Different planting material for establishment of the *Miscanthus* energy grass plantation

Rôzny sadbový materiál pre založenia plantáže energetickej trávy *Miscanthus*

Martin PRČÍK and Marián KOTRLA*

Slovak University of Agriculture in Nitra, Faculty of European Studies and Regional Development, Mariánska 10, 949 Nitra, Slovak Republic, *correspondence: marian.kotrla@uniag.sk

Abstract

Growing energy crops is one of the possibilities of using temporarily, respectively persistent unused agricultural land. In Slovakia, 44% (1,064,625 ha) of secondary and other land of the total land fund can be use also for establishment plantations of energy crops. The aim of this paper is to evaluate the impact of the planting material energy crop *Miscanthus* on canopied growth and productivity of the growth. Mortality of the individuals and the ability of the individuals to create aboveground organs in the year of the establishment and dynamics biomass production in the following years have been assessed. The growth of fast-growing crop *Miscanthus* was established on a field experimental basis. Two genotypes: *Miscanthus* × *giganteus* (planting materials were rhizomes) and *Miscanthus sinensis* Tatai (planting materials were in vitro seedlings) have been observed. Relatively high mortality of the individuals (31%) was confirmed in rhizomes plantation. In the first year of cultivation, the growth of the *Miscanthus* × *giganteus* created clusters with total average number 26.07 stems per cluster with count yield biomass 11.10 t*ha^{-1} within the research area. The growth of the *Miscanthus sinensis* Tatai was full canopied at the end of the growing period in the year of its establishment. *Miscanthus sinensis* Tatai created average 37.60 stems per cluster with count yield biomass 10.80 t*ha^{-1}. After the fifth vegetation year (2014), the growth reached the average production of 28.60 t*ha^{-1} of dry biomass. The growth established from rhizomes did not reach the full canopied in year of the establishment of the plantation and there was necessary to complete of the plantation.

Keywords: canopied growth, *Miscanthus*, plantation, production, rhizome, seedling in vitro

Abstrakt

Pestovanie energetických rastlín je jednou z možností, ako využiť dočasne, resp. trvalo nevyužívanú poľnohospodársku pôdu. Na Slovensku je 44% (1 064 625 ha) sekundárnej a ostatnej pôdy z celkového pôdneho fondu možné využiť aj na zakladanie plantáží energetických rastlín. Cieľom príspevku je zhodnotiť vplyv výsadbového materiálu energetickej byliny *Miscanthus* na celkovú zapojenosť a produktivitu porastu, zhodnotiť mortalitu jedincov a ich schopnosť vytvárať nadzemné orgány v roku založenia porastu a dynamiku produkcie biomasy v nasledovných rokoch. Porast bol založený na poľnej pokusnej báze Boli sledované dva genotypy: *Miscanthus* × *giganteus* (výsadbový materiál boli rizómy) a *Miscanthus sinensis* Tatai (výsadbový meteriál boli sadenice in vitro). Pri *Miscanthus*× *giganteus* bola potvrdená pomerne vysoká mortalita (31%). Rastliny vytvorili v prvom roku pestovania trsy s celkovým priemerným počtom 26,07 stebiel na trs s prepočítanou úrodou biomasy 11,10 t*ha^{-1}. Pri genotype *Miscanthus sinensis* Tatai bol porast plne zapojený. Rastliny vytvorili v priemere 37,60 stebiel na trs s prepočítanou úrodou biomasy 10,80 t*ha^{-1}. Po piatom vegetačnom roku (2014) dosiahol porast *Miscanthus* priemernú produkciu 28.60 t*ha^{-1} suchej biomasy. Porast založený z rizómov nedosiahol plné zapojenie v roku založenia plantáže a bolo potrebné doplniť výsadbu v nasledujúcom roku.

Kľúčové slová: *Miscanthus*, plantáž, produkcia, rizóm, sadenice in vitro, zapojenosť porastu

Introduction

The Slovak Republic has developed and adopted a National Action Plan for energy from renewable energy sources under Directive No. 2009/28/EC on the promotion of energy from renewable sources and amending and additions and subsequently repealing Directives 2001/77/EC and 2003/30 EC. National targets for 2020 for the share of energy in transport, electricity, heat and cold are set for renewable energy sources (RES). The Slovak Republic has a duty to increase the use of renewable energy to 14% of gross final energy consumption in 2020 (in 2005 the figure was 6.7%).

Growing energy crops is one of the possibilities of using temporarily, respectively persistent unused agricultural land. Since a large part of agricultural land in Slovakia is located in regions that are not suitable for intensive use, more attention needs to be paid to the cultivation of industrial and energy crops. The introduction of such crops into the system of land management should be considered as one of the most important innovations in crop production in the near future. Growing of these crops should become common and well supported and preferred part of the agrarian program. The potential for biomass and biogas production at agricultural subjects in Slovakia is significant. The use of this potential would be necessary not only for the energy yield and thus saving finance, but also for the disposal of agricultural waste, which causes frequent problems. Not only surplus agricultural land, but also others, differently devastated land can be advantageously used for obtaining energy phytomass (Jureková et al., 2015).

In order to achieve food self-sufficiency, Slovakia must have a minimum area of 1,367,853 hectares of agricultural land, which represents about 56% of currently registered agricultural land of Slovakia (Vilček, 2011). In addition to the primary land, also the secondary land forms the land fund of Slovakia. Secondary land occupies 696,038 hectares, i.e. about 29% of currently registered agricultural land in Slovakia together with other land which should preferably be used for alternative agricultural use, for energy crops and for various non-biological purposes (sporting, tourist and recreational). Other agricultural land occupies 368,587 hectares, i.e. about 15% of currently registered agricultural land of Slovakia.

Fast-growing crops (herbs) for energy purposes need to be intensively cultivate in the areas suitable for this purpose. Such areas are not directly intended to production of food. On the other hand, the soil could obtain a higher degree of economic and environmental value by the cultivation of energy crops. Herbaceous species *Miscanthus* can be grown on a fairly wide range of soils varying from sandy soils to soils with high organic content. *Miscanthus* is tolerant to a wide pH range. Optimal values for cultivation fall into the range pH range from 5.5 to 7.5 pH. According to Demo et al. (2013), the basic condition for the establishment of the plantation of energy crops is flat or slightly sloping area. Steepness exceeding 13% can cause problems, especially during the harvest. From the economic aspect, plantation area of energy crops must have at least 2 ha. Preparation of planting beds is an important activity in terms of pre-planting soil preparation. This soil preparation improving the aerodynamic properties of topsoil with a beneficial effect on the rooting of planted individuals. Whereas the period of 15-20 years of individuals´ vegetation at the place of its establishment is estimated, it is necessary to pay sufficient attention to the preparation of the soil. Suitable preceding crops for *Miscanthus* should be the low-water-use crops with short vegetative period. Application of broad-spectrum herbicides against multiannual weeds is followed by autumn deep tillage to a depth of 0.25 to 0.30 meters with rotary plough. This is necessary in order to avoid the spring tillage with potentially negative impact on soil moisture.

The ways of establishment *Miscanthus* plantations are based on different planting material. Energy grass *Miscanthus* plantations can be established by rhizomes or seedling in vitro (Filová, 2015). Atkinson (2009) notes, that difference of the planting material arise from their morphological features. Rhizomes ramification and sprawl take place under soil surface. They move roots from the nodes and aboveground stems. In vitro seedlings have established root systems and a number of stems. During the growing period, they form aboveground organs and rhizomes important for the supply of building materials, production of roots and stems from the nodes.

Atkinson (2009) summarizes the possibilities of *Miscanthus* plantations establishment under different planting methods and evaluates its impact on the surrounding landscape.

This paper evaluates the impact of the different planting material of the energy crop *Miscanthus* at canopied growth and productivity of the growth. Climatic conditions, mortality of the individuals and the ability of the individuals to create aboveground organs in year of the establishment and dynamics biomass production in the following years have been assessed.

Materials and methods

The research site, on which the established growth of fast-growing crop *Miscanthus* is located, lies on a field experimental basis of the Farm holding of Slovak University of Agriculture in Kolíňany (the coordinate of the experimental field: 48°21'22.1"N 18°12'23.9"E). The research area in Kolíňany is located 13 km from the town of Nitra and falls into the cadastral area of municipality Kolíňany. The soil quality defined by BSEU code is 0111002. The main soil type is gleyic fluvisol. Regarding its grain structure it belongs to moderately heavy soils. In terms of exposure, the area is plain without any occurrence of surface erosion. Soils are deep without skeleton. In terms of climatic conditions, the research area belongs to the warm, very dry, lowland climate region (Kotrla and Prčík, 2014).

At the time of establishment of plantations of fast growing grass *Miscanthus* were monitored the abiotic parameters - soil reaction, trophy of habitat and ecological continentality. Soil sampling was conducted in accordance with ISO/DIS 10381-5. The soil of research area is neutral to slightly alkaline (pH 7.28 to 7.55). In the research area, potassium and phosphate fertilizers in a dose of 50 kg*ha^{-1} K_2O, 21 kg*ha^{-1} P_2O_5, 25 kg*ha^{-1} S and 13 kg*ha^{-1} Ca were applied before tillage. Nitrogen fertilizer was applied in a dose of 50 kg*ha^{-1} in the spring before the planting of the *Miscanthus* seedlings.

Ecological continentality as the possibility of extreme temperature and humidity fluctuations was expressed on the basis of the climate diagrams according to Walter and Leith (1967) methodology. Climate diagrams determine the relation between the annual average of monthly precipitation and annual course of the average monthly air temperature at the research area in Kolíňany. The physiological drought period is the part of the curve where the sum of precipitation has lower value than the temperature curve. Temperature curve is an indicator of changes in evaporation power of the atmosphere during the year.

Table 1. The average monthly precipitation total and the course of the average monthly temperatures on research area in Kolíňany, Slovakia (2010 – 2014)

Tabuľka 1. Priemerné mesačné úhrny zrážok a priebeh priemerných mesačných teplôt na výskumnej lokalite v Kolíňanoch, Slovensko (2010 – 2014)

5 year average / month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
mm	44.4	31.8	33.8	34.7	73.6	65.6	60.6	52.7	55.4	38.9	40.6	36.4
°C	-0.04	0.62	6.08	11.65	16.42	19.55	22.26	21.29	16.31	10.52	6.82	0.88

Source: Slovak Hydrometeorological Institute, own processing

Zdroj: Slovenský hydrometeorologický ústav, vlastné spracovanie

Climate represents an important growth factor in the biomass production. Daily temperatures and precipitation can be considered as limiting factors. Accumulated effective air temperatures exceeding the minimum of 10 °C are important for the growth of species of the genus *Miscanthus*. Average monthly precipitation and the average monthly air temperature with locations in Kolíňany are shown in Table 1. Selected climatic parameters are measured from the establishment of the plantation.

Growth of the monitored energy crop *Miscanthus* was established in 2010. Plants were planted in the planting distance 1 x 1 m per 100 m^2 for each genotype separately. The difference between the studied genotypes of *Miscanthus* planting material was as follows (Jureková et al., 2012; Prčík and Kotrla, 2013):

- *Miscanthus* × *giganteus* is vital triploid hybrid (57 chromosomes) often used in the field experiments. Planting material consisted of rhizomes from Hannes Stelzhammer Austria. Fresh rhizomes weight in the planting was different (on average from 1.67 g to 3.54 g), the length of rhizomes were 50-85 mm in diameter.
- *Miscanthus sinensis* TATAI, triploid hybrid (57 chromosomes) cultivated by cross pollination of *Miscanthus sinensis* genotypes. Planting material consisted of seedlings growth in vitro in Power-H Kft, Hungary. Seedlings were planted in individual rooting containers with soil substrate.

Comparison of the individual's two *Miscanthus* genotypes was focused to identification of taking roots and mortality of individuals after planting in 2010. The height of the individuals determined as the distance from the soil surface to the top of longest stem was measured. Number of stems was assessed by counting the stems of the clump during the growing season. Selected indicators of growth were monitored in two-week intervals for 20 model individuals of the growth. Aboveground phytomass extraction was conducted in March of the following year after each growing year. The weight of the dry phytomass was monitored (harvest moisture). The part of the phytomass of the aboveground organs was dried in a dryer at 120 °C. After drying, the weight of dry matter of the aerial organs of model individuals and moisture content of the biomass was determined.

Statistical evaluation was carried out using the STATISTICA 12. The studied parameters were analysed by single factor analysis of variance (ANOVA) and statistically significant differences were tested Scheffe`s test.

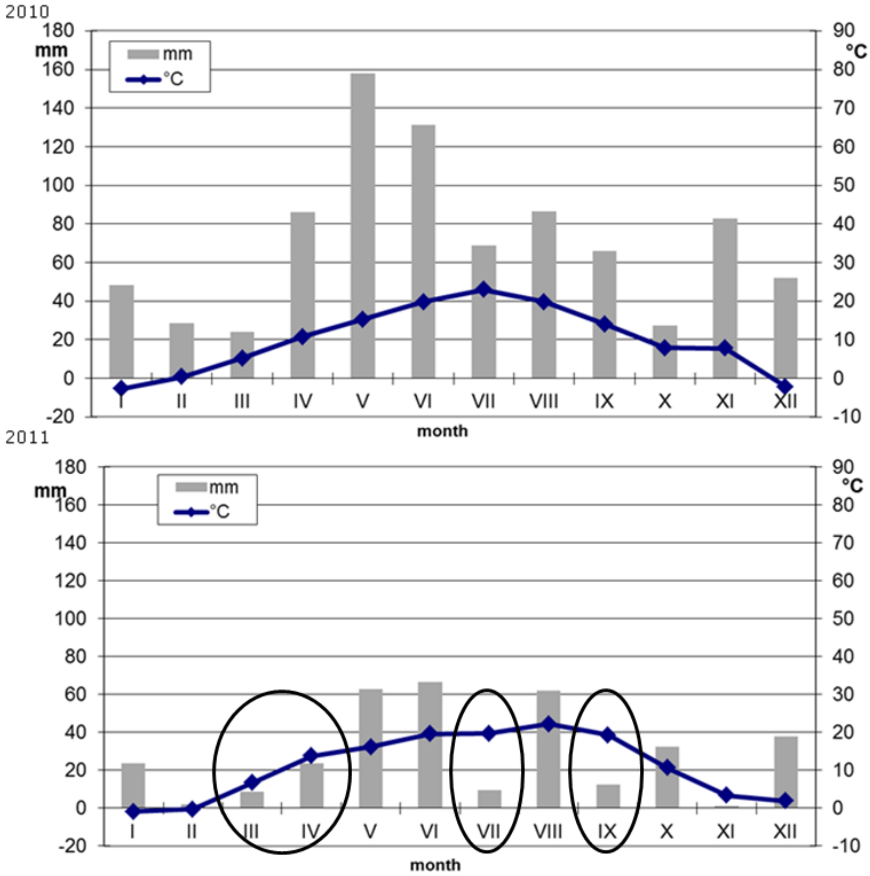
Results and discussion

Seedlings *Miscanthus sinensis* Tatai were shipped in containers with soil substrate and they were rooted. These seedlings were planted in the prepared soil in the planting distance 1 x 1 m. Planting density at planting distance 1 x 1 m should provide 10,000 plants per 1 ha.

Growth of the *Miscanthus* × *giganteus* genotype was established from rhizomes. Rhizomes are converted stems with a scaly leaves and buds. They mostly grow horizontally underground and create a large number of adventitious roots. They are typical especially for herbs.

Strašil (2009) notes, that the optimal temperature conditions for planting of *Miscanthus* are when the temperatures of soil layer in depth from 0.10 to 0.15 m is about 10 °C. Such conditions occur from the end of April until beginning of May. Planting at the research area in Kolíňany took place in early May 2010.

In terms of water balance habitat is for growth of fast growing grasses *Miscanthus* important whether it has enough water during the growing period, especially in the establishment of the growth and canopied growth. Relationship between climate indicators is expressed in climate diagrams for years 2010 (year of establishment of *Miscanthus* genotypes plantation) and 2011 (Figure 1).



Legend: physiological drought period

Legenda: obdobie fyziologického sucha

Figure 1. Climate diagrams for the years 2010 and 2011 at the research area

Obrázok 1. Klimadiagramy za roky 2010 a 2011 na výskumnej lokalite

In the year of the growth establishment (2010) the annual precipitation reached better-than-average values (860.2 mm). In this year, individuals did not suffer physiological drought. In terms of climatic indicators, individuals had suitable conditions for growth and for subsequent canopied growth. Nonetheless, *Miscanthus sinensis* Tatai reached 100% survival rate of planted individuals. The root system of in vitro plantings was better able to use moisture conditions in year of establishment. Rhizomes did not sufficiently developed root system and therefore rhizomes decomposed as a result of above-average moisture. The following year (second growing period in 2011) was characterized by low annual precipitation (341.9 mm). In this period, at the beginning of the growing season (March-April) was observed the physiological drought, especially during the peak growing season (July to September) when the production of biomass individuals culminates. However, in the second growing season, crops of both genotypes were already fully canopied and the periods of physiological drought only slowed down the dynamics of biomass production due to low total monthly precipitation.

Planting of in vitro seedlings (*Miscanthus sinensis* Tatai) and rhizomes (*Miscanthus* × *giganteus*) was manual – into the prepared holes.

Rhizomes used for crop establishment were 2-3 eyes and they were damp.

High mortality of individuals was confirmed in case of *Miscanthus* × *giganteus*. 31% rhizomes did not create aboveground biomass in the first vegetation period. At the beginning of the growing season of the second growing year, it was necessary to replant new rhizomes to the place where the original rhizomes did not create the aboveground biomass. This was carried out by the addition of individuals in order to encourage the growth to be full canopied.

The growth *Miscanthus sinensis* Tatai was full canopied at the end of the growing season 2010. At the beginning of the growing season of the second vegetation year, there was no need of adding of individual plants. The growth retained fully canopied after dormant period too.

Photo: authors

Foto: autori

Figure 2. Tillering circle at the beginning of the second growing season in the research area in Kolíňany

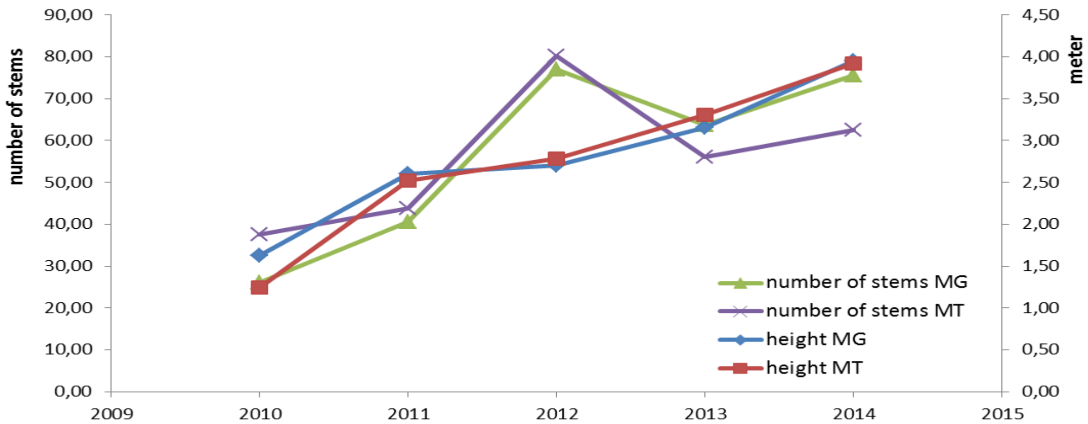
Obrázok 2. Odnožovací kruh na začiatku druhej vegetačnej sezóny na výskumnej lokalite v Kolíňanoch

Comparable results with emergence rate of *Miscanthus* × *giganteus* rhizomes was confirmed in the Czech Republic, where the mortality of individuals at the research area in Průhonice and Lukavec was from 6 to 25% (Strašil, 2009).

Maga et al. (2008) notes, that the reproduction of *Miscanthus* for energy purposes can be implemented only through rhizomes´ planting. The full root of individuals of currently using planting material in the form of in vitro-origin seedlings was confirmed by establishing plantations of *Miscanthus* in Kolíňany. After one year of the cultivation, the sprawl of the rhizomes of both experimental genotypes was compact.

Individuals of the *Miscanthus* grass are sprawling in a circle. Biomass being produced aboveground generates tillering circle. The width of the tillering circle at the end of the growing season in the second year after planting was 502 mm in average. In the third year after planting, the average width of the tillering circle was 641 mm (Jureková et al., 2012). At the end of the fifth growing year, the average width of the tillering circle was 972 mm. Comparable average size of the *Miscanthus*´ tillering circle in the conditions of the East Slovak Lowland was reached by the plants in the second year of growing (610 mm). At the end of the fourth growing year, the average size of the tillering circle in East Slovak Lowland had value of 810 mm (Porvaz et al., 2012).

As seen in Figure 2, there is no risk of uncontrolled spreading of the underground organs towards surrounding soil. Extension of the individual within the growth is keeping the shape of an imaginary circle and at the same time it is gradually sprawled around the perimeter of the circle. The competition relationships of the individuals (intraspecific competition) do not allow the occupancy of the area outside the tillering circle of the individual.



MG - *Miscanthus* × *giganteus*, MT - *Miscanthus sinensis* Tatai

Figure 3. Comparison of selected growth indicators of the *Miscanthus* genotypes: the average height of individuals and the average number of stems

Obrázok 3. Porovnanie vybraných rastových ukazovateľov genotypov *Miscanthus*: priemerná výška jedincov a priemerný počet stebiel

After the pre-harvest period, the aboveground biomass being produced during the previous growing year is harvested. The basic condition for the efficient production of energy crops is the ability of the species and its hybrids to adapt to the given climatic zone. *Miscanthus* × *giganteus* created clusters with the total average number 26.07 stems per cluster with count yield biomass 11.10 t*ha^{-1} at the research area (climatic conditions of southwest Slovakia) in the first year of cultivation.

Table 2. ANOVA and Scheffe`s test of plant height and number of stems of aboveground biomass

Tabuľka 2. ANOVA a Scheffe`s test výšky rastlín a počtu stebiel nadzemnej biomasy

	Analysis of variance P < 0.05						
	Sum of squares	Degree of freedom	Mean squares	F	P	Scheffe`s test P-value	Significance
Plant height	0.01	1	0.01	0.009431	0.431163	0.923341	n
Number of stems	172.13	1	172.13	0.326591	0.572987	0.572987	n

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

Hladina významnosti je definovaná ako: n: bezvýznamná, +: významná na P ≤ 0.05, ++: P ≤ 0.01 a +++: P ≤ 0.001

At the research area in Kolíňany, *Miscanthus sinensis* Tatai had created in average 37.60 stems per cluster with count yield biomass 10.80 t*ha^{-1}.

The yield of the biomass in both examined genotypes carried out via number of stems. Comparison of two *Miscanthus* genotypes points to moderate differences in their growth parameters. The height of individuals of *Miscanthus sinensis* Tatai moderately exceeds the average height of *Miscantus* × *giganteus* individuals (Figure 3). The number of stems is moderately higher in case of *Miscantus* × *giganteus*. The differences in the growth parameters of both *Miscanthus* were not statistically significant (Table 2).

From the aspect of the biomass produced by aboveground organs, *Miscanthus* growth was observed since the establishment of plantations in 2010 (Table 3). The moisture content of the harvest phytomass was from 17 to 20%. After the fifth vegetation year (2014), the growth reached the average production of 28.60 t*ha^{-1} of dry biomass (at harvest moisture) (*Miscanthu*s × *giganteus* 30.9 t*ha^{-1} and *Miscanthus sinensis* Tatai 26.3 t*ha^{-1}).

Table 3. Average values of dry biomass in aboveground organs´ of *Miscanthus* at harvest moisture in different growing years in $t*ha^{-1}*year^{-1}$

Tabuľka 3. Priemerné hodnoty suchej hmoty biomasy nadzemných orgánov *Miscanthus* pri zberovej vlhkosti v jednotlivých rokoch v $t*ha^{-1}*rok^{-1}$

Genotypes / Year	2010	2011	2012	2013	2014
Miscanthus × giganteus	11.1	18.1	27.1	30.3	30.9
Miscanthus sinensis Tatai	10.8	16.9	22.6	24.1	26.3

Differences in biomass production of both *Miscanthus* genotypes are statistically highly significant in each monitored vegetation period (Table 4 and Figure 4). Brosse et al. (2012) found out that the production of *Miscanthus* varies depending on environmental conditions, time management and harvesting. The results of studies on *Miscanthus* production in Europe and USA are presented by Heaton et al. (2010). The authors present a range of usable production starting at the amount of 5-55 $t*ha^{-1}$. In optimal conditions of the southern Europe, the production of dry biomass of the aboveground organs is about 25-30 $t*ha^{-1}$ (Angeliny et al., 2009), while irrigated conditions in Portugal increased the production at level of the 36 $t\ ha^{-1}$ (Clifton-Brown et al., 2001), 34-38 $t*ha^{-1}$ in Italy (Ercoli et al., 1999; Cosentino et al., 2007) and 38-44 $t*ha^{-1}$ in Greece (Danalatos et al., 2007).

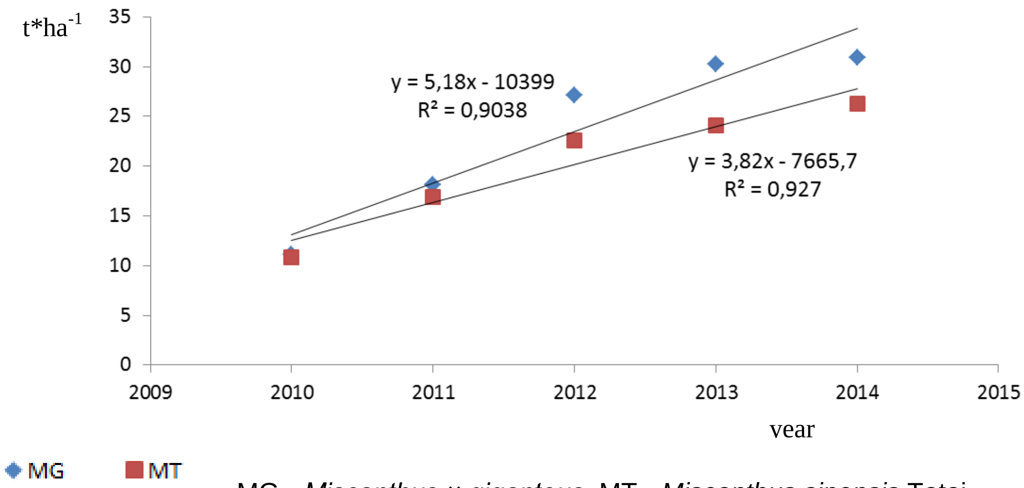
Table 4. Single-factor analysis of variance of the biomass yields between the *Miscanthus* genotypes and in each experimental year (2010-2014)

Tabuľka 4. Jednofaktorová analýza variancie úrody biomasy medzi genotypmi *Miscanthus* a medzi jednotlivými rokmi (2010-2014)

Analysed parameter	F	P-value	F critical	Significance
Miscanthus genotypes and Years	39.98384	$1.82E^{-34}$	1.947348	+++

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

Hladina významnosti je definovaná ako: n: bezvýznamná, +: významná na P ≤ 0.05, ++: P ≤ 0.01 a +++: P ≤ 0.001



MG - *Miscanthus* × *giganteus*, MT - *Miscanthus sinensis* Tatai

Figure 4. Linear trend function of the biomass growth of *Miscanthus* in $t*ha^{-1}*year^{-1}$ in the studied years at the research area in Kolíňany, Slovakia

Obrázok 4. Lineárna trendová funkcia rastu biomasy Miscanthus v $t*ha^{-1}*rok^{-1}$ v sledovaných rokoch na výskumnej lokalite v Kolíňanoch, Slovensko

For practical use of knowledge about the productivity of plantations of fast-growing grasses *Miscanthus* it is important the analysis of inputs (especially the cost of growing the planting material) from an economic point of view. Analysis is important for determining the profitability of the establishment of plantations on unused agricultural soils for practical use. In Central European conditions, the costs for the growing of seedlings in vitro are 0.28 € per piece. Given that the number of seedlings per 1 hectare is 10 000, then the costs will be 2,800 € per hectare. By this method of the establishment of the *Miscanthus* growth, 100% rootedness has been confirmed (i.e. zero mortality of the planted seedlings).

The costs needed for growing of the rhizomes 0.18 € per piece. The number of seedlings per 1 hectare is 10 000, thus in this case the costs will be 1,800 € per hectare. Regarding the fact that survival rate of the rhizomes is 69% (at the research area in Kolíňany), costs for repeated planting (replenishment of the planting) should be added to the basic costs. In this case the amount is 558 €. The total costs of establishment of the growth with the rhizomes are 2,358 €. Comparison of the planting material´s costs shows that the costs for seedlings in vitro are approximately 16% higher. Keeping the 100% survival rate of the *in vitro* planting, the growth is fully canopied in the second vegetation year. Such growth is able to provide a balanced yield of the aboveground biomass.

Christian et al. (2005) reported that in the conditions of south-east England, the costs of the plantation material in the form of rhizomes (including transportation costs) vary from 0.52 to 0.50 €. The costs for the purchase of plants (rhizomes) in Slovakia range from 0.30 to 0.40 € (Jandačka, 2010). According to the author, the costs of the plantation of *Miscanthus* from the rhizomes on 1 hectare vary from 3000 to 4000 € per hectare.

Conclusions

Due to the strict quota of emission limits, mainly the production intended for the production of clean energy is applicable. The current state of agriculture in Slovakia offers extensive possibilities for cultivation of energy plants. The introduction of the cultivation of energy crops in Slovakia can be regarded as one of the most important innovations of crop production and an important part of the agricultural sector.

The emergence rate and the rate of root taking of individuals depend on the type of planting in the first year of cultivation. Relatively high mortality rate of the individuals (31%) was confirmed in case of rhizomes´ plantation (*Miscanthus* × *giganteus*).

The growth of the *Miscanthus* × *giganteus* created clusters with a total average number 26.07 stems per cluster with count yield biomass 11.10 t*ha^{-1} at the research area in the first year of its cultivation. The growth of the *Miscanthus sinensis* Tatai (*in vitro* seedling) was fully canopied at the end of the growing period in the year of establishment. *Miscanthus sinensis* Tatai created average 37.60 stems per cluster with count yield biomass 10.80 t*ha^{-1} (at the research area in Kolíňany).

The yield of the biomass of both studied genotypes was made through the number of stems. Comparison of two *Miscanthus* genotypes indicates moderate differences in their growth parameters.

After the fifth vegetation year (2014), the growth reached the average production of 28.60 t*ha^{-1} of dry biomass at harvest moisture (*Miscanthu*s × *giganteus* 30.9 t*ha^{-1} and *Miscanthus sinensis* Tatai 26.3 t*ha^{-1}). The moisture content of the harvest phytomass was from 17 to 20%. Differences in biomass production of both *Miscanthus* genotypes are statistically highly significant in each monitored vegetation period.

Economic analysis has confirmed the difference of costs needed for the establishment of the growths. The costs for *in vitro* seedlings are approximately 16% higher than the establishment of the *Miscanthus* plantation using rhizomes. The growth of the *Miscanthus sinensis* Tatai was canopied at the end of the growing season. The growth established from rhizomes was not fully canopied in the year of its establishment. There was necessary to complete the plantation.

Comparison of the planting material´s costs shows that the costs for seedlings in vitro are approximately 16% higher. Keeping the 100% survival rate of the *in vitro* planting, the growth is fully canopied in the second vegetation year. Such growth is able to provide a balanced yield of the aboveground biomass.

Acknowledgements

This work was supported by the Slovak Research and Development Agency under the contract No. SK-SRB-2013-0031 and by the AgroBioTech ITMS 26220220180.

References

Angeliny, L. G., Ceccarini, L., Di Nasso, N. N., Bonari, E. (2009) Comparison of *Arundo donax* L. and *Miscanthus × giganteus* in a long-term field experiment in Central Italy: analysis of productive characteristics and energy balance. Biomass and Bioenergy, 33 (4), 635–643. DOI: 10.1016/j.biombioe.2008.10.005

Atkinson, C. J. (2009) Establishing perennial grass energy crops in the UK: a review of current propagation options for *Miscanthus*. Biomass and Bioenergy, 33 (5), 752-759. DOI: 10.1016/j.biombioe.2009.01.005

Brosse, N., Dufour, A., Meng, X., Sun, Q., Ragauskas, A. (2012) *Miscanthus*: a fast-growing crop for biofuels and chemicals production. Biofuels, Bioproducts and Biorefining, 6 (5), 580–598. DOI: 10.1002/bbb.1353

Christian, D. G., Yates, N. E., Riche, A. B. (2005) Establishing *Miscanthus sinensis* from seed using conventional sowing methods. Industrial Crops and Products, 21 (1), 109-111. DOI: 10.1016/j.indcrop.2004.01.004

Clifton-Brown, J. C., Lewandowski, I., Andersson, B., Basch, G., Christian, D. G., Kjeldsen, J. B., Jørgensen, U., Mortensen, J. V., Riche, A. B., Schwarz, K., Tayebi, K., Teixeira, F. (2001) Performance of 15 *Miscanthus* genotypes at five sites in Europe. Agronomy Journal, 93 (5), 1013–1019. DOI: 10.2134/agronj2001.9351013x

Cosentino, S. L., Patane, C., Sanzone, E., Copani, V., Foti, S. (2007) Effect of soil water content and nitrogen supply on the productivity of *Miscanthus × giganteus* Greef and Deu. in a Mediterranean environment. Industrial Crops and Products, 25 (1), 75–88.DOI: 10.1016/j.indcrop.2006.07.006

Council Directive 2001/77/EC of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market.

Council Directive 2003/30/EC of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport.

Council Directive 2009/28/EC 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.

Danalatos, N. G., Archontoulis, S. V., Mitsios, I. (2007) Potential growth and biomass productivity of *Miscanthus × giganteus* as affected by plant density and N-fertilization in central Greece. Biomass and Bioenergy, 31 (1-2), 145–152. DOI: 10.1016/j.biombioe.2006.07.004

Demo, M., Húska, D., Jureková, Z., Miklós, N. (2013) Ozdobnica čínska (*Miscanthus sinensis* A.) ako zdroj biomasy pre energetické účely – pestovateľské technológie. [Chinese silvergrass (*Miscanthus sinensis* A.) as a source of biomass for energy purposes - growing technologies.] Nitra: Slovak University of Agriculture, 43. ISBN 978-80-552-0978-4.

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*. Field Crops Research, 63 (1), 3–11. DOI: 10.1016/S0378-4290(99)00022-2

Filová, A. (2015) Metodická príručka pre zakladanie a pestovanie rastlín a drevín v podmienkach in vitro. [Methodological guide for the establishment and cultivation of plants and trees in vitro] Nitra: Polymedia, 120. ISBN 978-80-970764-3-6.

Heaton, E. A., Dohleman, F. G., Miguez, A. F., Juvik, J. A., Lozovaya, V., Widholm, J., Zabatina, O. A., McIsaac, G. F., David, M. B., Voigt, T. B., Boersma, N. N., Long, S. P. (2010) *Miscanthus*: a promising biomass crop. Advances in Botanical Research, 56, 75–137. DOI: 10.1016/S0065-2296(10)56003-8

Jandačka, J. (2010) Pestovanie ozdobnice čínskej v Poľnohospodárskom družstve v Košeci. [*Miscanthus* cultivation in Agricultural cooperatives in Košeca] [Online] Available at: http://www.biomasa-info.cz/cs/doc/S2_17.pdf [Accessed 4 February 2016].

Jureková, Z., Kotrla, M., Prčík, M., Hauptvogl, M., Pauková, Ž. (2015) Fast-growing energy crops grown in conditions of Slovakia in the context of the EU policy. Acta regionalia et environmentalica, 12 (1), 1-5. DOI: 10.1515/aree-2015-0001

Jureková, Z., Kotrla, M., Prčík, M., Pauková, Ž. (2012) The growth and yield of different *Miscanthus* genotypes in the condition of south-western Slovakia. Acta regionalia et environmentalica, 9 (2), 29-33.

Kotrla, M., Prčík, M. (2014) Growth dynamics of perennial energy grass genus *Miscanthus* studied in Slovakia. In: 14th International Multidisciplinary Scientific GeoConference SGEM 2014, SGEM2014 Conference Proceedings, Book 4, Vol. 1, 253-260, 19-25 June 2014, Sofia, Bulgaria DOI: 10.5593/SGEM2014/B41/S17.033

Porvaz, P., Tóth, Š., Marcin, A. (2012) Cultivation of chinese silvergrass (*Miscanthus sinensis* Andress.) on the Slovak lowlandas a potential source of raw material for energy purposes. Agriculture, 58 (4), 146-153. DOI: 10.2478/v10207-012-0016-5

Prčík M., Kotrla, M. (2013) Evaluation of dry matter production of *Miscanthus sinensis* (Tatai). Acta regionalia et environmentalica, 10 (2), 57-60. DOI: 10.2478/aree-2013-0012

Maga, J., Nozdrovický, L., Pepich, Š., Marhavý, Ľ., Hajdu, Š. (2008) Komplexný model využitia biomasy na energetické účely. [The comprehensive model of using biomass for energy purposes.] Nitra: Slovak University of Agriculture, 183. ISBN 978-80-552-0029-3.

Strašil, Z. (2009) Základy pěstování a možnosti využití ozdobnice (*Miscanthus*). [Basics of cultivation and possibilities for useing of *Miscanthus*.] Prague : Crop Research Institute, 48. ISBN 978-80-7427-006-2.

Vilček, J. (2011) Potential and quality parameters of farmland in Slovakia. Geographical Journal, 63 (2), 133-154. ISSN 0016-7193.

Walter, H., Leith, H. (1967) Klimadiagramm – Weltatlas. Jena: Gustav Fischer Verlag.