80 kg N, irrigated	Christou et al., 1998
Western Turkey, 38ºN	17.6ºC 698 mm	3	1		28	0-200 kg N, little effect of added N	Acaroglu and Aksoy, 1998

References

ACAROGLU, M. – AKSOY, A.S. 1998. *Third year growing results of C4 energy plant Miscanthus sinensis in producing energy from biomass*, 10th European bioenergy conference, Wurzburg, 1998, p. 758–759.

BAO IGLESIAS, M. – RODRIGUEZ, R.J.L., CRESPO, R.I. – LAMAS, J. 1996. *Miscanthus sinensis plantations in Galicia, north-west Spain: results and experience over the last three years*. 9th European bioenergy conference, Copenhagen, 1996, p. 608–612.

BEUCH, S. 1998. *Zum Einfluß des Anbaus und der Biomassestruktur von Miscanthus × giganteus (GREEF et DEU.) auf den Nährstoffhaushalt und die organische Bodensubstanz*. Shaker, Aachen, Germany, 1998.

BÖRJESSON, P. 1999. *Environmental effects of energy crop cultivation in Sweden-I*: *Identification and quantification*. In Biomass and Bioenergy, Vol. 16, 1999, p. 137-154.

BULLARD, M.J. – CHRISTIAN, D.G. – WILKINS, C. 1996. *The potential of graminaceous biomass crops for energy production in the UK: an overview*. 9th European bioenergy conference, Copenhagen, 1996, p. 24-27.

CHRISTOU, M. – PAPAVASSILIOU, D. – ALEXOPOULOU, E. – CHATZIATHANASSIOU, A. 1998. *Comparative studies of two potential energy crops in Greece*, 10th European bioenergy conference, Wurzburg, 1998, p. 935–938.

CLIFTON-BROWN, J.C. – LEWANDOWSKI. I. 2000a. *Water use efficiency and biomass partitioning of three different Miscanthus genotypes with limited and unlimited water supply*, In Annals of botany, Vol. 86, 2000a, p. 191-200.

CLIFTON-BROWN, J.C. – LEWANDOWSKI, I. 2000b. *Overwintering problems of newly established Miscanthus plantations can be overcome by identifying genotypes with improved rhizome cold tolerance*. In New Phytologist, Vol. 148, 2000b, p. 287-294.

CLIFTON-BROWN J.C. – LEWANDOWSKI I. – ANDERSSON B. et al. 2001. *Performance of 15 Miscanthus genotypes at five sites in Europe*. In Agronomy Journal, Vol. 93, 2001, p. 1013–1019.

DANALATOS, N.G. – DALIANIS, C. – KYRITSIS, S. 1996. *Growth and biomass productivity of Miscanthus sinensis "giganteus" under optimum cultural management in north-eastern Greece*. 9th European bioenergy conference, Copenhagen, 1996, p. 548-553.

DEFRA 2007. *Planting and growing Miscanthus. Best Practice Guidelines (for Applicants to Defra's Energy Crops Scheme)*, 2007, 18 pp.

DEFRA 2004. *Growing Short Rotation Coppice. Best Practice Guidelines (for Applicants to Defra's Energy Crops Scheme)*, 2004, 30 pp.

DEMETEROVÁ, B. 2002. *Hospodárenie s vodnými zdrojmi*. Košice : SHMÚ, 2002. 40 pp.

DEMO, M. – FAZEKAŠ, A. – HAUPTVOGL, M. – SKLADAN, B. – TÓTHOVÁ, M. 2011. *Produkčný a anergetický potenciál švédskych odrôd rýchlorastúcej enrgetickej dreviny rodu Salix pestovanej v suchších pôdno-klimatických podmienkach juhozápadného Slovenska*. SPU Nitra, 2011, 110 pp., ISBN 978-80-552-0577-9.

EUROPEAN UNION COM (2006) 231 *on the strategy for soil protection*

FARRELL, A.D. – CLIFTON-BROWN, J.C. – LEWANDOWSKI, I. – JONES, M.B. 2006. *Genotypic variation in cold tolerance influences yield of Miscanthus*, In Annals of Applied Biology, Vol. 149, 2006, p. 337–345.

GUPTA, R.B. – DEMIRBAS, A. 2010. *Gasoline, Diesel and Ethanol Biofuels from Grasses and Plants*, Cambridge University Press, New York, 2010, 244 pp.

HAUPTVOGL, M. 2011. *Vplyv pôdno-klimatických a hydrologických podmienok juhozápadného Slovenska na vybrané produkčné ukazovatele rýchlorastúcej energetickej dreviny rodu Salix.* Dizertačná práca, SPU Nitra, 2011, 119 pp.
HEATON, E.A. – CLIFTON-BROWN, J. – VOIGT, T.B. – JONES, M.B. – LONG, S.P. 2004. *Miscanthus for renewable energy generation: European Union experience and projections for Illinois*, In Mitigation and Adaptation Strategies for Global Change, Vol. 9, 2004, p. 433–451.
HEATON, E.A. – DOHLEMAN, F.G. – LONG, S.P. 2008. *Meeting US biofuel goals with less land: the potential of Miscanthus*. In Global Change Biology, Vol. 14, 2008, p. 2000–2014.
HIMKEN, M. – LAMMEL, J. – NEUKIRCHEN, D. – CZYPIONKA-KRAUSE, U. – OLFS, H-W. 1997. *Cultivation of Miscanthus under West European conditions: Seasonal changes in dry matter production, nutrient uptake and remobilization*. In Plant and Soil, Vol. 189, 1997, p. 117-126.
HOFMANN-SCIELE, C. – JUG, A. – MAKESCHIN, F. – REHFUESS, K.E. 1999. *Short-rotation plantations of balsam poplars, aspens and willows on former arable land in the Federal Republic of Germany*. I. Site-growth relationships. For Ecol Manag, 121, 1999, pp. 41–55.
HOTZ, A. – KUHN, W. – JODL, S. 1996. *Screening of different Miscanthus cultivars in respect of yield production and usability as a raw material for energy and industry*. 9th European bioenergy conference, Copenhagen, 1996, p. 523–527.
JACKS-STERRENBERG, I. 1995. *Untersuchungen zur Ertragsphysiologie von Miscanthus sinensis Anderss. hinsichtlich einer Verwendung als Energiepflanze*. Dissertation. Institut für Pflanzenbau und Pflanzenzüchtung I der Justus-Liebig-Universität zu Gießen, 1995.
JONES, M.B. – WALSH, M. 2007. *Miscanthus for Energy and Fibre*, Earthscan, London, 2007, 192 pp.
JØRGENSEN, U. *Miscanthus yields in Denmark*. 1996. 9th European bioenergy conference, Copenhagen, 1996, p. 48-53.
JUREKOVÁ, Z. – DRAŽIČ, G. – KOTRLA, M. – MARIŠOVÁ, E. –MILOVANOVIČ, J. – TÓTHOVÁ, M. – KONČEKOVÁ, L. 2011. *Biological factors governing the growth and biomass production of willows planted in southern Slovakia*. Acta regionalia et environmentalica, SUA Nitra, 2011 (in press)
JUVA, K. 1959. *Závlaha pudy*, Praha, SZN, 1959, 597 pp.
KOSTREJ, A. – DANKO, J. – JUREKOVÁ, Z. – ZIMA, M. – GÁBORČÍK, N. – VIDOVIČ, J. 1998. *Ekofyziológia produkčného procesu porastu a plodín*. SPU Nitra, 1998, ISBN 80-7137-528-4, 179 pp.
LEWANDOWSKI, I. – CLIFTON-BROWN, J.C. – SCURLOCK, J.M.O. – HUISMAN, W. 2000. *Miscanthus: European experience with a novel energy crop*. In Biomass and Bioenergy, Vol. 19, 2000, p. 209-227.
LEWANDOWSKI, I. – KICHERER, A. 1997. *Combustion quality of biomass: practical relevance and experiments to modify the biomass qualityof Miscanthus x giganteus*, In European Journal of Agronomy, Vol. 6, 1997, p. 163–177.
MEDIAVILLA, V. – LEHMANN, J. – MEISTER, E. – STÜNZL, H. 1997. *Biomasseproduktion mit Chinaschilf und einheimischen Gräsern*. In Agrarforschung, Vol. 4, 1997, p. 295-298.
PYTER, R. – HEATON, E. – DOHLEMAN, F. – VOIGT, T. – LONG, S. *Agronomic experiences with Miscanthus x giganteus in Illinois, USA*. In Biofuels: Methods and Protocols. NY, USA, 2009, p. 41-52.
SCHWARZ, K.U. – GREEF, J.M –SCHNUG, E. 1995. *Untersuchungen zur Etablierung und Biomassebildung von Miscanthus giganteus unter verschiedenen Umweltbedingungen.*

Braunschweig-Völkenrode, Germany: Bundesforschungsanstalt für Landwirtschaft, FAL, 1995, 122 pp.

SCHWARZ, H. – LIEBHARD, P. – EHRENDORFER, K. – RUCKENBAUER, P. 1994. *The effect of fertilization on yield and quality of Miscanthus sinensis ‘‘giganteus’’*, In Industrial Crops and Products, Vol. 2, 1994, p. 153–159.

STUPAVSKÝ, V. 2009. *Výběr vhodného stanoviště pro založení plantáže rychle rostoucích dřevin*. Biom.cz [online]. [cit. 2011-11-22]. Dostupné z www: <http://biom.cz/cz/odborne-clanky/vyber-vhodneho-stanoviste-pro-zalozeni-plantaze-rychle-rostoucich-drevin>. ISSN: 1801-2655.

ŠÚTOR, J. – GAMBOŠ, M. – MATI, R. 2005. *Kvantifikácia pôdneho sucha a jej interpretácia*. In Acta Hydrologica Slovaca, roč. 6, 2005, č. 2, p. 299-306.

VEREŠ, A. 1980. *Rez a vedenie viniča*. Bratislava: Príroda, 1980, ISBN 64-087-80, 277 pp.

WALTER, H. – LIETH, H. 1967. *Klimadiagram – Weltatlas*. NZ : Fisher, Jena, 1967.

WIKBERG, J. – ÖGREN, E. 2004. *Interrelationships between water use and growth traits in biomass-producing willows*. Trees 18:70–76.

4 Site preparation

4.1 Site preparation for fast-growing woods of genus Salix

Site preparation for establishment of fast-growing woody plants plantations depends on soil type, slope, terrain and soil classification (according to BSEU). Also operation factors such as location and shape of the plantation and the accessibility of mechanisms must be taken into account.

4.1.1 Soil properties

Site selection depends on the following parameters:
Soil properties
Different types of soils from clay to clay-sandy are utilized for the cultivation of energy plants. The most important characteristics of the soil are soil water content, aeration, soil depth, pH, texture and production potential. Crucial are interactions between the individual factors, which are more important than effects of the individual factors.
Soil water
Water in depth of up to 1m is considered as sufficient groundwater supply. Therefore, light sandy soil and gravel soils are not suitable for cultivation of energy woody crops. It is confirmed that the lack, as well as surplus of water in the site causes changes in growth. Maděra and Packová (2005), who observed the long-term impact of flooding on the population dynamics and growth of white willow in soft floodplain community, have shown that trees respond to water scarcity and water abundance by changes in growth that are characterized by eliminating of primary crown, which is later replaced by saplings of dormant buds from the vascular tissues of shoots. Secondary - forming the tree by coppicing has also other effects. The diameter of the crown is reduced, as well as the weight of the shoots.
According to Hall (2003) the average rainfall during the growing season should be 550 mm. The author assumes that less than 300 mm would cause a reduction of willow biomass production. Amount of water required to ensure the water regime of willows is a large, often greater than the amount of available water from precipitation. Therefore, if the willows are grown in sites with a little supplies of ground water, they may negatively affect the water cycle and reduce the water in the country.
Soil aeration
Soil aeration is a factor that depends on the circulation of oxygen and carbon dioxide between the soil and atmosphere. This circulation is conditioned by soil porosity. The porosity, which is determined by texture and structure, determines in addition to the gas diffusion also supply of nutrients and water to plant roots. The principle of this relation is based on the sufficient supply

of oxygen to roots required for the process of root respiration, from which the roots obtain energy for the uptake of water and nutrients. Loamy and sandy-loam soils that are recommended for planting of willows are slightly anaerobic, but retain larger quantities of water for a longer period of time. Conversely, water logged soils over prolonged periods are not recommended because they reduce the physiological activity of roots, which results in lower biomass production.

Soil depth

Soil depth means the availability of soil for the root system. It is the depth to which roots penetrate during the growth of the plant. Several authors describe that there can be big differences between the availability of soil for the root system and the actual depth of the soil. The limiting factor of soil depth could be a ground water level, massive layer of clay or stone bedrock. Soil depth can be verified directly in the field using a soil auger.

Soil texture

Soil texture is the composition of soil by size category of its particles. The effect of the soil texture effect is big, especially in terms of other soil characteristics such as soil water content, pH and aeration. It is therefore a very important indicator when selecting a site for the establishment of a plantation.

Soil pH

The concentration of hydrogen ions (soil reaction) is determined by the parent rock and interaction of physical, chemical and microbial processes in soil. Soil reaction may be acidic when rain water washes away cations from surface soil layers, by the effect of organic acids excreted by plant roots and by dissociation of carbonic acid, which accumulates in the soil as a product of respiration and microbial processes. Soil pH may also be alkaline when anions are washed away from the soil, or in the presence of hydrocarbonic ions. Acid soil reaction is present in podzols, slightly acid in luvisol, chernozems are generally neutral, brown soils are neutral or slightly acid. Acid environment of peat soils is not suitable for growing willows also because they cannot create a sufficiently stable root system.

Woody plants generally tolerate low pH better than field crops but in the case of willows the low pH inhibits the growth (Ferm, Hytönen 1988).

4.1.2 Site nutrition

Natural soil fertility depends on its chemical composition, parent rock, processes affecting the formation, evolution and decay of the soil, age of the soil, climate and vegetation. Growing of arable crops can significantly affect the above situation by the interruption of accumulation of mineral nutrition elements in soil, especially nitrogen by its denitrification, leaching and losses incurred by harvesting the biological yield of a crop from the growing area. In most cases, it is assumed that these losses can be supplemented by application of minerals. However, it was not confirmed in case of forest stands (Ballard, 1979).

The basic principle of application of mineral nutrients is the need to replace the minerals that were removed from the land by their accumulation in the woody biomass. Nutrients accumulated by leaves are continuously retranslocated and recirculated.

4.1.3 Crop spacing

Crop spacing is systematic distribution and planting of a material in the site (plantation) in order to provide each individual by the same space and resources, such as light, moisture and mineral nutrition. Site selection and areal distribution of individuals is crucial for their growth, health and biomass production. Any movement and operations performed on the plantation are also important. Crop spacing is a compromise of several factors and constraints.

Primarily, it is optimal conditions for growth resulting from environmental requirements of the species. Willows have high demands for light. The light is a limiting factor for their growth and they react very sensitively to the lack of sunlight. Researchers (Maděra *et al*,. 2003, Maděra and Packová 2005) found that in the closed, dense vegetation the speed of diameter increments decreases, which leads to a development of long thin branches. Other factors of the rapid growth are sufficient moisture, fertile soil (in natural conditions they grow on sediments rich in nutrients) and long growing season.

Willow is a typical population r-strategist. This type of population strategy is characterized by rapid growth especially in the first years of development (annual increments are 1 meter or more). To ensure the rapid growth, a strong leaf apparatus, optimum LAI values and high concentration of assimilation pigments are necessary.

Another condition is to use a mixture of clones randomly planted or diversification of clones into smaller blocks. Such layout is a good prevention against diseases and pests. According to Tóthová (2011), insects prefer some varieties over others and therefore their movements are slower in diversified crop stands. In addition, different varieties have in the same time different growth stages and there are known insect species that primarily seek the most intensely growing leaves.

As stated above, the vegetation structure significantly affects many physiological parameters and therefore it is crucial how dense the vegetation is established. 10,000-20,000 plants are recommended per unit area. Lower density (12,000 cuttings) positively affects the growth and thickness of future shoots.

In experiments in southern Slovakia (Kolíňany site), the plantation was established by planting of cuttings in double-rows with the distance of 1m between the rows in the double-row. The distance between the two double-rows was 2 m and the distance between the cuttings in the rows was 0.7 m. Thus, the density of the crop stand was 10,666 plants ha^{-1}. The layout of the trial

4.2 Site preparation for Miscanthus x giganteus

Miscanthus x giganteus is adapted to a wide range of soil conditions. Lowland agricultural land is considered suitable for *Miscanthus* grows with getting the greatest return on deep, moist soils (MAFF, 2001). The must productive yields are determined on a wide range of soils, from sandy soils to land with a high content of organic matter, primarily is most productive on soils well suited for corn production. Although it is tolerant to a wide range of pH, the optimum pH for *Miscanthus* is between 5.5 and 7.5. The highest yields are obtained on soils with good water capacity. The poor growth of miscanthus plants was reported on heavy clay soils (Venendaal *et al*., 1997). Its biomass yield will be limited on shallow, droughty, cold, and waterlogged soils. Conceiving after planting is better on sandy soils, mainly due to lower competitiveness with weeds, while the yields are higher at the longer period of time if it is planted on heavy soils with improved accessibility of water (Dželetović, 2010).

Giant *Miscanthus* is adapted to a broad growing range. Europe has shown successful stands from southern Italy (37° N latitude) to Denmark (56° N latitude). In the U.S. it has been successful from the Gulf of Mexico to central Canada (Scurlock, 2009). Preliminary analyses show that conditions in Serbia are in general favourable for *Miscanthus* cultivation, in areas situated below 500 m altitude, because of the possibility of rhizome freezing during the winter in the absence of snow cover, and with annual precipitation level above 700 ml, which may be corrected by irrigation systems, which however raise the production costs (Dražić *et al*., 2007).

Thorough site preparation is essential for good establishment, ease of subsequent crop management and high yields. As the crop has the potential to be in the ground for at least 15 years, it is important that it is established correctly to avoid future problems. As with any crop that is likely to be in the ground for number years, it is important that a number of issues (such as landscape, wildlife value, archaeology and public access) are considered in the selection of a site. *Miscanthus*, once established can grow to 3.5 m in height, it is therefore important to consider the visual impact this might have on the local landscape, especially if the site is close to a footpath or a favorite local view. *Miscanthus* has the potential to encourage a greater diversity of wildlife than some agricultural crops. This potential is most likely to be realized if it is grown as one component of a mixed cropping pattern and if it is located in an area of low conservation value or as a link between existing habitats. Care must be taken to prevent this new habitat from adversely affecting existing habitats, especially those within existing conservation areas.

The first step, in the autumn before planting, is to spray the site with an appropriate broad spectrum herbicide (e.g. glyphosate) for controlling perennial weeds. The site should be sub-soiled if necessary to remove compaction, then ploughed and left to over-winter. On light soils it may be more appropriate to spring plough. This will allow frost activity to break down the soil further. This may also help prevent ‘ley’ pests attacking the newly established plants, as any larvae or eggs already in the soil from the previous crop will have insufficient food over the winter to survive. In the following spring the site should be rotovated immediately prior to planting. This will not only improve establishment by aiding good root development but will also improve the effectiveness of any residual herbicides applied after planting. The essential point in funder land preparation is to avoid problems that can be caused by harvest machinery if the sol water content in winter and early spring is higher than tolerable level.

In the first phase in preparing soil for planting, plugging to 20-30 cm depth is recommended. Shortly before planting miscanthus rhizomes, tilling and harrowing are also recommended in order to reduce weed competitiveness. The young miscanthus plants from micro- or rhizome propagation are frost-sensitive and, therefore, should be planted in spring when no more frost (<-3℃) occurs. Planting densities in various trials have ranged from 1 to 4 plants m^{-2} (Schwarz *et al*., 1995; Pude *et al*., 1997; Boelcke *et al*., 1998). Advantages of a higher planting density include a higher yield in the first 2-5 years, but as this yield increase does not compensate for higher planting costs, a density of one plant per square metre is recommended. Mechanical propagation may result in a variable degree of emergence (around 70%), but this does not seem to be a problem since stand density levels out after a few years. In general, irrigation of newly planted miscanthus during the first growing season improves establishment rates (Lewandowski *et al*., 2000).

4.2.1 Soil properties

In Serbia, the experimental establishment of plantation is positioned in very different soils in aimed to examine possibility of use of land which is not suitable for production of crops for food. The examinations of biomass quantity and quality as well as morphophysiologycal characteristics have been performed in field experiments since 2006. During 2010 and 2011 at four specific locations the field experiments were established in order to examine possibilities of grown miscanthus at degraded soils in komaparison to one site with fertile soil.

Four substrate types were used for the experimental establishment. At experimental field choose as control (fertile), miscanthus plantation were done on smonitza (vertisol) soil type near city Paracin. Uniformly wetting smonitza provides the best conditions for exploiting its high production potential. Soil pH is about 6.5 to 8.0. Humus content in smonitza soil ranges from 3-5% to 7do 8% and the total nitrogen content is usually more than 2%. Smonitza contains an optimal quantity of phosphorus and potassium and it adequately reacts to mineral fertilizers addition.

In 2010 experiment was begin in field named Zasavica located just the border of protected natural reserve of same name in Srem region. The site is cultivated marsh clay previously used for corn production and was chosen because similarity with natural habitat of miscanthus plants. The soil belong to humogley type characterized by low content of humus and nitrogen and extremely bad water balance (due to high underground water level during winter and spring there the soil is over watered and in some areas occurs flogged, while in summer and fall relative water contents are very low and soil have deep ruptures).

In 2011 Miscanthus field were also established in Zasavica (to compare different ecophisiologycal conditions between years) and two extremely anthropogenic degraded soils belonging to deposol type. On overburden dump at Kolubara Mine Basin experimental sample plot the soil is formed by randomly depositing and it lacks the structure and texture (Table 4.1 and Table 4.2). In April 2011, land was leveled heavy machinery and basic processing is executed. Miscanthus is the first crop on site. On "Nikola Tesla" thermal plant ash disposal site substrate is extremely sandy (poor water retention) formed before 3 years and cowered with plant layer, mostly alfalfa sowed in 2010 during remediation activities (Table 4.3 and Table 4.4).

Table 4.1 Chemical composition of soil (0-30 cm deep) at Kolubara experimental field before planting of Miscanthus

Mode of use	pH 1M KCl	pH H_2O	P_2O_5 (mg/100g)	K_2O (mg/100g)	$CaCO_3$ (%)	N (%)	Humus (%)
establishment	6.40	7.40	7.62	23.50	0.42	0.10	0.64

Table 4.2 Heavy metal contents (total) in soil from experimental site Kolubara (0-39 cm deep)

As	Cd	Co	Cr	Cu	Mn	Ni	Pb	Zn	Fe
(mg/kg)									
4.59	0.71	16.50	58.75	19.32	565.50	78.65	15.14	48.65	1.94

Table 4.3 Chemical properties of soil at experimental "Nikola Tesla" thermal plant ash disposal site.

	pH	N	org. C	humus	NO_3	NO_2	P_2O_5	K_2O
	nKCl	%			(mg/kg)		(mg/100g)	
Ash								
2010., nov.	7.89	0.07	2.64	-	10.21	0.08	8.66	15.13
2010., dec.	7.62	0.08	2.78	-	10.34	0.06	8.5	15.03

Table 4.4 Heavy metal contents (total) and available (*) mg/kg, % for Fe, in soil at experimental "Nikola Tesla" thermal plant ash disposal site.

	Cr	Ni	Pb	Cu	Zn	Cd	Hg	B	As	Fe
2010., nov.	38.36	30.01	3.57	25.87	20.52	0.51	0.03	68.52	59.41	0.88
2010., dec.	36.65	27.26	3.71	21.62	21.28	0.26	0.04	67.99	58.73	0.81
2010., *nov.	26*	21.5*	0.1*	17*	12.1*	0.05*	0.01*	5.95*	0.05*	0.08*
2010., *dec.	23.8*	19.8*	0.11*	15.8*	11.6*	0.04*	0.01*	5.62*	0.078	0.08*

4.2.2 Plantation design

At Zasavica field sample, the experiment has been performed on humogley substrate since 2010. Experimental field was divided into two plots in equally distance from the sewer. First plot was planted without using of fertilizators, while the other plot were fertilized. Abowreground plant material was divided to stems and leaves and analized once per month (July-February).

At field sample on Kolubara Mine Basin and "Nikola Tesla" thermal plant ash dumps, rhizomes were planted in spring 2011. Experimental fields was divided into eight plots in both locations with defined fertilisation schedule. Research on the effect of agro-ecological factors (soil moisture and mineral fertilizer top dressing) on the yield of *Miscanthus* biomass were carried out on degraded soil structure in order to investigate the possibility of reaching the given yield (Figure 4.1)

a) b) c)

Fig. 4.1 Plantation design and establishment in Serbia: a) Kolubara Mine Basin experimental field; b)„Nikola Tesla" thermal plant experimental field**;** c) Zasavica experimental field

References

BALLARD, R. 1979. *Use of fertilizers to maintain productivity of intensively management forest plantations.* In Impact of intensive harvesting on forest nutrient cycling. Proc. Of a Symposium, Syracuse, NY, 1979, pp.321-342.

BOELCKE, B. – BUECH, S. – ZACHARIAS, S. 1998-b. *Effects of Miscanthus cultivation on soil fertility and the soil water reservoir*. In: Biomass for Energy and Industry (Eds. Kopetz H, Weber T, Palz W, Chartier P and Ferrero GL, Proceedings of the 10th European Conference, Würzburg, Germany, 8–11 June 1998. Rimpar, Germany), C.A.R.M.E.N., 1998, p. 911-914.

BREMNER, J.M. 1996. *Nitrogen-total*. In Methods of Soil Analysis, Part 3. Chemical Methods, Sparks DL (ed.). SSSA Book Series Number 5, ASA: Madison, WI; 1996, p. 1085–1121.

DRAZIC, G. – DZELETOVIC, Z. – MIHAILOVIC, N. 2007. *Miscanthus giganteus as the basis of new bioenergetic fuel: The establishment of a plantation.* 13th symposium on termal science an engineering of Serbia, Boog of papers, Sokobanja, 16-19.10.2007.

FERM, A. – HYTONEN, J. 2008. *Effect of soil a melioration and fertilization on the growth of birch and willow on cut-overpeat.* In Proc.of the VIII Intnl. Peat Congress, 1988, Section III, pp.268-279.

HALL, R.L. 2003. *Short rotation coppice for Energy Production* : Hydrological Guedelines: Report. Crown Copyright, 2003, 21pp.

LEWANDOWSKI, I. – CLIFTON-BROWN, J.C. – SCURLOCK, J.M.O. – HUISMAN, W. 2000. *Miscanthus: European experience with a novel energy crop*. In Biomass and Bioenergy, Vol. 19, 2000, p. 209-227.

MADĚRA, P. – KOVÁŘOVÁ, P. et al. 2003. *Přežívání dřevin na zaplavených plochách PR Věstonická nádrž v roce 2003 po zvýšení hladiny na kótu 170 m n.m.* Studie pro AOPK ČR, Brno. ÚLBDT MZLU, Brno, 2003, 26 pp.

MADĚRA, P. – PACKOVÁ, P. 2005. *Růstová odezva spoločenstva vrby bílé na stres spůsobený dlhodobým zaplavením.* Zb. příspevků z konference „Vplyv abiotických a biotických stresorů na vlastnosti rostlin“, Praha 2005, p.187-196.

MINISTRY OF AGRICULTURE, FORESTRY AND FISHERIES – MAFF. 2001. *Planting and Growing Miscanthus – Best Practice Guidelines*, DEFRA Publications, PB No. 5424, London, 20 p.

OLSEN, S.R. - SOMMERS, I.E. 1982. *Phosphorus*. In Methods of Soil Analysis, Part 2: Chemical and Microbiological Properties, Page AL (ed.). American Society of Agronomy/Soil Science Society of America: Madison, WI; 1982, p. 403–430.

PUDE, R. – FRANKEN, H. – DIEPENBROCK, W. – GREEF, J.M. 1997. *Ursachen der Auswinterung von einjährigen Miscanthus-Beständen*. Pflanzenbauwissenschaften, Vol. 1(4), 1997, p. 171–176.

SCHWARZ, K.U. – GREEF, J.M –SCHNUG, E. 1995. *Untersuchungen zur Etablierung und Biomassebildung von Miscanthus giganteus unter verschiedenen Umweltbedingungen.*

Braunschweig-Völkenrode, Germany: Bundesforschungsanstalt für Landwirtschaft, FAL, 1995, p. 1-122.
SCURLOCK, J. 1999. *Miscanthus: A Review of European Experience with a Novel Energy Crop*, Enviromnental Sciences Division, U.S. Department of energy, publication No 4845, 1999, Oak Ridge, Tennesssee. USA.
TÓTHOVÁ, M. 2011. *Výskyt živočíšnych škodcov a chorôb*. In DEMO, M. – FAZEKAŠ, A. – HAUPTVOGL, M. – SKLADAN, B. – TÓTHOVÁ, M. 2011. Produkčný a anergetický potenciál švédskych odrôd rýchlorastúcej enrgetickej dreviny rodu Salix pestovanej v suchších pôdno-klimatických podmienkach juhozápadného Slovenska. SPU Nitra, 2011, 110 pp., ISBN 978-80-552-0577-9.
VENENEDAAL, R. – JORGENSEN, U. – FOSTER, C.A. 1997. *European energy crops: a synthesis*. In Biomass and Bioenergy, Vol. 13(3), 1997,p. 147–185.

5 Plant materials for short rotation coppice

5.1 Species and clones used in the research plantation of Salix

Identification of the origin of willows is a fundamental issue, which may be decisive in the practical cultivation and management of willows.

Species used for energy purposes are primarily subgenus *Vetrix*, along with about 125 species distributed worldwide. Although they have many common features, they differ in growth, life cycle and resistance to pests and diseases. This diversity is important for the successful development and establishment of short rotation coppice plantations.

Another criterion for selection of a planting material is also knowledge of the potential production of the parent tree, resistance against diseases and pests, phenology of the species (variety), length of the growing season and ability to adapt to climate conditions of the site. Many species of willow, in particular scrub species develop primordial roots on 1-year-old shoots. It is a part of the normal morphogenesis of the individual. If the shoots or their cuttings get to a suitable environment, they create apical meristem of a root within 48 hours (Fjell, 1985). 1-2 m long 1-year-old shoots (hardwood), which are in the dormant stage after the growing season can be kept for vegetative reproduction in the next growing season. The planting material is collected, sorted and classified. Afterwards, it is stored in plastic bags at -2 to -4 °C. For the storage purposes, the dormant shoots can be also cut to 180 to 250 mm long cuttings and hold in the same conditions. Cuttings are removed approximately 48 hours before planting and stored at room temperature to initiate the activation of the root meristem. When the primordial roots are active in more than 90% of the cuttings, they may be planted into the soil. Table 5.1 shows collected information about indicators of quality and durability of willow cuttings suitable for planting.

Tab. 5.1 Parameters of quality and endurance of willow cuttings

Parameter	**Quality limits**	**Limiting parameters**
Clone purity	100%	
Length of the cuttings	200 mm +/- 20 mm	8 mm
Crook, flexure	< 10 mm	
Minimum diameter	> 7 mm	12 mm
Maximum diameter	22 mm	50 mm
Mechanical damage	> 2 mm on ross	8 mm
Storage	apical pole downwards	
Biological damage	insect, fungus, mildew	cuttings disposal
Buds activated during storage	inappropriate	cuttings disposal

Modified from Ledin *et al.*1992

The origin and quality of planting material are important for establishment of energy willow plantations. The material has to come from certified suppliers who grow it in controlled parental plantations. Use of other planting material is prohibited in the European Union. According to definition by Demo *et al.* (2011) planting material are cuttings taken from 1-year-old shoots in the stage of dormancy (December-March). Dormant shoots retain viability at low temperature (up to -5 °C) for three months or more.

In the experimental program in southern Slovakia (experimental plantation in Kolíňany), were included willow varieties originating from the Swedish research program. Certified supplier of the planting material was Lantmännen Agroenergi. Genetic characteristics of the varieties are in table 5.2.

Tab. 5.2 Characteristics of the studied willow genotypes

Salix varieties	genetic background
TORA	(*Salix schwerini* x *Salix viminalis*) cross between a Siberian basket willow and the Swedish willow variety ORM
GUDRUN	(*Salix dasyclados*) hybrid between the Russian variety Helga and the clone Långa Veka Röd
INGER	(*Salix triandra* x *Salix viminalis*) cross between a Russian clone and the Swedish variety Jorr
SVEN	*Salix viminalis* x (*Salix viminalis* x *Salix schwerini*) cross between the Swedish varieties Jorunn and Bjorn
TORDIS	(*Salix schwerini* x *Salix viminalis*) x *Salix viminalis* cross between the Swedish varieties Tora and ULV.

Planting material sent from Sweden was of good quality. The cuttings of individual varieties have been classified as "medium" in length from 110 to 200 mm (“short” in length of 60-100 mm and “long” in length of 210-300 mm, they were planted). The material was removed just before planting in the second decade of April. Later planting may be unsuitable because there is a risk that higher temperatures (above 0 °C) can lead to the premature termination of bud dormancy of the cuttings and activation of primordial roots. Intense respiration and water losses by transpiration could reduce the rate of root formation and establishment of the cuttings.

5.1.1 Crop spacing

Crop spacing is systematic distribution and planting of a material in the site (plantation) in order to provide each individual by the same space and resources, such as light, moisture and mineral nutrition. Site selection and areal distribution of individuals is crucial for their growth, health and biomass production. Any movement and operations performed on the plantation are also important. Crop spacing is a compromise of several factors and constraints.
Primarily, it is optimal conditions for growth resulting from environmental requirements of the

species. Willows have high demands for light. The light is a limiting factor for their growth and they react very sensitively to the lack of sunlight. Researchers (Maděra *et al.,* 2003, Maděra and Packová 2005) found that in the closed, dense vegetation the speed of diameter increments decreases, which leads to a development of long thin branches. Other factors of the rapid growth are sufficient moisture, fertile soil (in natural conditions they grow on sediments rich in nutrients) and long growing season.

Willow is a typical population r-strategist. This type of population strategy is characterized by rapid growth especially in the first years of development (annual increments are 1 meter or more). To ensure the rapid growth, a strong leaf apparatus, optimum LAI values and high concentration of assimilation pigments are necessary.

Another condition is to use a mixture of clones randomly planted or diversification of clones into smaller blocks. Such layout is a good prevention against diseases and pests. According to Tóthová (2011), insects prefer some varieties over others and therefore their movements are slower in diversified crop stands. In addition, different varieties have in the same time different growth stages and there are known insect species that primarily seek the most intensely growing leaves.

As stated above, the vegetation structure significantly affects many physiological parameters and therefore it is crucial how dense the vegetation is established. 10000-20000 plants are recommended per unit area. Lower density (12 000 cuttings) positively affects the growth and thickness of future shoots.

In experiments in southern Slovakia (Kolíňany site), the plantation was established by planting of cuttings in double-rows with the distance of 1m between the rows in the double-row. The distance between the two double-rows was 2 m and the distance between the cuttings in the rows was 0.7 m. Thus, the density of the crop stand was 10 666 plants ha^{-1}.

5.2 Species and clones used in the research plantation of Miscanthus x giganteus

5.2.1 Properties of species and clones

Energy crops offer clear ecological advantages over fossil fuels, such as a positive carbon balance (due to the photosynthesis of the biomass used as raw material) which contributes to the reduction of greenhouse gases emissions and the low sulphur and nitrogen contents, which contributes to the reduction of acidifying gases emissions (Gosse, 1995). Among the biomass crops, *Miscanthus* is one of the most interesting, since it can transform solar energy into electricity, and due to its high content in cellulose it can also be used for paper pulp production (El-Bassam, 1996). *Miscanthus giganteus* high level biomass production and possibility of cultivation on less quality soil (Heaton *et al*., 2004) make this crop very suitable as annual renewable raw material for bio-fuel production on uncovered, low quality or withdrawn forest

lands for other purposes (power level lines, telecommunications etc.) (Dražić and Milovanović, 2010). As a hybrid, *Miscanthus* has specificities related to heavy metals and other stressors, and that is probably consequence of *Miscanthus sinensis* as a parent, which has higher resistance comparing with other parent species *M. sacchariflorus* (characterized with high productivity). All these traits provide miscanthus with ability for development on low quality land (Ezaki *et al*., 2008; Scebba *et al*., 2006).
European *Miscanthus* production has focused on one single clone, *Miscanthus×giganteus,* according to demonstrated crop's potential throughout Europe. But, there are several problems that have also become apparent. *M.×giganteus* is not well adapted to all climatic zones and in the first year after planting, many *Miscanthus* plantations especially in the northern regions of Europe have suffered from poor survival. However, where no over-wintering problems have occurred, M.×*giganteus* has proven to be among the most productive of all genotypes tested to date (Clifton-Brown *et al*., 2001b). Although *M. x giganteus* is a productive genotype in southern and central Europe, (Lewandowski *et al.*, 1999), the new hybrids produced have been reached and even exceeded the yields of *M. x giganteus* (Clifton-Brown and Lewandowski, 2002). *Miscanthus sinesis* genotypes has proven to have a lower yield potential than *M.×giganteus* in most European locations except in northern regions.
Miscanthus giganteus has not been previously grown in Serbia, except sporadically as a decorative species. European experience in *Miscanthus* cultivation (Ercoli *et al*., 1999) many general advantages of *Miscanthus* biomass as an energy crop were observed. Mineral content is low at the early-spring harvest: 0.09-0.34% N. 0.37-1.12% K, 0.03-0.21% Cl; CO_2 emission up to 90% lower in comparison with coal; gross heating value of 17-19 GJ/t; net energy content 15.8-16.5 GJ/t ; water content at harvest 15%; chopped density at harvest of 70-100 kg/m^3 ; compacted bale density 150-300 kg/m^3, holocellulose content of 64-71%; ash content of 1,5–4,5 % ; ash fusion temperature of 1090°C; and sulphur content of 0,1%; Ash remained after Miscanthus combustion containes about 30-40% SiO2. 20-25% K, 5% P2O5, 5% CaO and 5% MgO. High biomass productivity and high heating value, low SO_2 and NOx production in comparison with fossil fuels, annual renewing and low requirements for canopy maintenance indicate the advantages of the plant over fossil fuels and other biomass sources (Kahle et *al.*, 2001).

5.2.2 Plant material propagation

There are two methods of propagation that are currently used for *Miscanthus* plants - rhizome division and micropropagation. The sterility of *M.×giganteus* necessitates vegetative propagation by either rhizome division or in vitro cultures. This results in very high costs for planting, making *Miscanthus* production economically non-viable. Furthermore, using a single clone carries a considerable risk of attack from pests and diseases. (Clifton Brown and Lewandowski, 2002). Rhizome division is more used method because it is less expensive and generally

produces more vigorous plants. To produce new planting material, two or three-year-old plants are split whilst dormant, using a rotary cultivator and the rhizome pieces collected for re-planting. A 30-40 fold increase in plants can be achieved this way over a period of 2-3 years, depending on soil conditions. Rhizome pieces must have at least 2-3 'buds' and must be kept moist before re-planting. This is best achieved by keeping rhizomes under cold-storage conditions, (<4°C) (possibly for up to a year) but they will remain viable in the field for a short period of time, if stored in a heap and covered with moist soil.
At the beginning of planting period in Serbia, *Miscanthus giganteus* rhizomes as plant material was used in the experimental program (Figure 5.1). It was purchased from commercial supplier and rhizomes were planted in previously analyzed soil in the spring. Experimental research results on miscanthus production in Serbia show that this kind of production is possible in our conditions; Although data are available only for the first few years of development. The quality of planting material is crucial for the establishment of plantations.

Fig. 5.1 *Miscanthus* rhizome (about 10 cm long) ready for planting

5.2.3 Crop spacing

High density plantation is very important feature for crop establishment because it extends it's competitiveness with weeds for nutrients and water. Although the costs are increased it's improves achieving high yields faster than using low-density planting (Christian and Haase, 2001). If the initial planting density is high (4 plants m^{-2}), it was showed that a large number of shoots disappears as a result of tough competition over of nutrients and light (Dželetović, 2010). This highlights the importance of selecting the optimal planting density.
The optimal planting density for either propagation system is 20,000 plants/ha, but this may vary slightly from site to site. Rhizomes need to be planted to allow for some expansion of the plant during the life of the crop and at a soil depth of 5-10 cm. The optimal planting date for rhizomes

is March-April. Early planting takes advantage of spring-time soil moisture and allows an extended first season of growth. This is important because it enables larger rhizome systems to develop. These are more robust in future years, and allow the crop to tolerate drought and frost better.

References

CHRISTIAN, D.G. – HAASE, E. 2001. *Agronomy of Miscanthus*. In Miscanthus for Energy and Fibre (Eds. Jones MB and Walsh M), James & James, London, 2001, p. 21–45.

CLIFTON-BROWN, J.C. – LEWANDOWSKI, I. – ANDERSSON, B. 2001. *Performance of 15 Miscanthus genotypes at five sites in Europe*. In Agronomy Journal, Vol. 93, 2001, p. 1013–1019

CLIFTON – BROWN, J.C. – LEWANDOWSKI, I. 2002. *Screening Miscanthus genotypes in field trials to optimise biomass yield and quality in southern Germany*. In European Journal of Agronomy, Vol. 16(2), 2002, p. 97–110.

DRAŽIĆ, G.-MILOVANOVIĆ, J. 2010. *Forest lands valorization possibility through fast growing energy crop Miscanthus giganteus cultivation.* International scientific conference »Forest ecosystems and climate changes«, Institute of Forestry Belgrade, IUFRO, EFI. Belgrade. 9-10 March. Proceedings, Vol. 2, 2010, p. 303-308.

DEMO, M. – FAZEKAŠ, A. – HAUPTVOGL, M. – SKLADAN, B. – TÓTHOVÁ, M. 2011. *Produkčný a anergetický potenciál švédskych odrôd rýchlorastúcej enrgetickej dreviny rodu Salix pestovanej v suchších pôdno-klimatických podmienkach juhozápadného Slovenska.* SPU Nitra, 2011, p. 60-61, ISBN 978-80-552-0577-9.

EL-BASSAM, N. 1996. *Performance of C4 plant species as energy sources and their possible impact on environment and climate.* In Proceedings of the 9th European Conference on Biomass for Energy and the Environment, Eds. Ph. Chartier, G. L. Ferrero, U. M. Henius, S. Hultberg, J. Sachau and M. Wiinblad, Londres, Pergamon Press, Vol.1,1996, p. 42-47.

ERCOLI, L. – MARIOTTI, M. – MASONI, A. – BONARI, E. 1999. *Effect of irrigation and nitrogen fertilization on biomass yield and efficiency of energy use in crop production of Miscanthus.* In Field Crop Research, Vol 63, 1999, p. 3-11.

EZAKI, B. – NAGAO, E. - YAMAMOTO, Y. - NAKASHIMA, S. - ENTOMOTO, T. 2008. *Wild plants, Andropogon virginicus L. and Miscanthus sinensis Anders, are tolerant to multiple stresses including aluminum, heavy metals and oxidative stresses*. In Plant Cell Reports, Vol. 27(5), 2008, p. 951-961.

FJELL, I. 1985. *Preformation of root primordia in shoot and root morphogenesis in Salix viminalis.* Nord. J. Bot. 5: 357–376, 1985.

GOSSE, G. 1995. *Environmental Issues and Biomass, Biomass for Energy, Environment, Agriculture and Industry*. In Proceedings of the 8th European Conference, Ed. P. Chartier, A.A.C.M. Beenackers, G. Grassi, Pergamon Press, Vol.1, 1995, p. 52 - 62.

KAHLE, P. - BEUCH S. – BOELCKE, B. – LEINWEBER, P. - SCHULTEN, H-S. 2001. *Cropping of Miscanthus in Central Europe: biomass production and influence on nutrients and soil organic matter*. In European Journal of Agronomy, Vol 15, 2001, p. 171-184.
LEDIN, S. – ALRIKSON, A. ed. 1992. *Handbook on how to grow short rotation forests*. Swedish University of Agricultural Sciences. Uppsala, Sweden ISBN 91-576-4628-7.
LEWANDOWSKI, I. - CLIFTON – BROWN, J.C. – DEUTER, M. 1999. *Potential of Miscanthus genotypes in Europe: over-wintering and yields*. In Alternative crops for sustainable agriculture (Eds. Mela T, Christiansen J, Kontturi M, Pahkala K, Partala A, Sahramaa M, Sankari H, Topi-Hulmi M and Pithan K), European Commission, BioCity, Turku, Finland, 1999, p. 46-52.
MADĚRA, P. – KOVÁŘOVÁ, P. et al. 2003. *Přežívání dřevin na zaplavených plochách PR Věstonická nádrž v roce 2003 po zvýšení hladiny na kótu 170 m n.m.* Studie pro AOPK ČR, Brno. ÚLBDT MZLU, Brno, 2003, 26 pp.
MADĚRA, P. – PACKOVÁ, P. 2005. *Růstová odezva spoločenstva vrby bílé na stres spůsobený dlhodobým zaplavením*. Zb. příspevků z konference „Vplyv abiotických a biotických stresorů na vlastnosti rostlin“, Praha 2005, p.187-196.
SCEBBA, F. - ARDUINI, I. – ERCOLI, L. – SEBASTIANI, L. 2006. *Cadmium effects on growth and antioxidant enzymes activities in Miscanthus sinensis,* In BIOLOGIA PLANTARUM, Vol. 50 (2), 2006, p. 688-692.
TÓTHOVÁ, M. 2011. *Výskyt živočíšnych škodcov a chorôb*. In DEMO, M. – FAZEKAŠ, A. – HAUPTVOGL, M. – SKLADAN, B. – TÓTHOVÁ, M. 2011. *Produkčný a anergetický potenciál švédskych odrôd rýchlorastúcej enrgetickej dreviny rodu Salix pestovanej v suchších pôdno-klimatických podmienkach juhozápadného Slovenska.* SPU Nitra, 2011, 110 pp., ISBN 978-80-552-0577-9.

6 Experimental and practical cultivation of short rotation coppice

6.1 Establishment of plantation of Salix clones

Experiences with the establishment and management of fast-growing woody crops plantations collected from several international projects summarized Ledin *et al.* (1992) already in the 1990's in the form of the following principles:

- Total site capture as rapidly as possible
- Elimination of competing vegetation
- Maximum yield of biomass for minimum cost
- Maintenance of site productivity
- Maximum net energy gain

Those principles and their observance are a prerequisite for selecting a suitable location for the establishment of fast-growing woody crops plantations and their successful cultivation. As mentioned above, a suitable location is such where mechanisms for the treatment, harvesting and transport can be used, with deep fertile soil and a good supply of groundwater. Despite a plenty of knowledge, it is impossible to give generally applicable principles for selecting a suitable location because it is always necessary to consider a certain interaction of other factors, for example soil characteristics, climate, previous land use and others.

Natural soil fertility depends on its chemical composition, parent rock, processes affecting the formation, evolution and decay of the soil, age of the soil, climate and vegetation. Growing of arable crops can significantly affect the above situation by the interruption of accumulation of mineral nutrition elements in soil, especially nitrogen by its denitrification, leaching and losses incurred by harvesting the biological yield of a crop from the growing area. In most cases, it is assumed that these losses can be supplemented by application of minerals. However, it was not confirmed in case of forest stands (Ballard, 1979).

The basic principle of application of mineral nutrients is the need to replace the minerals that were removed from the land by their accumulation in the woody biomass. Nutrients accumulated by leaves are continuously retranslocated and recirculated. Heilman (1992) states that fast-growing woody crops have the potential to integrate rapidly into agro-ecosystems and increase the environment of the agricultural land. Their impact on the species diversity, hydrological regimes, soil erosion and changes of nutrient concentration in the circulating water is also very important.

Nutrient uptake is species-specific it depends on the amount of nutrients in the soil and on their use by soil organisms. The amount of absorbed nutrients is always less than the amount of nutrients supplied to the soil, although this is dependent on environmental factors. For example, Ingestad and Ăgren, in earlier work (1988), indicate that uptake is considerably higher if the minerals are applied together with irrigation.

If we summarize the knowledge about the site selection for the establishment of fast-growing willow plantations, we can pick up a few basic characteristics, which determine its quality. In the first place, it is the depth of the soil and its fertility, the value of the hydrogen ions concentration in the soil solution, water supply and soil aeration.

The experience from Slovakia suggests that use of fertilizers is necessary, particularly in mineral-poor soils. In the phase of soil preparation, it is recommended to incorporate sludge from wastewater treatment plants, or manure, which improves soil quality as well as its retention characteristics. Demo *et al.* (2011) refer to the fact that the most intensive nitrogen losses occur in the stage of the plantation establishment after the removal of vegetation cover, after the planting of the crops and after the final removal of the vegetation stand. Therefore, fertilizers should not be applied in the time when the crops are planted, because poorly developed roots cannot absorb mineral ions from the soil.

In the experimental site in Kolíňany, the soil was ploughed to a depth of 0.20 to 0.30 m in the autumn before the establishment of fast-growing willows plantations. Following the ploughing, the soil was cultivated by disc roller. Mineral nutrition was applied in the spring in the form of divided doses: 100 kg N ha^{-1}, K 60 kg ha^{-1}, P 30 kg ha^{-1}. The amount of fertilisers was determined by agrochemical analysis of the soil before the planting of the cuttings and after the cutback. Results from agrochemical analysis of the soil in 2007 showed that the nitrogen amount was 900.77 mg kg^{-1}, potassium 213.88 mg kg^{-1} and phosphorus 115.00 mg kg^{-1}. Humus content was 1.81% and the soil chemical reaction was slightly alkaline, pH ranged from 7.18 to 7.35. There were no other mineral nutrients applied in the three-year growing cycle.

It is very important to secure protection against weeds prior to the plantation establishment. It is always necessary to identify weed species that grew in the site at the time when it was used as agricultural land. The presence of weeds is tied to the crop that was grown on that land in the previous growing season. Different weed species occur after cereals, root crops, technical crops and fodder. Diasporas remain in the soil after the harvest and form the basis of new plants in the next growing season. Therefore, especially abroad, herbicides such as glyphosphates (Roundup) and others are applied before planting. In our experimental conditions, mechanical weed suppression by hand hoeing, machine hoeing and mowing of the green mass was used. Herbicides were not applied.

6.1.2 Coppicing ability, vegetation period

The ability of plants to regenerate vegetative organs after a damage or cut is very high, particularly in willows and poplars. This fact can be used in the management of their production. The physiological background of the regenerative ability lies in the fact that callus is formed on the place of the cut, from which many buds regenerate through the stimulative impact of the roots. This process leads to a certain distortion of the plant integrity, which lasts as long as the activity of regulatory impacts of the root system. These are later suppressed by inhibitory

substances formed in the adult leaves. The restoration of the hormonal balance halts the growth of a large number of shoots and recovers the integrity of the plant. Their growth and longevity depend on the retarding effect of leaves, size of the leaf area and length of the functional activity of the leaves. The amount and development of the buds is a species and clone characteristic (Sennerby-Forsse and Zsuffa 1995).
The main apex primordium develops first, a little later one or two of its lateral buds occur. Lateral buds are usually smaller in size as they begin to grow in the autumn, when there is a less light. The development of shoots depends on the size of leaf area, which is formed from the beginning of the growing season.

6.1.3 Production system of the fast-growing willows

The biomass of fast-growing willows is created during the life cycle. The performance of the production system depends on the ecophysiological properties of its components and factors of the environment. The relationship is interactive in nature. The environmental factors determine the speed of the processes and the SRC stand affects the environment, in particular its microclimate.
The strategy of the tree growth lies in an ability to form and accumulate biomass and distribute it to the individual organs. The most important factors determining the growth strategy, according to Raven (1992) and Ceulemans *et al.* (1996) are as follows:

1. Plenty of storage substances in the roots, including hormones.
2. Enough water in the roots and leaves, which minimizes a potential water stress.
3. High photosynthetic efficiency of leaves.

Limiting external factors belong to the category of climatic and edaphic factors
The growth of fast-growing willows begins in early spring and continues into late autumn. The initial growth of willows is characterized by high dynamics and intensity at the beginning of the growing season. Later secondary growth is slower. The intensive formation of shoots in young stands at the beginning of the rotation cycle leads to a rapid coverage of the area, a large number of shoots creates a large leaf area, which later causes a competition for space and resources. Sato (1966) confirmed that increasing tree density in a forest stand leads to an increase in the relative share of the shoots on the total biomass. An increase in the thickness of stems reduces their height growth, which is typical for willow, particularly in the third to fifth year after the cutback. The number of shoots and their growth is thus the basis of the total biomass. Therefore, it is important to pay close attention to the cut in the rotation cycles. If the cut is made just above the soil surface, the dormant buds, from which new shoots are formed, can be removed. After such cut, Hytönen (1985) observed an increased dieback of trees and subsequent changes in the balance of the stand. A good cut is such that is made 10-15 cm above the ground. This maintains the basal parts of stems, which are the source of the buds and ensures a good development of the

apex and leaf area.

The growth, production and distribution of the biomass into individual shoots are also different depending on age of the trees and degree of the rotation. For example, production in the second rotation is much higher than in the first rotation as a result of the root system development. In the following rotations, the productivity maintains on the same level during the 20-25 years (Mitchell *et al.*, 1992). Sustainability and productivity of the system depends on the climate conditions, fossil energy inputs (eg. mineral nutrition, irrigation), diseases and infections as well as internal disturbance (eg. physiological stress).

During the realization of the final harvest, the growth rate of the leaf area and the length of its functional activity play an important role. According to Kostrej (1992), who analysed cereal crops for several years, in terms of the dynamics of leaf area creation, the optimal stands are those, which quickly (at the beginning of the growing period) reach a size of 4-5 10^4 m^2 ha^{-1}, keep the leaf area as long as possible in an active state and then reduce it by the influence of aging and dieback. In this process, the organic matter is diverted from the aging leaves to non-photosynthesising organs. Kozlowski *et al.* (1991) state that LAI value varies depending on the on the characteristics of the ecosystem beginning at values less than 1 m^2 m^{-2} in arid ecosystems and reaching 20 m^2 m^{-2} in conifers.

Květ *et al.* (1971) describes, in this regard, a so called integral leaf area (leaf area duration LAD) and integral biomass (biomass duration BMD). These characteristics take into account also the time factor of the production and anable to distinguish types of plants according to whether they maintain a fully developed leaf area and biomass during the long or short part of the growing period. The length of life activity of the leaves is a species-specific and may vary also during the growing period by a reduction due to pest and disease damage or climate factors. On the other hand, the leaf area, under appropriate conditions, can also regenerate. Sennerby-Forsse (1995) developed a production model of the willow growth and one of the indicators included in the model is the length of life activity of the leaves. In the aging process, coordinated changes in the structure and metabolism occur in cells. The changes are connected with the recycling of nutrients to other parts of the organism. The most of the absorbed nutrients in a given year come from the recycling. Even the use of fertilizers is only partial in the time of application. A large part is immobilized in the cells of microorganisms and only in the following years is recycled into higher plants. An important role play also processes of re-translocation of nutrients from older to young and/or forming organs. Developing leaves of deciduous trees contain high concentrations of major nutrients N, P, K. During the aging process, their concentration decreases. The main macro elements are re-translocated into the young leaves and old leaves accumulate Ca, S, Fe, Mn and B. It has been confirmed, in different willow species, that for example the nitrogen from leaves is used for the synthesis of protein stock, which is later (in the spring period) used for the growth of elements of wood and buds (Bollmark *et al.*, 1999). The mentioned relationships are also related to the allocation of dry matter into individual organs according to the principle that dry matter accumulates in the organ, which ensures the supply of the specific element. The above mentioned practically suggests that in the locations with fewer nutrients, plants allocate more nutrients and assimilates to the root and less to the above-ground photosynthesising organs. In such case, LAI (leaf area index) is lower and the production performance of the stand is reduced mainly because the crops cannot use the photosynthetically active radiation (PHAR). Leaf apparatus consists of a small number of small leaves, a smaller number of thin shoots is formed and total biomass yield is low (Bowman and Conant, 1994). Ibrahim *et al.* (1998), who worked with poplars, confirm that in such cases the assimilates are re-allocated to roots, which can potentially take up more nutrients.

In our experimental work, we used methods of growth analysis (Květ *et al.*, 1971; Poorter 1989a) for the evaluation of production indicators of fast-growing willow. It is a process based on an analysis of growth and its mathematical description. In the production ecology, the method of the leaf analysis is frequently employed (eg. Woodward, 1983; Shipley and Keddy, 1988; Poorter, 1989b; and many others). The advantage of the growth analysis method is in its simplicity and also that it requires only basic laboratory equipment for the acquisition of primary data. Various indexes and characteristics that describe the growth of plants and individual organs are determined from the average values, as well as the relationship between the assimilation apparatus and the dry matter production.

Assimilation apparatus is an important part of the plant body, which is significant in terms of converting of solar energy to chemical bonds and the exchange of gases that are necessary for the proper functioning of the organism. Leaves are involved in the process of photosynthesis, transpiration, respiration and evapotranspiration.

In the case of the genus *Salix*, assimilation organs are from ecological point of view characterized as follows:

- type and size of the leaves - submicrophyl,
- consistency of the leaves - mezomorphic, helomorphic and hydromorphic leaves
- durability of the leaves – summer assimilation organs.

6.1.4 Methodology of evaluation of selected ecophysiological characteristics of leaf apparatus of the studied genotypes

We collected leaves from individual trees by a destructive method during the growing period of 2009 (May-October) and 2010 (April-October). The actual collection was performed on 3 individuals from each genotype from the tops of the shoots and from the area of 1 m^3.

Analyses were performed in the Laboratory of Optical Microscopy in the Department of Ecology FESRR SUA in Nitra. We determined gravimetrically the fresh (FW) and dry (Dw) mass from the plant material samples. The size of leaf area was determined from the samples and then converted to m^2 with a predominance of sunny leaves in the sample by scanning the leaves followed with the use of AutoCAD and CorelDraw programs. The dry matter was determined thermogravimetrically after drying of Fw in thermostat (Heraeus) at 90 °C.

The dry weight was calculated from the following formula:

$\%Dw = (Dw / Fw) . 100$
(Dw is dry weight, Fw is fresh weight).

In order to evaluate the ecophysiological characteristics of *Salix* varieties, we have selected some of the static and dynamic indicators of the growth analysis. Thus, the primary values are the dry weight of plants or their parts and the size of the assimilation apparatus, which needs to be detected during the plant growth at appropriate intervals.
Evaluated static indicators of the growth analysis:
We determined the value of **LAI** (leaf area index) of the selected species. LAI is an indicator of the size of the assimilation organs (A) of the plant stand per unit area of soil (P). LAI is a fundamental value that is used for determination of other growth indicators. We can define it also as leaf area (A) of plants covering a certain land area. The leaf area was expressed as a dimensionless quantity.

$$LAI = A / P \quad [m^2\ m^{-2}]$$

(A leaf area, P is the area).

The value of **SLA** (specific leaf area), which expresses the relationship between the size of the transpiring surface and the dry matter of the leaves (Larcher, 2003), was calculated according to the formula:

$$SLA = A / Dw \quad [m^2\ g^{-1}]$$

(A leaf area, Dw is dry weight of biomass).

From the range of the dynamic indicators, we determined the value of RGR. RGR expresses an average increase in dry weight per unit of time, based on the unit of dry weight of plants or plant vegetation measured in a defined short time interval. RGR value represents the growth rate of the crop stand as the difference between natural logarithms of a dry weight at the end and beginning of the test interval in proportion to the length of the time interval. This method of determining of the growth rate used for practical calculation of relative growth rates of plants or their parts (aerial or underground parts of plants) of all types of phytocoenoses or idividual populations. Seasonal changes in RGR leaves can be correlated with changes in climatic factors such as the amount of sunlight and temperature, but only in young plants.

$$RGR_l = \ln W_2 - \ln W_1 / t_2 - t_1 \ [g\ g^{-1}\ \text{deň}^{-1}]$$

(W is weight of leaves, t is time).

The greenness or relative content of chlorophyl in leaves was measured by chlorophyl meter (SPAD – Soil Plant Analysis Development). The meter makes stanceous and non-destructive readings on a plant based on the quantification of light in tensity absorbed by the tissue sample. Pezeshki *el al.* (2007) similarly characterized the complex of assimilation pigments of leaves of

Salix nigra by non-destructive method. Peterson *et al.* (1993) and Netto *et al.* (2005) indicate a close link between leaf chlorophyl concentration and leaf N.

In the leaves of the individual genotypes, total nitrogen according to Kjeldahl by automatic analyzer PRONITRO was determined in the process of their aging.

6.1.5 Biomass production

The results in the Table 6.1 show that experimental varieties had different growth strategy for the development of biomass. The resulting biomass production in two varieties Tora and Tordis was realized through a smaller number of longer and thicker shoots. Here, the lower values of LAI are characteristic. The number of shoots at a density of 10,666 plants per hectare varied from 159,990 (TORA) to 179,082 (TORDIS). The resulting biomass production in varieties Gudrun and Inger was realized through a larger number of shorter and thinner shoots (Ø 12.05). The LAI values were higher (Ø 5.64). The number of shoots per hectare was in average 183,562. Tharakan et al. (2005) observed, from this perspective, 32 willow clones at a density of 18,000 individuals per hectare and confirmed that the clones had on average 5 to 14 shoots, so the number of shoots per hectare was up to 250,000 in the stand of willows, which increased the risk of infections, the formation of weaker shoots and even a dieback of individuals.

Tab. 6.1 Selected indicators of growth and biomass production of *Salix* varieties in the third year of growing (2009) in the research area in Kolíňany

Indicator	Varieties				
	TORA	GUDRUN	TORDIS	INGER	SVEN
Ø number of shoots $tree^{-1}$	**15.00**	**17.67**	**16.79**	**17.17**	**11.84**
Ø number of shoots ha^{-1}	**159 990**	**188 468**	**179 082**	**183 135**	**126 285**
Ø diameter of shoots (mm)	**1529**	**1268**	**1239**	**1109**	**1476**
Ø height of shoots (m)	**3.53**	**2.54**	**3.12**	**2.69**	**3.62**
Dry weight of individual (kg)	**4.77**	**3.10**	**4.68**	**3.55**	**3.65**
Biomass yield (t ha^{-1})	**50.88**	**33.06**	**49.92**	**37.86**	**38.93**
LAI (m^2 m^{-2})	**4.93**	**5.89**	**5.18**	**5.94**	**5.06**
SLA (mm^2 mg^{-1})	**15.80**	**14.80**	**14.90**	**14.80**	**14.90**

LAI – leaf area index, SLA – specific leaf area

Comparison of growth characteristics of five genotypes of Swedish willows indicates the existence of two functional groups with different growth strategy for the production of biomass. If we exlude the variety SVEN because in the big part of its stand the entire trees were damaged by pests and gradually died out, we can observe that the first group can include varieties TORA and TORDIS, which created a smaller number (Ø 15.89) of thick shoots (about 1 384 mm), with a relatively low LAI value (Ø 5.06), but larger tree volume (Ø 5.6 m^3). The differences in the values of SLA are negligible. The biomass yield is high (Ø 50.40 t ha^{-1}). The second group includes GUDRUN and INGER, which created a greater number (Ø 17.23 per tree) of thinner shoots (Ø 1188.5 mm), with higher LAI values (Ø 5.91).The tree volume in this group was smaller (Ø 3.92 m^3) and biomass yield was significantly lower (35.46 t ha^{-1}).

6.1.6 Evaluation of the leaf apparatus

Woody crops are permanently bound to the soil substrate and exposed to the influence of the environment in a particular area. A visual comparison of the individual fast growing *Salix* varieties in the research site in Kolíňany indicates the differences in the physiognomy of the trees. These differences are intimated also by the characteristics of the leaf apparatus (Figure 6.1). Results of the leaf area analysis, leaf tissue hydration, amount of dry matter and static and dynamic parameters of the growth analysis are compiled in the following section.

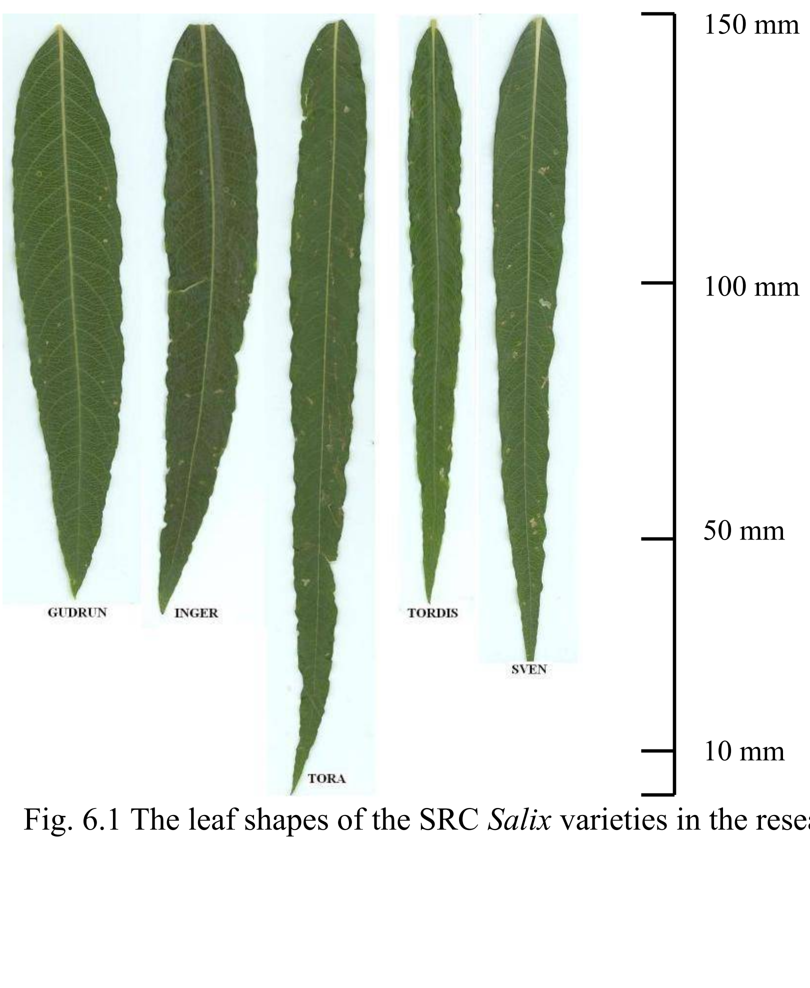


Fig. 6.1 The leaf shapes of the SRC *Salix* varieties in the research site in Kolíňany (July 2010)

Hydration of the leaf tissues (top storey) of the individual fast-growing *Salix* varieties is relatively high, ranging from 59 to 64% of water content in 2009 and from 61 to 67% of water content in 2010. From the perspective of the individual varieties, significant differences in the water content in the leaves were observed between varieties TORA and TORDIS, on average in both years 62.25% and the varieties GUDRUN and INGER with 36.09% of water content. Data on the dynamics of the dry leaf matter formation of the studied varieties are presented in Figure 6.2. The average dry matter content in the growing seasons of the analyzed years is similar: 37.05 g m^{-3} in 2009 and 38.02 g m^{-3} in 2010. The culmination of the dry matter content is different in the individual years. Based on our measurements in 2009, the maximum amount of the dry leaf matter was observed in the third decade of August (23/08/2009) in all varieties. In 2010, the amount of dry matter culminated in early September (09/06/2010) in the most varieties except of the variety Gudrun, which reached the maximum amount of the dry weight in the third decade of August (08/23/2010). The comparison of the two groups of Swedish willow varieties is as follows: TORA and TORDIS had a dry weight of leaves on average 33.71 gm^{-3} in 2009 and 37.55 gm^{-3} in 2010. GUDRUN and INGER had a higher dry weight of leaves (41.56 g m^{-3}) in 2009 than in 2010 (36.95 g m^{-3}).

Tab. 6.2 Statistic differences of dry matter formation of the *Salix* varieties in the growing seasons 2009 and 2010

	Salix varieties				
	SVEN	TORA	TORDIS	INGER	GUDRUN
$p < 0.05$	**0.0002**	**0.0067**	**0.0164**	**0.1298**	**0.3548**

Using the paired two-sample t-test (significance level α = 0.05), we investigated a statistical difference of dry matter formation of the varieties within two growing seasons. We found a highly significant difference in the variety TORA and a significant difference in the varieties SVEN and TORDIS (Table 6.2).

a) growing period of 2009 b) growing period of 2010

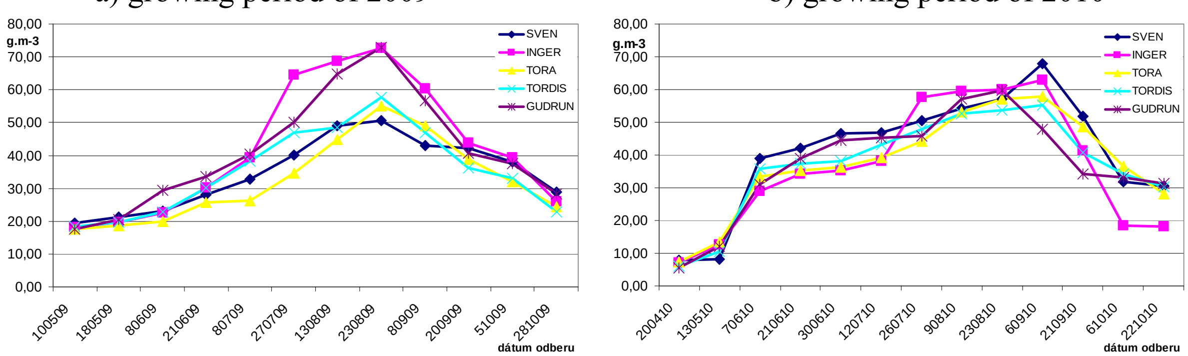


Fig. 6.2 Dynamics of the leaf dry matter formation (g m^{-3}) of the SRC *Salix* varieties in the research site in Kolíňany in the period of 2009 and 2010

The results of the leaf biomass values of the SRC *Salix* varieties during the two growing seasons of 2009 and 2010 show, in particular to climate conditionality of the biomass production. The decisive factor is a sufficient amount of water. Higher hydration of the leaf tissues and higher values of the leaf dry mass in 2010 may be related to the moisture conditions of the growing seasons 2009 and 2010, when 2010 is considered, in terms of moisture conditions, as more favourable (Chapter 3.1).
The next analysis have been done from point of view of the two experimental years 2009 and 2010 (Figure 6.2)

Tab. 6.3 Selected indicators of the growth analysis of *Salix* varieties in the growing seasons 2009 and 2010

indicator	Year	*Salix* varieties				
		TORA	TORDIS	INGER	GUDRUN	SVEN
LAI Ø $m^2.m^{-2}$	2009	**4.931**	**5.183**	**5.943**	**5.891**	**5.063**
	2010	**5.515**	**5.606**	**6.096**	**6.509**	**6.134**
$RGRw_l$ Ø mg $g^{-1}day^{-1}$	2009	**12.18**	**11.83**	**12.87**	**14.29**	**9.21**
	2010	**11.53**	**11.78**	**12.82**	**15.41**	**12.01**

The biomass production as a quantitative indicator of productivity is determined by the area of photosynthetizing organs and their photosynthetic productivity. We observed in more detail the dynamics of the leaf area index formation (LAI) and relative growth rate of leaf dry matter (RGRwl). Medina, Klinge (1983) too recommended the LAI analysis as an accurate indicator of the evaluation of the crop stand development. According to Maas *et al.* (1995) the seasonal development of LAI is often related to the development and production of biomass. Our results are shown in table 6.3 and figure 6.3.
We can observe that there are slight differences in the values of the growth analysis during the two studied years. Generally, higher values were in 2010. The values (Table 6.3) show that the RGR of the leaves is relatively low. Grime and Hunt (1975) determined values for various types of plants higher than 300 $mg.g^{-1}$ day^{-1}. The explanation is that trees are long-lived and are able to reach large sizes throughout the life. Therefore, they accumulate the organic matter more slowly compared to herbs. The highest average growth rate of leaf dry matter among the varieties was reached by GUDRUN and the lowest by SVEN. The faster growth is a prerequisite that the plant would enlarge its underground and above-ground organs faster and thus easier compete for space and resources (light, water and mineral nutrients) compared to plants with a low growth rate. However, it may not always mean that plants with rapid growth are more efficient in production compared to the species whose RGR values are lower. Also Waring et al. (1985) indicate that slow-growing species do not necessarily need to use the produced assimilates for the construction of their structures, but they can store them in reserve for the later growth.

LAI of the individual varieties reached higher values in 2010. The difference in LAI is on average 2.5% (INGER) to 10.5% (TORA). The dynamics of LAI formation of the *Salix* varieties in the research site in Kolíňany in 2009 and 2010 show Figure 6.3.

a) growing period 2009 b) growing period 2010

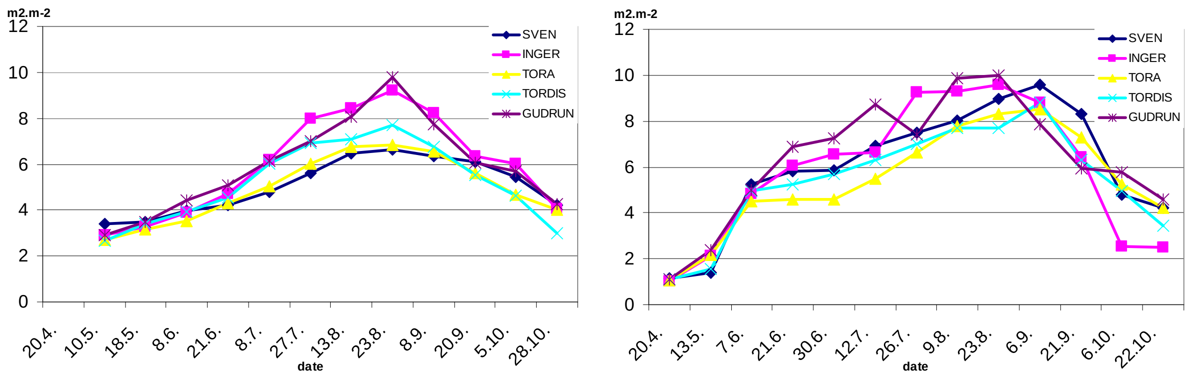


Fig. 6.3 LAI dynamics of the *Salix* varieties in the research site in Kolíňany in 2009 and 2010

LAI values ranged from 2.675 to 9.781 in 2009. The increase in the leaf area occurred intensively in the period from 21.6.2009 to 23.8.2009, when the leaf area and the LAI values culminated. Subsequently, the reduction in leaf apparatus occurred and at the same time also to reduction of the dry leaf matter increment (Figure 6.3). The trend of LAI, in the conditions of the research plantation in Kolíňany, can be described by one-peak curve in the both experimental years (2009 and 2010, the first rotation). Individual sections of the curve are characterized by typical changes, which we designate as phases of the LAI development. The LAI values of the genotypes ranged from 2.69 (TORDIS) to 3.39 (SVEN) m^2 m^{-2} at the beginning of May (10/05-21/06 2009, first phase). The second decade of June (21/06-27/07 2009, the second phase) was characterised by the beginning of a significant expansion of the LAI values ranged from 4.30 (TORA) to 5.06 (GUDRUN) m^2 m^{-2}. LAI culminated in the third decade of August (27/07-23/08 2009, the third phase), when a greater differentiation among genotypes occurred. The highest values of LAI were reached by GUDRUN (9.78 m^2 m^{-2}) and INGER (9.20 m^2 m^{-2}). The lowest LAI value achieved SVEN (6.62 m^2 m^{-2}). The studies of the LAI dynamics showed that willows often create small syleptical shoots, which increase the LAI values and fall of along with the leaves at the end of a growing period (Robinson *et al.*, 2004). This phenomenon has been studied more properly in poplars (Barigah, 1994; Scarrascia-Mugnozza, 1999). The fourth phase was characterized by a significant decline in LAI values caused by a beginning of the leaf cast, especially in the 09/08-20/09 2009. The last phase (20/09-28/10) is associated with destruction of the leaf apparatus, although even in early October the LAI values did not drop below 4.61 (TORDIS). The varieties INGER and GUDRUN kept the highest LAI values. The trend of the LAI formation was similar in 2010. The differences were only in the different values and a time shift of the phases. For example, GUDRUN reached LAI of 5 m^2 m^{-2} 14 days earlier (in the first decade of June 2010) than in 2009.

Results of the present study are comparable in numerous other studies (Ridge *et al.*, 1986; Bullard *et al.*, 2002; Pellis *et al.* 2004). Data on the dry mass of leaves can be reduced by premature defoliation and losses of the leaf area due to diseases and pests. This also indicates the trend of LAI values, which decreased from the second half of August (GUDRUN and INGER), and/or from the first decade of September (SVEN, TORDIS and TORA). Leaf fall occurred during September and October, when there was progressive senescence of the oldest leaves.

In present study, we paid a close attention to the aging (maturation) of leaves at the end of the growing period of 2009. We confirmed that relative value of the complex of assimilation pigments rapidly decline along with the decrease in LAI values. The values are genotype-conditioned.

Chlorophyll content was measured seven times during the growing season of 2010 using OPTI-SCIENCES CCM-200. The results are shown in Table 6.4.

Tab. 6.4 Relative content of chlorophyll in leaves of the *Salix* varieties in the research site in Kolíňany in 2010

Varieties	Date of the measurement						
	7.6.	21.6.	30.6.	26.7.	23.8.	6.9.	22.10.
SVEN	19.72	22.01	23.12	23.71	24.06	25.69	8.67
INGER	24.20	27.98	29.50	33.46	41.55	40.89	2.12
TORA	16.01	21.05	21.31	20.37	19.06	22.89	11.87
TORDIS	25.32	28.51	29.06	30.61	18.01	13.16	4.68
GUDRUN	15.03	20.31	26.64	27.34	30.59	20.39	14.51

The data in Table 6.4 show a strong heterogeneity of the relative pigment content in the leaves of the varieties and their different aging. High relative chlorophyll content was maintained by SVEN, INGER and TORA until the first decade of September. The complex breakdown in the TORDIS began in the second decade of August.

The comparison of LAI and the content of the assimilation pigments showed a linear relationship, which is illustrated in Figure 6.4.

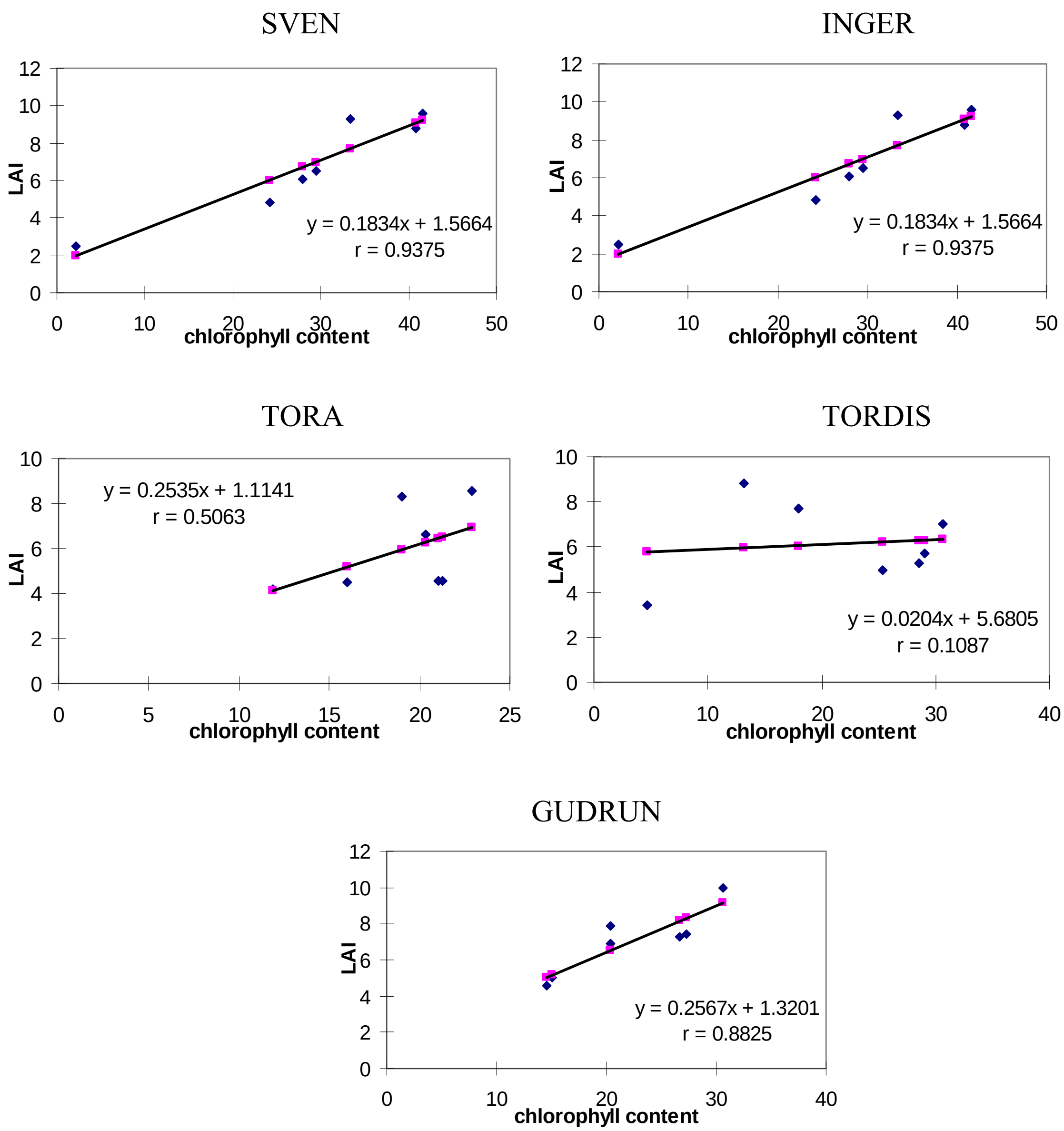


Fig. 6.4 Linear relationship between the leaf area index (LAI) and the chlorophyll content in leaves of the *Salix* varieties in the research site in Kolíňany in 2010

We confirmed a significant linear relationship between the leaf area index and the relative chlorophyll content in all varieties, except for TORDIS (r = 0.1087) (Figure 6.4). The significance of the correlation coefficient was determined by the regression analysis on the significance level $\alpha = 0.05$. The statistical relationship between LAI and the chlorophyll content can be confirmed only in the varieties GUDRUN (p = 0.0085), INGER (p = 0.0018) and SVEN (p = 0.0460). The statistical relationship in the varieties TORA and TORDIS is insignificant.

Tharakan et al. (2005) studied 32 clones of willows and divided them, based on growth characteristics and nitrogen content in the leaves of the clones, to a first group with lower growth and production performance and high nitrogen content in the leaves and a second group with a higher growth and production performance and low foliar nitrogen content.

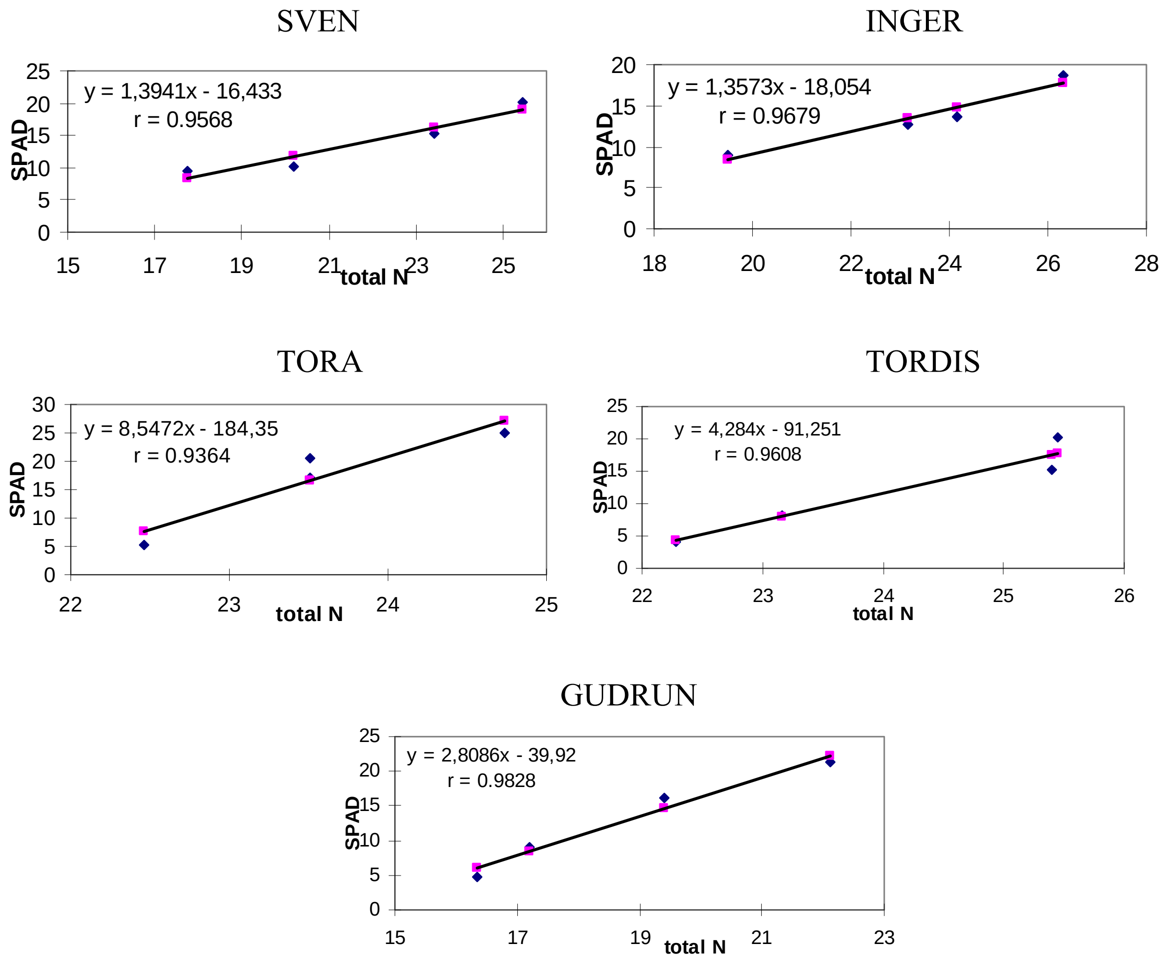
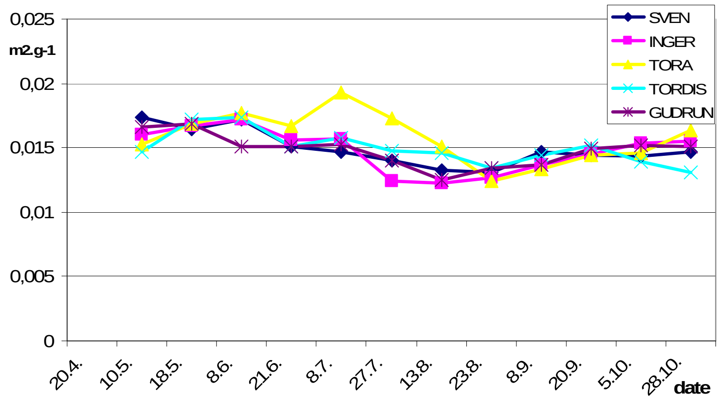


Fig. 6.5 Linear relationship between the relative pigment content and the total nitrogen content in the leaves of *Salix* varieties in the research site in Kolíňany in 2009

The presence of the nitrogen in the chlorophyll molecule leads to a search for a relationship between the chlorophyll content in leaves and the content of this element. Brown *et al.* (1991) confirmed this relationship in the form of a positive correlation between the relative pigment content and the total nitrogen content. This relationship is considered as an important indicator of aging. We also confirmed a linear relationship between relative pigment content and total nitrogen content. It is shown in Figure 6.5. The significance of the correlation coefficient was evaluated by regression analysis on the significance level $\alpha = 0.05$.

The results of our measurements revealed a high correlation relationship (from 0.9364 to 0.9828), which is statistically significant: SVEN p = 0.0432, INGER p = 0.0320, TORA p = 0.0436, TORDIS p = 0.0391 and GUDRUN p = 0.0171.

a) growing period 2009



b) growing period 2010

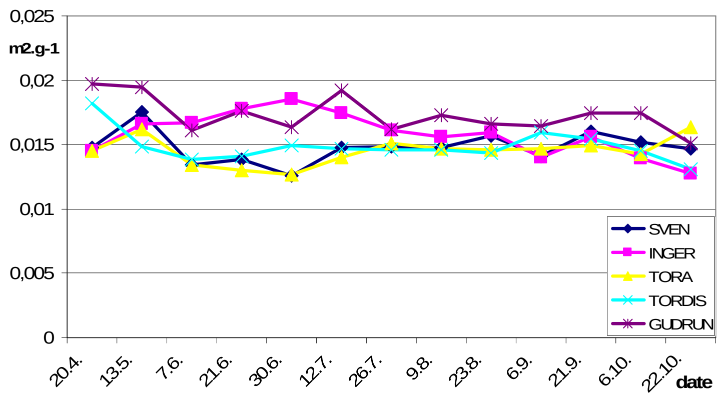


Fig. 6.6 Seasonal trend of the specific leaf area (SLA) values of the *Salix* varieties in the research site in Kolíňany during the two growing seasons

The relationship between the dry leaf matter and the leaf area testify the SLA value. SLA values integrate physiological processes (photosynthesis, respiration, leaf morphology, anatomical structure and chemical composition of the leaf). The SLA dynamics of the *Salix* varieties in the research site in Kolíňany in 2009 and 2010 is shown in the Figure 6.6.

The data in the Figure 6.6 show that the highest SLA values are in the early summer (until 8 of July 2009), later there is a slight decrease (to 238 of August) and subsequent stabilization of the values. The SLA values of individual varieties were different in the observed years. This can indicate that the leaves were thinner in the spring and early summer (they had higher SLA values). Many authors confirmed an inter-species difference in the SLA values (Poorter, 1989b; Dijkstra, 1989), as well as positive correlation with other growth indicators mainly RGR and NAR. The differences in SLA values can be caused by two leaf characteristics: the thickness (number of layers) of the palisade parenchyma and accumulated substances (secondary metabolites) such as lignin and phenolic compounds, which increase the dry weight of the leaves (Mooney and Gulmon, 1982). Our analysis does not allow us to define whether the chemical composition of leaves changed in the summer (July-August) and whether this change affected significantly the dry weight.

6.1.7 Varietal differences in biomass production of fast growing willows crown

An impact of thevarietal properties was also reflected in the allocation of biomass. Seasonal proportional allocation of biomass from leaves to shoots has retained in all experimental varieties. The competition for assimilates was increasing during the observing period (May-September 2010). For a better understanding and interpretation, we calculated RGRw of leaves and RGRw of shoots. The results are shown in Table 6.5.

Tab. 6.5 Relative growth rate (mg g^{-1} day^{-1}) of dry matter of leaves and shoots of willow varieties in the period of May-September 2010

Time period	**TORDIS**		**SVEN**		**GUDRUM**		**TORA**		**INGER**	
	leaves	shoots	leaves	shoots	leaves	shoots	leaves	shoots	leaves	shoots
7.6.’10	49.32	18.57	63.14	13.04	37.69	22.26	36.89	10.17	32.89	16.58
21.6.’10	3.25	8.90	5.44	10.15	16.30	5.76	3.56	7.72	11.77	26.99
30.6.’10	2.35	14.87	11.14	29.10	14.32	14.37	3.23	13.20	3.72	19.39
12.7.’10	10.30	1.30	5.10	9.82	1.67	6.31	6.54	4.89	6.67	9.40
26.7.’10	7.67	5.23	5.33	12.92	9.60	4.62	5.30	6.72	2.44	4.09
9.8.’10	1.24	3.13	5.08	20.81	15.74	7.45	13.21	15.57	5.10	2.78
23.8.’10	2.23	21.52	3.61	2.22	3.02	12.83	1.00	3.90	3.19	1.92
6.9.’10	-2.13	11.34	12.49	5.33	3.02	6.05	-11.51	10.06	-27.86	2.08
21.9.’10	-12.50	5.22	-17.86	6.56	-22.53	7.29	-18.59	17.64	-54.23	21.25

The data on specific growth rate of leaves show that the rate of the dry matter increment is highest at the beginning of the observed interval (the first decade of June 2010). The values of the increments vary from 32, 89 mg g^{-1} day^{-1} (INGER) to 63.14 mg g^{-1} day^{-1} (SVEN). During this period, the dry matter of shoots increased slower: from 10.7 mg g^{-1} day^{-1} (TORA) to 22.26 mg g^{-1} day^{-1} (GUDRUN). RGRw of shoots significantly increased in the last decade of June (gray boxes), which may be the result of relations between the organs producing assimilates (leaves – sources) and the organs storing assimilates (shoots – sinks). A similar situation occurred from the second decade of August (gray boxes), when RGRw of shoots increased in all studied varieties. In late September, the values of the RGRw of shoots were significantly higher, while the values of the RGRw of leaves were very low or negative. It is also due to the leaf fall, which causes changes in allometry between the biomass of woody organs and leaves. Overall, we may conclude that during the seasonal growth of the fast-growing willows, we identified three genotype-conditioned periods with a significant increase in the values of RGRw of shoots (the third decade of June and September and the second decade of August), accompanied by low values of RGRw of leaves. The negative RGRw values in the first decade of September (TORDIS, TORA and INGER) were coused by the leaf fall. Unfortunately, we do not have data on the distribution of matter in the roots for a causal explanation of the relationships and competition for the organic matter.

6.2 Establishment of Miscanthus x giganteus plantation

Miscanthus giganteus is a highly productive plant species, which has been cultivated in Europe for 20 years as energy crop. The remarkable adaptability of miscanthus to diferent environments makes this novel crop suitable for establishment and distribution under a range of European and North American climatic conditions (Lewandowski *et al.*, 2000). It produces no seed, so it must be established vegetative by planting divided rhizome (rootstock) pieces. This process results in high establishment costs relative to crops established from seed. As with other vegetative propagated crops, dry soil moisture conditions at and following planting greatly decrease establishment success.

Establishment success may be limited by death of plants in the first winter after planting. European research suggests new plantings of *Miscanthus x giganteus* may not survive where soil temperatures fall below -3.33°C at a depth of 2,54 cm. As an example, *M. sinensis and M. sacchariflorus* plantings have overwintered the first year in northern Europe where air temperatures have been as low as -17.78°C. Winter survival does not appear to be a problem in the second and subsequent years[4]. In Serbia, preliminary analyses show that conditions are in general favourable for *Miscanthus* cultivation, in areas situated below 500 m altitude, because of the possibility of rhizome freezing during the winter in the absence of snow cover, and with annual precipitation level above 700 ml, which may be corrected by irrigation systems, which however raise the production costs (Lewandowski *et al.,* 1999). Experiment with *Miscanthus* was exercised in the Republic of Serbia for the first time in 2007. Although it is necessary to perform long time monitoring of growth parameters (yield primarily) in function of environmental parameters, as well as genetic and physiological characteristics of plant in order to obtain relevant data, preliminary results point out that production of *Miscanthus* biomass is possible in Serbia (Dražić *et al.*, 2009).

Miscanthus was planted at 3 locations characterising by different siol properties to examine impact of soil type on miscanthus growth. Some of soils have extremly low content of N and

[4] Agronomics of production Switchgrass and Miscanthus×giganteus, Bioconference Growing the Bioeconomy: Solutions for Sustainability, Micshigan State University, Unated States,2009.

organic C. Soils with such properties were chosen in order to determinate the lowest quality of soil suitable for miscanthus growth.

The aim of the first stage of the investigation was to select appropriate plots (experimental field) for the establishment of *Miscanthus* canopy taking into consideration climate and pedologic characteristics, establishment of the field and pot experiments in order to monitor bioproduction in dependence on agro technical measures.

Plant material was purchased from commercial supplier. Rhizomes were planted in previously analyzed soils in the spring 2010 and 2011. The examination of growth rate and biomass quality was performed on three field experiments in Republic of Serbia.

The experiment

1. The experiment started in april 2010. The experimental field was established, and the entire surface of the experiment covering 40000 m^2 divided into two zones (A zone – sample plot 1 (P= 39 800 m^2), B zone – sample plot 2 (P= 200 m^2)) with different treatments in order to monitor the micanthus biomass development (Figure 6.7). Planting performed manually on humgley substrate at Zasavica location with 28 000 rhizomes planted (Figure 6.8).

Crop spacing, density of canopy: Rhizomes were planted at 10-20 cm of soil depth, at 0.50 m - 1 m spacing (2 plants/m^2) - with 1m between rows and 0.5 m between plants.

In A zone, intensive mechanical and weed control products with appropriate agro-technique measures and fertilizer applied was carried. Fertiliser was applied immediately before planting at the following rates: 150 kg/ha in NPK proportion 15:15:15. As a control sample plot, zone B was monitored without agro-technique measures and fertilizer addition, in order to obtain a difference in biomass production with or without treatments defined.

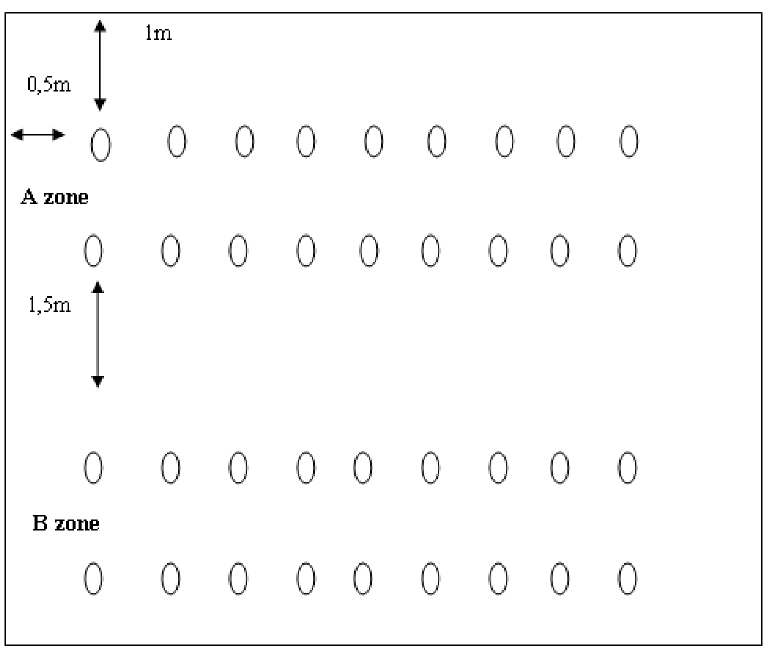


Figure 6.7 Zasavica experimental field scheme of *Miscantus*×*giganteus* plantation

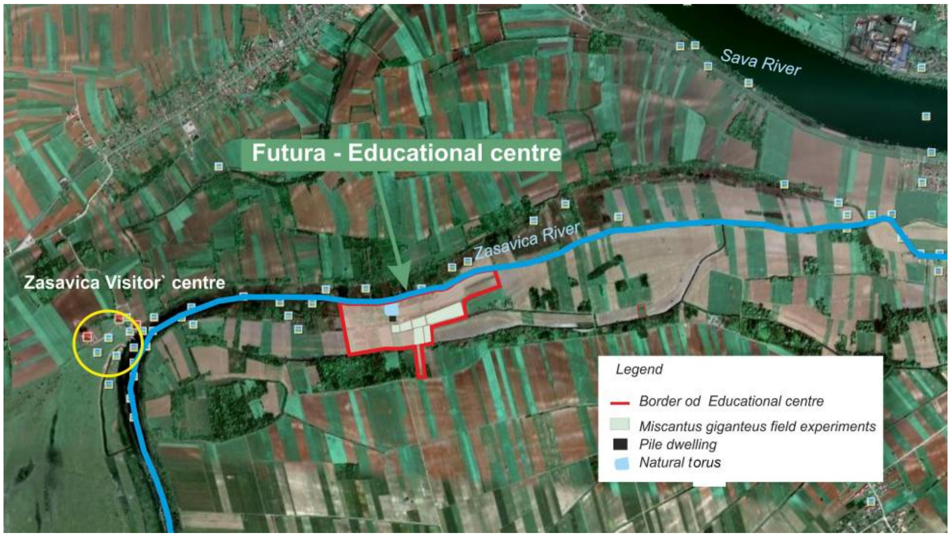


Figure 6.8. Zasavica experimental field location (established in 2010 and 2011)

In order to standardize the monitoring of biomass development, control list was designed of *Miscanthus* biomass development (Figure 6.9) which contains: experiment type, experiment site, measured parameters, measure units, dynamics of the measurement, ameliorative measure applied and effects of the melioration.

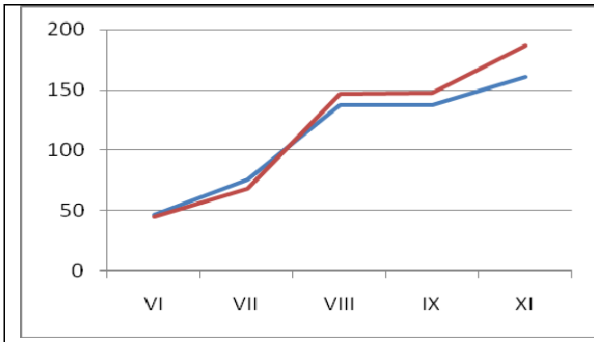
A control list

EXPERIMENT: SITE:

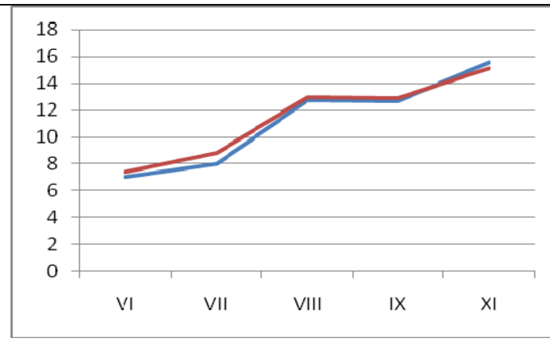
parameter/date	VI	VII	VIII	IX	X	XI	XII	I	II
stem height (cm)									
number of leaves									
length of leaf green part (cm)									
leaf width (mm)									
tillering potential (number of shoots per rhizome)									
stem radius (mm) – fourth leaf from the ground									
number of ”green leaves”									
number of dry/dead leaves									

Figure 6.9. MISCANTHUS BIOMASS DEVELOPMENT CONTROL LIST for the first year of the investigation

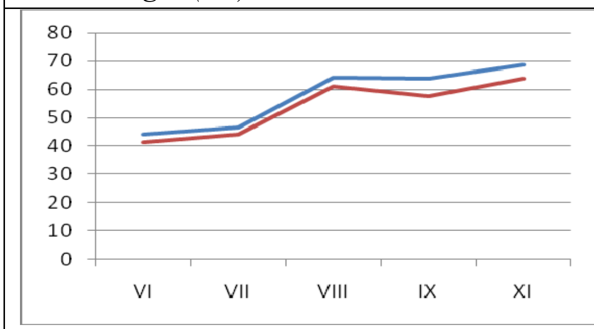
Results obtained on experimental field Zasavica are given in Figure 6.10.



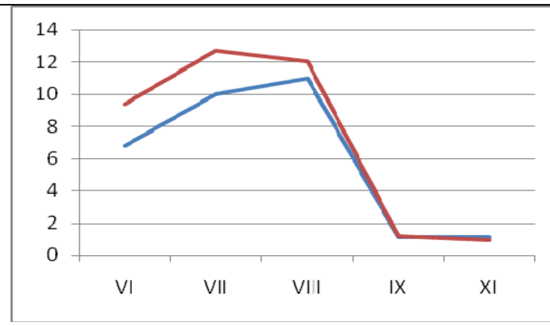
Steam height (cm)



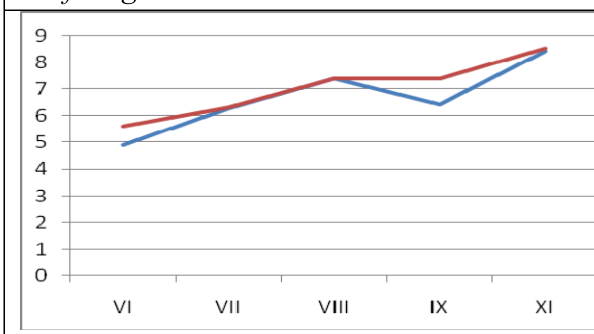
Number of leaves per steam



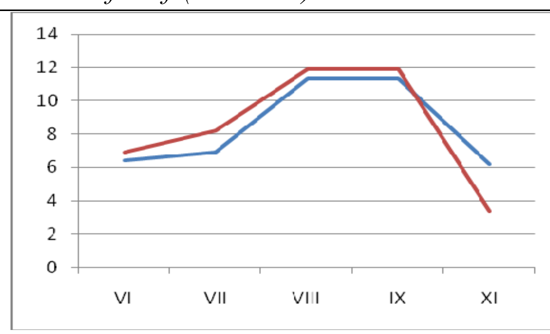
Leaf length



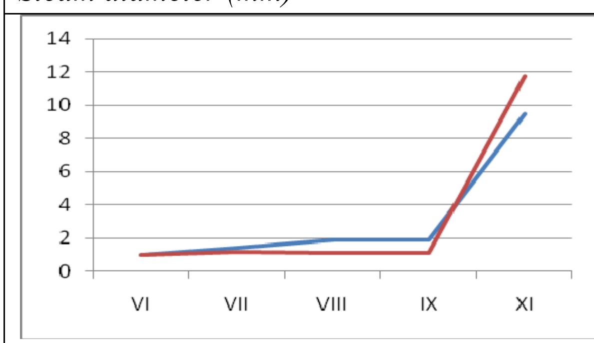
Width of leaf (maximal)



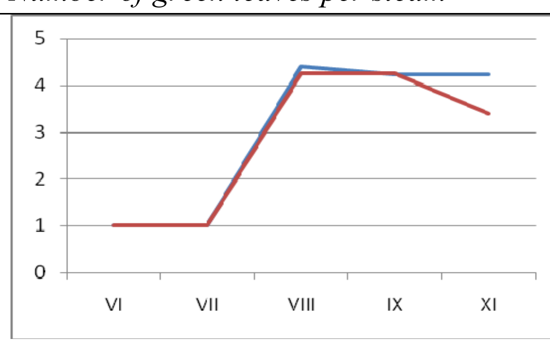
Steam diameter (mm)



Number of green leaves per steam



Number of dry leaves per steam



Number of steams per rhyzome

Figure 6.10 Morphological characteristics of Miscanthus plants during 1st year (established 2010).

Legend: Red – untreated (control) area

Blue – area under care with appropriate agro-technique measures and fertilizer applied

2. Field experiment in Kolubara was established on tailings base substrate and divide into 8 sample plots with defined treatments (time of fertilization, fertilization dose and fertilization frequency). Experimental scheme of miscanthus plantation with a marked crop space and density of canopy is shown in Figure 6.11.

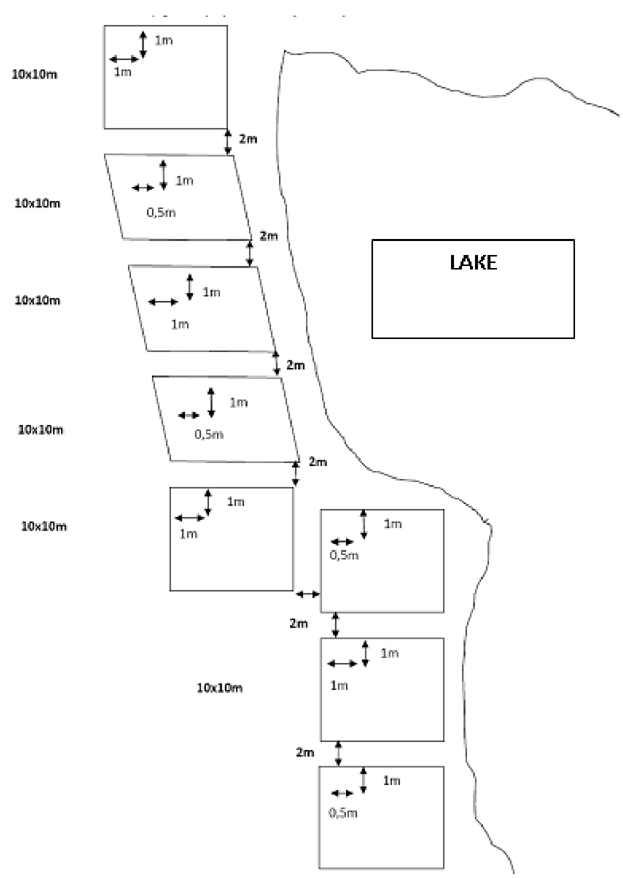


Fig. 6.11 Experimental sheme of miscanthus plantation on Kolubara Mine Basin tailings substrate.

Experimental field on Kolubara Mine Basin substrate was established in spring 2011 with 8 sample plots 10 x 10 m each, two planting densities (1 rhizome /m^2 and 2 rhizomes/m^2) two fertilization doses (50 kg/ha and 100 kg/ha) and term (june and july). First four experimental plots were planted with 200 rhizomes in distribution of 1m between rows and 1 m between plants. Remaining four experimental sample plots were planted with 100 rhizomes per plot in distribution of 1m between rows and 0,5 m between plants. The distance between adjacent plots is 2m.

3. Field experiment on “Nikola Tesla” thermal plant ash substrate (once recultivated before) were established in spring 2011. Experimental sample plots covering 18 ar with 8 plots are shown in Figure 6.12 Planting performed manually with two planting densities and two fertilization terms and doses.

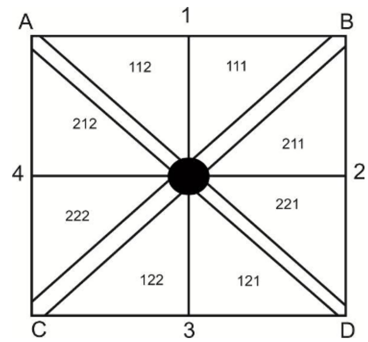


Fig. 6.12 Experimental sheme of miscanthus plantation on on “Nikola Tesla” termal plant ash substrate

<u>Explanation of experimental sheme shown in figure 6.12</u>

<u>A first number in the sequence:</u>

1. Rhizome planting density 1 rhizom/m^2 (ABP + CDP)

2. Rhizome planting density 2 rhizomes/m^2 (BDP + CPA)

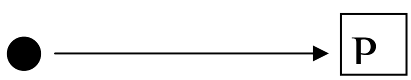
<u>The second number in the sequence:</u>

1. Fertilization dose (D1) – AB24 – 100 kg/ha

2. Fertilization dose (D2) – 42DC – 150 kg/ha

<u>A third number in the sequence:</u>

1.Fertilization term 1 (T1) – 1BD3 – initially (June 2011)
2.Fertilization term 2 (T2) - A13C – afterwards (July 2011)



P – water spayer
P of ABP zone = 4,5 ar; AP = 30m

6.2.1 Weed control in juvenile canopy

Weed control at establishment is very important because weeds compete with the crop for light, water and nutrients and can reduce yields. The establishment phase of the crop with weed control is essential because poor control can severely check the development of the crop. It is vital that proposed sites should be cleared of perennial weeds before any planting takes place. Weed treatment during establishment of the crop is essential and can easily be done with herbicides, but mechanical methods to reduce the chemical load are also feasible. Labeled herbicide choices are limited making a clean field at planting critical. Planting an herbicide tolerant crop in the previous year and using a cover crop prior to *Miscanthus* establishment can reduce weed pressure. The mature crop is, however, very competitive and only occasional weed treatment may be necessary if certain problematic weeds develop (Jørgensen, 2011).

The need for pesticide use is restricted to the control of weeds in the first-to second stand year (Lewandowski and Heinz, 2003). Herbicide application must not be made on miscanthus crops greater than 1 metre in height and the crop cannot subsequently be used for food or feed. A wide range of herbicides have been used effectively with no visible damage to the crop in Denmark and the UK (Figure 6.13). Following the establishment year, an annual spring application of a broad-spectrum herbicide may be needed to control grass weeds such as common couch and annual meadow-grass and broad-leaved weeds with early season vigour. Glyphosate and paraquat have been used in this dormant period between harvest and initiation of spring growth but they will cause severe damage to any new shoots which might have emerged. Once the crop is mature (i.e. from the summer of the second year), weed interference is effectively suppressed. This is initially due to the leaf litter layer on the soil surface and subsequently due to the closure of the crop canopy, which reduces the light penetrating into the under-storey. Weeds that do survive offer little competition to the crop. Since there are no labeled recommendations, all products used are at the users own choosing and the commercial risk is entirely theirs.

At the first phase after planting Miscanthus rhizomes within experiments established in Serbia, mixture of herbicide products (Calysto (Syngenta, 480 g/L mezotrion) 150 mL + Harmony 75 WG (Du Pont, Dipkon) 2,5 g + Atplus 0,5 L + Trend 150 mL) for agro-technique treatments were applied at the locations designated for that purpose.

Active Ingredient(s)	*Data Source*	*Notes*
atrazine	A	Gesaprim @ 2.5 l/ha
bromoxynil/ioxynil	A	Briotril @ 2.5 l/ha
bromoxynil/fluroxypyr/ioxynil	A	Advance @ 2 l/ha
clopyralid	A, B	Dow Shield @2.4 l/ha
dichlorprop	B	(667g/l of active ingredient) @ 5 l/ha
diflufenican/isoproturon	B	(100:500g/l of active ingredient)@3 l/ha
fluroxypyr	A, B	Starane 2 @ 2 l/ha
glyphosate[2]	A, B	Roundup @ 3 l/ha
isoproturon	B	Tolkan @ 4 l/ha
metsulfuron-methyl	A, B	Ally @ 30g/ha
metsulfuron-methyl + bromoxynil / ioxynil[3]	A	Ally @ 30g/ha + Deloxil @ 1 l/ha
metsulfuron-methyl+ fluroxypyr[3]	A	Ally @ 20g/ha + Starane 2 @ 0.5 l/ha
MCPA	B	(750g/l of active ingredient) @ 5 l/ha
MCPA + MCPB	A	Trifolex-Tra @ 7.7 l/ha
mecoprop-P	B	Duplosan @ 6 l/ha
paraquat2	A	Gramoxone @ 4 l/ha

[1] *(A) ADAS, (B) Georg Noyé Institute of Weed control 'Flakkebjerg', Denmark.*
[2] *Herbicides for use before miscanthus emergence.*
[3] *Tank mixtures.*

Figure 6.13 Herbicides which have been used successfully to control weeds in miscanthus[5]

[5] BEST PRACTICE GUIDELINES – For applicants to DEFRA'S Energy Crops Scheme, DEFRA PUBLICATIONS, 2001

6.2.3 Fertiliser and irrigation

The annual fertilizer demands of the crop are low. Like corn and other grass crops, Nitrogen will likely be the largest fertilizer requirement for *Miscanthus*. There are available different literature data on the necessity of nitrogen fertilization. On one side fertilizers are not needed in the first two years. Their application will create greater weed growth during establishment. Maintenance fertilizer rates are required in later years. This is due to good nutrient use efficiency and the plant's capability to re-cycle large amounts of nutrients into the rhizomes during the latter part of the growing season.
The harvest strategy of waiting until after frost will minimize N fertilizer need since the plants will translocation protein (N) to the roots where it is available for new shoot growth the following spring. It will require relatively low annual rates to support growth. This has two benefits: the nutrients in the rhizomes will be available for the next year's growth, reducing the fertilizer requirements; the low nutrient content of the harvested crop will minimize the problems of corrosion, slugging, fouling and emissions that can occur on combustion. As a consequence, nutrient off-take at harvest is low, as shown in Table 6.6. Since the leaves predominately remain in the field it is only necessary to account for the amount of nutrients removed in the stems. The nutrient requirements during the following seasons are met by leaf litter decomposition, natural soil nutrient reserves, rhizome reserves and atmospheric depositions. Mature rhizomes tend to store more nutrients than the crop needs, so after the first 2 years, only a small quantity of additional micro-nutrients may be required.
For good miscanthus yields a minimum phosphorus and potassium soil index of 1 should be aimed for and soil nitrogen supply should exceed 150 kg/ha in each of the first 2 seasons. When nutrients are needed in the first 2 seasons, this could come from farmyard manure or sewage sludge.

Tab. 6.6 Nutrient 'off-take' (kg/ha) for an 'average crop' consisting of 13.5 t/ha of stems and 4.5 t/ha leaf litter (DEFRA, 2001)

	Stem	**Leaf litter**
N	88	47
P	11	2
K	95	14

Fertilizer rate should anticipate future yield expectation and compensate for off-take to prevent depletion of soil reserves. The rate and timing of fertilizer application requires further investigation on a range of soil types (Christian et *al.*, 2008). N fertilizer rate did not affect P and K content in the established crop at harvest and the total amounts of each that were removed was less than the amount applied as fertilizer during the experiment. Application of NPK significantly increases yields (Table 6.7), but may reduce biological efficiency of the process itself. It was found that no yield response to nitrogen fertilizer.

Table 6.7 Maximal yield (kg/ha) of miscanthus at chernozem (Zemun) with application of (0, 50 and 100 kg/h) NPK fertilizer before planting (Dražić et *al*., 2009)

NPK Kg/ha	1 rhizome/m^2	2 rhizomes/m^2	3 rhizomes/m^2
0	1930±310	4980±540	4180±380
50	2120±330	8790±1250	6350±650
100	2990±420	8310±1200	6130±640

At the opposite side if the soil contains little nitrogen, or is it in the form of inadequate or if the weak activity of soil microbial nitrogen needs increase. In experiment performed at degraded soil in Kozjak application of 100 kg/ha NPK in second year of growth increase yield about two fold (results not show) (Drazic *et al*, 2009).

Watering needs depend mostly on weather conditions and soil properties, it is mostly done in first vegetation year and it significantly increases production price. On the other hand, provision of water and possible nutrient runoff should be taken into account. As with other vegetative propagated crops, adequate soil moisture at planting greatly favors establishment success. in all three experimental field is set for the watering system in the first year. During the experiment irrigation was conducted as required in accordance with weather conditions. Due to the surface characteristics of coal ash at the watering was done every day, except when it rains

6.2.4 Biomass production

The aim of the first stage of the investigation was to select appropriate plots for the establishment of *Miscanthus* canopy taking into consideration climate and pedologic characteristics, establishment of the field and pot experiments in order to monitor bioproduction in dependence on agro technical measures. Literature data show that *Miscanthus* biomass increases by third year and remains constant for several following years (Christian *et al*, 2008). Results from sample plots in Serbia pertain only four years, and in such case it is desirable to observe some characteristics of growth, such as height of crops and number of stems per rhizome (Jeżowski, 2008), for longer period. Although the experiment is positioned in very different soils in order to examine possibility of use of land which is not suitable for production of crops for food, it has been shown as possible, but with very modest yields. The results obtained in field experiments in Serbia have shown that *Miscanthus* biomass quality (water and element content), as well as caloric power (16 MJ/kg) is satisfying, but that yields are lower than it is necessary for cost-effective production. Application of NPK significantly increases yields, but may reduce biological efficiency of the process itself. For these calculations it is necessary to form database from perennial observations. It was found that no clear if yield response to nitrogen fertilizer. The lack of response results from soil type, previous cropping, the plant having a C4 photosynthetic pathway and the natural recycling of N (and other minerals) from stems and leaves into rhizomes at senescence and process reversal in the following spring to support early growth. N fertilizer rate did not affect P and K content in the established crop at harvest and the total amounts of each that were removed was less than the amount applied as fertilizer during the experiment in earlier years (Dražić *et al.*, 2009). Fertilizer rate should anticipate future yield expectation and compensate for off-take to prevent depletion of soil reserves. The rate and timing of fertilizer application requires further investigation on a range of soil types. According to our results, miscanthus on arable land requires no agro-technique (AT) measure and fertilizer application to achieve high yield per annum, while AT measures and fertilizer have to be applied to support yield increment on degraded land (Milovanović *et al.*, 2011)

Experimental research results on miscanthus production in Serbia show that this kind of production is possible in country specific conditions. Miscanthus yield strongly depends on agri-environmental conditions and long-term monitoring for experiments established on arable and degraded soil is necessary for decision making process in sustainable biomass production using this perennial grass.

The experience from the experiment establishing, in spite of being only a four years long, indicates that there are both administrative difficulties during the import, and biological burdens caused by weed presence on the experimental fields and late planting. These, and other problems encountered during the biomass growing, must be kept under strict control for at least two reasons: 1. Introduction of an exotic species destabilizes integrated agro ecological system of an area, which tends to eliminate the species and it is necessary to apply knowledge, energy and financial resources to provide its survival; 2. For the estimation of energetic and commercial parameters a systematic monitoring of biomass development is necessary (Dražić *et al.*, 2007). This is enabled by the proposed monitoring system.

References

BALLARD, R. 1979. *Use of fertilizers to maintain productivity of intensively managed forest plantations.* In Impact of intensive harvesting on forest nutrient cycling, proc. p. 321-342. SUNY Col. of Envir. Sci. and For., Syracuse, New York. 421 pp.

BARIGAH, T.S. – SAUGIER, B. – MOUSSEAU, M. – GUITTET, J. – CEULEMANS, R. 1994. *Photosynthesis, leaf area and productivity of 5 poplar clones during their establishment year*. Ann Sci For 51:613-625

BOLLMARK, L. – SENNERBY-FORRSSE, L. – ERICSSON, T. 1999. *Seasonal Dynamics and effects of nitrogen and carbohydrate reserves in cutting-derived Salix viminalis plants*. Can.J.For. Res.29:85-94

BOWMAN, W.D. – CONANT, R.T. 1994. *Shoot growth dynamics and photosynthetic response to increased nitrogen availability in the alpine willow Salix glauca.* Oecologia 97: 93–9.
BROWN, S.B. – HOUGHTON, J.D. – HENDRY, G.A.F. 1991. *Chlorophyll breakdown*, H. Scheer, Editor, Chlorophylls, CRC Press, Boca Raton, 1991, p. 465–489.
BULLARD, M.J. – MUSTILL, S.J. – CARVER, P. – NIXON, M.I. 2002. *Yield improvements throught modification on planting density and harvest frequency in short rotation coppice Salix spp.-2 Resource capture and use in two morphologically diverse varieties*. Biomass and Bioenergy 2002:22-27-39
CEULEMANS, R. – MCDONALD, A.J.S. – PEREIRA, J.S. 1996. *A comparison among eucalypt, poplar and willow characteristics with particular reference to a coppice, growth-modeling approach.* Biomass Bioenergy 11:215-231
DEFRA : Planting and growing Miscanthus, Defra Publications, PB No 5424, 2001
DEMO, M. – FAZEKAŠ, A. – HAUPTVOGL, M. – SKLADAN, B. – TÓTHOVÁ, M. 2011. *Produkčný a anergetický potenciál švédskych odrôd rýchlorastúcej enrgetickej dreviny rodu Salix pestovanej v suchších pôdno-klimatických podmienkach juhozápadného Slovenska.* SPU Nitra, 2011, 110 pp., ISBN 978-80-552-0577-9.
DIJKSTRA, P. 1989. *Cause and effect of differences in SLA*. In H. Lambers, M. L. Cambridge, H. Konings, I.L.Pons. eds, Causes and Consequences of Variation in Growth Rate and Productivity of higher plants, SPB Academic Publishing, 1989, The Hague, p.125-140
DRAZIC, G. – DZELETOVIC, Z. – MIHAILOVIC, N. 2007. *Miscanthus giganteus as the basis of new bioenergetic fuel: The establishment of a plantation.* 13th symposium on termal science an engineering of Serbia, Boog of papers, Sokobanja, 16-19.10. 2007.
DRAŽIĆ, G. - DŽELETOVIĆ, Ž. - ĐORĐEVIĆ, A. .2009. *Environmental impact on Miscanthus giganteus biomass quality measured as ecosystem processor activity*. Abstract Book. The Second International Environmental Best Practice Conference, Krakow, Poland, Septembar 14-18, 2009, p. 44.
DRAŽIĆ, G. – MITIĆ, M. – MIHAILOVIĆ, N. – ĐORĐEVIĆ, A. – MARKOVIĆ, S. 2009. *Produkcija biomase Miscanthus giganteus sa aspekta energetske i ekološke efikasnosti ekosistemskog procesora*. Zbornik radova, 14. Simpozijum Termičara Srbije, 13.-16. oktobar, Soko Banja, p. 450-456, ISBN 978-86-80587-96-7.
GRIME, J.P. – HUNT, R. 1975. *Relative growth-rate: Its range and adaptive significance in a local flora*. J.Ecol., 63, p. 393-422
HEILMAN, P. 1992. *Sustaining production: nutrient dynamics and soils.* In Mitchel, C.P. et all. Eds. Ecophysiology of short rotation forest crops., 1992, Elsevier applied science
HYTÖNEN, J. 1985. *Effect of cutting season, felling method and stump height on the sprouting ability of energy willows and some other hardwoods*. Metsäntutkimuslaitoksen tiedonantoja, 1985, 206, p.40-57
CHRISTIAN, D.G. - RICHE, A.B. – YATES, N.E. 2008. *Growth, yield and mineral content of Miscanthus × giganteus grown as a biofuel for 14 successive harvests*. In Industrial Crops and Products, Vol. 28(1), 2008, p.320-327.

IBRAHIM, L. – PROE, M.F. – CAMERON, A.D. 1998. *Interactive effects of nitrogen and water avilabilities on gas Exchange and whole-plant carbon allocation in poplar*. Tree physiol., 18(7):481-487

JEŻOVSKI, S. 2008. *Yield traits of six clones of Miscanthus in the first 3 years following planting in Poland*. In Industrial Crops and Products, Vol.27, 2008, p. 65–68.

JØRGENSEN, U. 2011. *Benefits versus risks of growing biofuel crops: the case of Miscanthus*. In Current opinion in Environmental Sustainability, Vol 3 (1-2), 2011, p. 24-30.

KOSTREJ, A. 1992. *Kvantitatívne charakteristiky a modelovanie produkčného procesu poľných plodín*. Acta fytotechnica, Nitra 1992 pp.180, ISBN 80-7137-053-3

KOZLOWSKI, T.T. – KRAMER, P.J. – PALLARDY, S.G. 1991. *The Physiological Ecology of Woody Plants.* Academic Press, New York, 657 pp.

KVĚT, J. – NEČAS, J. – ONDOK, J.P. 1971. *Metody růstové analýzy*. Studijní informace, ÚVTI, Praha 1971, pp.99

Larcher, W. 2003. *Physiological Plant Ecology: Ecophysiology and Stress Physiology of Functional Groups* (4th edition). Springer, Berlin, 513 pp.

LEDIN, S. – ALRIKSSON, A. 1992. *Handbook on How to Grow Short Rotation Forests*. International Energy Agency Bioenergy Agreement Task V, Energy Forestry Production Systems Activity, 1992, ISBN 91-576-4628-7.

LEWANDOWSKI, I. – CLIFTON – BROWN, J.C. – DEUTER, M. 1999. *Potential of Miscanthus genotypes in Europe: over-wintering and yields*. In: Alternative crops for sustainable agriculture (Eds. Mela T, Christiansen J, Kontturi M, Pahkala K, Partala A, Sahramaa M, Sankari H, Topi-Hulmi M and Pithan K), European Commission, BioCity, Turku, Finland,1999, p. 46-52.

LEWANDOWSKI, I. – CLIFTON-BROWN, J.C. – SCURLOCK, J.M.O. – HUISMAN, W. 2000. *Miscanthus: European experience with a novel energy crop*. In Biomass and Bioenergy, Vol. 19, 2000, p. 209-227

LEWANDOWSKI, I. – HEINZ, A. 2003. *Delayed harvest of miscanthus—influences on biomass quantity and quality and environmental impacts of energy production.* In Europ. J. Agronomy, Vol.19, 2003, p. 45-63.

MAAS, J.M. – VOSE, J.M. – SVANK, W.T. – MARTINEZ-YRÍZAR, A. 1995. *Seasonal changes of leaf area index (LAI) in a tropical deciduous forest in west Mexico*. Forest Ecology and management 74(1995), p. 171-180

MEDINA, E. – KLINGE, H. 1983. *Productivity of tropical forests and tropical woodlands*. In O.L. Lange, P.S. Nobel, C.B. Osmond, H. Ziegler (Eds.) Physiological Plant Ecology IV. Encyclopedia of Plant Physiology, New Series, Vol. 12D. Springer, New York, p. 281-303

MILOVANOVIĆ, J. - DRAŽIĆ, G. - IKANOVIĆ, J. - JUREKOVA, Z. - RAJKOVIĆ, S. 2011. *Sustainable production of biomass through Miscanthus giganteus plantation development*. 3rd International Scientific Conference Management of Technology-Step to Sustainable Production. June 8-10, Bol, Island Brac, Croatia. Conference Proceedings. 2011, p. 440-444.

MITCHEL, C.P. – FORD-ROBERTSON, J.B. – HINCKLEY, T. – SENNERBY-FORSSE, L. (Eds.) 1992. *Ecophysiology of Short Rotation Forest Crops*. Elsevier Applied Science, London and New York 1992

MOONEY, H.A. – GULMON, S.L. 1982. *Constraints on leaf structure and function in reference to herbivory*. Bio Science, 32, 198-206

NETTO, A.T. – CAMPOSTRINI, E. – CONCALVES DE OLIVEIRA, J. – BRESSAN-SMITH, R.E. 2005. *Photosynthetic pigments, nitrogen, chlorophyl a fluorescence and SPAD-502 readings in coffee leaves*. Scientia Horticulturae, Vol. 104, Issue 2., p.199-209

PELLIS, A. – LAUREYSENS, I. – CEULEMANS, R. 2004. *Growth and production of a short rotation coppice culture of poplar I.* Clonal defferences in leaf characteristics in relation to biomass production.Biomass and Bioenergy, 2004, Vol.:27, Issue 1. p.9-19.

PETERSON, T.A. – BLACKMER,T.M. – FRANCIS, D.D. – SCHEPPERS, J.S. 1993. *Using a chlorophyl meter to improve N management*. A Webquide in Soil Resource Management: D-13.Cooperative extension, Institute of Agriculture and Natural Resources, University Nebraska, Lincoln, NE, USA (1993)

PEZESHKI, S.R. – LI, S. – SHIELDS, F.D.JR. – MARTIN, L.T. 2007. *Factors governing survival of black willow (Salix nigra) cuttings in a streambank restoration project*. Ecological engineering 29 (2007) p.56-65

POORTER, H. 1989a. *Interspecific variation in relative growth rate: On Ecological causes and Physiological consequences*. In Causes and consequences of variation in growth rate and productivity of hight plants. Eds. Lambers, H. et al. 1989, SPB, p. 45-68

POORTER, H. 1989b. *Causes and consequences of variation in growth rate and productiívity of higher plants.* Ed.by H. Lambers et al., p.45-68

RAVEN, J.A. 1992. *The physiology of Salix*. The Royal Society of Edinburg 96B, p.49-62

RIDGE, C.R. – HINCKLEY, T.M. – STETTLER , R.E. – Van VOLKENBURGH, E. 1986. *Leaf growth characteristics of fast-growing poplar hybrids Populus trichocarpa x P. deltoides*. Tree Physiology, 1, p.209-216.

ROBINSON , K.M. – KARP, A. – TAYLOR, G. 2004. *Defining leaf traits linked to yield in short-rotation coppice Salix*. Biomass Bioenergy 26:417-431

SATO, T. 1966. *Production and distribution of dry mater in forest ecosystems*. Misc.Inf.Tokyo Univ.Forests. 1966, 16,1-15

SCARRASCIA-MUGNOZZA, G.E. – HINCKLEY, T.M. – STETTLER , R.F. – HEILMAN, P.E. – ISEBRANDS, J.G. 1999. *Production physiology and morphology of Populus species and their hybrids grown under short rotation.* III. Seasonal carbonall ocation patterns from branches. Canadian Journal o fForestry 1999., 29:1419-32

SENNERBY –FORSSE, L. – ZSUFFA, L. 1995. *Bud structure and sprouting in coppiced stools of Salix viminalis, S.eriocephala Michx. and S.amygdaloides Anders.* Trees . 9:224-234

SENNERBY-FORSSE, L. 1995. *Growth processes.* Biomass and Bioenergy. 9(1–5):35–43.

SHIPLEY, B. – KEDDY, P.A. 1988. *The relationship between relative growth rate and sensitivity to nutrient stress in twenty-eight species of emergent macrophytes.* J.Ecol., 76, 1101-1110

THARAKAN, P.J. – VOLK, T.A. – LINDSEY, C.A. – ABRAHAMSON, L.P. – WHITE E.H. 2005. *Evaluating the impact of three incentive programs on the economics of cofiring willow biomass with coal in New York State*., Energy Policy, 33, 337-347, http://www.sciencedirect.com/science/article/B6V2W-49S7Y5G-1/2/6e672e3e3f2a49820827672d74720dfe

THELEK, K. – GAO, J. – WITHERS, K – Everman, W. 2009. *Agronomics of production Switchgrass and Miscanthus × giganteus.* Bioeconference Growing the Bioeconomy: Solutions for Sustainability, December 1, 2009, Michigan State University.

WARING, R.H. – MCDONALD, A.J.S. – LARSSON, S. – ERICSSON, T. – WIREN, A. – ARWIDSSON, E. – ERICSSON, A. – LOHAMMAR, T. 1985. *Differences in chemical composition of plants grown at constant relative growth rates with stable mineral nutrition.* Oecologia 66, 1985, p. 157-160.

WOODWARD, F.I. 1983. *The significance of interspecific differences in specific leaf area to the growth of selected herbaceous species from different altitudes*. New Phytol., 95,313-323

7 Biotic interactions

7.1 Weed, pest and disease control of Salix

7.1.1 Weed control

Weeds, if not controlled, can at a higher abundance compete with the crop production for light, water and nutrients and thus reduce yields. According to "Guidelines for efficient biomass production with the safe application of waste water and sewage sludge" (Heinsoo *et al.*, 2008), the competition with weeds is a problem that affects the growth of fast growing woody crops during the first growing season and may result in lower increments, higher percentage of mortality and poor yields from the plantation during its lifetime (duration).

After the planting of cuttings until the canopy closure, it is necessary to implement a weed control the production plantations of the fast growing trees. Depending on location, we can start with mechanical control of weeds immediately after planting, because the weeds can be effectively eradicated in this period. Willows and poplars do not tolerate well a competition with weeds and even a low level of weed infestation causes their uneven growth and strongly influences the yields (Tubby and Armstrong, 2002).

According to Weger and Havlíčková (2002), the weed control should be carried out adequately to the state of the weed infestation in the plantation one to three times per year. The authors argue that the weed control is particularly important in terms of reducing the competitiveness of weeds. In the improperly maintained areas where the weed competition is high, it leads to a decrease of the increments and due to the competition in the root zone to a slowdown of the growth and eventually to a shift of the first harvest time by a few years.

Davies (1985) found that in the weedy stands, the growth of young trees planted on farmland was reduced as a result of competition for nutrients and water. The effect of weeds depends on age of the crop, a degree of the weed occurrence on the site and the diversity of the weed species. Like other crops, SRC are sensitive to a competition with common field weeds. Any yield loss of SRC caused by weed infestation is a very important factor. Parfitt *et al.* (1992) found in stands of willows and poplars 50 to 95% reduction in their growth under the influence of persistent (vigorous) weeds in the first year after planting. The competition with annual weeds is highest in the period from April to June. Therefore, the protection against weeds is necessary in the production of SRC.

According to Celjak (2010) the weed infestation, in combination with other adverse effects (drought, slow weed eradication), may result in the high losses in the first year, because in 2-4 weeks after planting, the weeds create a canopy closure over the sprouting shoots, which tend to decay. Shoots from the well-sprouting cuttings overgrow the weeds as late as in the summer months, when they reach to 50-80 cm.

Sage (1999) found that in the first year of SRC growth, tall weeds competing for light and space (compared to competing for water and nutrients) resulted in a growth of fewer and higher shoots, what ultimately meant the reduction of the biomass yields. However, in areas that were treated with herbicides in the first year, the following weed infestation in the second growing season did not affect the growth of shoots and no biomass losses were observed.

Weger (2009) states, that if the planting is realized by hand-planting, the weed eradication in the rows begins immediately after the substitution of the plants. During this period, the weeds can be controlled quite effectively even manually (hoe) without subsequent damage of the sprouting cuttings.

Chemical protection against weeds is used only in rare cases (on the areas with a strong weed infestation before the planting). According to Heinsoo *et al.* (2008), perennial weeds should be removed during the active growth before autumn tillage by glyphosate herbicide. Depending on the previous land use and the quality of management, the second application of the same herbicides is needed in a few weeks later. In the spring, an additional weed control should be carried out before planting by application of seed herbicides without additional tillage. After the occurrence of the first buds, it is recommended to use contact herbicides or mechanical weed control between inter-rows. The usage of biodegradable herbicides during the growing season is difficult due to greater sensitivity of willows to the glyphosate and/or its salts (Weger and Havlíčková 2002). The regulation of emerging weeds is difficult without the application of direct preparations. As recommended by several authors (Tubby, Armstrong 2002, Dawson 2007), the presence of grass in SRC stands is possible to control by the use of products with active ingredients cycloxidim, propaquizafop or fluazifop-p-butyl and weeds from the *Asteraceae* family by products with the active ingredient clopyralid. If the problems with weed infestation persist it is possible to apply glyphosate during the early spring period in the second growing season in case of the cutback of one-year-old shoots. If the weed control is successful during the first two growing season, the canopy closure of SRC will suppress light demanding weeds. After the harvest, the weed infestation is lower due to rapid growth of shoots and strong root system (Heinsoo *et al.,* 2008). In case of applying waste waters or sludge on the SRC stands it is necessary to increase a monitoring of the weed infestation because additional irrigation and nutrients intensify the growth of several weed species.

Weed eradication and soil aeration in SRC stands are very important. It is possible to use mechanism for gentler inter-row soil cultivation of agricultural land, for example weeder hoe or rotary cultivator. The most often used cultivation in rows is hand-hoeing or mowing around the planted cuttings (Čížek, 2006). These operations can be considered as ecologically most suitable because they have the lowest disturbing impact on emerging microclimate for organisms (particularly soil organisms) and provide conditions for the highest accumulation of the organic matter and nutrients in the soil (Weger, 2009). A probable lack of mechanization is one of the reasons of the insufficient maintenance of young SRC stands.

Mechanisms that are used for weed control in vegetable production can be used for tillage in the early phases of SRC growth. In later phases, this method can damage soft roots situated in depth of 100 mm. In this case, a milling machine can be used for the weed control. A special device containing a tank for glyphosate is used for contact weed control where hoses are placed in inter-rows.

Mechanical regulation or weed control is usually done by ploughing, mowing, hoeing (hand motor hoes) or by a cultivator. Weeds in inter-rows can be relatively easy removed by standard agricultural machinery. The space inside the double-rows (in double-row planting system) is relatively easy to maintain by a small motor hoe or cultivators.

Chemical plant protection with the active ingredient glyphosate is necessary to perform by the sprinklers with secured covers.

An appropriate measure in case of small plantations is mulching with mown plant biomass eventually with bark, which creates favourable moisture conditions in top soil and thus allow the stands of SRC to use a number of rapidly available nutrients (Weger and Havlíčková, 2002). Kratochvílová (2009) mentions a possibility of using biodegradable mulch sheets, particularly on lands where, due to operational and/or financial reasons, a precise and effective protection against weeds was not made on fertilized land, because the application of fertilizers in the first year stimulates the growth of weeds rather than SRC clones.

A number of weeds remain in the field throughout the whole period but without any impact on biomass production. At certain periods of year, the weeds may even help to maintain soil moisture and prevent soil erosion. Plant soil cover helps increase biodiversity, and therefore an excessive weed control is neither economically nor environmentally suitable.

On the research plantation in Kolíňany, we applied mechanical control of weeds by hand-hoeing in rows during the first year of planting. Weed control was provided five times during the growing period because the soil was not treated by contact herbicides before the planting of willows and due to a high air-raid of weed seeds from surrounding agricultural land during the growing period. The inter-rows were mowed by hand motor mower.

7.1.2 Pest and disease control

Willows (Salix spp.) are grown as a major crop in short rotation coppice (SRC) willow plantations for renewable energy because of their yield potential and coppicing ability.

When willows are cultivated in plantations, the ecological balance of habitat is changed and so different problems arise. During the second and third year of growth, plants are infected with fungal plant pathogens, dominant insect species become characteristic and form more or less stable complex of phytophagous pests in a plantation. It is necessary to study such changes in plantations in order to avoid the effect of monoculture (Noreika and Smaliukas, 2005). The objective of the present research was to identify the most important animal pests and fungal plant pathogens harmful to willows growing in south Slovak industrial plantations.

Fungal plant pathogens

During the period 2007-2009, leaf rust caused by *Melampsora* sp. a stem canker – *Cryptodiaporthe salicella* were the most important pathogens. This finding is in accordance with a report from Swedish conditions, where the field survey of natural fungal infections revealed several fungal genera on cancered willow stems, but many of these genera may have been secondary colonizers (Astrom and Ramstedt, 1994).

The most common symptom of the *C. salicella* infection is a bark necrosis, leading to dieback of young stems (Christersson *et al.* 1992). According to Astrom and Ramstedt (1994) cancer expansion is occurring mainly during August and September, with very little growth during the rest of the year. In Kolíňany (Slovakia), the stem cancer was first time observed in spring 2009, next year after the cutback of the two years old plantation. The focal spot was localized in the centre of variety Inger (3rd of four planted Swedish variety). This variety was the most severely attacked, some of the plants died out. The infection invaded also to the adjacent sides, to variety Sven on the left side and Tordis on the right one. The first symptoms of stem cancer in previous year were probably overlooked due to occupation of stems by the stem feeding aphids – *Tuberolachnus salignus*.

With favourable condition, in Sweden, *Cryptodiaporthe* could kill the main stem of fully grown willow of 6-7 m in height (Christersson *et al.* 1993). In Slovak conditions, the killed stems and whole plants were 3-4 m in height (Figure 7.1). No symptoms were found on GUDRUN and TORA onward to the right side of the plantation. EXPRESS and CSALA, planted in spring of the same year as *Cryptodiaporthe* stem cancer occurred, were symptomless.

Fig. 7.1 Biomass willows damaged by the fungus *Cryptodiaporthe salicella* (Photo: M. Tóthová)

Damage caused by *Cryptodiaporthe* was localized around the focal point of *Tuberolachnus* outbreak in previous year. The assumption of the possible impact of *Tuberolachnus* infestation on outbreak of *Cryptodiaporthe* stem canker comes from the observed changes in bark features at the feeding spots. However, not all of the varieties reacted equally.

One of the reason why *C. salicella* appears to be a greater problem in Sweden, than in other countries may be the use of clones selected for an extreme biomass production potential, which generally implies a long growth period, in combination with a comparatively severe climate, resulting in frequent frost injuries (Astrom and Ramstedt, 1994). According to our observations, *C. salicella* may present as serious problem in biomass willow plantations in Slovakia as in Sweden, especially in the case of variety INGER.

Cryptodiaporthe is a weak parasite (Butin 1960), usually attacking plants in a weakened condition e.g. plants of low bark turgour (Bier, 1959) or plants grown in frequent drought stress during a critical period before growth starts in spring (Astrom and Ramstedt, 1994). In our conditions, to all of these factors, which could potentially contribute to the infection outbreak, we can add one more – the severe outbreak of stem infestation (from August to October 2008) caused by the sap feeding aphid *Tuberolachnus salignus*.

Another predisponing factor may be a heavy infection by leaf rust (*Melampsora* sp.), which through defoliation, interferes with the winter hardening process and makes the plant more sensitive to frost damage (Astrom and Ramstedt, 1994).

In outdoor pot experiment cancers caused by *C. salicella* were considerable larger on *Salix viminalis* plants suffering from nitrogen deficiency than on plant receiving normal fertilization, however in the field condition it is unlikely that plant will suffer from such unbalanced nutrient supply. From a practical viewpoint, excessive amounts of nitrogen are more detrimental since the plants become more prone to frost damage and subsequently to cancer infection. Therefore the recommendation for the farmers should be to use moderate amount of nitrogen fertilizer and to select sites with low frost risk. Futhemore, the findings that several fungal isolates readily colonize newly cut stumps emphasizes that harvest of biomass willows should be carried out in sub-zero temperatures (Astrom and Ramstedt, 1994).

The next very serious disease in SRC plantations was rust caused by the fungus *Melampsora* (Figure 7.2). In most willows, rust only infects fully developed leaves. However, in some willows, such as *Salix viminalis* and *S. caprea*, rust also attacks stems and young leaves (Pei and Hunter 2000). Severe rust infection defoliates susceptible plantings prematurely, reduces yields by as much as 40% (Parker et al., 1995), and predisposes plants to infections by secondary pathogens which may lead to death of the plants. The impact of rust is likely to intensify if no control measures are undertaken (Pei and Hunter 2000).

Of the two rust species most common in SRC willow plantations *M. epitea* is more common than *M. capraearum* (Pei *et al*., 1993). Between late spring and autumn, the rusts are seen as yellow-orange pustules containing urediniospores. The urediniospores are producing the next generation of the same type of spores in 6-7 days. In the autumn, the rusts produce teliospores and overwinter on fallen willow leaves. In spring, the teliospores germinate to produce basidiospores that infect larch (*Larix decidua*), where the aeciospores capable infect only willows are forming (Pei and Hunter 2000). Stem infecting form is occurring on *S. viminalis* clones and has only a single spore stage (the urediniospore), which over winters on infected willow stems or buds, causing new infections early in the season (Pei *et al*., 1993). This form of infection was not observed in our experimental plantation.

Fig. 7.2 *Melampsora* rust on fully developed leaves of biomass willow (Photo: M. Tóthová)

SRC willow is a new crop and there are no long-established protocols for disease and pest control. Routine use of fungicide in SRC plantations is not practicable for economic, technical and environmental reasons. A more acceptable strategy of rust control in SRC plantations is the integrated utilisation of host resistance and natural processes that limit the damage by rust. Thus the integrated control of willow rust involves the breeding for resistant clones, planting host genotype mixtures and deployment of biological control agents (Pei and Hunter 2000).

As large scale monoculture plantings are known to be particularly vulnerable to pathogen attacks, one of the strategies to reduce the risk is to plant clone mixtures accepted for biomass production to increase genetic diversity.

Compared with annual crops, SRC is better suited for biocontrol because of the carry-over effect on biological control agents, assuming a 3-5 year harvest interval. *Sphaerellopsis filum* is a fungal hyperparasite that attacks a wide range of rust fungi, including willow *Melampsora* spp. Under experimental conditions, the hyperparasite can reduce willow rust spore production by up to 98%.

As European larch serves as an alternate host of willow rust, planting SRC willows near larch will cause early disease onset and more severe infection. Therefore, willow plantings should be sited as far away from larch plantations as practicable to delay the onset and reduce rust severity.

Insect pests

Aphids

From among insect pests, the big attention was paid to the stem-feeding aphid species forming colonies on the trunk or branches, not on the leaves. During the period 2007-2009 three stem-feeding aphid species were identified on Swedish varieties - *Tuberolachnus salignus*, *Plocamaphis americanae* and *Pterocomma* sp. (Figure 7.3 – 7.5). *Plocamaphis* and *Pterocomma* have occurred sporadically and in very low population densities. The most abundant and probably the most damaging species was *Tuberolachnus salignus*, which was first observed by the first week of August 2008 and 2010.

Fig. 7.3 Stem feeding aphid *Tuberolachnus salignus* forming colonies on the trunk of biomass willow (Photo: M. Tóthová)

Fig. 7.4 Stem feeding aphid *Plocamaphis americanae* forming colonies on the trunk of biomass willow (Photo: M. Tóthová)

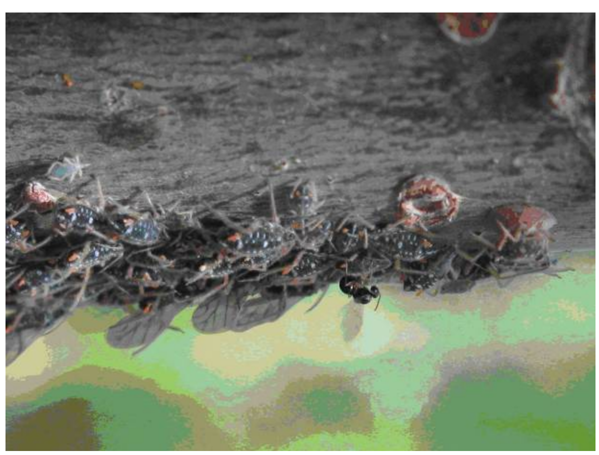


Fig. 7.5 Stem feeding aphid *Pterocomma sp.* forming colonies on the trunk of biomass willow (Photo: M. Tóthová)

Tuberolachnus is one of the largest (5 mm) and longest-lived aphids ever recorded (Blackmann and Eastop, 1994, Collins *et al.* 2001). It is regarded as economically important pest of short rotation coppice willow, on which it can cover more than 50% of 1-3 year old stem surface of infested trees (Collins and Leather, 2001). It is almost cosmopolitan species (Blackmann and Eastop, 2004) and is present also in Slovakia.

In 2008, the focal spot of *Tuberolachnus* outbreak was localized at the same place as the outbreak of *Cryptodiaporthe* in the following spring - in the 2^{nd} – 3^{rd} (of 4) replication of INGER (Swedish variety). This variety was the most severely attacked also by aphid by the second week of August 2008. Gradually they spread to the left side of the plantation (Sven) and to the right side (TORDIS, GUDRUN, TORA). However, GUDRUN was the last variety attacked by aphids. The aphids were probably spreading to GUDRUN from adjacent varieties TORDIS and TORA. By the beginning of October the whole willow stand - each Swedish variety was equally infested by the aphids: in the mid-area, as well as in the edge. From mid November their population declined, but probably by December many died and remained sticked to the stems until late spring. In Turkey and United Kingdom the aphids has been recorded on trees from august to early March and then disappeared (Collins and Leather, 2001).

Different situation was observed in 2010, when *Tuberolachnus salignus* colonies were observed only on the stems of TORA and GUDRUN localized at the edge of the plantation. Moreover, they did not spread inward to the plantation and other willow varieties due to severe epizootics of *Neozygites turginata* (Zygomycetes: Entomophtorales) in *Tuberolachnus salignus* populations (Figure 7.6). The infested aphids were hanging on their proboscis from the branches. After some time, aphid cadavers dried up, felt down to the soil or they liquified. The resting spore mass spread out on a bark of the trees and they could be found on the trees even afte one year (Barta and Cagáň, 2006).

Fig. 7.6 *Tuberolachnus salignus* infested by entomopathogenic fungi Neozygites turbinata are hanging on their proboscis from the branches

Fungi of the order Entomophtorales (Zygomycota, Zygomycetes) are considered as a major pathogenic group of sap sucking aphids (Latgé and Papierok 1988) and have a high capacity for use in biological control. The most noteworthy characteristics favouring their use in biological control are the great capacity for multiplication and expansion in the host population (Latgé *et al*. 1983). This species has no known parasitoids in Europe (Blackman and Spence, 1996), but in Kolíňany predation by lady bird adults and larvae had been observed.

Similarly, as in the case of biomass willow diseases, control of aphids with insecticides is questionable and not practicable. The inclusion of relatively resistant host clones in a mixed planting scheme has the potential to reduce the impact of *T. salignus* on the host trees in several ways. In the short term, aphids on resistant hosts will have lower population growth rates, while the intergenerational effect of maternal and/or early larval nutrition reduces the fecundity of those that disperse from poor quality to good quality hosts. In the longer terms, variation in resistance (and, ideally, variation in resistance mechanisms) will reduce the strength of selection for increased virulence on a given host (Collins *et al.* 2001). Meantime, any list of resistant cultivars does not exist. One of the reasons is a constant breeding of new cultivars. In the study carried out by Collins *et al*. (2001) willow clone Q83 (*S. triandra* x *S. viminalis*) proved to be the poorest quality food plant for the *Tuberolachnus salignus* clone used in the laboratory experiment. In the field, cultivar Orm (*S. viminalis*) had the lowest level of infestation. Unfortunately, clone Q83 was not selected for census in field conditions.

Coleopteran pests

Phratora vitellinae (L.) together with *P. vulgatissima* (L.) and *Plagiodera versicolora* (Laich.) (Coleoptera, Chrysomelinae) belong to the most abundant and most harmful mainly blue or green coloured chrysomelids on tree species from the family Salicaceae. In Czech Republic under favourable conditions, they reproduce often on a mass scale and then heavily damages particularly young trees. Temperate and dry winters and excessively dry and warm springs participate in their activation (Urban 2006).

Both, adults and larvae feed on plants. Larvae feed on the underside (*Phratora* spp.) or both side (*Plagiodera* sp.) of the leaves, leaving a thin layer of upper (lower) epidermis untouched. Adults feed through the leaves creating holes.

According the study carried out in Sweden, high defoliation caused by adults and larvae of *Phratora vulgatissima* reduced the stem wood production by 32 and 39% in two years respectively. The medium level defoliation reduced the stem wood production by 16% in one year. In the other year, the stem wood production did not differ significantly from stools exposed to low defoliation; i. e. there was full compensatory growth (Böjrkman *et al.* 2000)

However the species composition from sweep net collections in Koliňany was not identified (Figure 7.7), from the plant visual inspection it is obvious, that the severe leaf damage has not occurred. In Slovakia, except of the above mentioned chrysomelid species, round holes (Figure 7.8) in the *Salix* sp. leaves were caused also by Alticinae flea beetles. Čížek (2006) in his work listed seven species - *Crepidodera aurea, C. fulvicornis, C. aurata, C. plutus, C. nitidula, Chaetocnema semicoerulea* and *Altica tamaricina.* The last three mentioned species are considered as rare.

A recent study has shown that the inclusion of a less preferred willow variety in a willow plantation affects the distribution pattern of *P. vulgatissima* and delays the beetles colonization and expansion on favourable varieties (Peacock *et al.* 1999).An option for pest management is a mixture of five willow varieties, at least one of which has low susceptibility to the willow beetle, grown in a random planting of varieties. The choice of variety is important, especially the susceptibility to the rust disease, as are physiological interactions between varieties that might affect beetle ecology (Peacock and Herrick 2000).

Fig. 7.7 Skeletonized leaf by unidentified larvae of chrysomelid beetle (Photo: M. Tothová)

Fig. 7.8 Round holes in the biomass willow leaves caused by chrysomelid species (Photo: M. Tóthová)

7.2 Weed, pest and disease control of Miscanthus

Successful *Miscanthus* crops require careful management of weed control, particularly during the first two years of crop establishment, but few diseases or pests have been found in European crops to date (McKervey *et al*., 2008). Cultivation operations including plowing, planting, and chemical applications all constitute energy inputs and fuel crops need therefore to have a form and life cycle that would minimize the need for these operations (Heaton *et al*., 2003).

7.2.1 Weed control

Miscanthus has low competitiveness during the first months after planting (Christian, 1994; Himken *et al*., 1997, Figure 7.9). Main weeds within miscanthus plantation are common couch and annual meadow-grass and broad-leaved weeds with early season vigour (MAFF, 2001). Weeds compete with the crop for light, water and nutrients and can reduce yields. Weed control in the establishment phase of the crop is essential, because poor control can severely check the development of the crop. It is vital that proposed sites should be cleared of perennial weeds before any planting takes place.

Fig. 7.9 Weed invasion during the first year after planting (Serbia, 2010)

Following the establishment year, a spring application of a broad-spectrum herbicide may be needed to control grass weeds. Once the crop is mature (i.e. from the summer of the second or third year, depending on site and climate), weed interference is effectively suppressed. Weeds that do survive offer little competition to the crop.

Herbicides such as those suitable for use on maize can be recommended for weed control in *Miscanthus* (Table 7.1, Serafin and Ammon, 1995). Following successful establishment of the crop, the necessity for further weed control is significantly reduced in subsequent years (Thiemann, 1995). Having in mind that pesticide application is not necessary every year, Christian *et al*. (2008) consider this crop as low-demanding (with low inputs requirements) and high sustainable for 14 years period.

Clapham and Slater (2008) recorded 31 weed species within miscanthus plantation, and the most frequent were: *Epilobium montanum, Rumex obtusifolium* and *Ranunculus repens.* Glyphosate and Paraquat can be applied during winter time, between harvest and spring growth, but some damages could appear on new aboveground parts of plants (MAFF, 2001). Herbicide application must not be made on miscanthus crops greater than one meter in height and the crop cannot subsequently be used for food or feed.

Table 7.1 Herbicides used successfully for weed control in *Miscanthus*

[1] (A) ADAS (B) Georg Noyé Institute of Weed Control 'Flakkebjerg' Denmark

No	Active ingredient	Reference[1]	Herbicide	Application rate l/ha
1.	Atrazine	A	Gesaprim	2.5
2.	Bromoxynil/ioxynil	A	Briotril	2.5
3.	Bromoxynil/fluroxypyr/ioxynil	A	Advance	2.5
4.	Clopyralid	A, B	Dow Shield	2.4
5.	Dichlorprop	B	(667 g/l of active ingredient)	5.0
6.	Diflufenican/isoproturon	B	(100:500g/l of active ingredient)	3.0
7.	Fluroxypyr	A, B	Starane 2	2.0
8.	Glyphosphate	A, B	Roundup	3.2
9.	Isoproturon	B	Tolkan	4.0
10.	Metsulfuron-methyl	A, B	Ally	30 g/ha
11.	Metsulfuron-methyl + bromoxynil/ ioxynil	A	Ally + Deloxil	30g/ha + 1 l/ha
12.	Metsulfuronmethyl+ fluroxypyr	A	Ally + Starane 2	20g/ha + 0.5 l/ha
13.	MCPA	B	(750g/l of active ingredient)	5.0
14.	MCPA + MCPB	A	Trifolex-Tra	7.7
15.	Mecoprop-P	B	Duplosan	6.0
16.	Paraquat 2	A	Gramoxone	4.0

Miscanthus from the sample plots in Serbia has been treated with the mixture of Calysto (Syngenta, 480 g/L mesotrione) 150 mL + Harmony 75 WG (Du Pont, Dipkon) 2,5 g + Atplus (wetting agent) 0,5 L + Trend (wetting agent) 150 mL, during the first year after planting (Dzeletovic, 2010). Almost immediate implications on weed reduction were recorded and further development of weed has been stopped.

No chemical application for weed control was performed in following years of miscanthus cultivation (Figure 7.10), because appearance of weed has no influence on crop development and increament (Drazic *et al*., 2010). On the other hand, mechanical methods of weeding (e.g., hacking, harrowing) can be very effective, firstly for accessibility and maintenance of field research.

Fig. 7.10 Weed appearance within two-year old miscanthus plantation (Serbia, 2011)

7.2.2 Pest and disease control

Miscanthus species are susceptible to pests and diseases in the areas to which they are native (Asia) but, as yet, none of these has been reported in Europe (MAFF, 2001; Lewandowski *et al*., 2003). Trials with *Miscanthus* in Europe have not displayed any major problems with disease, but this may be due to the fact that it is still a relatively recently introduced crop. However, several researchers have reported the susceptibility of *Miscanthus* to common crop diseases such as *Fusarium*, Barley Yellow Dwarf Virus (BYDV) and *Leptosphaeria sp* (*Miscanthus* blight) (Thinggaard, 1997; Christian *et al*., 1994; O'Neill and Farr, 1996, Figure 7.11). BYDV causes chlorosis, stem stunting and reddening of the lower leaves (Huggett *et al.*, 1999). Since *M. giganteus* is extensively reproduced by rhizome propagation, if the parent stock was infected with the virus, this could potentially affect subsequent stock and pose a significant threat to the increased establishment of *Miscanthus.*

No disease symptom appearance has been detected and recorded within the field trials of miscanthus in Serbia. Phytopathological inspections are very often in all field trials.

There are no reported insect pests in Europe that have significantly affected the production of miscanthus. However, two 'ley pests', the common rustic moth and ghost moth larvae feed on miscanthus and may cause problems in the future. As *Miscanthus* is a long term energy crop, it can remain *in situ* for >10-15 years and it has the potential to act as an intermediate host for the aphids between their infestation of summer wheat and barley crops and subsequent infection of winter grasses and cereals.

However, no insect attack is recorded within the field trials in Serbia until now, as well as no damage from wild animals feeding or sheltering.

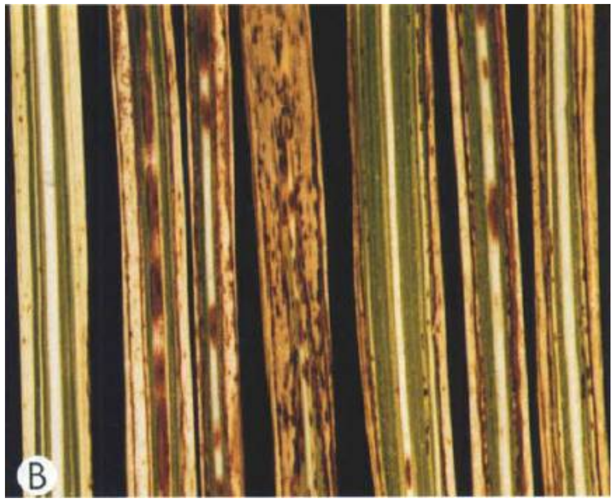


Fig 7.11 *Miscanthus* blight symptoms from the field experiment (O`Neill and Farr, 1996)

References

ASTROM, B. – RAMSTEDT, M. 1994. *Stem canker on Swedish biomass willows caused by Cryptodiaporthe salicella and other fungi*. In European Journal of Forest Pathology, Vol. 24, 1994, p. 264-276.

BARTA, M. – CAGÁŇ, Ľ. 2006. *Aphid pathogenic Entomophtorales*. Their taxonomy, biology and ecology. In Biology (Bratislava), Vol. 61, 2006, Supl. 21, p. 543-616.

BIER, J.E. 1959. *The relation of bark moisture to the development of cancer diseases caused by native facultative parasites. I.* Cryptodiaporthe cancer on willows. In Canadian Journal of Botany, Vol. 37, 1959, p. 229-238.

BLACKMAN, R.L. – EASTOP, V.F. 1994. *Aphids on the world´s trees: an identification and information guide*. London : CAB International, 1994. 986 pp. ISBN 0851988776.

BÖJRKMAN, CH. – HÖGLUND, S. – EKLUND, K. – LARSSON, S. 2000. *Effects of leaf beetle damage on stem wood production in coppicing willow*. In Agricultural and Forest Entomology, Vol. 2, 2000, No. 2. p. 131–139.

BUTIN, H. 1960. *Die Krankheiten der Weide und deren Erreger.* In Mitteilungen aus der Biologischen Bundesanstalt für Land- und Forstwirtschaft, Heft 98. 46 p.

CELJAK, I. 2010. *Pěstování topolů pro energetické účely – 2.* Biom.cz [online]. 2010-08-30 Dostupné z www: <http://biom.cz/cz/odborne-clanky/pestovani-topolu-pro-energeticke-ucely-2>. ISSN: 1801-2655.

CLAPHAM, SJ.-SLATER, FM. 2008. *The biodiversity of established biomass grass crops*. Aspects of Applied Biology, Vol. 90: *Biomass and energy crops III* (Eds: E. Booth, M. Green, A. Karp, I. Shield, D. Stock and D. Turley, AAB conference, 10-12 December 2008., Sand Hutton, UK), p. 325-329.

COLLINS, C.M. – FELLOWES, M.D.E. – SAGE, R.B. – LEATHER, S.R. 2001. *Host selection and performance of the giant willow aphid, Tuberolachnus salignus Gmelin – implication for pest management*. In Agricultural and Forest Entomology, 2001, No. 3, p. 183-189.
COLLINS, C.M. – LEATHER, S.R. 2001. *Effect of temperature on fecundity and development of giant willow aphid, Tuberolachnus salignus (Sterrnorhyncha: Aphididae).* In European Journal of Entomology, Vol. 98, 2001, p. 177-182.
ČÍŽEK, P. 2006. *Dřepčíci* (Coleoptera: Chrysomelidae: Alticinae). Nové Město nad Metují : Městské Muzeum Nové Město nad Metují, 2006. 76 p. ISBN 80-239-6406-2.
ČÍŽEK, V. 2007. *Základní předpoklady pro zakládání plantáží a pěstování rychle rostoucích dřevin v podmínkách ČR.* In. Expertní studie k projektu BRIE – Regionální trh s biomasou 2007. Valašské Meziříčí, 2007, s. 39.
DAVIES R. J. 1985. *The importance of weed control and the use of tree shelters for establishing broadleaved trees on grass-dominated sites in England*. In *Forestry*, 58, 1985 p. 167-180.
DAWSON, W. M. 2007. *Short rotation coppice willow best practice guidelines.* Renew Project Belfast, N. Ireland, 50 pp.
DRAŽIĆ, G., MILOVANOVIĆ, J., IKANOVIĆ, J., GLAMOČLIJA, Đ. 2010. *Uticaj agroekoloških činilaca na produkciju biomase miskantusa (Mischanthus giganteus)*. Arhiv za poljoprivredne nauke. Sveska 63. Vol. 71 (253), 2010, p. 81-85.
DZELETOVIC, Z. 2010. *Uticaj azota i gustine zasada na morfološke osobine i prinos biomase vrste Miscanthus x giganteus Greef et Deu*. Doktorska disertacija, Poljoprivredni fakultet Beograd, 2010, 122 p.
HEATON, E.A.-CLIFTON-BROWN, J.-VOIGT, T.B.-JONES, M.B.-LONG, S.P. 2004. *Miscanthus for renewable energy generation: European Union experience and projections for Illinois***.** In Mitigation and Adaptation Strategies for Global Change, 9 (4), 2004, p. 433-451.
HEINSOO, K. et al. 2008. Guidelines for efficient biomass production with the safe application of waste water and sewage sludge. Ulster Farmers Union, pp.155. [online] < http://www.biopros.info/fileadmin/user_upload/WP_05/Task_5_1_1-Guidelines >
HIMKEN, M.-LAMMEL, J.-NEUKIRCHEN, D.-CZYPIONKA-KRAUSE, U.-OLFS, H-W. 1997. *Cultivation of Miscanthus under West European conditions: Seasonal changes in dry matter production, nutrient uptake and remobilization*. In Plant and Soil, Vol. 189 (1), 1997, p. 117-126.
HUGGETT, DAJ.-LEATHER, SR.-WALTERS, KFA. 1999. *Suitability of the biomass crop Miscanthus sinensis as a host for the aphids Rhopalosiphum padi (L.) and Rhopalosiphum maidis (F.), and its susceptibility to the plant luteovirus Barley Yellow Dwarf Virus*. In Agricultural and Forest Entomology, Vol. 1 (2), 1999, p. 143–149.
CHRISTERSSON, L. – RAMSTEDT, M. - FORSBERG, J. 1992. *Pest, diseases and injuries in intensive short rotation forestry*. In Mitchell C. P., Ford-Robertson J. B., Hinckley T., Sennerby-Forsee, L. (eds.) Ecophysiology of short rotation forest crops. London : Elsevier, 1992. p. 185-215.

CHRISTIAN, D.G. - LAMPTY, J.N.L.- FORDE, S.M.D.- PLUMB, R.T. 1994. *First report of barley yellow dwarf luteovirus on Miscanthus in the United Kingdom*. In European Journal of Plant Pathology, Vol. 100 (2), 1994, p. 167-170.

CHRISTIAN, D.G. 1994. *Quantifying the yield of perennial grasses grown as a biofuel for energy generation*. In Renewable Energy, Vol. 5 (5-8), 1994, p. 762-766.

CHRISTIAN, DG.-RICHE, AB.-YATES, NE. 2008. *Growth, yield and mineral content of Miscanthus × giganteus grown as a biofuel for 14 successive harvests*. In Industrial Crops and Products, Vol. 28 (1), 2008, p. 320-327.

KRATOCHVÍLOVÁ, Z. 2009. Rychle rostoucí dřeviny (vrby a topoly) pěstované s použitím mulčovací folie. *Biom.cz* [online]. 2009-07-06 [cit. 2011-09-27]. http://biom.cz/cz/odborne-clanky/rychle-rostouci-dreviny-vrby-a-topoy-pestovano-s-pouzitim-mucovaci-folie ISSN 1801-2655.

LATGÉ, J. – SILVIE, P. P. – PAPIEROK, B. – REMAUDIERE, G. – DEDRYVER, C.A. – RABASSE, J. M. 1983. *Advantages and disadvantages of Conidiobolus obscures and of Erynia neoaphidis in the biological control of aphids*. In Cavalloro, R. (ed), Aphid Antagonists. Rotterdam : Balkema, 1983. pp. 20-32.

LATGÉ, J. P. – PAPIEROK, B. 1988. *Aphid pathogens*. In Minks, A.K. and Harrevijn, P. (eds.) Aphids. Their biology, natural enemies and control. Amsterdam : Elsevier, 1988, Vol. 2B. p. 323-335.

LEWANDOWSKI, I.-SCURLOCK, JMO.-LINDVALL, E.-CHRISTOU, M. 2003. *The development and current status of perennial rhizomatous grasses as energy crops in the US and Europe*. In Biomass and Bioenergy, Vol. 25 (4), 2003, p. 335-361.

McKERVEY, Z., WOODS, V.B., AND EASSON, D.L. 2008. *Miscanthus as an energy crop and its potential for Northern Ireland: A review of current knowledge*. Agri-food and Biosciences Institute, Global Research Unit, Occasional Paper No. 8.

MINISTRY OF AGRICULTURE, FORESTRY AND FISHERIES – MAFF. 2001. *Planting and Growing Miscanthus – Best Practice Guidelines*, DEFRA Publications, PB No. 5424, London, 20 p.

NOREIKA, R. – SMALIUKAS, R. 2005. *Phytophagous insects – pest of industrial plantations of willows Salix L. (Salicacea) in Lithuania*. In Ekologija, 2005, No. 2, p. 11-14.

O'NEILL, NR.-FARR, DF. 1996. *Miscanthus blight, a new foliar disease of ornamental grasses and sugarcane incited by Leptosphaeria sp. and its anamorphic state Stagonosphora sp*. In Plant Disease, Vol. 80 (9), 1996, p. 980-987.

PARFITT, R.I. et al. 1992. *Weed control in new plantations of short-rotation willow and poplar coppice*. In Aspects of Applied Biology, 29, 1992, p. 419-424.

PARKER, S.R. – PEI, M.H. – ROYLE, D.J. – HUNTER, T. – WHELAN, M.J. 1995. *Epidemiology, population dynamics and management of rust diseases in willow energy plantations : Final Report of Project ETSU B/W6/00214/REP*. Energy Technology Support Group, Department of Trade and Industry, UK.

PEACOCK, L. – HERRICK, S. – BRAIN, P. 1999. *Spatio-tem- poral dynamics of willow beetle (Phratora vulgatissima) in short-rotation coppice willows grown as monocul- tures or a genetically diverse mixture.* In Agricultural and Forest Entomology, Vol.1, 1999, No. 4, 287-296.

PEACOCK, L. – HERRICK, S. 2000. *Responses of the willow beetle Phratora vulgatissima to genetically and spatially diverse Salix spp. Plantations.* In Journal of Applied Ecology, Vol. 37, 2000, No. 5, p. 821-831.

PEI, M.H. – HUNTER, T. 2000. *Integrated control of willow rust in renewable energy plantations in the UK*. In Pesticide Outlook, Vol. 11, 2000, No. 4. p. 145-148.

PEI, M.H. – ROYLE, D.J. – HUNTER, T. 1993. *Identity and host alternation of some willow rusts (Melampsora spp.) in England.* In Mycological Research, Vol. 97, 1993, No. 7. p. 845–851.

SAGE R.B. 1999. Weed competition in willow coppice crops: the cause and extent of yield losses. In *Weed Research*, 39, 1999, p. 399–411.

SERAFIN, F.-AMMON, HU. 1995. *Unkrautbekämpfung in Chinaschilf*. Die Grüne, Vol. 6 (1), 1995, p. 18-19.

THIEMANN, R. 1995. *Produktionstechnik von Miscanthus*. In: *Symposium Miscanthus - Biomassebereitstellung, energetische und stoffliche Nutzung., Schriftenreihe "Nachwachsende Rohstoffe"*. Münster, Germany: Landwirtschaftsverlag, Vol. 4, 1995, p. 103-112.

THINGGAARD, K. 1997. *Study of the role of Fusarium in the field establishment problem of Miscanthus*. Acta Agriculturae Scandinavica*, Section B, Soil and Plant Science,* Vol. 47 (4), 1997, p. 238-241.

TUBBY, I. – ARMSTRONG, A. 2002. *Establishment and management of short rotation coppice*. Practice note. Forestry commission Crown Copyright, p.12. ISSN 1460-3810.

URBAN, J. 2006. *Occurrence, development and economic importance of Phratora (= Phyllodecta) vitellinae (L.) (Coleoptera, Chrysomelidae).* In Journal of Forest Science, Vol. 52, 2006, No. 8, p. 357–385.

WEGER, J. 2009. *Topoly a vrby k energetickému užití*. Biom.cz [online]. 2009-08-10 [online] <http://biom.cz/cz/odborne-clanky/topoly-a-vby-k-energetickemu-uziti>. ISSN: 1801-2655.

WEGER, J. – HAVLÍČKOVÁ, K. 2002. *Pěstování rychle rostoucích dřevin*. In *Agro magazín*, č. 2, 2002, p. 41-43.

8 Harvest and post-harvest treatments

8.1 Genus Salix

Production performance of plant species depends on the biological characteristics and environmental conditions. Primary factors influencing the process of photosynthesis (the basic process in which organic matter is produced) are sunlight and temperature. In the case of trees used for energy purposes, the biological yield (BY) is represented by the above-ground woody stems (cca 60%), leaf apparatus (cca 10%) and root system (cca 30%).

Leaves and fine root system (including root hairs) are recycled in one year cycle. In the case of fast-growing willows, the yield is expressed in tonnes of dry matter (DM) per hectare per year.

To optimize the amount of biological yield of the tree crown (crop canopy) it is needed to reach its maximum value as soon as possible and keep it as long as possible during the growing period. It would ensure an efficient capture of solar energy, and thus the realization of the yield potential. Canopy closure or complete site capture is usually achieved in the second year in suitable sites and/or in the third year in poorer locations resulting in a yield reduction (Dawson, 2007).

Harvesting is carried out in a three-year cycle. Yields above 30 t DM / ha / year have been achieved in the case of nutrition and water additions. Such yield is considered to be the theoretical maximum and not a commercial reality.

In the case of the use of bred varieties and in very suitable sites, it is expected to obtain a sustainable yield of 10-12 t DM / ha / year. If any of the abiotic factors is poorer (soil, food, lighting, water availability), the yield will be smaller.

Yields from the first production cycle are lower than yields in subsequent cycles because the full use of area (complete site capture) is achieved only in the second year of the first production cycle. The yield also depends on the microclimate conditions in individual years (and/or production cycles).

Plantations of fast growing trees are harvested in a 3 to 6 years long cycle in our conditions. This means that during the whole period of the plantation existence, which is 19 to 25 years, it is possible to made 6 to 8 harvests in the three-year cycle. New highly productive willows are harvested in a two-year cycle. According to the experience from abroad it is not recommended to harvest in shorter intervals because there is a decrease of the total yields during the existence of the plantation. Around the age of 15 to 25 years when the yields of the plantation begin to drop below the economic profitability, the plantation should be removed.

Heinsoo *et al*. (2008) state that the essential parameter for the harvest is the diameter of shoots, as the efficient harvesters are able to cut up to 8 cm thick shoots. The harvest should be carried out in the period from October to March after the fall of leaves and before the bud opening. In this period, the trees are in the dormancy phase and nutrients are accumulated in the underground

parts and the water content is the lowest (approx. 50%). Late harvest is not recommended because it could damage the crops, due to the allocation of nutrients from the underground parts to the stems, which would caused an unnecessary loss of energy and thus slow down the deployment of new shoots and reduced competitiveness against weeds (Anonymous, 2006).
The essential criteria for selecting the appropriate harvest time, machinery and harvest methods are following (Heinsoo *et al*. 2008):

- shoot diameter up to 8 cm (depending on the machinery),
- suitable period for harvesting – the winter season from November to March (during this period the biomass has the lowest moisture content, the soil is frozen and it is a so called deaf period in crop production allowing the use of free labour and machinery),
- the minimum water content of biomass (approx. 50%),
- soil compaction hazard (on wet soils),
- suitable drying method,
- requirements of customers for productivity and quality.

According to Wickham *et al* (2010), the most frequently used harvesting systems in practice are the following:

1. **Harvest and chipping.** This is an operation, in which adjusted forage harvesters are used with immediate transport of the woody biomass to the end user or to a drying chamber with ventilation. The end product is woodchip of the size up to 5 x 5 x 5 cm (the size may be different depending on customer requirements and the mechanization used). In case the woodchip size and quality is important, it is recommended to chip the raw material. The raw woodchip must be dried immediately after the harvest. The disadvantage of the raw woodchip is that during the storage its temperature increases up to 60 ° C in 24 hours, which leads to its biodegradation. It reduces the calorific value of the woodchip (energy value reduction of up to 30%). Overgrowth of bacteria and microscopic fungi during the decomposition represents a health risk (DEFRA, 2004). Drying of woodchip to the humidity of 35% (or less) takes from 6 to 8 weeks in proper storage and air circulation. Most of the machinery created for the direct-chip harvest is designed for harvesting of twin-rows in one sequence. Modified harvesting heads mounted on standard forage harvesters are a necessity. The harvesters cut the standing crops, then chip them and blow the chips into to the trailer of the accompanying mechanization, which transports the woodchip from the plantation. In the medium and small production, the conventional types of silage machinery can be used to transport the woodchip from the plantation to the place of drying and storage, and later to the final user. If the woodchip is made from the fresh biomass its quality is maximized and the requirements on the machinery performance are minimized.

Direct chipping is the most efficient harvesting operation, but requires satisfactory and adequate equipment for drying, in order to prevent a natural decomposition, which is similar to composting. This would lead to deterioration of the woodchip and losses of energy value. The woodchip can be dried by the same technique, which is used for drying of cereal grain (it is

favourable to schedule the harvest of the fast-growing crops and subsequent drying of the woodchip for the period when grain drying is over, which allows further use of this expensive technology).
Harvesting capacity of such harvesting machinery used for cutting and direct chipping is 5-6 ha per day.

Fig. 8.1 Direct-chip harvesting and Harvested woodchip (photo DEFRA, 2004)

2. **Cutting of the whole shoots** immediately during their harvest to 5-20 cm long logs with subsequent transport to the storage with drying equipment or to the end user. In the case of storage, the empty spaces among the logs allow more intensive natural air circulation and thus better drying compared with the woodchip (the product dries naturally). Biodegradation of the organic matter is not as intense as in the woodchip.
The harvesters have been developed from the machinery, which is used to harvest sugar cane. The product is blown from the harvester by a stream of air into the trailer of the accompanying mechanization. Before using, the logs are chipped in order to maximize combustion/heating efficiency, but unlike the whole shoots it is easier to handle them. The quality of the woodchip from logs may be lower, because the logs are relatively dry when chipped (with the humidity of 30%).
3. **Cutting of the whole shoots**, eventually their tying into bundles by special harvesters with subsequent transport of the biomass to a place of drying and then chipping (it is possible to chip the whole shoots in fresh as well as dried state) and transportation to the end-user after the drying. The whole shoots may reach a length up to 8 m at harvest. A modification is to cut the shoots into 2.5 m long parts, which makes the handling and transport easier.
The result of the work of the harvesters is individual entire shoots, which are then collected and transported to a storage place. The manipulation with individual shoots 6-8 m long, or bundles of the long shoots is difficult.
The whole cut shoots and/or shoots cut to desired length are kept directly in the plantation or they are piled in an elevated landing where they dry if there is a sufficient air movement (unlike

the production of chips, there is no need for any special drying equipment). A modification is the transport of whole shoots (and/or shortened shoots) to a drying place and further processing (chipping). In the conditions of Ireland, the shoots are left to dry up until the early spring and during the 8-12 weeks the moisture content is reduced to about 30%. The harvest of the whole shoots is relatively simple. A certain disadvantage is the loss of biomass of the whole shoots when they are left on the place of the harvest or piled on a landing and the need of chipping the shoots before their use (Wickham *et al.,* 2010).

During the harvest time, the moisture content of willow biomass range from 45 to 60%, which is more than is desirable, therefore the shoots must be kept drying for 3-4 months until the moisture content is 30% (DEFRA, 2004).

Spinelli and Kofman (1996) identify four main operations in SRC harvesting: cutting, collection, extraction and chipping. The main functional differences among harvester types are the number and type of operations that they can perform. In order of growing degree of integration, the following functional types can be described:

- Cut-only harvester. The harvester cuts the stems and lays them in windrows or heaps. The cut stems are then collected by a separate unit, which delivers them to a chipper. As an alternative a chip forwarder can be used to collect, chip and extract in one pass.
- Cut-and-bundle harvester. The harvester cuts the stems and collects them in bundles. Bundles are dropped on the field like hay bales. They are later collected by a separate unit, most often a conventional forwarder or a farm tractor with forestry trailer.
- Cut-and-extract harvester. The harvester cuts the stems, collects and loads them over a deck of some sort. It then takes its load to the field edge or to any suitable landing. Chipping is the only operation delegated to a separate unit.
- Cut-and-chip harvester. The harvester cuts, collects and comminutes the crop, delivering the chip to the field edge. In alternative, the extraction can be delegated to chip shuttles, to keep the harvester going. Chip shuttling is preferably used when the extraction distance is large.

Post-harvest treatment of the site

After the termination of the plantation, the area may be turned to grassland or recultivated to arable land (Dawson, 2007). The soil condition after the long-term (15-25 year) of SRC growing depends on several factors, the most important of which are soil fertility and cultivation methods. The decisive factor may also be the fertilization of SRC plantations (Weger, 2003).

After the final harvest, it is recommended to allow the growth of new shoots up to 30-50 cm (mid-May). Willow is extremely sensitive to herbicides and their application (eg. 5 l/ha of glyphosate) will kill all the stools. Herbicides should be left to act at least for 2 weeks to allow the full penetration and translocation of the herbicide.

A heavy sub-soiler or forestry mulcher will transform the shoots and the soil surface layer into a form of shallow top soil where a grass can be sown. Such soil recultivation retains most of the

root system in the place and do not cause any damage to the soil structure. It is known that in many water logged locations the root system of fast-growing plants improves soil structure and its mechanical removal would cause a significant damage.
Restoration of the grassland lasts one season. Restoration of the arable land takes a longer period (Dawson, 2007).
Weger (2003) states that in Austria, lower parts of stems (shoots) or parts of the SRC root system are removed by special cutters after the final harvest. The remaining roots are then removed by a deep tillage or sub-soiler. The root residues serve in the soil as drainage and help to aerate deeper soil layers. If the soil conditions (physical properties, humus condition) after the removal of the productive plantation, are good or better than it was before the establishment of the plantation, the area can be sown by a target crop in the spring. If the soil nutrient balance is disturbed, it is recommended (based on the soil analysis) to use fertilizers or meliorate it biologically {eg. clover, clover-grass mix).

8.2 Genus Miscanthus

Miscanthus giganteus (*Miscanthus×giganteus* Greef et Deu.) is a multi-year crop used for biomass production with a specific way of cultivation and is used as an energetic raw material (i.e. bioenergetic crop) for burning in incinerator utilities.
Every year when soil temperature reaches 10-12°C Miscanthus giganteus produces new upper part of a plant from a dormant winter rhizome. It sprouts during April with upper parts growing upright with sturdy stems, 5-15 mm in diameter that reach 1-2,5 m in height. Stems look like bamboo stick, don't have branches and have solid cores. Harvest is done yearly and the whole aboveground parts of plants are baled. This cycle is repeated for 15-20 years.

8.2.1. The time of harvest

Miscanthus giganteus is harvested once a year because more often harvesting damages its rhizomes and Miscanthus giganteus itself. In its prime, in the beginning of autumn the crops are green and percentage of moist is high. Postponing harvest after that period improves the burning quality of biomass in the way of reducing percentage of moist and unwanted components in biomass (Lewandowski and Kicherer, 1997), but this also causes losses in biomass due to defoliation and crop flattening (Lewandowski and Heinz, 2003), so making a decision on harvest date becomes a compromise between maximum amount of harvested crop and crop quality. Optimal dates for harvest can vary based on the weather conditions of a particular region (Lewandowski and Kicherer, 1997).
Harvesting period in Miscanthus giganteus production is limited between first cold periods in autumn and the moment it starts growing again in spring. It depends on local conditions and it is

done between November and April. Postponing harvest from autumn to the beginning of spring the next year lowers the amount of harvested crops but increases the burning quality by reducing moist, ash, chorine and nitrogen in all Miscanthus genotypes (Clifton-Brown and Lewandowski, 2002). Late harvest has the most influence in locations which have great potential for producing dry biomass (Miguez *et al*., 2008). For longer harvesting period crops can be harvested wet and then artificially dried or stored in silos (Huisman, 1998). Late harvest is recommended, while a moist level is lower than 30%, for economical reasons because of lower costs of harvest and drying biomass, which are increased with an increased moist level in Miscanthus.

In Central Europe Miscanthus is harvested early in the spring, stems are dried during winter and a part of unwanted components in biomass like: N, K, S and Cl are rinsed by sedimentation or relocated to rhizomes, which drastically improves burning quality (Jørgensen and Sender, 1997; Lewandowski and Kicherer, 1997; Lewandowski and Heinz, 2003). In Germany and Netherlands moist level is reduced from 70% (based on fresh sample mass) in November to 20% and less in March and April (Kath-Petersen, 1994).

Postponing harvest causes losses in biomass due to defoliation and tips of steams falling off. According to Kath-Peterson (1994), real harvesting losses are around 25% while stubble makes for 17% losses. In Denmark postponing harvest till beginning of February decreases moist level from 63% in October to 29% and average decrease in crops are 34% (Jørgensen et *al*., 2003). Potassium, chlorine and ash content are drastically lower in early-spring harvest.

However, Beuch *et al*. (2000) estimate that only 50% of crops of biomass produced every year are suitable for harvest due to losses before harvest and after harvest remainders. During winter most of leaves and top parts of Miscanthus plants that didn't harden fall off. These losses stretch from 3-25% in December to 15-25% in March (Kath-Petersen, 1994). Defoliation during winter changes quality of harvested biomass as leaves contain large quantities of nutrients like N and K (Jacks-Sterrenberg, 1995). Losses during winter in leaves and top parts of plants can cause decrease in crop yield from 30-50% of dry material (Jørgensen, 1997). In Netherlands losses between 1st of October till March are between 29-42% (35,5% on average), and this varies depending on weather conditions of a particular year and location of Miscanthus crops (Lewandowski *et al*., 2000). Gezan and Riche (2008) determined the maximum of biomass quantity around October 5 and from that moment it decreases at rate of 31,1 kg per hectare. They assume that this is caused by respiration, degradation and defoliation. Most of the losses are caused by defoliation which forms a dense layer underneath the crops. This layer prevents weed growth and play important role in recycling of nutrients (Gezan and Riche, 2008).

Early harvest of Miscanthus maximizes energy yield and prime energy collection per hectare and late harvest lowers them. Namely, results of field experiments in Germany show energy yield of 187-528 GJ per hectare harvested Miscanthus in December (Lewandowski and Heinz, 2003). These bioenergetic yields decrease with harvest postponement by 14-15% between December and February and 13% more between February and March. This is connected with significant decrease in content of water, ash, nitrous, chlorine and sulfur in biomass (Lewandowski and Heinz, 2003).

According to our research results, in agro-ecologic conditions in Serbia (northern Sumadija, Podrinje and Srem) maximum in biomass is achieved during September. In total mass of harvested parts above the ground content of N, P and K as well as content of moist reach minimal values by the end of December (Dzeletović *et al*., 2009). By postponing harvest to the end of December in mentioned agro-ecological conditions there can be provided needed burning quality of biomass of Miscanthus. For harvesting from the end of December to beginning of April it is necessary not to rain or snow for couple of days so the harvest can be done (for harvesting machines to be able to move on fields) (Dzeletović *et al*., 2009). At the same time, dynamics of decreasing harvested biomass of Miscanthus during autumn and winter 2008/2009 is identical to the model of decreasing harvested biomass of Miscanthus in Netherlands stated by Lewandowski *et al*. (2000).

8.2.2 Harvesting methods

Miscanthus harvest can be done with existing machines for mowing and baling for different purposes: as a building material, for making energy and for making paper pulp. To use Miscanthus as a special building material and geotextile whole stems are needed and machines for cutting and tying whole plants into bundles are necessary.

For a harvest to be done properly it is necessary to adjust machines to a standard Miscanthus height (2-3,5 m) and rigidness to Miscanthus crops (Venturi and Huisman, 1998). Standard machines for harvesting cereal crops or mowing grass are not good for harvesting tall, hard stems of Miscanthus even though harvesters with rotating head can be adjusted for this type of work. “Kemper” harvester attached to silage harvester (silage corn combine harvester) will work god, although higher harvesting would be better (Huisman and Kortleve, 1994). Miscanthus plants are tolerant to low height of harvesting of 15 cm above the ground.

Multiphase harvesting methods include: mowing, rotating mowed crops, collecting and baling, with or without pressing bales. Multiphase methods allow for crops to dry when cut, which is faster than upright crops due to high moist level and microclimate in lower levels. Crops are first cut with mower. It cuts harder stems, allows faster decrease of moist, provides light. This introduces easier baling, helps to dry of material by increasing outer surface and air circulation in mowed Miscanthus.

In single-phase harvesting methods moving and later treatments are combined in one machine. This saves time and decreases losses that are present in collecting and packing. Under normal land conditions multiple crossings of machines over land will not decrease yields due to land compaction because pressure tires create on the ground is less than 2 bars (200 kPa) (Kath-petersen, 1994).

Baling Miscanthus is possible with any kind of baling machines. There are many different types of baling devices, which produce different bales (rectangular, round and compactly rolled), suitable for different demands for burning in incinerators. Density of dry material in round bales should be around 130 kg/m^3, and in rectangular bales around 150 kg/m^3 (Venturi *et al*., 1998). Using self-propelled bailing machines is the cheapest option, while cutting and compacting after postponing are more attractive option due to provided drying and lower costs of transport (Venturi *et al*., 1998).

Harvest can also be done with silage combines. Density in silage compartment depends on the length of segments. With a length of 11mm the density of dry material is 95 kg/m^3 and with a length of 44 mm it is 70kg/m^3. Mechanical compacting can bring density up to 130kg/m^3. Chopped up Miscanthus can be compacted more if it is necessary. For example, stationary paper-recycling machine for baling provides density of 265kg/m^3 (Huisman *et al*., 1997). In tests with a prototype of a mobile palletization machine for plant biomass 350-500kg/m^3 density was reached (Hartmann, 1997).

8.2.3 Bale storage

Standard methods for hay and straw can be used for collecting and handling bales of Miscanthus during transport and storage. Nevertheless, shape of Miscanthus bales tends to be rounded and uneven (Lewandowski *et al*., 2000). Methods for handling chopped material can be similar to the ones for silaged corn. For a long-term dry storage moist content should be 15% or less (Huisman and Kortleve, 1994). With a higher moist percentage mold can appear, but this can be prevented by a level of natural ventilation up to moist level of 25%. Spontaneous self-combustion in storage can be controlled by providing ventilation due to low air-flow resistance in bales and in bundles of chopped material (Tack and Kirschbaum, 1995).

Storage can be in covered space (a space with a roof construction), under an awning or a plastic cover. Storage under roof demands big investments but it will reduce work space and allow control of a covered layer, stop rain leakage and due to that stop losses in quality and quantity. Bales that stand not covered in fields absorb moist which leads to reduction in biomass quality, while covered bales on fields lose moist (8% in average) as well as bales inside covered space (11% in average) (Nolan *et al*., 2008). Miscanthus bales have to be stored covered, inside and out, with use of plastic and waterproof canvas to prevent rotting of bales and enable drying (Nolan *et al*., 2008).

8.2.4 Drying bales

Venturi *et al*. (1998) concluded that safe storage of Miscanthus is possible after drying material to 15% of moist in field or ventilated storage space. If complete drying is not possible in field, additional drying will be required right after harvest (if moist content is over 25%), or during storage (if moist content is up to 25%) if there is ventilation. When moist content is above 25% there can be self-heating of stored material, with a risk of fire ignition when there is a lack of

ventilation (El Bassam and Huisman, 2001). At the same time bales with less density (<250kg/m^3) can be stored without any fear of self-heating (El Bassam and Huisman, 2001; Tack and Kirschbaum, 1995). This happens to bales with higher density and restricted air flow.
In naturally ventilated pile of harvested Miscanthus in Denmark, Kristensen (1995) find that when harvested Miscanthus with a moist content of 59% is aired (ventilated) with 21.500m^3/h moist content will drop to 17,5% after 91 hours. If there is no self-heating losses will be moderate. Tack and Kirschbaum (1995) report about 4-6% losses in test in which were bales with 50% moist level ventilated with non-heated air and biomass temperatures below 20°C. In Netherlands bales with moist level of 25% are stored in stacks in fields, covered with awning with plenty space between bales (very loosely stacked bales). After a summer and a winter moist level will get down to 12%. The price of drying by ventilation with non-heated air is relatively low, up to 15 Euros per ton of dry material for crops harvested in January (Jonkanski, 1994).

8.2.5 Silage

Miscanthus can be stored in anaerobic conditions by closing pile of cut material under a plastic cover. The amount of sugar in biomass is sufficient for production of lactic acid which will suppress the most of microbiological activities (Huisman and Kortleve, 1994). According to our researches around 80% of biomass is carbohydrates of which cellulose is ≥32%. Protein content in biomass is ≤0.05% and fat is ~1%.
For Miscanthus silage it is best to remove excess air if it is possible by compacting before covering with new mass, e.g. by running it over with a tractor. If moist level in material is 60% pH value will be reduced to 4.2 in 2 weeks. With lower moist content pH value will stay higher but conserving material will be more efficient. Without inoculation with bacteria, which is required in practice, methodology is very similar to silage of chopped corn. Silage of vacuum sealed bales with plastic cover is hard to achieve due to very hard Miscanthus stems. If it is used for burning, moist level can be reduced with excess heat from incinerators. Press can be used for compacting which can decrease moist from 55 to 40%. Mineral content is also reduced in this process (Lewandowski *et al*., 2000).

8.2.6 Clearence (liquidation) of coppice

Growing miscanthus in Serbia has been started lately (only a few years). During that time many attempts were made to establish this plant canopies on larger or smaller parcels and lands of different types. Some of these attempts were successful and the other is shown that given the conditions are not sufficient for the survival of the plants. As the field miscanthus growing crops (15-20 years remains the same area) and cultivation in successful cases, we were not in a position to clean up after miscanthus plot. Nevertheless, even the first attempts at cultivation test

were performed with total herbicid (glyfosat). In terms miscanthus on chernozem in the first year of breeding, this product removes it completely.
According to literature data, is to remove the parcel miscanthus recommended a total herbicide and the next two years grow foreign grain on the same plot (Defra, 2007).

Reference

ANONYMUS 2006. *Growers' Guide to Short Rotation Coppice*. [online]. Coppice Resources Ltd., 13 p. <http://www.coppiceresources.com. pdf>

BEUCH, S. – BOELCKE, B. – BELAU. L. 2000. *Effect of the Organic Residues of Miscanthus×giganteus on the Soil Organic Matter Level of Arable Soils*. In Journal of Agronomy and Crop Science, Vol. 184 (2), 2000, p. 111-120.

CLIFTON-BROWN, J.C. – LEWANDOWSKI, I. 2002. *Screening Miscanthus genotypes in field trials to optimise biomass yield and quality in southern Germany*. In European Journal of Agronomy, Vol. 16 (2), 2002, p. 97–110.

DAWSON, M. 2007. *Short-rotation coppice willow : best practice guidelines* [online]. In: <http://www.ruralgeneration.com/Boiler%20Brochures/best%20practice%20guide.pdf> [18.11.2011]

DEFRA, 2004. *Growing Short Rotation Coppice*. Best Practice Guidelines For Applicants to Defra´s Energy Crops Scheme. Department for Environments Food and Rural Affairs, London, England, 32 p.

DEFRA 2007. *Planting and growing Miscanthus. Best Practice Guidelines (for Applicants to Defra's Energy Crops Scheme)*, 2007, 18 pp.

DŽELETOVIĆ, Ž. - MIHAILOVIĆ, N. - GLAMOČLIJA, Đ. - DRAŽIĆ, G. 2009. *Odložena žetva Miscanthus×giganteus – uticaj na kvalitet i količinu obrazovane biomase*. U PTEP – časopis za procesnu tehniku i energetiku u poljoprivredi, Vol. 13 (2), 2009. p. 170-173.

DŽELETOVIĆ, Ž. - DRAŽIĆ, G. – BLAGOJEVIĆ, S. MIHAILOVIĆ, N. 2006. *Specifični agrotehnički uslovi gajenja miskantusa*. U Poljoprivredna tehnika, Vol. 31 (4), 2006, p.107-115.

EL BASSAM, N. – HUISMAN, W. 2001. *Harvesting and Storage of Miscanthus.* In Miscanthus for energy and fibre (Eds MB Jones and M Walsh), James & James, London, 2001, p. 86-108.

GEZAN, S.A. – RICHE, A.B. 2008. *Over-winter yield decline in Switchgrass and Miscanthus*. In Aspects of Applied Biology, Vol. 90: Biomass and energy crops III (Eds: E. Booth, M. Green, A. Karp, I. Shield, D. Stock and D. Turley, AAB conference, 10-12 December 2008., Sand Hutton, UK), p. 219–223.

HARTMANN, H. 1997. *Analyse und Bewertung der Systeme zur Hochdruckverdichtung von Halmgut*. Gelbes Heft 60. Institut und Bayerische Landesandstalt für Landtechnik der Technische Universität München-Weihenstephan, 1997, p. 63.

HEINSOO, K. – DIMITRIOU, I. – BUERGOW, G. (eds.) 2008. *Metodika bezpečné aplikace odpadních vod a kalů s vysoce efektivní produkcí biomasy rychle rostoucích dřevin*. In:<http://www.biopros.info. pdf>

HUISMAN, W. – KORTLEVE, W.J. 1994. *Mechanization of crop establishment, harvest, and post harvest conservation of Miscanthus sinensis "Giganteus".* In Industrial Crops and Products, Vol. 2 (4), 1994, p. 289-297.

HUISMAN, W. – VENTURI, P. – MOLENAAR, J. 1997. *Costs of supply chains of Miscanthus giganteus*. In Industrial Crops and Products, Vol. 6 (3-4), 1997, p. 353-366.

HUISMAN, W. 1998. *Harvesting and Handling of PRG Crops*. In Production and use of perennial rhizomatous grasses (PRG) in the energy and industrial sector of Europe (Ed. Lewandowski I), Institut für Pflanzenbau und Grünland, Stuttgart, 1998, p. 42–47.

JACKS-STERRENBERG, I. 1995. *Untersuchungen zur Ertragsphysiologie von Miscanthus sinensis Anderss. hinsichtlich einer Verwendung als Energiepflanze*. Dissertation. Institut für Pflanzenbau und Pflanzenzüchtung I der Justus-Liebig-Universität zu Gießen, 1995, p. 115.

JONKANSKI, F. 1994. *Miscanthus - the future biomass crop for energy and industry*. *In Biomass for energy, environment, agriculture and industry* (Eds. Chartier P, Beenackers AACM, Grassi G, Proceedings of the Eighth European Biomass Conference, 3-5 October 1994., Vienna, Austria), Pergamon, Oxford, p. 372-379.

JØRGENSEN, U. – MORTENSEN, J. – BONDERUP KJELDSEN, J. – SCHWARZ, K-U. 2003. *Establishment, Development and Yield Quality of Fifteen Miscanthus Genotypes over Three Years in Denmark*. In Acta Agriculturae Scandinavica*, Section B – Plant and Soil Science*, Vol. 53 (4), 2003, p. 190-199.

JØRGENSEN, U. – SANDER, B. 1997. *Biomass requirements for power production: how to optimise the quality by agricultural management*. In Biomass and Bioenergy, Vol. 12 (3), 1997, p.145–147.

JØRGENSEN, U. 1997. *Genotypic variation in dry matter accumulation and content of N, K, and Cl in Miscanthus in Denmark*. In Biomass and Bioenergy, Vol. 12 (3), 1997, p.155-169.

KATH-PETERSEN, W. 1994. *Leistungfähige und bodenschonende Erntetechnik für Miscanthus.* Dissertation. Institut für Agrartechnik, Christian-Albrecht-Universität, Kiel, 1994, p. 249.

KRISTENSEN, E.F. 1995. Miscanthus. *Harvesting technique and combustion of Miscanthus sinensis „Giganteus" in farm heating plants*. In Biomass for energy, environment, agriculture and industry (Eds. Chartier P, Beenackers AACM, Grassi G, Proceedings of the Eighth European Biomass Conference, 3-5 October 1994., Vienna, Austria), Pergamon, Oxford, p. 546-555.

LEWANDOWSKI, I. – CLIFTON-BROWN, J.C. – SCURLOCK, J.M.O. – HUISMAN, W. 2000. *Miscanthus: European experience with a novel energy crop*. In Biomass and Bioenergy, Vol. 19 (4), 2000, p. 209–227.

LEWANDOWSKI, I. – HEINZ, A. 2003. *Delayed harvest of miscanthus - influences on biomass quantity and quality and environmental impacts of energy production*. In European Journal of Agronomy, Vol. 19 (1), 2003, p.45-63.

LEWANDOWSKI, I. – KICHERER, A. 1997. *Combustion quality of biomass: practical relevance and experiments to modify the biomass quality of Miscanthus×giganteus.* In European Journal of Agronomy, Vol. 6 (3-4), 1997, p.163-177.
MIGUEZ, F.E. – VILLAMIL, M.B. – LONG, S.P. – BOLLERO, G.A. 2008. *Meta-analysis of the effects of management factors on Muscanthus×guganteus growth and biomass production.* In Agricultural and Forest Meteorology, Vol. 148 (8-9), 2008, p. 1280–1292.
NOLAN, A. – McDONNELL, K. – McSIURTAIN, M. – CARROLL, J.P. – FINNAN, J. – RICE, B. 2008. *Conservation Miscanthus sinensis × giganteus in bale form*. In Aspects of Applied Biology, Vol. 90: Biomass and energy crops III (Eds: E. Booth, M. Green, A. Karp, I. Shield, D. Stock and D. Turley, AAB conference, 10-12 December 2008., Sand Hutton, UK), p. 255-262.
SPINELLI, R. – KOFMAN, P. 1996. *A review of short-rotation forestry harvesting in Europa*. In Proceedings of the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, Kentucky, USA, September 23-25
TACK, F. – KIRSCHBAUM, H.G. 1995. *Verfahren und Technik der Lagerung von Miscanthus*. In: Symposium Miscanthus - Biomassebereitstellung, energetische und stoffliche Nutzung, Dresden, 1994. Schriftenreihe „Nachwachsende Rohstoffe". Vol. 4. Münster, Germany: Landwirtschaftsverlag, p. 129-141.
VENTURI, P. – HUISMAN, W. – MOLENAAR, J. 1998. *Mechanization and Costs of Primary Production Chains for Miscanthus×giganteus in The Netherlands*. In Journal of Agricultural Engineering Research, Vol. 69 (3), 1998, p.209-215.
VENTURI, P. - HUISMAN, W. 1998. *Modelling the optimization of primary production costs of miscanthus*. In Biomass for Energy and Indu*stry* (Eds. Kopetz H, Weber T, Palz W, Chartier P and Ferrero GL, Proceedings of the 10th European Conference, Würzburg, Germany, 8–11 June 1998. Rimpar, Germany), C.A.R.M.E.N., p. 806-809.
WEGER, J. 2003. *Biomasa – obnoviteľný zdroj energie v krajině*. Pelhřimov : Nová tiskárna s.r.o., 52 s. ISBN 80-85116-32-4
WICKHAM, J. – RICE, B. – FINNAN, J. – Mc CONNON, R. 2010. *A review of past and current research on short rotation coppice in Ireland and abroad.* Dublin : COFORD, 2010, 36 p. ISBN 978-1-902696-65-2

9 Ecological and environmental aspects of short rotation coppice

9.1 Genus Salix

Energy use of biomass is beneficial to the environment in several aspects. The most important benefit is the reduction of greenhouse gas CO_2. The energy utilization of biomass in terms of CO_2 production is based on the fact that burning of biomass is neutral, in the sense of changes in quantity of CO_2. Unlike fossil fuels, the burning of biomass does not increase the concentration of CO_2 in the atmosphere.
Another benefit is a reduction in consumption of non-renewable fossil fuels as exhaustible natural resources and overall reduction of the emission and imission load generated by burning of the fossil fuels. The use of biomass within each regional system reduces transportation costs and thus also reduces CO_2 production.
In addition to these positive characteristics, resulting from the Kyoto Protocol on the reduction of greenhouse gases emissions, the growing of SRC brings many other benefits for the country. In many countries, poplar and willow plantations are principally used for an environmental improvement. For example, in the U.S, there are hundreds of smaller poplar plantations used as riparian buffer zones, for wastewater treatment, phytoremediation and carbon sequestration (Ball *et al*., 2002). In China, the stands of willows and poplars are used to stabilize sand dunes. In Bulgaria and Chile, the willows are planted along rivers in order to stabilize banks and reduce sedimentation.

9.1.1 Impact of SRC on soil

Positive impact on arable lands results mainly from the fact that the SRC represents an extensive method of cultivation and a form of perennial crops on the arable land.
SRC cultivation improves the physical condition of soil and increases humus content, improves soil absorption capacity and reduces water and wind erosion (Weger and Havlíčková, 2002). Impacts of SRC cultivation within the soil environment also affect the carbon sequestration, nutrient cycles and development of soil microorganisms. Nair *et al*. (2009) indicate that carbon sequestration in the arable land depends on number of locally specific biological, climatic, soil and management factors. The determined values of total carbon sequestration by SRC are significantly higher compared to arable crops cultivated on the arable land, but they are still lower than the values of carbon sequestration by mature forest stands (Boman, Turnbull, 1997, Table 10.1). However, according to Weih and van Bussel (2006), the carbon sequestration also depends on the genotype, i.e. individual clones of willows. The increased concentrations of C in soils where SRC are grown can be explained by low inputs in the process of soil cultivation and

high annual amount of the litter lying on the soil surface (on average 1-5 tons ha^{-1}) (Boman and Turnbull, 1997).

Generally, we can assume that carbon sequestration is higher in the SRC growing on agricultural land compared to conventional crops, but the amount of carbon stored also depends on the initial soil characteristics.

Tab. 9.1 Average carbon sequestration in arable land, SRC and forests in t ha^{-1} (Boman and Turnbull, 1997)

Components	**Arable use**	**SRC**	**Forest**
Leaves	4.0	2.5	2.5
Trunks	0	21.0	70.0
Weed	0.5	1.0	2.0
Litter	0.5	5.0	15.0
Roots	2.0	5.5	10.0
Soil	25.0	35.0	45.0
Total	**32.0**	**69.5**	**144.5**

A significant benefit of SRC growing is also an ameliorative function of these stands. Contiguous stands of willows and poplars, even on a small area, reduce adverse effects of wind erosion and prevent soil erosion because the stands create (already two years after planting) a strong root system firming the surface layers of the soil (Jech *et al*., 2003).

Important attributes for the implementation of this function is the high rooting ability, extensive growth of the root system, tolerance to flooding and deposition. Fast-growing willow species can create attractive and effective windbreaks in the landscape, which ensure a protection of agricultural land, provide shade and shelter for animals and create elevation elements within an extensive plain along, for example, motorway sections (Kuzovkina and Quigley, 2005). Furthermore, trapping of pollutants on the surfaces of the tree windbreaks reduces imission falls on the soil.

Annual leaf cast ensures the circulation of nutrients and increases the proportion of humus content in the soil. Carbon (plant biomass) gradually enriches the root zone and the upper soil layers due to an increase in root mass or eventually grass sod. These processes tend to increase the soil fertility.

A stabilization of hydrological conditions: water erosion is significantly reduced in comparison to the cultivation of annual crops. Short rotation plantations, as well as other woody crop stands stabilize drainage conditions, especially during greater rainfalls and reduce soil erosion during extreme rainfalls. SRC plantations withstand flood waters well (high flexibility and stability of woody crops) and are able to grow even on damaged soils (Weger *et al*., 2002).

Weger *et al*. (2002) state, on the basis of field measurements of climatic and hydrological parameters in SRC stands, that changes caused by planting and thus covering the soil by higher vegetation are desirable in terms of climate conditions in the country because it leads to a cooling of the surface above the vegetation. Weger *et al*. (2004) confirm that the change does not adversely affect the soil water regime and does not cause excessive drying of the soil, nor increase of the water runoff.

The growing of SRC is a suitable way of short recovery of the water cycle in a landscape that was largely disrupted by a large-scale deforestation and agricultural activity. SRC stands reduce evaporation from the soil, contribute to the stabilization of drainage conditions and compensate local climate conditions.

9.1.2 Phytoremediation

Phytoremediation ability of SRC species depends on soil properties. SRC woody crops are also used for phytoremediation effects leading to an improvement and/or cleaning of the substrate from hazardous substances such as heavy metals and some organic substances. Although SRC crops are not hyper-accumulators of hazardous substances, they are preferred in commercial phytoremediation projects because of their rapid and height growth.

SRC crops achieve high values of the total evaporation from plants and tolerate high concentrations of metals in soils (Hammer *et al*., 2003). The resistance of willows to some metals and their ability to accumulate significant quantities of metals in plant tissues (Kuzovkina and Quigley, 2005) and their tolerance to anaerobic conditions (Jackson and Attwood, 1996) predetermined them, already in the early stages of their commercial use for energy purposes, to the decontamination of soils (contaminated especially by Cd). Initially, the most researches aimed at the research of the Cd uptake by willows and later also other metals, such as Cu, Pb, Zn, Cr, Ni (Kuzovkina *et al*., 2004). Keller *et al*. (2003) reported the following heavy metal concentrations found in the biomass of *Salix viminalis* cultivated on contaminated soils in field conditions: Cd from 3.3 to 3.4 mg kg^{-1}, Cu from 12.0 to 14.0 mg kg^{-1}, Zn from 240.0 to 294.0 mg kg^{-1}.

Phytoremediation potential of willows is given by the combination of high metal accumulation by plant tissues, large amounts of biomass produced, extensive root system (possibility of decontamination of greater soil depths) and perennial habitus. SRC plantations can be also used for final treatment of waters from municipal wastewater treatment plants.

Poplars and willows are able to absorb nitrogen originating from intensive livestock productions (Aronsson, 2000). Data from Sweden show, for example, that 1 ha of a willow plantation is able to absorb 150 to 200 kg of nitrogen per year.

9.1.3 Impact of SRC on water

SRC plantations are involved in improving of water quality in areas where they are grown because of the procedures applied during their cultivation (herbicides and soil tillage are applied only during the establishment of the plantations; lower doses of mineral fertilizers in comparison to other crops). Authors of research studies focused on leaching of N and P into the groundwater found very low concentrations of N in the groundwater in intensively fertilized SRC plantations (less than 1 mg l^{-1} at an average annual dose of 112 kg N ha^{-1}) (Bergstrom and Johansson, 1992; Aronsson, 2000). In the common practice, the sludge from wastewater treatment plants is applied to SRC stands. Leaching models of P substances are different from N substances, due to the fixation of P to soil particles. The results of studies suggest that willows can accumulate approximately 8 kg P ha^{-1} $year^{-1}$ and doses of P from the sewage sludge range from 22 to 35 kg P ha^{-1} $year^{-1}$ (depending on P content in the soil) (Dimitriou and Aronsson, 2005). Larsson (2003) indicates a positive effect of irrigation by wastewater from the wastewater treatment plants in order to increase biomass production of willow plantations (waste water purified in a conventional treatment plant contains nutrient residues of N and P and in some cases small amounts of heavy metals: Cu, Cd and Zn).

9.1.4 Impact of SRC on biodiversity

SRC plantations can be classified, in term of the agricultural use, as permanent crops with a number of positive aspects to the landscape and environment. In comparison with an intensive crop production on arable land, the energy crops, particularly SRC have in many aspects positive impacts on ecosystem functions and landscape. In particular, the impact on soil, moisture and microbiological conditions that affect the character of individual habitats, the possibility of a development of various biocenoses and restoration of species biodiversity is of a great importance.

Impact of SRC on vegetation

Composition of species in the herbaceous storey of SRC plantations largely depends on the light intensity, which is the largest in young plantations. Baum *et al*. (2009) indicate that light intensity depends also on the tree species, which significantly influence the development and species composition of the vegetation undergrowth. For example, species that require plenty of light and nutrients and mild temperatures colonize SRC stands in initial stages when annual plant species dominate the herbaceous storey. Later, with the canopy closure of the upper vegetation layer, the intensity of radiation and temperature decreases and changes occur also in the species composition of vegetation undergrowth – there is a shift from ruderal and pioneer species to forest species, i.e. from the annual and biennial species to the perennial species (Delarze and Ciardo, 2002; Cunningham *et al*. 2004; Cunningham *et al*. 2006).

Newly established SRC stands are characterized by a low coverage and domination of annual plant species, which are characteristic for disturbed habitats. Fry and Slater (2009) recorded, in the initial year of the SRC stand establishment, approximately balanced occurrence of annual species (34%), perennial species with a short life cycle (39%) and perennial species with a long life cycle (35%).

Heilmann *et al*. (1995) found an occurrence of typical weed communities five years after the establishment of a SRC stand (54% of species were perennial species, mainly grasses, 6% were forest species and 40% were ephemeral species).

In the terms of plant community succession, Sage and Robertson (1994) found that annuals and short lived perennial species were gradually replaced by long lived stable perennials.

The results of Cunningham *et al*. (2006) indicates that commercially planted ex-grassland SRC generally supported a richer plant community than the grassland control plots, which represented the previous land use. These findings are similar to those obtained when ex-arable SRC plots were compared with arable plots (Cunningham, 2004).

Shade tolerant plant species can be found under dense canopy of fast-growing woody crops and on the other hand, the headlands and rides may provide conditions of woodland edges, in which an edge effect occurs causing a thriving of flowering plant species (Tubby and Armstrong, 2002).

Typical woodland specialist species (adapted to competing for scarce resources in shaded habitats) tend to be very poor colonisers. Dzwonko (2001) states that one of the most important factors of the colonization of SRC stands by these species is their occurrence frequency in the surrounding environment. Other factors, which affect the ability of forest plant species to colonize SRC stands, are the soil type and the amount of available water in the soil as well as the species of the tree grown in the plantation.

Smith and Watson (2011) observed that the understorey habitat under the dense stands of fast-growing trees will provide habitat for a limited abundance and species richness of common and widespread plants, but can also provide suitable habitat for specialist woodland plants. The rides and other open areas associated with SRF will provide valuable habitat for species-rich assemblages of plants typically associated with woodland edges and rides.

The appearance of rare and endangered plant species in SRC plantations has been reported only in rare cases.

The herbaceous storey, which is formed inside a dense SRC stand (especially in the third and fourth year after the planting) has a positive impact on communities of invertebrates, for instance. The presence of flowering plants is a positive element for pollinating insects (Weger *et al*, 2002).

Impact of SRC on fauna

Fast-growing woody crops create together with the plant community an interesting vegetation cover that provides new habitats and living space for vertebrates and invertebrates. The diversity of species in SRC plantations depends on several factors. Habitat conditions for animals, which depend on spatial structure, vegetation density, vegetation canopy closure, shading and moisture conditions, vary depending on the age of SRC stands. Berg (2002) found that with increasing height of the *Salix* stands increases the diversity of birds. Depending on the age structure of the stand, Sage *et al*. (2006) and Berg (2002) state that the greatest number of species and the largest population density of birds were found in the shrub phase of the SRC stand. SRC can create, under certain conditions, transient communities, which are characterized by a high diversity of species. Results of research in SRC stands focusing on the expansion of forest birds indicate that the SRC stands create conditions for more species-diverse transient communities than typical forest stands (Weger *et al*., 2006). The size of SRC growing areas also affects biodiversity of birds living in these stands. Sage *et al*. (2006) found that significantly greater number, as well as higher concentration of birds inhabits marginal parts of SRC stands. Therefore, small size plantations where the edge effect occurs to a greater extent are more suitable. Generally, we can say that willow stands are inhabited by a larger number of permanent and migratory songbirds and invertebrates compared to poplar plantations grown for energy purposes (Sage and Tucker, 1997; Dhondt *et al*., 2007). Willow stands (male and female flowers of *Salix viminalis*) provide an important food source for bees, bumblebees and other species pollinating flowering plants. They also provide habitats for nesting birds (eg. pheasants and/or singing birds).

Weger *et al*.(2006) propose planting of *Rosa canina*, which plays an important role in terms of hiding and nesting opportunities for insectivorous birds and small animals in marginal strips of the production stands, in order to increase their ecological stability (and also propose to leave the *R. canina* shrubs on the site after the harvest of the production plants).

It is not possible to say that SRC stands have generally a clearly positive impact on the diversity of animals, as there are differences among individual animal classes, location of SRC stands in the landscape and their relations to surrounding biotopes as well as ecological conditions of these stands.

The growing of fast-growing woody crops should be in accordance with the standards and basic design of the cultivation of forest stands. Therefore, it is important to consider impacts of SRC woody crops on the landscape and integrate the principles of forest design already in the initial planning stage of such plantations (Bell and McIntosh, 2001; Tubby, Armstrong, 2002).

Weger (2004) focused on increasing of the ecological stability of monoculture (single-species, uniclonal) stands of SRC by creating mixed stands of different clones of poplar and willow planted in rows. Based on the obtained results, he concludes that in properly selected mixed stands, the yields are comparable to monoculture stands.

Weih (2008) provides the following summary of circumstances that could support the development of biodiversity in SRC plantations:

- establish rather larger number of smaller plantation,
- locate the plantations close to native woodlands and/or incorporate `islands` of native trees in the plantation,
- keep a buffer zone without crops or with native vegetation at the edges of the plantations,
- plant several varieties (preferably of different sex) in one plantation in sections of parallel rows due to easier harvest of the yield,
- apply herbicides only during the establishment of the plantations,
- do not apply higher amount of fertilizers than required for production of biomass during the growing season,
- carry out the harvest when the ground is frozen,
- carry out the harvest in parts in different years,

- locate, design and manage the plantation, so that the variation in the types of habitats and landscapes are maximized.

9.2. Environmental aspects of genus Miscanthus

9.2.1 Impact on soil fertility

Unlike annual crops, the need for cultivation of land under perennial grasses is limited to the year in which the crop is planted. Environmental benefits of a long period without treatment are to reduce the risk of soil erosion and corresponding increase in carbon content in soil (Kahle, 2000; Ma *et al*., 2000). Because of the long period under the plant cover and high inputs of organic matter from miscanthus fallen leaves, can be expected that land will increase the organic matter content and improve the structure of land during the breeding of mischantus, compared with other cultivated crops.

An increase in soil organic matter over a long period of growth of some crops for biomass, compared with the contents of the land used for annual crops, two factors probably contribute. First, perennial crops grown in the main tend to leave more organic matter in soil in the form of roots and root exudates, but annual crops. The roots of grasses are important as additional organic matter in soil, encourage microbial biomass formation and physical bonding of the soil aggregates (Haynes and Bear, 1996). The observations suggest the large inputs of roots and rhizomes of miscanthus (Christian and Riche, 1998; Kahle *et al*., 2002). Second, the absence of treatment for perennial crops probably slows down the decomposition of soil organic matter to some degree. The combination of these reasons leads to the land under grass cover a long period of time contain more organic than anything with the land under annual crops. Increased humus content in soil is characteristic for miscanthus plantation, as well as increasing of exchangeable capacity, porosity and water retention, while reducing moisture and soil volumetric mass (Boelcke *et al*., 1998; Kahle *et al*., 2002). Roots penetrate up to 250 cm and deeper (Werner, 1995; Neukirchen *et al*., 1999). Maximum root density after three years has been established at 0-40 cm depth. First soil layer (0-30 cm) contains 28% of root biomass (Neukirchen *et al*., 1999). Miscanthus plantation accumulates 10-20 t of rhizomes dry matter per hectare in the surface layer of soil (up to 25 cm depth) and an additional 6-8 t of root dry matter (Boelcke *et al*., 1998).

Total pre-harvest and harvest losses may amount to about 2/3 fall biomass and these losses provide a significant input of carbon in the soil (Hansen *et al*., 2004). The contribution of organic matter, Beuch *et al*. (2000) estimated at 3.1 t ha-1 of carbon annually accumulated leaf litter and 9.1 t ha-1 accumulated carbon rhizomes and roots. These organic remains are largely characterized by high rates of decomposition. Organic matter originating from miscanthus is constant such as that organic matter derived from S3 grass. What is more, transformation time of organic matter increases with time of miscanthus growing (Foereid *et al*., 2004). Through the establishment of miscanthus plantation, the production of organic substances is allowed, which is comparable with manure fertilization in terms of impact on soil organic matter (Beuch *et al.*, 2000). Beuch *et al*. (2000) found that after 6-8 years of growing Miscanthus × giganteus soil organic matter increases by about 0.5% on sandy soils, and by 0.2% in powder soils. Hansen *et al*. (2004) have estimated reserves of soil organic carbon and circling under 9 and 16 years old miscanthus plantation on loamy sand, near Hörnum, Denmark. They concluded that, at the depth of 0-20 cm, mass of rhizomes is 10.9 to 12.6 t of dry matter per ha, and mass of large roots is 3.2 to 3.7 t of dry matter per ha. However, rhizomes and roots were not observed in the deeper soil layers. Concentrations of soil organic matter were higher in all soil depths under 16 years old miscanthus, since 9 years old miscanthus and reference plots show similar concentrations of soil organic matter.

Grass species have low impact on the quantity and circulation of soluble organic sulphur, soluble organic nitrate and inorganic nitrate (Khalid *et al*., 2007). The presence of plants causes the biodegradability of soluble organic S. Then, miscanthus as a crop affects the quality of soil organic matter: increasing the proportion of alkanes, alkenes, sterols and free fatty acids (Kahle *et al*., 2001). Leaf litter is mostly composed of leaves that have fallen upon aging, and the differences in annual leaf litter mass were mainly due to the amount of fallen leaves before harvest due to wind (Christian *et al*., 2008). The mass of leaf litter is quite stable. An exception can occur only in those years when the amount of leaf litter is higher, causing lower harvest yield in that year, with smaller leaves that remain on the stem. Otherwise, Christian *et al*. (2008) have not shown the influence of N-treatments on leaf litter mass in any year during the growing of miscanthus.

A significant effect of temperature on the nitrogen losses by decomposition, are not found (Magid *et al*., 2004). Decomposition at +3°C leads to larger ratio S:N in plant residues, at +3°C has no net N immobilization, while at +9°C strong net immobilization occurs. The addition of inorganic nitrogen lowers carbon mineralization in all soils under miscanthus (Foereid *et al*., 2004).

9.2.2 Impact on nitrate leaching

Of all the crops grown for energy purposes, perennial C4 grasses such as *Miscanthus* are regarded as the most efficient Nitrogen users. This is due to the recycling of Nitrogen from year to year through the rhizome system and in the leaf fall. The non-disturbance of the soil, combined with the deep root system results in slow rates of organic Nitrogen release and the uptake of Nitrogen from deeper soil layers, thereby reducing the risk of Nitrogen leaching losses (McKervey *et al*., 2008).

Nitrate leaking occurs mainly in the year of miscanthus plantation establishment. Dense root system that develops 2-3 years, it prevents flushing of nitrate. This is important for erosion, because the plants remain small in the first year, adopted a little nitrogen and is not provided full land cover. Christian and Rich (1998) measured the leaching of nitrate during the first three winters after planting of miscanthus on the powder-clay-loam soil. During the first year, when the plants are very small, and the adoption of N is slight, nitrate losses were high: 150 kg N ha-1. From the third year, leaching covers from 3 kg N ha-1 (without fertilizer) to 30 kg N ha-1 (entering 120 kg N ha-1), which is close to value recorded in soils under grasslands that are managed extensively. In subsequent years, losses amount to 10 kg N ha-1, which is much lower than the loss under annual crops, amounting to 20-60 kg N ha-1 (Allingham *et al*., 2002). Total losses of N under 2 and 3 years old plants were similar to those of arable land and permanent grass crops on the same soil type, that have been made in the same amounts of N (Christian *et al*., 2006).

9.2.3 Impact on biodiversity

Miscanthus has a very long life span (of about 20 years) and can grow up to 4 m in height in the UK. This may create a visual impact on the rural landscape. Therefore, when selecting sites for *Miscanthus*, one should take account of the landscape aesthetics and public foot path access, as well as local archaeology (McKervey *et al*., 2008).

High miscanthus plantations can serve as a habitat for birds and mammals (Loeffel and Nentwig, 1997). According to Jodl *et al*. (1998), miscanthus plantations contain more larger animals (mammals, birds) than other grass crops plots (corn, cane), probably more diversity of structure leads to cover a larger number and wider range of ecological niches. However, while the number of insects increase compared with other cultivated crops, the number of individuals at the miscanthus stands shows a decrease. This could partly be explained by low digestibility of miscanthus organic matter.

There have been some concerns whether *Miscanthus*, as an introduced species, might be an invasive plant. However, this is not a problem because most varieties used for biomass are sterile hybrids and ornamental *Miscanthus* varieties have been around in our gardens for a number of years. In addition, *Miscanthus* is easy to get rid of by harvesting the rhizomes using modified potato harvesters or kill the crop using glyphosate herbicides (McKervey *et al*., 2008).

Biodiversity research on perennial grasses have shown more diverse birds, small mammals and invertebrates, especially of birds within the plot and all the edges, compared to the surrounding meadows and annual crops (Semera and Slater, 2007; Bellamy *et al.* , 2009). Crop height is more important for species density that crop type (Clapham and Slater, 2008). A number of birds in the fields under miscanthus during winter is probably attracted to the shelter provided by the cultivated crop and abundance of non-crop plants (Bellamy *et al*., 2009). Despite the significant effect of shading the surface when the crop covers the land during the growing season, non-crop vegetation survives, providing additional food sources for animals (Clapham and Slater, 2008). However, the miscanthus crop provides less insects as food for birds, than wheat.

Also, changes in agricultural practices in recent years, such as an increased use of herbicides and pesticides and modifications to land management through farm mechanization and field enlargement have affected the wildlife flora and fauna of the countryside. This situation could be further altered with the potential increase in the production of renewable energy crops such as *Miscanthus* (McKervey *et al*., 2008).

In any case the balance of the environmental impacts can be considered positive and represent a gain in primary energy sources consumption, which is essential for sustainable development in poor regions like south-eastern european areas, in general (Luisa Fernando *et al*., 2010).

References

ALLINGHAM, K.D. - CARTWRIGHT, R. – DONAGHY, D. – CONWAY, J.S. – GOULDING, K.W.T. – JARVIS, S.C. 2002. *Nitrate leaching losses and their control in a mixed farm system in the Cotswolds*, *England*. In Soil Use and Management, Vol. 18 (4), 2002, p. 421–427.

ARONSSON, P. 2000. *Nitrogen retention in vegetation filters in short-rotation willow coppice.* In Acta Universitatis Agriculturae Sueciae. Silvestria 16/1, 2000 ISBN 91-576-5895-1

BALL, J. – CARLE, J. – DEL LUNGO, A. 2002. *Contribution of poplars and willows to sustainable forestry and rural development*. [online] <http://www.fao.org/docrep/008/a0026e/a0026e02.htm>

BAUM, C. et al. 2009. *Effects of Short Rotation Coppice with willows and poplar on soil ecology*. In Landbauforschung*,* 59(3), 2009, p. 183-196.

BELL, S. – Mc INTOSH, E. 2001. *Short Rotation Coppice in the Landscape*. Forestry Commission Guideline Note 2. Forestry Commission, Edinburgh.

BELLAMY, P.E. - CROXTON, P.J. – HEARD, M.S. – HINSLEY, S.A. – HULMES, L. – HULMES, S. – NUTTALL, P. – PYWELL, R.F. – ROTHERY, P. 2009. *The impact of growing miscanthus for biomass on farmland bird populations*. In Biomass and Bioenergy, Vol. 33 (2), 2009, p. 191-199.

BERG, A. 2002. *Breeding birds in short-rotation coppices on farmland in central Sweden – the importance of Salix height and adjacent habitats*. In Agriculture, Ecosystems & Environment*,* 90 (3), 2002, p. 265–276.

BERGSTRÖM, L. – JOHANSSON, R. 1992. *Influence of fertilized short-rotation forest plantations on nitrogen concentrations in groundwater*. In Soil Use Manage 8, 1992, p. 36-40.

BEUCH, S. – BOELCKE, B. - BELAU, L. 2000. *Effect of the Organic Residues of Miscanthus×giganteus on the Soil Organic Matter Level of Arable Soils*. In Journal of Agronomy and Crop Science, Vol. 184 (2), 2000, p. 111-120.

BOELCKE, B. – BUECH, S. - ZACHARIAS, S. 1998. *Effects of Miscanthus cultivation on soil fertility and the soil water reservoir*, In: Biomass for Energy and Industry (Eds. Kopetz H, Weber T, Palz W, Chartier P and Ferrero GL, Proceedings of the 10th European Conference, Würzburg, Germany, 8–11 June 1998. Rimpar, Germany), C.A.R.M.E.N., 1998, p. 911-914.

BOWMAN, U. – TURNBULL, J. 1997. *Integrated biomass energy systems and emission of carbon dioxide*. In Biomass Bioenergy,13, 1997, p. 333-343.

CLAPHAM, S.J. – SLATER, F.M. 2008. *The biodiversity of established biomass grass crops*. In Aspects of Applied Biology, Vol. 90: *Biomass and energy crops III* (Eds: E. Booth, M. Green, A. Karp, I. Shield, D. Stock and D. Turley, AAB conference, 10-12 December 2008., Sand Hutton, UK), p. 325-329.

CUNNINGHAM M.D. et al. 2006. *The effects on flora and fauna of converting grassland to short rotation coppice.* Report B/W2/00738/00/00. URN: 06/1094. A report for the Department of Trade and Industry by The Game Conservancy Trust and The Central Science Laboratory.[online] http://www.berr.gov.uk/files/file29233.pdf.

CUNNINGHAM, M.D. et al. 2004. *ARBRE monitoring - ecology of short rotation coppice.* Report B/U1/00627/REP. DTI/PUB URN 04/961. A report for the Department of Trade and Industry by The Game Conservancy Trust and The Central Science Laboratory.[online] http://www.berr.gov.uk/files/file14870.pdf.

DELARZE, R. – CIARDO, F. 2002. *Rote Liste-Arten in Pappelplantagen*. Informationsblatt Forschungsbereich Wald WSL Birmensdorf 9:3-4

DHONDT, A.A. et al. 2007. *Avian species richness and reproduction in short-rotation coppice habitats in central and western New York*. In Bird Study*,* 54(1), 2007, p.12–22.

DIMITRIOU, I. – ARONSSON, P. 2004. *Nitrogen leaching from Short-Rotation Willow Coppice after intensive irrigation with wastewater*. In Biomass and Bioenergy, Vol 26/5, 2004, pp 433-441.

DZWONKO, Z. 2001. *Effect of proximity to ancient deciduous woodland on restoration of the field layer vegetation in a pine plantation*. In Ecography, 24, 2001, p. 198-204.

FOEREID, B. - DE NEERGAARD, A,. - HØGH-JENSEN, H. 2004. *Turnover of organic matter in a Miscanthus field: effect of time in Miscanthus cultivation and inorganic nitrogen supply*. In Soil Biology and Biochemistry, Vol. 36 (7), 2004, p. 1075-1085.

FRY, D. – SLATER, F. 2009. *The biodiversity of short rotation willow coppice in the Welsh landscape*. [online] http://www.willow4wales.co.uk/

HAMMER, D. – KAYSER, A. – KELLER, C. 2003. *Phytoextraction of Cd and Zn with Salix viminalis in field trial.s* In Soil Use Manage*,* 19, 2003, p. 187-192.

HANSEN, E.M. - CHRISTENSEN, B.T. - JENSEN, L.S. - KRISTENSEN, K. 2004. *Carbon sequestration in soil beneath long-term Miscanthus plantations as determined by ^{13}C abundance*. In Biomass and Bioenergy, Vol. 26(2), 2004, p. 97-105.

HAYNES, R.J. - BEARE, M.H. 1996. *Aggregation and organic carbon storage in Mesothermal humid soils*. In Structure andOrganic Matter Storage in Agricultural Soils (Eds Carter MR and Stewart BA), Boca Ration, Florida, CRC Press, 1996, p. 213-262.

HEILMANN, B. - MAKESCHIN, F. – REHFUESS, K.E. 1995. *Vegetationskundliche Untersuchungen auf einer Schnellwuchsplantage mit Pappeln und Weiden nach Ackernutzung*. In Forstw Cbl, 114, 1995, p. 16-29.

CHRISTIAN, D.G, - POULTON, P.R. - RICHE, A.B. - YATES, N.E. - TODD, A.D. 2006. *The recovery over several seasons of ^{15}N-labelled fertilizer applied to Miscanthus×giganteus ranging from 1 to 3 years old*. In Biomass and Bioenergy, Vol. 30(2), 2006, p. 125–133.

CHRISTIAN, D.G. - RICHE, A.B. 1998. *Nitrate leaching losses under Miscanthus grass planted on a silty clay loam soil*. In Soil Use and Management, Vol. 14(3), 1998, pp. 131-135.

CHRISTIAN, DG, RICHE, AB, YATES, NE. 2008. *Growth, yield and mineral content of Miscanthus × giganteus grown as a biofuel for 14 successive harvests*. In Industrial Crops and Products, Vol. 28 (1), 2008, pp. 320-327.

JACKSON, M.B. – ATTWOOD, P.A. 1996. *Roots of willow (Salix viminalis L.) show marked tolerance to oxygen shortage in flooded soils and in solution culture*. In Plant Soil, 187:37-4.

JECH, D. et al. 2003. *Funkce porostů rychle rostoucích dřevin v krajině. In: Weger, J. (ed.) Biomasa obnovitelný zdroj energie v krajině*. VÚKOZ Průhonice, s. 36–39.

JODL, S. - EPPEL-HOTZ, A. - MARZINI, K. 1998. *Examination of the ecological value of Miscanthus expanses - faunistic studies*. In Biomass for Energy and Industry (Eds. Kopetz H, Weber T, Palz W, Chartier P and Ferrero GL, Proceedings of the 10th European Conference, Würzburg, Germany, 8–11 June 1998.), C.A.R.M.E.N., Rimpar, Germany, 1998, p. 778-779.

KAHLE, P. - BELAU, L. - BOELCKE, B. 2002. *Auswirkungen eines 10-jährigen Miscanthusanbaus auf ausgewählte Eigenschaften eines Mineralbodens in Nordostdeutschland*. In Journal of Agronomy and Crop Science, Vol. 188(1), 2002, p. 43-50.

KAHLE, P. - BEUCH, S. - BOELCKE, B. - LEINWEBER, P. - SCHULTEN, H-S. 2001. *Cropping of Miscanthus in Central Europe: biomass production and influence on nutrients and soil organic matter*. In European Journal of Agronomy, Vol. 15(3), 2001, p. 171-184.

KAHLE, P. 2000. *Auswirkungen eines mehrjährigen Miscanthus-Anbaus auf ausgewählte Bodeneigenschaften*. In: Miscanthus—vom Anbau bis zur Verwertung, (Ed. Pude R), Verlag M. Wehle: Wittenschlick, Bonn, 2000, p. 43–47.

KELLER, C. et al. 2003. *Root development and heavy metal phytoextraction efficiency: comparison of different plant species in the field.* In Plant Soil, 49, 2003, p. 67-8.

KHALID, M. - SOLEMAN, N. - JONES, D.L. 2007. *Grassland plants dissolved organic carbon and nitrogen dynamics in soil*. In Soil Biology and Biochemistry, Vol. 39(1), 2007, p. 378-381.

KUZOVKIN, A Y.A. – QUIGLEY, M.F. 2005. *Willows beyond wetlands: uses of* Salix *L. species for environmental projects.* In Water, Air and Soil Pollution, 162, 2005, p. 183-204.

KUZOVKINA, Y.A. et al. 2004. *Cadmium and copper uptake and translocation in five willow (Salix) species*. In Intern J Phytorem, 6, 2004, p. 269-287.

LARSSON, S. 2003. Full Scale Implementation of Short Rotation Willow Coppice (SRC) in Sweden. Örebro : Agrobränsle AB, Svalov, 2003.

LOEFFEL, K. - NENTWIG, W. 1997. *Ökologische Beurteilung des Anbaus von Chinaschilf (Miscanthus sinensis) anhand faunistischer Untersuchungen*. Agraökologie Vol. 26, Verlag Agraökologie, Bern, Switzerland.

LUISA FERNANDO, A. - SANTOS OLIVEIRA, J.F. 2010. Some aspects of Environmental Impact Assessment of *Miscanthus x giganteus* production in Portugal - Application of a model. Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa.

MA, Z. - WOOD, C.W. - BRANSBY, D.I. 2000. *Soil management impacts on soil carbon sequestration by switchgrass*. In Biomass and Bioenergy, Vol. 18(6), 2000, p. 469–477.

MAGID, J. - LUXHØI, J. - LYSHEDE, O.B. 2004. *Decomposition of plant residues at low temperatures separates turnover of nitrogen and energy rich tissue components in time*. In Plant and Soil, Vol. 258, 2004, p. 351-365.

McKERVEY, Z. - WOODS, V.B. - AND EASSON, D.L. 2008. *Miscanthus as an energy crop and its potential for Northern Ireland: A review of current knowledge*. Agri-food and Biosciences Institute, Global Research Unit, Occasional Paper No. 8.

NAIR, P.K.R. et al. 2009. *Agroforestry as a strategy for carbon sequestration*. In J Plant Nutr Soil Sci, 172, 2009, p. 10-23.

NEUKIRCHEN, D. - HIMKEN, M. - LAMMEL, J. - CZYPIONKA-KRAUSE, U. - OLFS, H-W. 1999. *Spatial and temporal distribution of the root system and root nutrient content of an established Miscanthus crop*. In European Journal of Agronomy, Vol. 11(3-4), 1999, p. 301-309.

SAGE, R. – TUCKER, K. 1997. *Invertebrates in the canopy of willow and poplar short rotation coppices*. In Aspects of Applied Biology, 49, 1997, p. 105-111.

SAGE, R. et al. 2006. *Birds in willow short-rotation coppice compared to other arable crops in central Enland and a review of bird census data from energy crops in the UK*. Ibis 148 (1)p. 184–197.

SAGE, R.B. – ROBERTSON, P.A. 1994. *Wildlife and Game Potential of Short-Rotation Coppice in the UK*. In Biomass & Bioenergy, 6, 1994, p. 41-48.

SEMERE, T. - SLATER, F.M. 2007. *Ground flora, small mammal and bird species diversity in miscanthus (Miscanthus × giganteus) and reed canary-grass (Phalaris arundinacea) fields*. In Biomass and Bioenergy, Vol. 31(1), 2007, p. 20-29.

SMITH, M. – WATSON, G. 2011. *Potential impacts of Short Rotation Forestry on Biodiversity in Britain*. In Short Rotation Forestry: review of growth and environmental impacts. Forest Research Monograph [ed. McKay, H.], 2, Forest Research, Surrey, 212pp. ISBN 978-0-85538-827-0

TUBBY, I. – ARMSTRONG, A. 2002. *Establishment and management of short rotation coppice.* Practice note. Forestry commission Crown Copyright, p.12. ISSN 1460-3810.

WEGER, J. – HAVLÍČKOVÁ, K. 2002. *The first results of the selection of woody species for short rotation coppices in the transitional oceanic-continental climate of the Czech Republic*. 107-110 pp., Twelfth European Conference Biomass for Energy, Industry and Climate Protection, Amsterdam, ETA Florence, ISBN 88-900442-5-X.

WEGER, J. - ŠÍR, M. - SYROVÁTKA, O. 2004. *Landscape Functions of Short Rotation Coppice and Possibilities for Sustainable Land Management*. 2nd World Conference Biomass for Energy, Industry and Climate Protection, Rome, ETA Florence and WIP-Munich, 2004, p. 265-267.

WEGER, J. 2004. *A Multi-Species Energy Crop System to Sustainably Produce Biomass in the Czech Republic*. 2nd World Conference Biomass for Energy, Industry and Climate Protection, Rome, ETA Florence and WIP-Munich, 2004, p. 256 – 258.

WEGER, J. et al. 2002. *Výzkum krajinných funkcí cílené produkce biomasy (rychle rostoucími dřevinami) – zejména jejich přínosy pro diverzitu krajiny a hydrologický režim*. Závěrečná zpráva projektu VaV320/3/99. Průhonice : VÚKOZ, 2002, 34 s.

WEGER, J. et al. 2006. *Výmladkové plantáže rychle rostoucích dřevin pro produkci biomasy.* In Životné prostredie, 40, 3, 2006, p. 137 – 142.

WEIH, M. – van BUSSEL, L. 2006. *Effect of root and leaf allocation on soil carbon sequestration potential of Salix bioenergy plantations in Sweden*. In: Proc. COST E38 workshop Woody Root Processes, revealing the hidden half, Sede Boqer, Israel, 4-8 Feb. 2006, p. L2

WEIH, M. 2008. *Perennial Energy Crops: Growth and Management*. In: Crop and Soil Science, Willy H. - Verheye [Ed.], in Encyclopedia of Life Support Systems (EOLSS), Developed under the Auspice of the UNESCO, Eolss Publishers, Oxford, UK. [online] http://www.eolss.net.

WERNER, I. 1995. *Umweltaspekte im Miscanthusanbau - Wurzeluntersuchungen, phytosanitäre Untersuchungen and Untersaaten*. In:Symposium Miscanthus-Biomassebereitstellung, energetische und stoffliche Nutzung, Dresden, 1994. Schriftenreihe „Nachwachsende Rohstoffe". Vol. 4. Münster, Germany: Landwirtschaftsverlag, 1995, p. 87-101.

10 Utilisation of biomass for energy production

10.1 Utilisation of Salix biomass

The primary producer of bioenergy in Slovakia is agriculture and forestry. The total production consists of agriculture and forestry waste biomass and biomass produced purposely as a result of a productive activity. Energy Concept of SR (2007) states that the energy potential of the country represents 46.5 petajoul (PJ) of energy that can be produced each year on agricultural land, without affecting animal production and having any negative impact on its quality. This potential far exceeds current energy consumption in agriculture (9.4 PJ). Therefore, it is counted on a more efficient use of renewable resources for the heat production. One of these sources is the biomass grown on plantation of energy trees and plants. Burning of the biomass has specific characteristics that are dependent on the quality characteristics such as calorific value, volatile matter content and ash content and quality. From the quantitative characteristics, determining are size of biomass production and the price per tonne.

The way of the energy use of biomass is also a subject of the research. The following basic quality parameters of biomass are taken into account:

- energy characteristics (energy value of dry matter, heating value, calorific value),
- chemical characteristics (water content, organic and elemental composition of dry matter, ash content),
- physical characteristics (size of biomass and its form, density, particle size, cohesion and dust generation),
- technical (burning properties, content of combustible substances, proportion of volatile and non-volatile substances, generation of emission, particularly emissions of sulphur and nitrogen),
- hygienic characteristics (presence and amount of (mainly) pathogenic microorganisms and fungi, their ability to multiply during storage, presence of spores that might threaten health of the staff working with the biomass).

Usťak (2006) compared the most important characteristics of woody biomass with conventional fuels (brown and black coal). He states that the calorific value of wood biomass is 15-17 MJ kg^{-1}, brown coal 12-20 MJ kg^{-1}, black coal 28-32 MJ kg^{-1}. The ash content of wood biomass is 05-3% and black and brown coal it is 3-18%. The content of volatile substances in woody biomass is 60-70%, in the brown coal 40-60% and in the hard coal 8-35%. The parameters show that the wood biomass has better characteristics of calorific value and ash content and higher content of volatile substances compared to the brown coal.

The willow woody biomass of was analyzed also after the harvest of the experimental material of the five Swedish varieties grown in the conditions of the experimental plantation in Kolíňany (Demo *et al.* 2011). The chemical composition is shown in Table 10.1.

Tab. 10.1 Selected indicators of the chemical and energy analysis of the -growing willow biomass in 2009 (Demo *et al.* 2011)

Varieties	Elemental analysis			Ash [%]	Heating value [MJ kg^{-1}]	Calorific value [MJ kg^{-1}]
	C [%]	N [%]	S [%]			
INGER	50.05	0.48	0.16	1.44	19.85	18.55
TORA	49.82	0.55	0.17	1.97	19.42	18.11
SVEN	48.88	0.46	0.10	1.44	19.68	18.37
TORDIS	49.94	0.40	0.17	1.75	19.60	18.28
GUDRUN	49.87	0.51	0.17	1.89	20.01	18.70

The results of elemental analysis and other qualitative indicators point to the fact that the values are not varietal-conditioned. An important feature is the low-sulphur (S) content, which is multiple times lower than in fossil fuels (eg. brown coal). Also the ash and nitrogen content (N) is very low. Several authors (Daugherty 2001, Jandačka *et al.* 2007) indicate that the content of emission nitrogen in the woody biomass should not exceed 1.5% in the dry matter. This quality condition was met by all experimental varieties. When compared the C:N ratio, based on the elemental analysis results, it can be seen that the interaction is highly in favour of carbon (C). This means that willows are suitable for direct combustion in modified boilers. All varieties met the criterion of calorific and heating value.

Willows are also suitable for use in biological sewage treatment plants. Two functions are combined here. Fast-growing willows are used for energy purposes and they are also species capable of bioremediation of heavy metals and other pollutants from wastewater.

10.2 Utilisation of Miscanthus biomass for energy production

The use of renewable energy sources is becoming increasingly necessary, if we are to achieve the changes required to address the impacts of global warming. Biomass is the most common form of renewable energy, widely used in the third world but until recently, less so in the Western world. Latterly much attention has been focused on identifying suitable biomass species, which can provide high-energy outputs, to replace conventional fossil fuel energy sources. The type of biomass required is largely determined by the energy conversion process and the form in which the energy is required.

Except utilization of miscanthus biomass as a raw material for energy production, it can be used as a feedstock for biofuels production . It is expected that miscanthus will provide a cheaper, more sustainable source of cellulose for production of bioethanol than annual crops such as corn. Advantage of miscanthus in comparation with other feedstock for biofuels production, like agricultural residues such as corn stover and wheat straw, is that miscanthus can be cultivated in polluted area, or on low-quality arable land, improper for other crops.

Miscanthus has emerged as one of the most promising candidates for lignocellulosic energy crops in the temperate regions (Lewandowski *et al*., 2000; Somerville *et al*., 2010). Harvestable yields reach a full maturity after 3-5 years, sometimes in excess of 20 t/ha/yr. The yield potential of this novel annually harvested bioenergy crop has been shown to be substantial, but some concerns remain about disadvantages such as its relatively high establishment costs.

10.2.1 Yield and combustion characteristics of *Miscanthus×giganteus*

Yields of miscanthus are found to vary considerably according to site and climate, with the highest yields being recorded in southern European sites when water was not a limiting factor. Actually, a considerable number of field experiments, carried out during the last decades, reported variable dry matter yields of miscanthus, broadly ranging from 4–25 t/ha in central European countries to 30–40 t/ha for southern Europe (Lewandowski *et al*., 2000; Lewandowski and Kicherer, 1997; Schwarz *et al*., 1994; Jorgensen, 1997)

In the case of *Miscanthus×giganteus*, there is a trade-off between the quantity and the quality of harvested biomass in relation to harvest time (Jones and Walsh, 2007). Winter losses of dead and decaying leaves and upper stem parts can cause yield reductions from 30 to 50% dry matter (Jorgensen and Sander, 1997), but field drying reduces both the mineral and water content of the crop, allowing for a cleaner fuel and retention of more nutrients in the field (Dželetovic *et al.,* 2009a; Dželetovic *et al*., 2009b; Babovic *et al*., 2010). In the UK it is current commercial practice for the harvest of miscanthus grown for combustion to be delayed, until late winter/early spring, which reduces concentrations of moisture, ash, and alkali metals at the expense of dry matter yield (Lewandowski *et al.,* 2003). The mineral content of miscanthus biomass is low compared with wheat straw, but higher than for willow/poplar coppice. Acording to Lewandowski and Kicherer (1997) mineral concentrations are reported to be low at the time of the early spring harvest: 0.09-0.34% N; 0.37-1.12% K; 0.03-0.21% Cl and 1.6-4.0% ash [23]. The composition of miscanthus ash includes approximately 30-40% SiO_2, 20-25% K_2O, 5% P_2O_5, 5% CaO, and 5% MgO - a range of values from different studies (Moilanen *et al*., 1996; Hallgren *et al*., 1998).

A drawback to combustion of miscanthus is the low ash, melting point of the biomass which might be related to the simultaneous presence of high Si, K and Ca, as Si in itself has a high melting point (1700°C), which can be problematic in some boiler systems. Ash behavior (sintering) is no worse than many other biomass ashes, and Miscanthus ash showed clear sintering tendencies at temperatures as low as 600°C, compared with reed canary grass and willow (the latter of which was inert up to 900° C). Therefore, agricultural strategies aimed at reducing the leaf component (e.g. by delaying the harvest) may considerably improve the suitability of biomass for current combustion plants (Monti *et al.,* 2008).

10.2.2 Combustion

Since the chemical composition of *Miscanthus×giganteus* is favorable for combustion, it is commercially grown in the European Union as a combustible energy source. *Miscanthus×giganteus* has a net calorific value, on a dry basis, of 17 MJ/kg, with a 2.7% ash content. The energy value of 20 t (1 ha) of dry miscanthus would be equivalent to that of 8 t of coal (Defra, 2007). Generally dry mass (DM) yield and the heating value of the crops are the most important factors in determining the energy source potentials for solid fuels. Therefore, it should be noted that dry mass yield largely depends on soil and climate conditions whereas the water content depends on the time of harvest.

Miscanthus biomass can be used for co-firing in coal power stations, for large-scale electricity power stations and for small scale heat production. For large power stations (30 MW+) requiring hundreds of thousands of tonnes of biomass annually, while for small-scale systems (on-farm or single building) requiring just a few dozen tonnes during winter months. Several boiler manufacturers have boilers which are equipped to burn miscanthus as chip, bale, briquettes or pellets. Miscanthus has been successfully burned on a commercial scale in Denmark using a 78 MW circulating fluidized-bed combustor (50% co-firing with coal) and 160 MW powered fuel combustor (20% co-firing) (Jones and Walsh, 2007). Currently, most miscanthus biomass in Europe is used in combustion. Miscanthus is typically large-baled and transported to an industrial facility where the bales may be stored for use on demand.

Straw-burning power stations have been used successfully to combust miscanthus (e.g. Elean Power Station, Ely, UK). Pure biomass-burning power stations in the UK receive high financial incentives through a scheme of renewable obligation certificates (ROC). While infrastructure to fire biomass is developing, co-combustion with coal is being pioneered by several power generators in the UK: Drax (Yorkshire, UK) and Aberthaw (South Wales, UK). Miscanthus is currently co-fired in Drax pulverised coal boilers in the UK and can also be co-fired using fluidised bed technology.

Spliethoff and Hein (1998) investigated the effects of co-combustion of miscanthus, straw and municipal sludge together with primary fuel hard coal in pulverized fuel furnaces. They found that SO_2 emissions decreased with the addition of miscanthus, straw and wood. Collura et al. (2006) have examined combustion of *Miscanthus×giganteus* straw and pellets in standard conditions by using 25 and 60 KW boilers. They have observed that emission factors for SO_2, NO_x and total organic carbon (TOC) in the exhaust meet the European standards for biomass boilers.

10.2.3 Potential production of bioethanol

In recent year, the use of lignocellulosic biomass as feedstocks for biofuels development has received considerable attention (Tilman *et al*., 2006). Owing to its high cellulose content and high biomass yield, miscanthus has been described as a candidate energy resource for the production of high levels of fermentable glucose into bioethanol. Cellulose and hemicellulose can be enzymatically hydrolyzed to its monomeric constituents (glucose units) and then fermented to bioethanol for the production of bioethanol. As a substitution for gasoline bioethanol has great potential since the distribution system for liquid fuel already exists, and regular cars with today's engines can without further adjustment run on up to 10% bioethanol.

Tab. 10.2 Composition of *Miscanthus × giganteus* (Villaverde *et al.* 2010)

Components		**Percentage (dry basis)**
Ash		0.8
Lignin	Acid insoluble	20.8
	Acid soluble	0.9
Polysaccharides	Holocellulose	36.5
	α-cellulose	50.9
	β-cellulose	11.9
	γ-cellulose	10.6
Monosaccharides	Arabinose	1.1
	Xylose	14.9
	Mannose	0.0
	Galactose	0.3
	Glucose	38.0
	Rhamnose	0.0
	Uronic acids	1.2

Table 10.2 gives estimates of the composition of miscanthus according to Villaverde *et al.* (2010). As can be seen from Table 1 *Miscanthus×giganteus* presents a fibrous material with a proportion of lignin which is remarkable for a grass and α-cellulose accounts for half the dry mass of miscanthus. Composition of miscanthus varies with seasonal changes, harvesting date and with its bioclimatic location. The literature suggests that total lignin content accounts 23%, cellulose 37%, and hemicellulose 22% of Miscanthus×giganteus dry matter according to studies summarized by Han *et al.* (2011), while it was reported that dried biomass of *Miscanthus×giganteus* consists of 38% cellulose, 24% hemicellulose and 24% Klason lignin (de Vrije *et al.,* (2002). Sørensen *et al*. (2008) reported that dried biomass of *Miscanthus×giganteus* consists 40% cellulose, 18% hemicellulose and 25% Klason lignin.

High lignin concentrations have been found to be inhibitory to biological conversion processes such as fermentation and anaerobic digestion due to an increased resistance to microbial and fungal degradation. Lygin *et al.* (2011) found that lignin content and cellulose/lignin and cellulose/xylan ratios could be the major determinants of miscanthus biomass degradability. They concluded that breeding and selection of miscanthus genotypes with decreased lignin content in the future can maximize for both the higher biomass production and higher efficiency of biomass conversion to be able to produce the most biofuel per unit land area possible.

A small number of studies have been published on the pretreatment and enzymatic hydrolysis of Miscanthus for producing bioethanol. The pretreatments applied on miscanthus include ammonia

fiber expansion (Murnen, 2007), dilute acid presoaking combined with ethanol organosolv process (Brosse *et al*., 2009; Brosse *et al*., 2010) and dilute acid presoaking combined with wet explosion (Sørensen *et al*., 2008). In previous papers enzymatic hydrolysis of the biomass followed after the pretreatments was performed using a commercial cellulase mixture supplemented with β-glucosidase. The aqueous phase from the enzymatic hydrolysis experiments were fermented using baker's yeast (Brosse *et al.,* 2010).
The pretreatment process continues to be one of the most expensive steps, therefore lignocellulosic bioethanol is technically more demanding and thus more expensive. The choice of the pretreatment technology used for a particular biomass depends on its composition and the byproducts produced as a result of pretreatment. It should be noted, that pretreatment technologies can provide good results in terms of sugar conversion, but a full recovery of the feedstock through optimum utilisation of all lignocellulosic components, including nonsugar compounds, as marketable products should be one of the major goals of optimizing a biomass-to-bioethanol process, which is best evaluated in the context of biorefinery. Thus, the key issues concerning the process of pretreatment lignocellulosic biomass are manifold: (1) to optimize hydrolysis of the hemicelluloses by limiting their degradation to furans, which act as fermentation inhibitors; (2) to recover the cellulose in a less recalcitrant form, thereby facilitating its reactivity to cellulases; (3) to recover the lignin and to avoid its degradation and recondensation from the perspective of valorisation; and (4) to develop a process that can be applied at the pilot, demonstration, and commercial scales (Brosse *et al*., 2009; Brosse *et al*., 2010).

10.2.4 Other uses of Miscanthus

Except its utilisation for direct energy production and biofuels, *Miscanthus×giganteus* may be used in a wide variety of applications as: paper, building materials, thatching, geotextiles, fiberboard, fiber production, cellulose derivatives, etc. (Babović *et al*., 2011; Jones and Walsh, 2007).

Construction/Building Material

Miscanthus has been a subject of interest as a source of fibre to be used in building materials. The use of miscanthus for production of medium density fibreboard (MDF) has been investigated by Harvey and Hutchens (1996). They reported that *Miscanthus* fibre structure is particularly suitable for the MDF production. They found that sample MDF made from *Miscanthus* was comparable with that made from wood chips. However, currently forest waste is a cheaper raw material source and commercially more viable than either miscanthus or hemp, for production of fibreboard.
Light natural sandwich (LNS) materials are light building materials used for plane and mould structural parts with high form stability at low weight, used for a broad range of applications. It is anticipated that LNS materials would replace current market products that are based

predominantly on PVC, polyurethane or aluminium. The use of miscanthus as the core material for LNS has been demonstrated in Germany (Jones and Walsh, 2007) and EC-funded research of development LNS from micanthus (FAIR5-CT97-3784). The European Union supported a demonstration project in 1992 which investigated the used of Miscanthus for the production of panel boards and building blocks (Mangan, 1994).

Thatching

Traditionally, *Miscanthus* has been used as thatching material for roofs of traditional houses and buildings in Japan. Its use as a thatching material has now been taken up also in Denmark to substitute or supplement the traditional use of common reed (*Phragmites*) which partly grown in Denmark and partly imported (Jones and Walsh, 2007). The yield of reed is declining and the demand is increasing. Therefore it was decided to investigate whether miscanthus could be used as thatching material. A project entitled Thatching: use of *Miscanthus* was conducted in Denmark during 1995-1996, aimed at scaling up production and investigating possible commercialisation of the utilisation of miscanthus for thatching. Conclusion was that only miscanthus varieties like *Miscanthus sinensis* can be used. So far approximately 30 hectares in Denmark have been set aside for this purpose, and these are all planted with *Miscanthus sinensis* which has slim stems like the common reed.

Composting

The fibres of *Miscanthus* can be used as raw material for obtaining compost. Kresten Jensen et al. (2001) reported that English ivy (*Hedera helix*) grew well in composted miscanthus (*Miscanthus ogiformis*) substrates. Physical characteristics of miscanthus based composts was investigated by Wethje (2004). It was reported that miscanthus based compost media had low total bulk density, high air-filled porosity and a high diffusion coefficient of oxygen compared to peats, and require further investigation before they can be used directly as an alternative to peat.

Paper pulp production

Pulping for papermaking is a process of delignification, whereby lignin is chemically dissolved permitting the separation of fibres in the raw material. Commercial non-wood pulp production has been estimated to be 6.5% of the global pulp production and is expected to increase. Republic of China produces 77 % of world´s non-wood pulp. The variety *Miscanthus sacchariflorus* is one of the main papermaking raw materials in the Republic of China. In addition, a number of investigations have been carried out in European countries on the production of paper pulp from *Miscanthus*×*giganteus* (Villaverde *et al.,* 2009). At present, the use of fibres from non-woody crops for paper pulp production in Europe is below 1% of total production. Paper pulp from non-woody crops is mainly produced in developing countries and the raw materials which are most widely used are straw, bagasse and bamboo.

Fermentation product

The chemical composition of *Miscanthus sinensis* leaves and stalks have been analysed (Lange, 1992) in a comparative study of green plants harvested in September and dry plants harvested in March. Analysis of the lipophilic and hydrophilic constituents indicated that green plants contained higher amounts of glyceride and other fatty esters than dry plants. The predominant fatty acids were linoleic acid, linolenic acid and palmitic acid. D-Sucrose, D-glucose and D-fructose contents of green plants also exceeded those of dry plants. Whereas the leaves of dry plants were a poor source of constituents due to senescence and leaf- fall during winter, those of green plants were rich in fatty acids and other lipids. The green stalks were particularly rich in soluble sugars. On the basis of the high cellulose, sugar and lignin content, *Miscanthus sinensis* has been evaluated as a raw material for the production of fermentable pentose sugar solution.

Fertiliser

Some of the uses which have not already been mentioned are the use of *Miscanthus* fibre material in geo-textiles, its use as canes to support ornamental pot plants and the use of miscanthus ash arising from combustion processes as a fertilizer (Jones and Walsh, 2007). The quantity and quality of ash in herbaceous biomass depends on a large amount of factors including plant type, plant fraction, growing conditions, fertilisation, choice of harvest date, harvest techniques, and conversion systems.

Bioremediation

Established areas of *Miscanthus* could have valuable environmental benefits by acting as absorbing disposal areas for wastewater and some industrial effluents. Also the establishment on of *Miscanthus* on contaminated land can be beneficial for the reduction of aerial dispersion and runoff, soil erosion, the improvement of visual impacts, and providing a natural habitat for wildlife.

EC-funded BioReNew project examined the potential for the use of biomass fuel crops in the bioremediation and economic renewal of industrially degraded land. The main objective of the BioReNew project was to develop a system for the rehabilitation of heavy metal contaminated land using biomass fuel crops, which brings a net environmental benefit and contributes to the economic regeneration of areas suffering industrial decline. A number of field screening trials of *Salix*, *Phalaris* and *Eucalyptus* in the UK, Sweden and Spain were undertaken; along with the screening of 150 *Salix* clones, 20 *Phalaris* clones and 10 *Miscanthus* for the uptake of heavy metals. Also, in England the BioReGen project was demonstrated the feasibility of reusing brownfield sites to grow biomass energy crops at a commercial scale on a variety of contaminated sites. Duplicate experimental plots were planted with willow short rotation coppice (variety Tora), miscanthus (*Miscanthus*×*giganteus*), reed canary grass and switchgrass (variety Cave-in-rock). The brownfield site was originally a brick clay pit, backfilled over 50 years ago with domestic coal ash, privy waste and incineration residues. The resultant heavy metal contamination includes phytotoxic levels of Zn (400-1000 ppm), Cu (100-500 ppm) and Ni (100-200 ppm) and levels of Pb (300-2000 ppm) and As (50-200 ppm) which are significant for human health concerns. Miscanthus could be successfully grown on contaminated land, although high levels of heavy metals may reduce crop productivity. Most heavy metals accumulate in the roots and rhizomes, rather than in the harvested aerial parts.

Ministry of Science and Technological Development of the Republic of Serbia supported project "Biorational usage and ecoremediation of land and water by growing plants for industrial processing" (TR 20208, from 2008 to 2010). Ministry of Science and Technological

Development of the Republic of Serbia and Electric Power Industry of Serbia were supported project TR 31078 (from 2011 to 2014), which will investigate potential for growing *Miscanthus×giganteus* on degraded land, and potential for bioremediation of contaminated land.

Reference

ACAROGLU, M. – AKSOY, A.S. 1998. *Third year growing results of C4 energy plant Miscanthus sinensis in producing energy from biomass*. 10th European bioenergy conference, Wurzburg, 1998, p. 758–759.

BABOVIĆ, N. – DRAŽIĆ, G. – ĐORĐEVIĆ, A. 2011. Potential uses of biomass from fast-growing crop *Miscanthus x giganteus*. Chemical industry, doi:10.2298/HEMIND110711082B, 2011.

BABOVIĆ, N. – DŽELETOVIĆ, Ž. – ĐORĐEVIĆ, A. – DRAŽIĆ, G. 2010. *Interaction between rhizome size and aboveground growth dynamics of Miscanthus×giganteus*. 6th scientific-research symposium on breeding and seed production, Vršac, 2010 p. 98.

BAO IGLESIAS, M. – RODRIGUEZ, R.J.L. – CRESPO, R.I. – LAMAS, J. 1996. *Miscanthus sinensis plantations in Galicia, north-west Spain: results and experience over the last three years*. 9th European bioenergy conference, Copenhagen, 1996, p. 608–612.

BROSSE, N. – SANNIGRAHI, P. – RAGAUSKAS, A. 2009. *Pretreatment of Miscanthus x giganteus using the ethanol organosolv process for ethanol production*, In Industrial and Engineering Chemistry Research, Vol. 48, 2009, p. 8328–8334.

BROSSE, N. – EL HAGE, R. – SANNIGRAHI, P. – RAGAUSKAS, A. 2010. *Dilute sulphuric acid and ethanol organosolv pretreatment of Miscanthus x Giganteus*. In Cellulose Chemistry and Technology, Vol. 44, 2010, p. 71–78.

COLLURA, S. – AZAMBRE, B. – FINQUENEISEL, G. – ZIMNY, T. – WEBER, J.V. 2006. *Miscanthus x giganteus straw and pellets as sustainable fuels*, *Combustion and emission tests.* In Environmental Chemistry Letters, Vol. 4, 2006, p. 75–78.

CHRISTOU, M. – PAPAVASSILIOU, D. – ALEXOPOULOU, E. – CHATZIATHANASSIOU, A. 1998. *Comparative studies of two potential energy crops in Greece*, 10th European bioenergy conference, Wurzburg, 1998, p. 935–938.

DAUGHERTY, E.CH. 2001. *Biomass Energy Systems Efficiency*. Masters's of Science Thesis

DEFRA 2007. *Planting and growing Miscanthus. Best Practice Guidelines (for Applicants to Defra's Energy Crops Scheme)*, 2007, 18 pp.

DEMO, M. – FAZEKAŠ, A. – HAUPTVOGL, M. – SKLADAN, B. – TÓTHOVÁ, M. 2011. *Produkčný a anergetický potenciál švédskych odrôd rýchlorastúcej enrgetickej dreviny rodu Salix pestovanej v suchších pôdno-klimatických podmienkach juhozápadného Slovenska.* SPU Nitra, 2011, 110 pp., ISBN 978-80-552-0577-9.

DE VRIJE, T. – DE HASS, G.G. – TAN, G.B. – KEIJSERS, E.R.P. – CLAASSEN, P.A.M. 2002. *Pretreatment of Miscanthus for hydrogen production by Thermotoga elfii*, In International Journal of Hydrogen Energy, Vol. 27, 2002, p. 1381-1390.

DRAŽIĆ, G. – SEKULIĆ, S. – MILOVANOVIĆ, J. – ALEKSIĆ, J. 2010. *Master plan plantaže energetskog useva Miscanthus x giganteus*. Međunarodno savetovanje „Energetika 2010“. Zlatibor. 23-26.03. Zbornik radova. p. 96-99.

DŽELETOVIĆ, Ž. – MIHAILOVIĆ, N. – GLAMOČLIJA, Đ. – DRAŽIĆ, G. 2009a. *Postponed harvest of Miscanthus × Giganteus: Influence on the quality and quantity of accumulated biomass*, In Journal on Processing and Energy in Agriculture, Vol. 13, 2009a, p. 170-173.

DŽELETOVIĆ, Ž. – MIHAILOVIĆ, N. – GLAMOČLIJA, Đ. – DRAŽIĆ, G. 2009b. *Harvesting and storage of Miscanthus × giganteus Greef et Deu.*, In Agricultural Engineering, Vol. 34, 2009b, p. 9-16.

HALLGREN, A.L. – OSKARSSON, J. 1998. *Minimization of sintering tendencies in fluidized-bed gasification of energy crop fuels*, 10th European bioenergy conference, Wurzburg, 1998, 1700-1703.

HAN, M. – CHOI, G.W. – KIM, Y. – KOO, B.C. 2011. *Bioethanol production by Miscanthus as a lignocellulosic biomass: Focus on high efficiency conversion to glucose and ethanol*, In BioResources, Vol. 6, 2011, p. 1939-1953.

HARVEY, J. – HUTCHENS, M. 1995. *Progress in commercial development of Miscanthus in England*, 8th EC Conference, Biomass for Energy, Environment, Agriculture and Industry, Oxford, 1995, p. 587-593.

JANDAĆKA, J. – MALCHO, M. 2007. Biomasa ako zdroj energie. 2007, 75 pp., ISBN 978-80-969161-4-6.

JONES, M.B. – WALSH, M. 2007. *Miscanthus for Energy and Fibre*, Earthscan, London, 2007, 192 pp.

JORGENSEN, U. 1997. *Genotypic variation in dry matter accumulation and content of N, K and Cl in Miscanthus in Denmark*, In Biomass and Bioenergy, Vol. 12, 1997, p. 155–169.

JORGENSEN, U. – SANDER, B. 1997. *Biomass requirements for power production: How to optimise the quality by agricultural management*, In Biomass and Bioenergy, Vol. 12, 1997, p. 145–147.

KRESTEN JENSEN, H.E. – LETH, M. – LONSMANN IVERSEN, J.J. 2001. *Growth of Hedera helix L. container plants in compost substrates made with Miscanthus ogiformis Honda straw and various N-sources*, In Compost Scence and Utilization, Vol. 9, 2001, p. 206–214.

LANGE, W. 1992. *Extracts of miscanthus grass (Miscanthus sinensis Anderss.). A comparison of the ‘summer-green’ and the ‘winter-dry’ plant*. In Holzforschung, Vol. 46, 1992, p. 277–282.

LEWANDOWSKI, I. – CLIFTON-BROWN, J.C. – SCURLOCK, J.M.O. – HUISMAN, W. *Miscanthus: European experience with a novel energy crop*, In Biomass and Bioenergy, Vol. 19, 2000, p. 209-227.

LEWANDOWSKI, I. – KICHERER, A. *Combustion quality of biomass: practical relevance and experiments to modify the biomass quality of Miscanthus x giganteus*, In European Journal of Agronomy, Vol. 6, 1997, p. 163–177.
LEWANDOWSKI, I. – CLIFTON-BROWN, J.C. – ANDERSSON, B. – BASCH, G. – CHRISTIAN, D.G. – JORGENSEN, U. – JONES, M.B. – RICHE, A.B. – SCHWARZ, K.U. – TAYEBI, K. – TEIXEIRA, F. *Environment and harvest time affects the combustion qualities of Miscanthus genotypes*. In Agronomy Journal, Vol. 95, 2003, p. 1274–1280.
LYGIN, A.V. – UPTON, J. – DOHLEMAN, F.G. – JUVIK, J. – ZABOTINA, O.A. – WIDHOLM, J.M. – LOZOVAYA, V.V. 2011. *Composition of cell wall phenolics and polysaccharides of the potential bioenergy crop – Miscanthus*. In GCB Bioenergy, Vol. 3, 2011, p. 333-345.
MANGAN, C.L. 1994. *Non- food crops and non-food uses in EC research programmes*, 7th EC Conference, Biomass for Energy, Environment, Agriculture and Industry, Bochu, 1994, p. 341–347.
MCKENDRY, P. 2002. *Energy production from biomass (part 1): overview of biomass*, In Bioresource Technology, Vol. 83, 2002, p. 37-46.
MOILANEN, A. – NIEMINEN, M. – SIPILA, K. – KURKELA. E. 1996. *Ash behavior in thermal fluidizedbed conversion processes of woody and herbaceous biomass*, 9th European bioenergy conference, Copenhagen, 1996, 1227-1232.
MONTI, A. – DI VIRGILIO, N. – VENTURI, G. 2008. *Mineral composition and ash content of six major energy crops*, In Biomass and Bioenergy, Vol. 32, 2008, p. 216-223.
MURNEN, H.K. – BALAN, V. – CHUNDAWAT, S.P.S. – BALS, B. – DA COSTA SOUSA, L. – DALE, B. E. 2007. *Optimization of ammonia fiber expansion (AFEX) pretreatment and enzymatic hydrolysis of Miscanthus x giganteus to fermentable sugars*, In Biotechnology Progress, Vol. 23, 2007, p. 846–850.
PRICE, L. – BULLARD, M. – LYONS, H. – ANTHONY, S. – NIXON, P. 2004. *Identifying the yield potential of Miscanthus x giganteus: an assessment of the spatial and temporal variability of M. x giganteus biomass productivity across England and Wales*, In Biomass and Bioenergy, Vol. 26, 2004, p. 3–13.
SCHWARZ, H. – LIEBHARD, P. – EHRENDORFER, K. – RUCKENBAUER, P. 1994. *The effect of fertilization on yield and quality of Miscanthus sinensis ''giganteus''*, In Industrial Crops and Products, Vol. 2, 1994, p. 153–159.
SOMERVILLE, C. – YOUNGS, H. – TAYLOR, C. – DAVIS, S.C. – LONG, S.P. 2010. *Feedstocks for lignocellulosic biofuels*, In Science, Vol. 329, 2010, p. 790-792.
SØRENSEN, A. – TELLER, P.H. – HILSTRØM, T. – AHRING, B.K. 2008. *Hydrolysis of Miscanthus for bioethanol production using dilute acid presoaking combined with wet explosion pre-treatment and enzymatic treatment*, In Bioresource Technology, Vol. 99, 2008, p. 6602-6607.
SPLIETHOFF, H. – HEIN, K.R.G. 1998. *Effect of co-combustion of biomass on emissions in pulverized fuel furnaces*, In Fuel Processing Technology, Vol. 54, 1998, p. 189-205.

TILMAN, D. – HILL, J. – LEHMAN, C. 2006. *Carbon-negative biofuels from lowinput high-diversity grassland biomass*. In Science, Vol. 314, 2006, p. 1598-1600.
USŤAK, S. 2006. Biomasa-obnovitelný zdroj energie. New energy, 2006, p. 48-50.
VILLAVERDE, J.J. – LIGERO, P. – DE VEGA, A. 2010. *Miscanthus x giganteus as a source of biobased products through organosolv fractionation: A mini review*, In The Open Agriculture Journal, Vol. 4, 2010, p. 102-110.
VILLAVERDE, J.J. – LIGERO, P. – DE VEGA, A. 2009. *Bleaching Miscanthus x giganteus Acetosolv pulps with hydrogen peroxide/acetic acid. Part 1: Behaviour in aqueous alkaline media*, In Bioresource Technology, Vol. 100, 2009, p. 4731–4735.
WETHJE, C.A. 2004. *Physical characteristics of Miscanthus ogiformis composts compared to peat and wood fiber growth substrates*, In Compost Science and Utilization, Vol. 12, 2004, p. 219-224.

11 EU and National Legislation of Slovakia and Serbia

11.1 EU legislation of renewable energy sources

The basic document that promotes the use of renewable energy sources in EU Member States for the period until the year 2010 is called "White Paper on Energy Policy for Europe" (COM (95) 682) (1997). This document, as well as other EU and Slovak directives and regulations implementing this legislative instrument, follow the declared objectives of the Kyoto Protocol (1997), which commits its signatories to reduce greenhouse gases (CO_2, CH_4, N_2O, HFC_s, PFC_s and SF6), in average of 5.2% by 2008-2012 compared to reality in 1990.
Based on the White Paper the European Commission launched in 1999 initialization campaign (1999-2003), under which European Commission tried to stimulate the development of the use of renewable energy sources. The result of this activity is the "**Green Paper on European Strategy for Sustainable, Competitive and Secure Enegry**", adopted by the Commission (COM/2006/0105) on 8th March 2006 (Green Paper).
The Green Paper sets out the basic objectives that are formulated as follows:

- Sustainable development
- Competitiveness
- Safety of energy supply.

The priority areas in terms of EU energy strategy are:

1. To complete the European market with electricity and gas,
2. To build the European market with energy that guarantees security of supply (solidarity between Member States),
3. To solve security and competitiveness of energy supply: more sustainable, more efficient and more diverse energy assortment,
4. Integrated approach to solve climate changes,
5. Innovation support: European strategic energy technology plan,
6. Unified external energy policy.

The Green Paper notes that Europe has entered into a new energy era and new investments replacing aging infrastructure in the next 20 years amounting to around one trillion euros, are urgently needed. In the event of a failure to increase domestic energy more competitive in the next 20 to 30 years around 70% of the Union's energy requirements, compared to 50% today will be met by imported products, some from regions threatened by insecurity. Global demand for energy is increasing. It is expected that by 2030 the world demand for energy - and CO_2 emissions - about 60% will increase. Global oil consumption since 1994 has increased by 20%, and global oil demand to grow annually by 1.6%. Oil and gas prices are rising. Over the past two years the EU has almost doubled and electricity prices follow this trend. For consumers, this situation is difficult. With increasing global demand for fossil fuels, stretched supply chains and increasing dependence on imports and higher oil and gas prices, will probably remain. It may, however, trigger greater energy efficiency and innovation. Our climate is getting warmer. According to the Intergovernmental Panel on Climate Change (IPCC), greenhouse gas emission in the world temperature has increased by 0.6 degree. If no action is taken, it causes the end of this century, increasing from 1.4 to 5.8 degree. All regions in the world - including the EU - will face serious consequences for their economies and ecosystems.

Europe has not yet developed fully competitive internal energy markets. Only when such markets exist, EU citizens and businesses will enjoy all the benefits of security of supply and low prices. To achieve this goal should be to develop interconnections, to introduce and practice fully applied effective legislative and regulatory framework and vigorously enforce the Community competition rules.

Furthermore, the consolidation of the energy sector should be market oriented if Europe is to successfully address the many challenges it faces and conduct reasonable investments for the future. New energy profile for 21st century is therefore an environment where global economic regions are interdependent in ensuring energy security and stable economic conditions and for ensuring effective action against climate change.

The Green Paper notes that the EU is dependent on external energy supply and it is therefore necessary to diversify and provide different kinds of energy balance. To achieve this goal a series of partial steps in different sectors are directed.

The EU has adopted following directives to achieve this objective related to renewable energy sources:

- Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC,
- Directive 2009/29/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading scheme of the Community,
- Decision No 406/2009/EC of the European Parliament and of the Council of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020,
- Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide and amending Council Directive 85/337/EEC, European Parliament and Council Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC and Regulation (EC) No 1013/2006.

Promotion of renewable energy sources

European Parliament and Council 2009/28/EC of 23 April 2009 on the promotion of renewable energy sources (Art.1) established a common framework for the promotion of renewable energy. It sets mandatory national targets for the overall share of renewable energy sources to gross final energy consumption and the share of renewable energy sources in transport. It lays down rules relating to statistical transfers between Member States, joint projects between Member States and third countries, certificates of origin, administrative procedures, information and training and access to the electricity grid for renewable energy sources. It establishes sustainability criteria for biofuels and bioliquids.

Directive states (Art. 1) that the control of European energy consumption and the increased use of energy from renewable sources, together with energy savings and increased energy efficiency, constitute important parts of the package of measures needed to reduce greenhouse gas emissions and comply with the Kyoto Protocol to the United Nations Framework Convention on Climate Change, and with further Community and international greenhouse gas emission reduction commitments beyond 2012. Those factors also have an important part to play in promoting the security of energy supply, promoting technological development and innovation and providing opportunities for employment and regional development, especially in rural and isolated areas.

The use of energy from renewable sources in transport are some of the most effective tools by which the Community can reduce its dependence on imported oil in the transport sector, in which the security of energy supply problem is most acute, and influence the fuel market for transport.

Production of energy from renewable sources often depends on local or regional small and medium-sized enterprises. The opportunities for growth and employment that invest in regional and local production of energy from renewable sources bring about in the Member States and their regions are important. The Commission and the Member States should therefore support national and regional development measures in those areas, encourage the exchange of best practices in production of energy from renewable sources between local and regional development initiatives and promote the use of structural funding in this area.

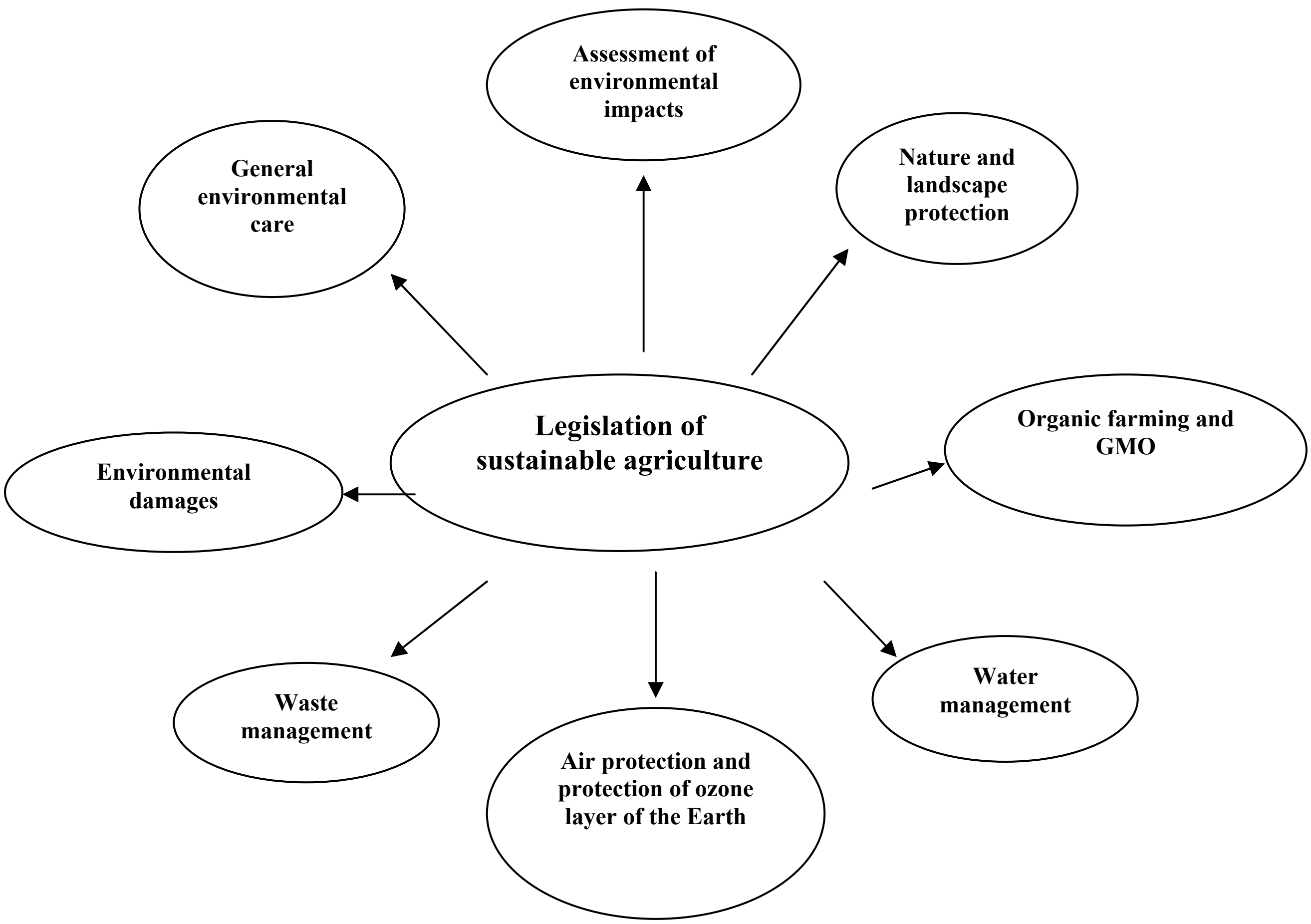
The Commission communication of 10 January 2007 entitled "Renewable Energy Roadmap - Renewable energies /article 8 of directive) in the 21st century states: building a more sustainable future" demonstrated that a 20 % target for the overall share of energy from renewable sources and a 10 % target for energy from renewable sources in transport would be appropriate and achievable objectives, and that a framework that includes mandatory targets should provide the business community with the long-term stability it needs to make rational, sustainable investments in the renewable energy sector which are capable of reducing dependence on imported fossil fuels and boosting the use of new energy technologies. Those targets exist in the context of the 20 % improvement in energy efficiency by 2020 set out in the Commission communication of 19 October 2006 entitled "Action Plan for Energy Efficiency: Realising the Potential", which was endorsed by the European Council of March 2007, and by the European Parliament in its resolution of 31 January 2008 on that Action Plan.

Action plan supposed preparation of national action plan since the task of all member states is to achieve significant improvement of energetic efficiency in all sectors.
The achievement of the objectives of this Directive requires that the Community and Member States dedicate a significant amount of financial resources to research and development in relation to renewable energy technologies. In particular, the European Institute of Innovation and Technology should give high priority to the research and development of renewable energy technologies.
Based on Action Plan for Energy Efficiency, Slovak Republic prepared its own strategy, the so called „Long-term strategy on utilization of agricultural and non-agricultural crops for industrial purposes (2009) in the Slovak Republic".
The main purpose of mandatory national targets is to provide certainty for investors and to encourage continuous development of technologies which generate energy from all types of renewable sources.
As for the increasing worldwide demand for biofuels and bioliquids, and the incentives for their use provided for in this Directive, should not have the effect of encouraging the destruction of biodiverse lands. Those finite resources, recognised in various international instruments to be of value to all mankind, should be preserved, the Directive states in Art. 69. Consumers in the Community would, in addition, find it morally unacceptable that their increased use of biofuels and bioliquids could have the effect of destroying biodiverse lands. For these reasons, it is necessary to provide sustainability criteria ensuring that biofuels and bioliquids can qualify for the incentives only when it can be guaranteed that they do not originate in biodiverse areas or, in the case of areas designated for nature protection purposes or for the protection of rare, threatened or endangered ecosystems or species, the relevant competent authority demonstrates that the production of the raw material does not interfere with those purposes.
The sustainability should promote the use of restored degraded land, because the promotion of biofuels and bioliquids contribute to the growth in demand for agricultural commodities. Although biofuels themselves are made from raw materials grown on arable land, the net increase in demand for crops caused by the promotion of biofuels could lead to a net increase in arable land. The restoration of land that has been severely degraded or heavily contaminated and therefore cannot be used, in its present state, for agricultural purposes is a way of increasing the amount of land available for cultivation.

11.1.1 Sustainable agriculture and organic farming

Sustainable agriculture is one of the objectives of the Common Agricultural Policy (CAP) in the global environment. Direction of the current CAP reflects strategic objectives related with competitive agriculture that is competitive on world markets, while respecting the strict legislation on the environment, food safety and animal welfare within a sustainable rural economy.

Legislation of sustainable agriculture is regulated by directions of the Slovak Republic and the European Union, which can be incorporated into the eight groups:



The European Union adopted new regulations for organic farming, which abolished the legal framework established in the EU Parliament in 1991.

- Commission Regulation (EC) No 889/2008 of 5 September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control,
- Commission Regulation (EC) No 1254/2008 regulates the activity as the production of yeast - Commission Regulation (EC) No 710/2009 introduces a new area: animal aquaculture and production of seaweed in the eco system,
- Commission Regulation (EU) No 271/2010 of 24 March 2010 amending Regulation (EC) No 889/2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007, as regards the organic production logo of the European Union.

11.1.2 The legislative framework for organic farming in Slovakia

Particular attention to organic farming in Slovakia began to pay particularly after 1990 when the law was adopted on organic farming and organic food production (Act No. 224/1998 Coll.) Development has required to readjust the relations in this area, and thus to adopt a new regulation that has been in the 2004 Act No. 421/2004 (Coll.) and in 2009 Act No.189/2009 (Coll.).

Last of the mentioned legal act - Act No. 189/2009 (Coll.) on organic farming, which became operational on 1st of June 2009 was caused by circumstances which were mainly related to changes in the definitions in Regulation (EC) No. 834/2007 on organic production and labelling of organic products and Commission Regulation (EC) 889/2008 of 5th September 2008 laying down detailed rules for implementing Council Regulation (EC) 834/2007 organic production and labeling of organic products with regard to organic production, labeling and inspection.

According to the stating memorandum to the newly adopted law causes expansion of primary agricultural production by system of organic farming and organic food production increasing of employment in rural areas. It is related mainly to the area of agro-tourism and local processing and selling. Therefore, also the part of the grants planned for the development of the country (Rural Development Plan 2007-2013) should be focused on the development of organic farming, especially in regions with the low priority in this field. Proceedings under this Legal Act are regulated by the Administrative Procedure Act (Act no. 71/1967 Coll on Administrative Procedure, as amended by Law 527/2003 and 445/2008 Coll.)

Administrative Procedure Code is a general law which governs the administrative proceedings (i.e. ministries, central and local government bodies and municipalities) and there is a subsidiarity in case that any other specific laws have not specific arrangements related to the administrative proceedings.

11.1.3 Competence, control, administrative procedures and responsibility of organs for organic farming

Government authorities in the field of organic farming are the Ministry of Agriculture of the Slovak Republic and the Central Control and Testing Institute of Agriculture (Control Institute).

Ministry of Agriculture of the Slovak Republic acts as a controlling and coordinating body in the care of the development of organic farming and decides on appeals against the decision of the Control Institute. Control Institute is a administrative body, acting on organic farming as a first instance authority and imposes sanctions for breach of obligations established by the Act for organic farming. In addition, this organ keeps a register of operators and inspection bodies, issues an authorization for inspection body for controlling organic farming and supervises its activities.

Control Institute in relation to the operator and importers:
a) Registers an operator and makes changes in the registry
b) Issues approval for import of products of organic farming under special regulations.

In relation to the EU, informs and cooperates with the competent authorities of the European Union and the competent authorities of the Member States of the European Union and inspection organizations of the EU Member States and also other countries.

Registration procedure
Registration begins on the proposal of the applicant, which must be submitted on a form issued by the Control Institute. To the application for registration must be attached annex, by which applicants declare their business structure on land identified by an extract from the ownership or lease and must be accompanied by a graphic attachment with situational designation of the land on which the applicant intends to carry out organic farming. Deadline for entry is 30 days after receiving a complete application for registration. If the application contains all required information and annexes Control Institute invite the applicant for registration within 30 days from delivery of application to complete it. During the passing of this period the procedure is interrupted, so the period for registration does not pass for the Control Institute.
The applicant must within this period complete the application. If applicant fails to do so in accordance with § 19.3 of Administrative Code, the Control Institute stops the registration procedure.
Applicant must be informed about these effects in the Invitation, if not, there would be a violation of rights of the applicant as a party in the procedure and the applicant in this case could apply its right on compensation for damages against the State (Ministry of Environment) under Law no. 514/2003 (Coll.) on responsibility for damages in the performance of public administration. After making the entry Control Institute within 15 days informs the operator in written form about the registration into the register. In register must be entered the following information:
1. Name, surname, place of residence, identification number of organization (in case it is a natural person) or business name, address and identification number (in case it is a legal person),
2. Type and location of activity,
3. Registration number assigned by Control Institute,
4. Inspection organization.

Operator has an obligation to carry out organic farming under this Act and under the special regulations as well and also concludes a written contract with the inspection body authorized to carry out the control within 30 days from receiving notification on registration. After the conclusion of the contract, operator must again within 30 days inform the Control Institute in written form on contracting with the specific inspection organization. In case that operator changes his data which are entered in the Register, he must inform Control Institute within 30 days. If the operator no longer meets the conditions for organic farming, or he requests cancellation of registration, the Control Institute cancels the registration of the operator in the register.

Inspection Organizations and the inspectors of organic farming

The Act defines in § 8 quo. Act "Inspection Organizations" which carry out the control by inspectors of organic farming production.

Inspection organization is an entrepreneur who is capable and authorized to carry out the control under Council Regulation (EC). 834/2007 of 28 June 2007 on organic production and labeling of organic products and repealing Regulation (EEC) 2092/91 and is accredited according to the Slovak technical standards (STN EN 45 011 General requirements for bodies operating in certification systems of the products). In addition, it must be established in Slovakia or his authorized representative and authorization to carry out the control must be given by Control Institute. The law provides strict restrictions on the inspectors, subsidiary regulated by § 9 of Administrative Code on condition of exclusion of an administrative body, in case there is a uncertainty about his impartiality to the matter.

Inspector of organic farming may not be an operator of organic farming, and also he may not be an operator for placing the product of organic farming into the market. Moreover inspectors may not control the same operator of the organic farming more than 3 consecutive years, or be an inspector for more than one inspection body.

The inspection body must immediately notify the inspection institute:

a) Withdrawal of marking and withdrawal of product certification of organic farming,

b) Any change of registered operator of the data found during the inspection,

c) A proposal to impose fines for violations of duties imposed by this Act or special regulations.

Fines for breaking the law No. 189/2009 (Coll.) according to § 11, impose the inspection institute during the administrative procedure. The penalty proceedings may be commenced within one year from the date when control institutes or control body when learned about the infringement or within three years from the date when the breach occurred the latest.

The law allows penalizing:

• Operator
• Inspection organization
• Natural and legal persons

If the operator fails to comply with the obligation to inform in writing the Control Institute on the conclusion of a contract with the Inspection organization within 30 days from the date of its entry into force, a fine is from 100 to 3000 EUR. In case the operator fails to comply with the obligation to inform within 30 days Control Institute about any change of the data contained in the application for registration and in announcement of the registration as well as the absence of concluded written contract with Inspection organization authorized for control, within 30 days

from delivery of announcement of the registration, may Control Institute impose a fine to the operator from 200 EUR to 8,000 Euros.
The highest penalty that allows this law is to impose a fine to operators for untagged products of organic farming by graphic logo of organic farming, and this fine is up to 10 000 EUR.
If the Inspection organization does not respect the regulation § 9 quo of the Act when is carrying out the control on operators, the Control institute may impose a fine ranging from 300 to 10,000 EUR.
Control Institute has authorization to penalize a natural or legal person who, in contravention of this Act or special regulations use fraudulent information that agricultural product or foodstuff from the conventional production comes from the organic farming, and fine may be up to 50,000 EUR.

11.1.4 Renewable energy sources

We analyzed the current legislation of the EU in field of renewable energy sources in the introductory part of the Chapter 12. Slovak Republic has adopted "Long-term strategy on utilization of agricultural and non-agricultural crops for industrial purposes" based on Action plan for energetic effectiveness approved by the European Council on meeting in March 2007 and by European Parliament in its resolution of 31 January 2008.

Long-term strategy on utilization of agricultural and non-agricultural crops for industrial purposes (2009) in Slovakia
Introduction of the Strategy states that in recent years the Government of Slovak Republic has approved strategic and conceptual documents related to the biomass:
1. The Concept of renewable energy sources (2003)
2. The Concept of using agricultural and forest biomass for energy purposes (2004)
3. Analysis of the impact of existing legislation to support use of biomass for energy purposes and proposal for further processing (2006)
4. Strategy for greater use of renewable energy sources in Slovakia (2007)
5. Action Plan of Biomass use for the years 2008 - 2013 (2008)
6. Strategy of Energy Security of the Slovak Republic approved by the Government resolutio no.732/2008
7. Proposal of the implementation of Strategy of energy security in the Slovak Republic
8. Report on progress in the production of electricity from renewable sources and proposed measures in this area
9. Certificates on compliance of investment plan with long-term concept of energy policy of the Slovak Republic

Analysis of the appropriateness of the landscape for growing energy plants in the framework of adopted strategy

Common Agricultural Policy (CAP) of the EU raised the issue of soil which is temporarily or permanently unnecessary for agricultural sector. One of the effective solutions how to use these areas is for growing energy crops. Possible biomass production in these areas could guarantee environmentally and economically more friendly effects than conventional production of agro products. This means in better environmental conditions use land intensively to produce food products, which will be able to compete with the difficult conditions of world agricultural market. Agriculture should focus on non-food agricultural production, on production called "agrificated" (plant) materials and bioenergy in less productive areas. Since a large proportion of agricultural land in Slovakia is located in areas for intensive use of inappropriate plants, attention should be paid to the growing of industrial and energy plants. The introduction of these crops into the land management system should be considered as one of the most important innovation in plant production in the near future and cultivation should become a common and well supported and preferred part of the agricultural program.

Potential to produce biomass and biogas in our agricultural enterprises is substantial. Its use would be necessary not only for energy gain and thus for saving money, but also for the disposal of agricultural waste, which causes frequent problems. To obtain energy phytomass is possible to use advantageously not only the surplus agricultural land, but also other, different ways devastated land.

Agriculture may be one of the main sources of raw materials for biomass for production of bioproducts, e.g. bioenergy (biodiesel) and biomaterials (eg, bioplastics). The biggest problem still remains in relatively high prices of most agricultural raw materials of biomass and bioproducts that are able to replace derivate of fossil fuels compared to current prices of fossil fuels. Production of agricultural biomass will be sustainable in case this production is economically efficient and profitable, socially acceptable; reports net benefits to environmental protection and rural development. It must be also consistent with the objectives of agricultural, environmental, energy and industrial policies in the broader context of trade liberalization and sustainable development. When comparing the net balance of costs and benefits of biomass products and their alternatives from fossil fuels, the most important is how environmental benefits and costs (i.e. externalities) are rated. One of the tools which were developed for this purpose is called: LCA (life-cycle analysis). Recent studies of LCA suggest that in comparison with the use of traditional crops such as cereals and sugar crops, also the cellulosic plant materials can bring significant economic and environmental benefits (grass and wooden crops)

Using cellulosic by-products can reduce the production of "waste" and to ensure utilization of the entire crop. The use of perennial grasses and woody crops reduce application of fertilizers and pesticides when we compare this with arable crops. The strategy assumes that potential interested persons for growing energy crops (especially woods) will not tend to use the "inferior" land, but they will try use mostly the best quality of land.

The reason is simple - bioenergy production on quality soils is economically much more efficient: low cost - high growth of biomass. Therefore it will be necessary to identify suitable areas for land and also to identify supposed economic parameters (efficiency).
Effective searching for solutions or compromise between using land for conventional agricultural production, for leaving production, or respectively for growing energy crops can help special-purpose categorization of agricultural land that consider interests of the agricultural sector.

According to this categorization we can divide agricultural land:
Primary agricultural land – is land which has to be reserved for direct agricultural use from the strategic purposes, i.e. for the crop production and for livestock and that amount do not endanger the population food sufficiency. This land should be maintained primarily for the purposes of agricultural production - primary - basic soil.
National food security in terms of Slovakia's population according to preliminary calculation is sufficient if there is available 1 048 500 ha of arable land and 383,000 ha of permanent grassland. In this area are not included: vineyards (about 12 000 ha), hop-fields (about 300 ha), gardens and orchards. In this variant, accounts for 0.19 ha per capita arable land (5.5 million inhabitants). Primary land occupies about 60% of currently registered agricultural land.
Secondary agricultural land – is land that in case of interest of society is possible to use temporarily also for other purposes such as food production. During this use in not allowed to degrade this land – its character, quality remain practically unchanged).This land can be set aside for alternative agricultural uses. It occupies about 40% of agricultural land. Calculations show that reserve of arable land is 18%, but the reserve of production to maintain food sufficiency is only 10-14% depending on the commodity.
Unoccupied "free land" is related mostly with the area of permanent grassland. In the case of secondary agricultural land fund, there is available about 513.800 ha of permanent grassland, of which about 1 / 3 means 171.200 ha can be used intensively. Alternative soils represent about 342.500 ha of permanent grassland.

Potential of agricultural land for growing energy crops

Possibilities of using agricultural land for growing energy crops depend on quality and appropriateness of the habitat of the individual crop. Because of enough land that are able to ensure food security in Slovakia, is possible to use large part of agricultural land for such purposes. Therefore there are many significant possibilities in Slovakia.
It is logical that the cultivation of any crop is economically and practically more favorable on better soils, where is expected higher natural and financial revenue.
This soil is soil of the lowland, or basin, or south-oriented temperate slopes, soils without soil skeleton, deep soil, and soil with favorable water, air and nutrient regimes, which are located close to the potential processing of biomass. Localization of energy crops is related to many risks. The main risk is that most quality soil could be used therefore it must be protected and use mainly for the food production. In this case legislative and economic instruments must be used

for the protection of primary agricultural land. There is a possibility of lack of subsidy incentives for such activities especially in marginal areas and regions.
There is an expectation that distribution of subsidies will be conditioned by the inclusion of land into the system LPIS.
This may lead to less willingness to "invest" in land that is not currently in the subsidy system for the various reasons (most significant reason is overgrowing by natural self-seeding).
The risk is also the threat of physical and chemical soil degradation, especially for non-agricultural crops, such as fast-growing trees. The root system of these crops may cause disruption of soil structure and the loss of soil nutrients and water. It will be necessary to support research activities aimed at analyzing and monitoring of the development of soil parameters. Certain risks may be also in excessive activity leading to oversized use of land for such purposes. Its results (after the initial enthusiasm) may be a new abandoned and overgrown farmland.
Temporary set aside of agricultural land for cultivation of non-agricultural crops should be conditioned by preparation and implementation of the project of the recultivation.
There are possibilities that new risks occur that are currently unknown. The positive thing is that Slovakia is able to deal with such activities professionally and effective. Crops and plants use for non-food purposes should be grown preferably on emissions loaded, water-protection and marginal lands. Fast-growing trees have never been grown on large areas of agricultural land in Slovakia. In the world and occasionally in Slovakia is growing of the fast-growing trees managed in the form of plantations. In the framework of the research project: SK-SRB-0029-09 there was established plantation, where were planted energy crops, which are analyzed in detail in Chapter 6.
Objectives that were approved in the "Long-term Strategy for cultivation of agricultural and non-agricultural crops for industrial purposes" requires the creation of legislative preconditions for environmentally acceptable and effective establishment of agricultural biomass crops, oilseeds, industrial plants, energy crops and fast-growing trees on agricultural land - in 2009 – 2015 period.
In the context of the hypothetical establishment of plantations, cultivation of crops for non-agricultural purposes requires the monitoring of agricultural land in connection with food production.
The strategy emphasizes the solution of research tasks in the form of applied research in operating conditions and the subsequent creation of the biomass market and applied research focusing on the introduction of technology, training and utilization of biomass energy in practice - in 2009 - 2020 period. Part of the objectives and strategy is also preparation of the complex analysis of the impact of biofuel production in relation to the sustainability from production of raw materials through their processing to their production. The strategy also adopted important measures to protect nature and landscape:
- to ensure that any intentional establishment of any species into the nature, which is not originally from Slovakia, must be managed in way to prevent damage of original habitats or damage native species of animals and plants

- development of general criteria and requirements for fast-growing monocultures of energy wood and energy plants by plantation manner together with the methodology of the authorization of geographically non-native (introduced) plant species (trees and herbs) for growing on agricultural land.

11.1.5 Using renewable sources of energy in production of electricity

In the "Statement of Policy for the period 2006-2010" the Government of the Slovak Republic, undertook to create conditions for increased use of renewable energy sources (RES) in production of electricity and heat, as well as the use of biofuels in transport.

The new government in its policy statement (2010) followed up on their goals, and stressed that in building energy infrastructure, the Government will consistently seek to protect the environment, as well as to meet strict environmental aspects and reduce dependence on imported fossil fuels, developing the use of forest and agricultural biomass. In this chapter we focus on renewable energy sources (RES) in electricity production, because it is a substantial movement in improving legislation, renewable energy sources.

Slovak Republic adopted based on Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC and based on Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market and Act No. 309/2009 (Coll.) on promotion of renewable sources of energy and high-efficiency cogeneration. The Act came into force on 1.1.2011 and has been amended four times. Last amendment is Act No. 136/2011, with effect from 1.5.2011.

According to the explanatory memorandum of the quoted act, its role is to optimize the electricity market in renewable energy sources and to promote decentralized production of electricity. The law creates conditions for environmental protection and development of high efficient combined production of electricity and production of electricity from renewable energy sources.The aim of the Act is better utilization of primary energy sources in energy supply through high efficient combined production of electricity or mechanical energy and heat with a consequent reduction in greenhouse gases, particularly carbon dioxide.

The measure has a positive impact on the environment, especially by saving of primary energy resources (particularly fossil fuels), which will lead to smaller outflow of the emissions into the air. The law has undoubtedly a positive impact on the business environment by promoting the construction and reconstruction of the facilities for combined production and support of innovation in this field by using innovative technologies in energy supply.

This Act establishes the means and conditions to support the production of electricity from renewable energy sources, biomethane and electricity by high-efficient and combined production.

In the individual regulations establishes the rights and obligations of electricity producers, rights and obligations of other participants in the electricity and gas market, as well as rights and obligations of the legal person or natural person who launches motor fuels and other energy products used for transport purposes in the market. By adopted act there is an increase in minimum limitation of the share of renewable sources of energy in the fuel up to 30%. Increasing the share of renewable energy in the fuel in combined heat and power production from 20% to 30% causes the production of electricity from renewable energy sources by individual producers will be increased in the same proportion, as well.

The regulation moves the construction of solar power plants on buildings and therefore they will not occupy large areas of arable land for the construction of solar power plants. In addition, the place for production of electricity moves closer to its consumption and that reduces losses in electricity distribution. Promoting the production of electricity is related mainly to the smaller power sources. The producer of electricity from renewable energy sources and combined production, has according to the § 3 segment 1 of Act right for preferential connection to the facilities for the production of electricity into the regional distribution system, priority access to the system, preferential transmission, distribution and supply of electricity regardless of device performance. The basis of the support of the renewable energy sources is in guaranteed purchase of electricity, in guaranteed purchasing prices, and in guaranteed movement of the purchasing prices depending on inflation and other macroeconomic indicators. Price of electricity produced from renewable energy sources and combined heat and power production will be set by the Regulatory Office for Network Industries (Slovak abbreviation: URSO) on the basis of profit.

Price for electricity set by this Authority is in a way that take into account the types of renewable energies, the technology used, the date on which the facility to generate electricity go into the operation process and size of the installed equipment.

The Slovak Republic has important obligations to the European Commission resulted from the adopted law. Ministry of Economy of the Slovak Republic must submit to the European Commission:

- Till 31 December 2011 and every two years until 2021 progress report on the promotion and use of renewable energy sources.
- Till 31 December 2011 must publish following information on the website:

a) Information on supporting measures for consumers, builders, plumbers, architects and suppliers of heating, cooling and electricity equipment and systems, as well as vehicles which can be used renewable energy sources

b) Information on the benefits, costs and energy efficiency of the equipment and systems using for heating, cooling and electricity from renewable energy sources

c) information on the optimal combination of renewable energy, highly efficient technologies and long-distance heating and cooling, which are useful in planning, designing, building, construction and renovation of industrial or residential areas,

d) information on the measures to increase knowledge and professional training in the use of renewable energy sources in cooperation with local government organs with the objective to inform on the benefits of renewable energy sources.

Legislation of the renewable energy sources in the Slovak Republic has also a number of shortcomings that are criticized by energy producers, and also by professionals. One the contentious point is that the State will be obliged to purchase electricity from renewable sources only 15 years. Most of the countries in the European Union have this deadline longer (e.g. Germany, Spain, Italy).Slovakia is still lagging, in comparison and nuclear power plants produce four times more energy than renewable energy sources. Fossil fuels are still on the first place and in total energy consumption of the world they present 87.8 percent. Fossil fuels dominate also in Slovakia and on production of the energy they represent 71 percent.
According to the directions of the European Union, Slovakia should produce 14 percent of all energy from renewable sources by 2020. Many energy producers argue that despite on the adopted legislation this commitment will not be completed.

11.1.6 Protected Areas and limits for farming (ecological stability) in Slovakia

Sustainable use of agricultural land, its management and use, as well as the protection of its quality and functions are regulated by Act No. 220/2004 (Coll.) on "The protection and use of agricultural land". The purpose of this legislation is to regulate its use in the manner and extent to preserve its biological diversity, soil fertility, regeneration ability and ability to perform all functions. Act besides the definition of environmental functions of agricultural land (biomass production, filtration, neutralization and conversion of substances in nature, maintaining ecological and genetic potential of living organisms in nature) remember to protect agricultural land from unauthorized use for non-agricultural use, and provides penalties for violation of obligations established by this Act. In accordance with § 3 of the quoted Act, every owner of agricultural land or the lessee and manager must perform agro-technical measures to protect and preserve the qualities and functions of agricultural land and to prevent its damage and degradation and ensure the use of agricultural land in the way that ecological stability of the area is not endangered and functional interrelatedness of natural processes in landscapes will be maintained.Because of the interest of administrative register of real estate in the Slovak Republic, owner of land is obligated to organize and to harmonize the type of agricultural land with its registration in the land cadastre. Agricultural land is primary production factor and also the natural resource which is unique in that land is immobile and therefore all other mobile sources, as well as production processes must adapt to the environment in which the land is situated (Legal and Economic aspects of agricultural land rent (Lazíková and Takáč, 2010).
As we mentioned in Chapter 12.1, Common Agricultural Policy of the EU raised the issue of soil that are temporarily or permanently unnecessary for agricultural production. One of the possible

alternatives of the use of agricultural land which is not profitable for food production is for production of biomass for energy production. The main types of biomass resources are fast growing trees (e.g. willow, poplar, alder, and black locust). Fast-growing trees compared to energy woods have advantage that the period between planting and logging is significantly shorter. Period is between 2 to 5 years and planting is renewed after 20 to 30 years.

For growing energy crops on agricultural land is necessary (according to the § 17 quot. Law) tp temporary withdraw agricultural land because the agricultural land can be used for non-agricultural purposes only in necessary cases and in reasoned range. Decision on withdrawal issues organ responsible for protection of agricultural land in responsible territory - where is agricultural land situated (relevant District Land Office). Relevant Land Office considers the draft of non-agricultural use of agricultural land for planting fast-growing tree species on the basis of the agronomic and pedologic results means according to the quality of the soil: soil and ecologic unit (Slovak abbreviation: BPEJ). The law designates Soil and Ecologic unit (BPEJ) as a classification and identification figure for the quality and value of production-ecological potential of agricultural land in the given area. Agricultural land is classified into the 9 groups of quality according to the 7-digit code of Soil and Ecologic unit (BPEJ). Specifically protected land for agricultural use is land classified into the group 1 – 4 according to the Soil and Ecologic unit (BPEJ). Potentially suitable land for planting fast-growing trees are the agricultural land classified under Soil and Ecologic unit (BPEJ) into the group 6-9 and according to the Annex No.3 of the Act No. 220/2004 (Coll.) of the Protection and use of agricultural land.District Land Office after receiving a request from a natural or legal persons for the withdrawal of agricultural land will assess whether the principles of protection of agricultural land are fulfilled and in the decision specify mainly the following facts:

- Purpose of the issued permission that agree with the temporary withdrawal of agricultural land,
- Period of temporary withdrawal (up to 10 years),
- Parcels, its parts and cadastral territory that are related to the withdrawal,
- Approve the project of retrospective recultivation of temporary withdrawal of agricultural land.

Basis for a decision is the opinion of the government bodies that may be directly influenced by implementation of proposal of fast growing plants such as government authorities in the field of forestry and in the field of nature and landscape protection. The decision on temporary withdrawal will expire after the expiration period for which it was issued. Decision on the permanent withdrawal will expire if, within five years after the decision wasn't land used for plan referred to in the decision on withdrawal.

If the growing of fast growing trees exceeds 10 years, the grower is required to apply for a new decision, before the expiration of the temporary withdrawal of the previous decision. In accordance with § 12 quot. Act, those who propose a non-agricultural use of agricultural land is required in addition to the principles of protection of agricultural land for non-agricultural uses of land, pay for permanent removal or temporary withdrawal of agricultural land under the code of soil-ecological units (BPEJ). The amount of the transfer is regulated in Government

Regulation No. 367/2008 (Coll.), these days being prepared new amendment of the Act No. 220/2004 (Coll.) on the protection and use of agricultural land, which should take effect from 1 September 2011 and proposes to abolish the provisions on contributions. Proposal of the quot. Act has been prepared with the aim to simplify administrative procedures and to solve problems of the application practice in deciding on changes of land types in the proceedings with a large number of participants. Reason of the proposal of the abolition of payment for the withdrawal of agricultural land is a large number of exemptions on contributions related to the withdrawal of agricultural land. Enumerative specified exceptions represent 70% of all occupied agricultural land. By this arrangement Institute has became undemocratic and non-system and therefore this adjustment failed to finish the original intention of the highest quality agricultural land. Amendment of the Act proposes a modification of the principles and procedures for setting up of fast trees on farmland.

There is a register of fast growing trees grown on agricultural land that is managed by the District Land Office, with the intention of necessity of control over the principles of land protection also control over the backward recultivation of farmland.

In case that principle of land protection is not fulfilled by grower, Soil service announces this fact to the administrative authority to initiate proceedings for an offense or administrative offenses. The provision regulates fast-growing tree plantations on agricultural land of lower quality and flood prone soils, as a measure against flooding and erosion. In conclusion**,** we can summarize, that growing of fast growing trees on agricultural land requires:

• Use of lower quality agricultural soils, which are expendable in terms of food safety law,

• Obligation to producers of fast growing plants "to return agricultural land to its original quality state." Temporary use of agricultural land for non-agricultural purposes as a growing fast-growing plant has a significant impact on the quality of agricultural land, because root system is not only on the ground but also under the ground of the soil.

Growing of these special energy trees on agricultural land also need special cultivation and land management. Therefore temporarily excluded agricultural land must be taken into the original qualitative state after the cultivation by backward recultivation.

The European Union support growing of energy crops via direct payments for energy crops. Regulation (EC) No. 1782/2003 established specific support for energy crops to help develop this sector. Due to recent developments in the bioenergy sector and due to high demand for these products in international markets and the introduction of binding targets for the share of bioenergy in total amount of fuel by 2020 (Action Plan for Energy Efficiency), the EU has concluded that there is no sufficient reason to grant special support for energy crops.

Reason to doubt the necessity of such support was in sufficient agrarian and other economic and political incentives for renewable energy production. Consequently, the aid for energy crops was repealed by Council Regulation (EC) No. 73/2009 of 19^{th} of January 2009, that establishes common rules for direct support schemes for farmers under the Common Agricultural Policy and establishes certain support schemes for farmers.

11.1.7 Nature and landscape protection

Nature and landscape protection in Slovakia is included in the 78 legal acts on nature and landscape protection with direct and indirect amendments. Most of the legislation (73) regulates the protection of territory. Protection of fauna and flora is regulated by 5 legal acts. The basic national legislation is Act No. 17/1992 (Coll.) on Environment and Act. No. 543/2002 (Coll.) on Nature and landscape protection as amended. Current legislation on nature protection aimed on adopting the obligations arising mainly from the COUNCIL DIRECTIVE 97/62/EC of 27 October 1997 adapting to technical and scientific progress Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora which has become an essential means to protect fauna and flora species and their habitats, and from Council Directive of 2 April 1979 on the conservation of wild birds (79/409/EEC) that protects wild birds and important habitats, breeding areas for conservation (81/854/EEC, 85/411/EEC, 91/244/EEC, 94/24/EEC and 97/49 EC – that protects wild species of birds and important habitats, nests for their conservation from COUNCIL DIRECTIVE 1999/22/EC of 29 March 1999 relating to the keeping of wild animals in ZOOs and from COMMISSION DECISION of 18 December 1996 concerning a site information format for proposed Natura 2000 sites (97/266/EC) concerning the format of information for proposed Natura 2000 sites, which must be completed by each Member State for its proposed location in the file NATURA 2000.

The law reflected the obligations arising from international conventions to which the Slovak Republic is bound, especially by the Convention on Wetlands that has international importance in particular waterfowl habitat and the protocol of amendment (registered in part 67/1990 Coll.), The Convention on the Conservation of European Wildlife and Natural Habitats (Notification no. 93/1998 Coll.), the Convention on the Protection of Migratory Species of Wild Animals (Notification no. 91/1998 Coll.), and the Convention on the Protection of World Cultural and Natural Heritage (Notification no. 159/1991 Coll.). Cultivation of energy crops and plants and their use for energy purposes has besides positive impacts also the limitations and risks. Country on the one hand provides opportunities to meet the needs of society; on the other hand, its ecological potential based on the points that arising from the legislative definition.

Act No. 543/2002 (Coll.) on Nature and Landscape conservation as amended, creates the conditions for permanent maintenance, restoration and rational use of natural resources, preservation of natural heritage, and the characteristic landscape to maintain ecological stability and to contribute to preserving the diversity of conditions and forms of life on Earth. Nature and landscape protection under this Act means reducing actions that may endanger, damage or destroy the conditions and forms of life, natural heritage, landscape, reducing its ecological stability, as well as the consequences of such interventions.

The ecological value of forests and energy plantations depends on the context of a country the size of cultivation area and production management. For example: poplar intensive production areas on a large area, reduced diversity of species in comparison with slow-growing stands of old trees (Hartley 2002).

According to Gustafsson (1987) and Weih et al (2003) is a crucial size of the planting area. Increase of the biodiversity in agricultural land was confirmed in the cultivation of fast-growing willow and poplar trees on smaller plantations.

Energy crops must not be planted in protected areas. In this context, it is necessary to highlight the legislation of the Slovak Republic, which requires government bodies and villages as legal and natural person's responsibilities for nature and landscape protection and creation of the conditions for permanent maintenance, restoration and rational use of natural resources.

Law on the Nature and Landscape protection regulate five degrees of protection in detail. Range of the restrictions increases with increasing degree of protection. Locations where there are habitats of European importance, habitats of national importance, habitats of species of European importance, habitats of species of national importance and the habitats of birds, including migratory species whose protection declares protected areas, significant landscape features or areas of international importance, can be declared as protected areas. Creating and maintaining the territorial system of ecological stability is of public interest. Entrepreneurs and legal persons, who realize the activities which may endanger or impair the territorial system of ecological stability, are also required to propose measures that will contribute to the creation and maintenance of the area.

In case their activities affect the ecosystems, their components or elements, they are required to implement measures to prevent and reduce their damage and destruction. The law even requires from the entrepreneurs the obligation to include into the project proposals, programs, plans and other documentation, measures to support the territorial system of ecological stability.

Ministry of Environment of Slovak Republic is currently preparing a new law on nature and landscape protection. Into the preparation of the new law were involved expertises, but also the general public with the opportunity to express their opinions and ideas about what form should have a new law. 800 candidates used this opportunity and expressed their opinions.

Most of the comments and objections had the public on issues relating to satisfaction with the applicable law of nature and landscape protection, excavation and protection of trees in our communities, human interventions in areas with the highest degree of protection and restrictions on the movement of tourists in national parks.

82.4% of respondents expressed dissatisfaction with the currently applicable laws of Nature and Landscape protection. The most common reasons were that the management of forest protected areas and other valuable areas should be managed only by the resort of the environmental sector, and if the state wants to protect nature, it should also own declared protected areas. 70.6% of all respondents are dissatisfied with the current conservation status of trees.

This should be mitigated and it should be related only with the landscape and historically important plants. More than 80% of respondents believe that it is right that in strict protected areas where the most protected forests, ecosystems are, should be valid prohibition of any zasahovania without any exceptions. Three quarters of respondents considered that it is necessary to increase the number of hiking trails, improve their signs and define spaces for sports activities such as mountaineering, alpine skiing and so on.

Public debate was announced by the Ministry of Environment in order to solve the problems or shortcomings that proved practical and daily life in the application of previously existing law. For instance, the zoning of protected areas - particularly TANAP (Tatra's National Park), effectively solutions of the compensation for limitation of going management - property loss, or changes in the way of calculating the damages caused to human health by protected animals.

11.2 Biomass energy production legal-institutional and socio-economic frameworks in Serbia

11.2.1 Organic production in Serbia

Organic production in Serbia is increasingly popular and economically important, and thanks to the resources that are primarily reflected in the fragmented and owned land that is contaminated with harmful substances, this type of agriculture can contribute significantly to the development of rural areas, and thus agriculture in general. Due to the fact that organic production is set as a priority the development of agriculture, it stands for an integral part of the Republic of Serbia Strategy for rural and agricultural development.

Production of agricultural products obtained by organic production methods, objectives and principles of organic production, organic production methods, control and certification of organic production, processing, labeling, storage, transportation, trade, import and export of organic products, monitoring the execution of delegated work as well as other issues of importance to organic production are the issues of the Law on Organic Production ("Official Gazette" no. 30/10) that went on application on 1 January 2011.

On the basis of this law, the main target of the Department established for organic production, the Directorate of National Reference Laboratories is to establish and maintain effective control systems in organic production through monitoring and controlling organizations authorized manufacturers. Also, this department will be responsible for prescribing procedures and conditions to be met by accredited inspection bodies and certification of control, keeping aggregate records of organic production and monitoring of imports and exports of organic products. The jurisdiction of the Department are activities related to making decisions to approve the use of reproductive material from conventional production and the decision whether to consent to shorten or extend the period of conversion and issuance of exemptions from the rules of organic production.

Said law strengthens the institutional capacity in order to contribute to achieving the main goals of organic production, such as: increasing the area under organic production, the development of local markets for organic products, organic products export promotion and harmonization of the legal framework that defines organic production with the European Union.

11.2.2 Legal-institutional framework and aspects of biomass industry in Serbia

Strategic importance of legal frameworks to promote energy production from renewable biomass, especially in Republic of Serbia, is presented in several key documents adopted by Government. National Sustainable Development Strategy of Serbia for period 2009-2017, with the Implementation Action Plan, sets the most important biomass energy potential from renewable sources. The biggest problems of low level of utilization of renewable energy sources, particularly biomass, are listed in the Strategy:

- Insufficient infrastructure,
- Incomplete legal framework for promoting the use of biomass,
- Lack of reliable data on the potential, and
- Absence of an effective system of financial instruments for massive use.

The most important conclusion of the Strategy refers to the energy resources of Serbia that are assessed as relatively poor, of unfavorable composition (due to dominance of lignite) and unevenly distributed geographically. It warns that in case of failure to ensure the sustainable development of the energy sector, a security of consumers' supply might be seriously compromised, even to the point to become an obstacle to economic growth. Components of the sustainable energy sector development are, first of all: infrastructure, rational and economically effective usage of energy, reduced energy intensity and optimal use of domestic renewable energy sources.

The meaning of Government Decree on measures of incentives for the electricity production using renewable energy sources and combined heat and power is derived from the EU Directive from 2008 to reach 20% renewable energy production in the member states by 2020.

Valid until end of 2012 year, with successive extension, it is among other things:

a) Provide incentives for the production of electricity using renewable energy sources – particularly biomass and biogas,

b) Prescribe measures for the purchase of that energy - *Feed-in-tariff*;

c) Provide measures of reading and balancing,

d) Define energy facilities that produce electricity from renewable sources,

e) Regulate the content of the contract for the purchase of electricity by incentive measures (Table 11.1),

f) Governing the reimbursement of costs of energy produced by the buyer.

The meaning lies in the incentives for higher purchasing prices in the first phase of the introduction of electricity generation from renewable sources, and tax and other financial and non-financial incentives at a larger stage. Higher purchase prices for electricity produced using renewable energy sources are based on higher investment and operating costs (such production is more expensive than energy production from fossil fuels with the usage of conventional technology) and the duration of the privileged producers' status as a projected payback period.

Tab. 11.1 Purchase prices regarding plant types and installed capacity

Installed capacity (MW)	Stimulus measure – purchase price (c€/1 kWh)
Plant on biomass	
0,5 MW - 5 MW	13,845 – 0,489*P
5 MW - 10 MW	11,4
Plant on biogas	
up to 0,2 MW	16,0
0,2 MW - 2 MW	16,444 – 2,222*P
above 2 MW	12,0

The following by-law of the importance for creating conditions for the production of energy from renewable sources in Republic of Serbia is the Government Regulation on conditions for granting the status of privileged power producers and criteria for assessing compliance with those conditions, which entered into force in September 2009. The first manufacturer who can gain this privileged status is the one who use renewable energy sources or waste separated fraction in the production of electricity. Privileged may be those who generate electricity in small plants (small plants have installed capacity to 10mnj) and those who simultaneously generate electricity and heat, under condition that they meet criteria of energy efficiency.
A privileged status is obtained if the energy value of biomass used annually (biomass or biomass combination with some additional fossil fuel or waste) accounts for at least 80% of total primary energy. The key to the privileged status of producers is reflected in its priorities right at the electricity market, if supply conditions are equal, and the right to subsidies, customs, tax and other incentives. Amending the Regulation on the Establishment of the Implementation Program of the Energy Development of Republic of Serbia until 2015 for the period 2007-2012 is important, inter alia, from the perspective of defining the goals, regarding the renewable energy sources usage, and taking certain international obligations that fulfillment automatically routed to the creation of institutional support to this usage.

Fundamentals of generic objectives are: more efficient use of domestic resources in energy production, reduced greenhouse gases emissions, reduced fossil fuels imports, domestic industry development (primary at the local level) and job creation. The specific objectives sound like these: 7.4% greater presence of renewable energy sources in 2012 compared to 2007, and at least 2.2% share of bio-fuels in transport by year 2012. This requires a turnover of at least 130,000 tons of biodiesel in the domestic market and budgets that include between 140,000 and 250,000 tons of biodiesel production potential in Serbia per year.
Finally, the last document of importance for understanding the strategic framework of the biomass utilization in Serbia development is the Biomass Action Plan 2010-2012.

According to it, the most promising opportunities for biomass utilization in Serbia are:
a) Space heating in homes and buildings using wood pellets or briquettes from biomass,
b) Co-combustion or complete replacement of fuel oil or coal combustion in power stations,
c) Production of electricity using waste from agriculture and wood, and
d) Production of biofuels for transport.

Obstacles and problems to create the conditions for the use of biomass as a renewable source of energy in Serbia are classified according to plan, in six categories, namely:
- Security of supply and use of raw materials,
- License,
- Communication,
- Technology and science,
- Financial and economic aspects;
- Implementation and monitoring.

There is a plan to overcome these problems by developing the following measures and activities:
- Harmonisation of technical standards on Serbian biomass andwaste with the EU,
- The project to develop biofuels market - assessment of biomass availability,
- Develop a policy for long-term supply of biomass,
- Pleminary feasibility study on the collection of wood waste from forestry in Serbia,
- Development of sustainable biofuels certification in accordance with EU standards,
- Development of a network of sustainable cities in Serbia,
- Develop a communication strategy for renewable energy in Serbia,
- Training for successful project proposals for EU funds,
- Demonstration projects related to biomass in accordance with EU best practice,
- Preparation of guidelines for applying for financial support from banks – best practices.

Within this defined and insufficiently worked out National strategy for biomass resources usage, there is a space for entrepreneurs' activities who point out to cooperation with the local communities as to concretize projects and resolve legal and administrative problems. Experience has shown that importance of good copperation with local levels' governments to obtain necessary permits for the projects' realization in three key terms of location, building and occupancy permits. All problems associated with this projects' frameline have origin in the absence of adequate legislation at all governmental levels in Serbia, as well as in low level of relevant institutions knowledge.
Having all this in mind, we can say that the most urgent problem to be addressed in legal and administrative issue is building permits obtainment. In fact, as the first in a serie of permits to be obtained, this one stands as a proving ground for developing cooperation and trust among investors and authorities, and provides a road map of collaboration in other documents, making it easier to obtain other licences.

Other problems that arise during the project implementation are:
• Poor and incomplete legal regulations related to construction of power plants;
• Unsolved urban regulatory plans and the municipal level;
• Lack of proper procedure – necessary documents for the power plant construction;
• A large number of institutions at different governmental levels to be addressed for the provision of documents (local government, relevant electric distribution companies, relevant utility companies, etc.);
• A low level of competence and expertise of employees in the institutions who are responsible for issuing certain projects' documents.

Regulation of the Government on the acquisition of the privileged power producers defines precisely the key concepts in eco-energy policy, the application of renewable energy sources, particularly biomass, biogas, i.e.:
Biomass is a readily "biodegradable materials dreamed in agriculture, forestry and associated industries and households and include: plants and plant parts, fuel derived from plants and plant parts, plant debris and byproducts created in agriculture (eg straw, twigs, stones, shells, corn), residues resulting in animal agriculture (manure), remains of forest plants (remains of deforestation), biodegradable and remains in timber industry that do not contain hazardous substances, and separated biodegradable fraction of municipal solid waste. In contrast, the biomass does not include fossil fuels, peat, paper and cardboard, textiles, animal body parts, industrial waste but the one that is meant by the biomass, municipal waste, waste treatment plants for municipal waste water and commercial waste. Biogas is a gas formed from biomass, anaerobic processes and synthetic gas that generates pyrolytic decomposition and separation of biomass fraction of municipal waste."
Gro potential of biomass in Serbia lies in agricultural residues and wood biomass, totaling about 2.7 million toe (1.7 million toe in the remains of agricultural production and about 1 million toe in wood biomass).
Previous experience in Europe and the rest of the world show that many problems lie in long-term stable supply of biomass, that provoke us to say something about the potentials of Serbia in this field and prospects for the bio-plants construction and operation. Gro potential of biomass in Serbia lies in agricultural residues and wood biomass, totaling about 2.7 million toe (1.7 million toe in the remains of agricultural production and about 1 million toe in wood biomass).
Apart from these two sources of biomass, it would be significant to mention the rest of the livestock production. The second large group of biomass energy sources consists of plants (eg. mishantus, fast-growing poplar and the like) and plants that serve as a raw material for biodiesel, bioethanol (rapeseed, sunflower, corn, etc). (Table 11.2)

Tab. 11.2 Biomass potential quantities from agriculture production residues in Serbia

No.	Culture	Area (10^3 ha)	Yield (t/ha)	Biomass totality (10^3 t)
1.	Wheat	850	3,5	2975
2.	Barley	165	2,5	412,5
3.	Oats	16	1,6	25,6
4.	Rye	5	2	12
5.	Corn	1300	5,5	7150
6.	Seed corn	25	2,3	86,25
7.	Cob *	-	-	1430
8.	Sunflower	200	2	800
9.	Sunflower shells	-	-	120
10.	Soy	80	2	320
11.	Rapessed	60	2,5	300
12.	Hop	1,5	1,6	7,92
13.	Tobacco	3	1	1,05
14.	Orchards	275	1,05	289,44
15.	Vineyards	75	0,95	71,55
16.	Manure **	-	-	110
	Total:	3055,5		12571,31

** Cob weight is calculated in the maize weight*
*** Liquid manure mass is not included in total biomass amount*

It is estimated that the total potential of biomass from agriculture in Serbia is approximately 12.5 million tons a year, in terms of energy about 1.7 million toe. However, experts from different fields came to the conclusion that it is not justified all biomass obtained from agricultural residues to use in energy purposes.

It can be said that farmers, livestock breeders, technologists, mechanical engineer, economists and other potential users of biomass from agriculture share conflict opinions on what purpose would be the most adequate to use biomass for. Farmers believe the most of biomass should be plowed to increase soil fertility. Thermal-engineers believe that biomass should be used primarily to produce heat. On the other hand, it is known that huge quantities of biomass are irrationally used in renewable process each year; the rest of harvest is usually burned directly in the field, which is prohibited by law.

As a compromise solution, we might opt for the following projection: ¼ of biomass – into the mat back field, ¼ for animal food production, ¼ for heating buildings, and ¼ for other purposes (alcohol industry, furniture, building materials, paper, packaging, etc.).

In this way, all economic activities would be settled as the biomass residues from agricultural production is found in sufficient quantities. What can be seen from the previous analysis? The total quantity of biomass residues from agricultural production intended for heating purposes (just over 3 million tons) could save the equivalent amount of about 1317x103 tones of light fuel oil. Identical mass of diesel fuel is used in the overall agricultural production in Serbia (Figure 11.1).

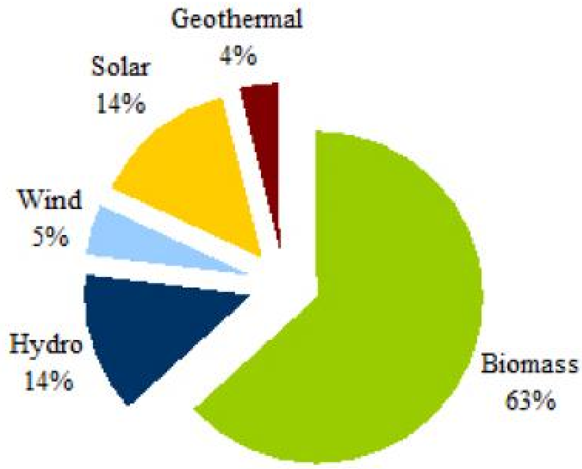


Fig. 11.1 Technically usable potential of renewable energy in Serbia

Another major source of biomass in Serbia, apart from agriculture, is wood-biomass that Serbia has a considerable amount. Tendency in all countries with developed timber industry shows that wood is largely used in energy purposes. The most commonly way of using it is in the form of pellets and wood chips. Both wood pellets production and its market price are going high. In addition, recently developed technology of pellet production ensures better combustion in furnaces and boilers, particular that are so constructed to provide a considerable extent in an automated way of lighting (such as furnaces and boilers on liquid fuel or gas). According to the Public Enterprise, the total area of forests and forest land in Serbia is 2,429,642 ha.

Estimated amount of wood biomass only in Serbia, which can be used as fuel, is about 1.65 million m3 per year, while the energy potential of forest biomass left to decompose after a forest product production, estimated at 15.6 million GJ per year.

However, despite this potential, wood still occupies a low position in meeting energy needs. Main reason for this is a great misunderstanding that domestic supply of wood biomass can provide clean energy from renewable sources as well as additional benefits the wood provides. In case of Serbia, some of these benefits include increased investment in forest development that would result in increased economic activity in forestry, sustainable management of forests land, reducing cost of fossil fuels that are imported, as well as reducing greenhouse gases that would occur by using efficient and low emission technology devices based on wood biomass. With more than 12 million tones of wood waste per year, Serbia has a future potential in developing its bio-energy sector, particulary for electricity and heat.

The rest of the livestock production is also a potentially interesting source of renewable energy in Serbia. According to statistical data available from the Statistical Office of Serbia, the total livestock is: 757,000 cattle, 47,000 horses, 1,475,000 sheep, 1,983,000 pigs and 9.3 million poultry. Since the biogas depends on many factors, only certain amount is reachable from organic substances. (Table 12.2.3)

Table 11.3 Amount of biogas obtained from certain types of organic matter

Organic matter	Biogas amount m^3/l
Beef manure	90 – 310
Pig manure	340 – 550
Chicken manure	310 – 620
Livestock manure	175 – 280

In addition to agricultural residues, wood waste and cattle production scrap usage biomass is available from growing energy plants (e.g. mishantus, fast-growing poplar, etc.) and plants that serve as raw material for biodiesel, bio-ethanol, etc. Total arable land in Serbia is 3,355,019 hectares. Intensive crop production is carried out in Vojvodina region, where the sowing area under maize dominates with over a million hectares, followed by wheat with half less covered surface.

Corn sowing unit is the most frequent in Central Serbia, but unlike the AP Vojvodina territory, Central Serbia abundates with areas left in the neglected land. Those areas are potentially interesting ones for the power plants infrastructures. For example, mishantus has the potential to yield from year to year to over 10 tons of dry biomass per hectare (resulting biomass is highly caloric, level of brown coal).

Vojvodina is very little wooded and problems of soil erosion under the influence of wind abundant. Fast growing poplar trees could be a solution for erosion, apart from being a substantial source of wood biomass. Serbia is suitable for rapeseed, which is one of the most important raw materials for biodiesel production; approximately 4 tons of corps per hectare (under optimal weather conditions) gives approximately 1 ton of biodiesel.

World experience marks the following groups of problems that need attention in addressing the continuous raw material supply issues:

1. Transport of biomass to energy plants (here we observe typical cases):

a) Cost of shipping is 2 to 3 times lower when it comes to transport crop residues in relation to forest residue;

b) Transport of crop residues can be improved with the sanctioning of field fire and subsidizing their transportation to the potential power plant;

2. Power plant sites: some bio-plants are able to keep costs of biomass supply due to the location close to the wood processing plant, or placing their fields within the power plants near existing urban irrigation purified waste water;

3. Way of sub-contracting supply with biomass producers: it turned out that the long-term supply contracts led to problems due to inability of either party to operates under the initial conditions, hence better results were achieved from short-term contract;
4. Flexibility of technologies to produce energy: crucial for long-term stable energy production is possibility for technology to use different types of biomass or biomass combined in direct combustion processes;
5. Problems within bio-plant itself: increased wear of equipment, congestion supply, variations in the percentage of biomass moisture, biomass different components separation processes, etc;
6. Providing reliable long-term work and prompt payment of subcontractors, the conditions of mutual trust and building a stable partnership.

Legal framework evolution

The Republic of Serbia in 2006 ratified the Treaty establishing the Energy Community Treaty signed between the EU and the countries of Southeastern Europe. In accordance with the provisions of Article 20 Agreement, the Republic of Serbia is obliged to, one year after ratification, prepare a program of implementation of Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market and Directive 2003/30/EC on the promotion of the use of the use of biofuels or other renewable fuels for transport.

In order to encourage investment in RES, Republic of Serbia has adopted a number of laws and documents. The White Paper on Renewable Energy, as the first document published in 1997 year, establishes the obligation of share of renewable energy reaches 12% by 2010 and pointed some very important principles for the renewable energy usage, such as: preventing climate change, reducing air pollution, security of energy supply, encouraging competition and encouraging industrial and technological innovation.

Biomass Action Plan (APB) in 2005 was defined as a document that should specify measures to promote biomass in heat and electricity and transport, followed by the subsequent actions related to common issues concerning biomass supply, financing and research.

All these documents established sustainability criteria for biofuels and liquid fuels. APB for Republic of Serbia lies in accordance with its obligations under the Energy Community Treaty and in the spirit of the Directive 2009/28/EZ. We conclude that more successful and applicable harmonization is necessary, while Serbia announced settlement of new targets in accordance with the Directive 2009/28/EZ in 2012.

11.2.3. Socio-economic framework of biomass industry

According to the recent studies, the most promising options for biomass utilization in Serbia are:
- Space heating in households and buildings using biomass pellets or briquettes,
- Co-firing or total replacement in district heating plants that currently burn heavy oil or coal,

- Production of electricity utilizing agricultural and wood residues, and
- Production of biofuels for transport.

According to the Changes and Additions in the Regulation of the Programme for Implementation of the Energy Sector Development Strategy 2007-2012, the main goals of biomass policy in Serbia are:
- Efficient use of available resources for the production of energy,
- Rreduction of GHG emission,
- Decreased dependence on import, and
- **Creation of new jobs.**

The main goal of growing agro-energetic crops is reducing energy costs. The main obstacle to increased use of biomass to produce electricity is low electricity proces. The approved incentives for electricity produced from biomass have created favorable conditions for investors interested in building these plants. Regarding the use of biomass for heat generation, current conditions justify the use of biomass instead of natural gas or luquid fuels. Coal, which produces much more pollution, is cheap and there is a lack of motivation from investors to switch from coal to biomass. Financial and economic support for biomass usage is a complex issue and requires a period of introduction. According to the other countries' experience, one might expect that the introduction period lasts from 5 to 10 years until self-sustaining conditions for further development of biomass sector are gained. Biomass development is not possible without foreign investment and various financial and economic measures. Currently, five different credit lines exist for renewable energy, including biomass utilization. In the future, it could be expected Serbia to offer investors' incentives far most attractive in the region, taking into account the exemption period from corporate income tax, tax credits for open positions, one of the lowest corporate tax in Southeastern Europe and cheap labor.

Biomass cogeneration

Reduce dependency on fossil fuels - to increase the level ofregional security.

Decrease in inventories of mineral energy resources - oil, natural gas and coal is evident. In recent decades society has become aware of the negative effects caused by the imbalance of CO2 andother gases that produce greenhouse effects, the so-called GHG (Greenhouse Gases).

The solution is seen to increase energy efficiency in all segments and greater use of new and renewable energy sources (RES), including biomass occupies the first andmost important place. Term includes solid biomass (agricultural residues, agricultural products, wood mass, remnants of forestry and wood processing, various processing residues, municipal solid waste, etc.), liquid (vegetable oil, biodiesel, bio-ethanol and liquid processing residues) and gaseous (biogas) matter.

Past experience has shown that the production of electricity using wind turbines and photovoltaic cells is expensive and depends on the availability of these resources. In addition to using potential energy of water sources, biomass is the most important potential renewable source, although it is already widely used as a source of thermal energy and increasing the use of means of transport as fuel for internal combustion engines. In this regard, the combined production of electricity and thermal energy, cogeneration and tri-generation are technically and economically advantageous method of administration.

Experience shows that the biomass cogeneration can make the cost of producing electricity is lower than or equal to thoseobtained from the use of fossil fuels. However, the goal is to implement cogeneration using biomass so that the economic indicators are favorable.

The impact of economic indicators:

1. Price systems,
2. Fuel prices,
3. Engagement of the plant during the year and utilization of thermal energy,
4. Costs of the plant,
5. Efficiency: electrical, thermal, total,
6. Price of electricity and heat.

References:

JOVANOVIC, B. – SPASIC, S. 2010. *Bio-ecological powerplants management in terms of energy production from renewable sources in Serbia stimulus*. SYMORG 2010 Conference, Serbia.

LAZÍKOVÁ, J. – TAKÁČ, I. 2010. *Právne a ekonomické aspekty nájmu poľnohospodárskej pôdy.* Slovenská poľnohospodárska univerzita, 2010, 100 pp., ISBN978-80-552-0447-5

EU legislation:

Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

Regulation (EC) No. 834/2007 on organic production and labelling of organic products and Commission Regulation

Slovak legislation:

Act No. 189/2009 (Coll.)

Act No. 220/2004 Z.z. on agricultural land protection and use

Act No. 543/2002 Z.z. on nature and country protection

Explanatory statement to proposal of amendment to act No. 220/2004 Z.z. on agricultural lan protection and use

Laws of Srbia:

Energy Law of Republic of Serbia

Law on Construction of Republic of Serbia

Law on Ratification of the Treaty establishing the Energy Community between the EU and the Republic of Albania, Bulgaria, Bosnia and Herzegovina, Croatia, Former Yugoslav Republic of Macedonia, Republic of Montenegro, Romania, Serbia and the UN Interim Administration Mission in Kosovo in accordance with Security Council Resolution 1244 UN

Law on Regional Development of Serbia

Decrees and Regulations:

Decree on measures of incentives for the production of electricity using renewable energy sources and combined heat and power

Regulation on conditions for obtaining the status of privileged producer of electricity and criteria for assessing compliance with these requirements

Strategies:

Action Plan for Energy Efficiency (2008)

European Union Biomass Plan 2010-2030

Green Paper on a European Strategy for Sustainable, Competitive and Secure Energy", adopted by the Commission (COM/2006/0105)

Long-term strategy on utilization of agricultural and non-agricultural crops for industrial purposes (2009) in Slovakia

National Strategy for Sustainable Development of Serbia 2009-2017

Republic of Serbia Biomass Action Plan for 2010-2012

Rural Development Strategy to 2013

Strategy of Energy Development of the Republic of Serbia until 2015

White Paper on Energy Policy for Europe" (COM (95) 682) (1997).

Studies:

Possibilities of combined heat and power from biomass in the AP Vojvodina

Potentials and opportunities and briquetting of biomass pelleting in the AP Vojvodina

Energy Potential and Characteristics of biomass and technology for its application and utilization of energy in Serbia

Possibilities of using renewable energy sources within the Clean Development mechanisms

The possibility of development of bioethanol in the AP Vojovidina

The possibility of development of biodiesel production in AP Vojvodina

Conclusions

The results of the multi-year research (2007-2011) focused on the impact of external and internal factors on growth and biomass production of fast-growing willow genotypes can be summed up in the following findings and conclusions. Genotypes of Swedish willow grown on arable land in the environmental conditions of southern Slovakia have adapted well to the environment and vegetated in interactive relationships, in which environmental factors determined the speed ecophysiological processes and the crops reacted to the microclimate environment. Limiting factors confirmed the abiotic (mostly climatic) and biotic factors (biological characteristics of the varieties, pests and diseases, biotic interactions). We confirmed phenotypic plasticity in the adaptation of the varieties to the environmental conditions. The studied *Salix* varieties are huge bushes with plenty of shoots and uneven arrangement of leaves with different ecophysiological features.

The comparison of growth characteristics of the five Swedish willow genotypes indicates the existence of two functional groups with different growth strategy for the biomass production. We divided the varieties into two groups. The first group includes varieties TORA and TORDIS. TORA produced a lower number (Ø 15.00 plant^{-1}) of thicker (Ø 1529 mm) and longer (3.53 m) shoots than TORDIS with the density of 159 990 shoots per ha. TORDIS produced 16.79 of shoots plant^{-1}, with the average diameter of 1239 mm and length of 3.12 m, with the density of 179 082 shoots per ha. The second group includes INGER and GUDRUN, in which GUDRUN has created more (Ø 17.23 plant^{-1}), thinner (Ø1188.5 mm) and shorter shoots, with the density 188 468 shoots per ha. INGER created Ø 17.17 shoots plant^{-1} with the diameter of 1109 mm and length of 2.69 m. The density was 183 135 shoots per ha. These characteristics influenced the architecture formation of individual shrubs and the whole stand and interactions between genotype and environment. According to that context, the leaf area changed over time, which consequently affects the penetration of radiation into individual bush storeys and distribution of the radiation in the stand. The radiation regime, as a decisive factor of the photosynthetic rate, determines the basic functions: absorption and transmission of the radiation, which depend on the height of the radiation source, the stand density, the orientation of leaves and so on. Our measurements were focused on the dynamics of the leaf area index (LAI) and growth rate of the leaf dry matter. Seasonal LAI development in the climatically different years 2009 and 2010 had a shape of one-peak curve with maximum in the third decade of August (2009). According to the percentage of long-term rainfall, it was a dry year, with the occurrence of physiological drought. In the low moisture conditions of 2009, the genotype TORA reached its highest biomass production (50.88 t ha-1) at the lowest value of LAI (Ø 4.93), low specific leaf area (15.80 mm^2 mg^{-1} SLA) and high hydration of leaf tissues (61.5%). The low SLA values are evidence of high abundance of mechanical tissues in leaves. In the other studied varieties, those relationships were created in higher values of LAI and lower values of SLA. The biomass production was significantly lower.

In order to interpret those relationships, many authors point to the indicative impact of leaf aging on the LAI changes in relation to the amount of yield. The values of correlation coefficients between LAI and the content of assimilation pigments, which were calculated, confirmed a significant linear relationship between LAI and the content of assimilation pigments in the varieties SVEN (r = 0.7630), INGER (r = 0.9375) and TORA (r = 0.5063).We also confirmed a high correlation between the relative content of assimilation pigments and the content of total nitrogen.

The size of leaf area and LAI was affected by the damage caused by diseases and pests (biotic interactions) and premature defoliation. In the late summer, we observed a fall of the oldest and smallest leaves. This is confirmed by the course of LAI, which values decreased since the second half of August (particularly INGER) and/or since the first decade of September (SVEN, TORDIS, TORA).

During the period 2007-2009, leaf rust caused by *Melampsora* sp. a stem canker – *Cryptodiaporthesalicella* were the most important pathogens. In Kolíňany (Slovakia), the stem cancer was observed in spring 2009, next year after the cutback of the two years old plantation. INGER was the most severely attacked variety, some of the plants died out. No symptoms were found on GUDRUN and TORA.

Melampsora rust was the next very serious disease in SRC plantations. Between the late spring and autumn, the rusts are seen as yellow-orange pustules containing urediniospores. In most willows, rust only infects fully developed leaves. Severe rust infection defoliates susceptible plantings prematurely, reduces yields by as much as 40% (Parker et al., 1995), and predisposes plants to infections by secondary pathogens which may lead to death of the plants.

From among insect pests, the big attention was paid to the stem-feeding aphid species forming colonies on the trunk or branches, not on the leaves. During the period 2007-2009 three stem-feeding aphid species were identified on Swedish varieties - *Tuberolachnussalignus*, *Plocamaphisamericanae* and *Pterocomma* sp. *Plocamaphis* and *Pterocomma* have occurred sporadically and in very low population densities. The most abundant and the most damaging species was *Tuberolachnussalignus*, which was first observed by the first week of August 2008 and again in 2010. It is regarded as economically important pest of short rotation coppice willow, on which it can cover more than 50% of 1-3 year old stem surface of infested trees. INGER was the most severely attacked variety by the second week of August 2008. Aphids gradually spread to the whole. GUDRUN was the last variety attacked by aphids. The aphids were spreading to GUDRUN from adjacent varieties TORDIS and TORA. By the beginning of October the whole willow stand - each Swedish variety was equally infested by the aphids. Different situation was observed in 2010, when *Tuberolachnussalignus* colonies were observed only on the stems of TORA and GUDRUN localized at the edge of the plantation. Moreover, they did not spread inward to the plantation and other willow varieties due to severe epizootics of *Neozygitesturginata* (Zygomycetes: Entomophtorales) in *Tuberolachnussalignus* populations.

Values of the specific growth rate of leaves (RGRwl) and shoots (RGRws) confirmed that the rate of the leaf dry matter increase was greatest in the first decade of June. RGR of shoots was significantly lower. In the late June, but especially in the second decade of August, there was a significant change in relations between the organs producing (leaves-source) and depositing the assimilates shoots-sinks) when RGR_{ws} significantly increased in all studied varieties The changes in the allometry of organs between woody organs and leaves, which were observed in September, were affected by aging and falling of the leaves.

Genotypic differences were confirmed also in the allocation of biomass. All experimental varieties preserved the seasonal proportional allocation of biomass from leaves to shoots. The highest total biomass yields, in the conditions of southern Slovakia, were reached by TORA (50.88 t ha^{-1}) and TORDIS (49.92 t ha^{-1}). The lowest biomass yields were given by GUDRUN (33.06 t ha^{-1}).

The yield decrease in the individual willow varieties in the first year after the planting could be caused by higher competition with weeds for nutrient sources. Already a low level of weed infestation may cause uneven growth of willow stands and thus affect significantly the total yield. In this regards, we recommend to carry out a weed regulation accordingly to the state of the weed infestation in the plantations. Annual weeds compete with the willows the most significantly during the period from April to June. In the case of vigorous weeds, the growth reduction can be affected in a bigger scale during the first year after the planting. The weeds may, within 2-4 weeks after the planting, outgrow the sprouting willow shoots, which tend to rot away. In combination with other unfavourable conditions (drought, humidity and occurrence of diseases and pests) we may expect high yield losses.

Agro-energetic plants as a source are reliable, can be produced by individuals, can be easily transported, are economically competitive in the market place and are environmentally sustainable. According to estimates of the EU Biomass Plan 2010-2030, to 300.000 people per year may be employed or self-employed in the EU in the biomass industry or its complementary industries. Legislation of the renewable energy sources in the Slovak Republic has also a number of shortcomings that are criticized by energy producers, and also by professionals. According to the directions of the European Union, Slovakia should produce 14 percent of all energy from renewable sources by 2020. Many energy producers argue that despite on the adopted legislation this commitment will not be completed.

According to obligations emanating from the implementation of Kyoto Protocol and in accordance with the sustainable development priorities of Serbia in the period until 2015, provided in the National Strategy of Science Development and National Energy Development Strategy and Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market, production and use of biomass is of crucial importance for provision of annually renewable domestic source of energy and for environmental protection. Integrated approach to the production of energy crops, both farming and forest ones, is the imperative, because estimated available biomass (as waste, harvesting remains and manure) is not satisfactory in terms of its quality and quantity.

Target production of agro-energy crops provides for: annually renewable energy source, extraction of CO_2 from the atmosphere, sustainable use and remediation of degraded areas, conservation of fertility of agricultural land. According to the Millennium Ecosystem Assessment, this transforms ecosystem functions into the ecosystem services (benefits that people obtain from an ecosystem) through: products – food, fuel, fibers, genetic resources; regulation – climate, floods, water quality, waste removal; social aspects – annually renewable energy source and support to other values – production of atmospheric oxygen through photosynthesis, formation of soil and prevention of erosion, pollination, recycling of nutrients and water, maintenance of habitats).

Biomass of miscantus and willows in fast rotation is characterized by high energy contents (about 16 GJ/t) and low production of ash and nitrogen oxides after combusting. The disclosed yield greatly varies depending on climate and agro-ecological conditions, as well as genotypes, so efforts are made to adapt the existing cultivation technology to local conditions. Investments into the production of biomass of perennial grass are limited to the first year (establishment of a plantation is the most expensive: preparation of land, protection against weed, procurement of seedling material and planting of rhizomes, irrigation, when necessary). Once planted grounds provides yield over the next twenty years with virtually no further investments (annual harvesting for perennial grass, every 3 years for fast-growing willows). Preliminary analyses show that it is necessary to achieve yield of technologically dry mass of 10-15 t/ha/year in order to make production cost-effective. Energy generation from this biomass is still considerably more expensive than energy generation from fossil fuels, but ecological parameters are far more favorable for biomass.

Conservation of agricultural land fertility and remediation of degraded land are also priorities of the Strategy of Science Development in Serbia until 2015. The production of agro-energy crops in fertile soil should be designed in the manner to preserve its fertility and to give priority to healthy and environmentally safe food. It is necessary to explore possibilities for such soils to use harvesting remains from conventional crops from the environmental, energy and economical efficiency aspects. Degraded areas, on the other hand, must be prioritized for production of agro-energy crops. The reason is that these plants, especially willows, have significant capacities for soil, air and water cleaning treatment and high adaptability to pollutant presence.

Production of agro-energy crops is CO_2 neutral, because carbon absorbed during photosynthesis process is released in combustion. Miscanthus biomass contains 48% of carbon so estimated production of 20t per hectare annually removes about 9.6t of carbon. It is crucial for production of agro-energy crops, in addition to the price expressed in money terms, the price expressed in energy and removal of CO_2 from the atmosphere. Therefore, it is necessary to compare energy balances of production of various types of agro-energy crops on specific grounds. Literature data related to perennial production of these crops show that miscanthus plantations and special willow clones plantations are extremely positive in energy balance. However, these data are related to different agro-ecological conditions, so they require checks for Serbia. Also, in addition to the above-ground biomass used as fuel, its underground organs also retain CO_2.

Systematic collection and critical analysis of the results obtained in experimental measurements of biomass production gained from agro-industrial crops through field tests from the environmental, energy and economic efficiency aspects. The first category includes field tests previously established, currently in their full development phase (miscanthus, willow in fast rotation and sorghum). The Second one includes target tests which will be established at the research Beneficiary's grounds and in other degraded areas. The third one includes field tests which will be established with other agro-energy crops which prove to be interesting for biomass production. The data collected through analyses performed by accredited laboratories with regard to field tests will be compared with literature data and other data obtained in the analyses of biomass from harvest remains and agricultural waste.

The beneficiary is provided with specific results related to production of agro-energy crops in degraded areas and agricultural land: the areas needed for achievement of biomass production of 10% of fossil fuels consumption with measured yields in the own tests for miscanthus and fast-growing wooden plants (willows and poplars). Agricultural crops and new agro-energy crops which will be introduced in tests, material and energy investments in the production of biomass and environmental aspects presented through ecosystem services.

Special attention is paid to socio-economic aspects of agro-energy crops production through the analysis of energy, ecological and economic incoming and resulting parameters through application of adequate methods. This analysis should serve to assist a decision-maker in estimating further development of production and use of agro-energy crops from the aspect of natural resources management in accordance with national and international standards in place.

Bearing in mind that this is a brand new area of study, it is also necessary to implement general awareness raising campaign about the necessity of energy crops production. With regard to that, it is planned to establish a network of institutions (scientific and educational) which will serve as consultants to the economic subjects that decide to produce and process biomass and energy crops and they will actively participate in adoption and harmonization of standards in this area.