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Cultivation of *Miscanthus* × *giganteus* for biofuel and its tolerance of Lithuania's climate

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Abstract

During the period 2007–2009, field trials were conducted at the Lithuanian Institute of Agriculture on *Miscanthus* × *giganteus* cultivation for biofuel. The plant was tested for tolerance of our climate and environment conditions: over winter survival, growth rate and development peculiarities in the first-third cultivation years, biomass potential and the effect of nitrogen fertilizers on the productivity. *Miscanthus* × *giganteus* seedlings (2-leaf stage) were introduced from Austria and were planted in an *Eutri-Cambic Arenosol* (*ARb-eu*) at a rate of 20 seedlings per 10 m^2. Plant height and number of stems were estimated monthly. Stem thickness was measured and biomass yield and its chemical composition were determined at the end of the growing season. Three nitrogen fertilization levels (0, 60 and 120 kg ha^{-1}) were explored from the second year of growing.

It was found that *Miscanthus* × *giganteus* persistence after the three years of cultivation was 65%, including seedling introduction in the first year of cultivation, tolerance of the weather of two winters and contrasting weather of two springs and shortage of moisture in the summer of the second year of growth. *Miscanthus* biomass yield increased with every year from on average 20 t ha^{-1} fresh biomass and 6 t ha^{-1} dry matter in the second year to 28 and 11 t ha^{-1}, respectively in the third year. Nitrogen fertilizer increased the yield only in the second year of growth. The hybrid *Miscanthus* × *giganteus* can be recommended for growing in Lithuania for bioenergy purposes.

Key words: *Miscanthus* × *giganteus*, tolerance, biomass, productivity, fertilization, biofuel.

Introduction

One of the renewable energy resources is plant biomass. Research done in the USA and Europe in various climate zones, soils and regions over the last 20 years has proved *Miscanthus* to be a plant possessing one of the highest energy biomass potentials (Clifton-Brown et al., 2004; Hastings et al., 2008; 2009; Heaton et al., 2008). The advantage of *Miscanthus* over other energy plants is undoubted in many countries of warmer climate zones; however, research evidence obtained in the cooler climate zones is rather diverse. The summarised results of tests done on 15 *Miscanthus* genotypes in Sweden, Denmark, England, Germany and Portugal suggest that the biomass yield is increasing with every year of cultivation from 2 t ha^{-1} in the first year to 9–18 t ha^{-1} in the second and third years. The green biomass of individual hybrid lines totalled from 29 to 40.9 t ha^{-1} (Clifton-Brown et al., 2001). It has also been noted that the genotypes that yielded better in cooler climate zones were less productive in warm climate zones.

There is little research in Lithuania into the choice and cultivation of plants designed for energy needs. In the Institute of Agriculture, in Dotnuva, the yield of dry biomass of perennial tall grasses amounted to 6–9 t ha^{-1} and only in favourable years it amounted to up to 12 t ha^{-1} (Kryževičienė, 2006; Kryzeviciene et al., 2007; Jasinskas et al., 2008; Lemežienė et al., 2009; Tilvikienė et al., 2009). In Vokė, willow trees grown on light soils produced an annual biomass yield of 5.60 t ha^{-1} over the first three years of cultivation (Nedzinskas, Nedzinskienė, 2005). Continuing the search for potential energy crops and expecting that the global climate change processes and climate warming will become conducive to warmth-loving C_4 type plants, we chose *Miscanthus* hybrid as a research object, which was tested under field conditions in Lithuania.

Miscanthus is a plant belonging to *Poaceae* family, *Miscanthus* genus. The most valued *Miscanthus* species are as follows: *M. sinensis*, *M. floridulus*, *M. Sacchariflorus* hybrid *Miscanthus × giganteus* Greef et Deu. (Greef, Deuter, 1993). The distinct advantage of *Miscanthus × giganteus* hybrid is long productive age and biomass use as renewable energy source and for lignin cellulose production (Heaton et al., 2008; Vrije et al., 2009). The biomass of *Miscanthus* (C_4 type) was found to contain much more carbohydrates compared with legumes and C_3 type plants and this facilitates its use for energy production (Pappas et al., 2009). An especially high emphasis is placed on *Miscanthus* effect on the environment, which is very favourable and beneficial for the maintenance of sustainable ecosystems (Clifton-Brown et al., 2001; Semere, Slater, 2007). In Denmark, it was found that after continuous growing of *Miscanthus* on the same site for a long time (9–16 years), the content of organic carbon in the soil markedly increased: in the 0–20 cm layer the concentration increased to 65%, in the 20–50 cm layer to 9%, in the 50–100 cm layer to 6% (Hansen et al., 2004). *Miscanthus* can form symbiosis with nitrogen-fixing bacteria (Eckert et al., 2001), therefore nitrogen fertilization is not always needed to increase biomass yield (Danalatos et al., 2007). However, *Miscanthus* utilizes nitrogen fertilizer much more effectively compared with *Phalaris arundacea* and wheat biomass grown for biofuel (Lewandowski, Schmidt, 2006). Experiments done over the last 20 years in agro-climatic zones of eastern and northern Europe and Central Asia have exhibited a wide range of energy plants that still need thorough studying (Hastings et al., 2009).

In the countries with a cooler climate, the spread of *Miscanthus* species is constrained by its susceptibility to contrasting, especially to low temperatures, and by the fact that the plants do not ripen seed (Lewandowski et al., 2000). However, *Miscanthus × giganteus* Greef et Deu. hybrid possesses a unique adaptivity trait, compared with other C_4 type plants (*Saccharum officinarum*, *Sorghum vulgare*, *Zea mays*), which allows it to adjust to the new climate and environmental conditions (Wang et al., 2008). Intensive research done in Europe evidenced that only first-year *Miscanthus* hybrids do not tolerate low temperatures (Lewandowski et al., 2000; 2003; Hastings et al., 2009). To facilitate wintering and to accelerate crop formation, it is enough to cover the plants with straw or other mulch in the autumn of the first year. Later the plants form a strong root system in the soil, reaching a 3–4-meter depth, and which makes up from 15 to 25 t ha^{-1} of rhizome dry biomass and at the same time enriches the soil with N, P, K and Mg (Clifton-Brown, Lewandowski, 2000; Kahle et al., 2001). In England, the data of long-term experiments done in 7 locations indicate that the variation of *Miscanthus* productivity is largely determined by moisture regime (Heaton et al., 2008). The soil moisture is often a greater limiting factor for productivity than nitrogen fertilization. The plants utilise much water, their roots have high sorption power and effectively filtrate soil moisture. Water use efficiency of *Miscanthus* is 0.6–0.8%, while that of C_3 plants 0.19–0.37%. In Lithuania, plants are often damaged by late frosts in spring and co-occurring soil droughts and hot weather spells. As a result, research on *Miscanthus* adaptivity in specific conditions is necessary.

The study was aimed to determine *Miscanthus × giganteus* hybrids' adaptation to Lithuania's climate and environmental conditions.

Materials and methods

The trials were conducted at Lithuanian Institute of Agriculture in Dotnuva (lat. 55º 24′ N, 23º 52′ E), in a reclaimed river bed territory. The soil is light, sand on sand with small stone and gravel admixture, *Eutri-Cambic Arenosol* (*ARb-eu*). The soil chosen for these experiments is suited for cultivation of forest plantation (Malinauskas, Urbaitis, 2010) or other plants. The soil is neutral, deeper alkaline, with a humus status of 2%, with moderate total nitrogen, available phosphorus and potassium contents. The pre-crop was red clover of the third year of use. Early in spring, the clover field was ploughed; the soil was prepared for *Miscanthus* planting by a cultivator and a harrow. Phosphorus (superphosphate) and potassium (potassium chloride) fertilizers were applied at a rate of 60 kg ha^{-1} (active ingredient).

Table 1. Soil characteristics

Soil depth cm	Total N %	$C_{org.}$	P_2O_5 mg kg^{-1}	K_2O mg kg^{-1}	pH_{KCl}
0–30	0.14	1.27	122	166	7.9
30–60	0.10	0.76	52	99	7.9

The seedlings of the *Miscanthus* hybrid were obtained from Austria. They were grown up to 2–4 leaves using the vegetative propagation method – chopped rhizomes. A total of 348 seedlings were planted in 10 meter-long rows, laid out in three replications, with 1 meter-wide row spacings, 0.5 m intervals between plants in rows (2 plants m^{-2} or 20 000 plants per ha). *Miscanthus* was not cut in the autumn of the first year of cultivation, and the stands were mulched with winter wheat straw. The plants were assessed for the following parameters: establishment, growth, tillering or emergence of lateral shoots, overwinter survival, and resumption of vegetation. To ascertain the dynamics of plant height variation and number of shoots per bunch, assessments were made once a month. In the first year, after the plants had become established, complex fertilizers were applied at a rate of NPK 16:16:16 400 kg per ha. In the spring of the second and third year, *Miscanthus* was fertilized according to the scheme 1 – N_0, 2 – N_{60} and 3 – N_{120}. The experiment was designed as a randomized complete block with three replicates.

The weather conditions exerted a marked effect on plant development and biomass increase (Table 2). In the dry summer of 2007, the planted *Miscanthus* was watered twice. Later in the season, there was enough warmth and moisture for plant growth. The winter of 2007–2008 was mild and snowless; however, the weather in spring was very changeable and adverse for young plants. The second winter of 2008–2009 was also by 1.5ºC milder than usual with up to 5 cm snow cover persisting only in the first ten-day period of January and in February.

To estimate biomass yield, the plants were cut at the end of vegetation (in 2008 on October 10, in 2009 on October 4) and fresh mass was immediately weighed. To calculate dry biomass yield, 5–6 stems were taken from each treatment replication and chopped, the mass was weighed and dried at +105ºC to a constant weight, and weighed again. Chemical analyses were done on composite chopped mass samples taken from 3 replications then dried at +65ºC and ground.

The research results were processed using the statistical analysis software package *Selekcija*, software *Anova* and *Stat* (Tarakanovas, Raudonius, 2003). We used LSD_{05} – least significant difference at 95% significance level; $\bar{x} \pm S\bar{x}$ – yield average and standard error of the mean.

Table 2. Temperature and precipitation

Data from the Dotnuva Meteorogical Station

Month	Air temperature (ºC)				Precipitation (mm) and hydrothermal coefficient (HTC)						
	2007	2008	2009	1924–2008 mean	2007		2008		2009		1924–2008 mean
					mm	HTC	mm	HTC	mm	HTC	
January	1.0	0.5	−2	−4.8	88.3	–	68.8	–	41.0	–	30.2
February	−7.4	2.2	−3.5	−4.5	25.7	–	31.1	–	18.7	–	25.3
March	5.2	2.6	0.9	−0.8	23.6	–	53.4	–	53.9	–	28.5
April	6.9	8.8	8.9	5.8	15.8	0.0	38.7	–	13.1	–	36.9
May	13.5	12.2	12.7	12.2	98.2	1.8	13.2	0.4	26.7	0.5	51.8
June	17.6	16.1	14.6	15.6	61.5	1.2	49.2	1.0	168.6	3.6	62.4
July	17.2	18.2	18.1	17.6	118.1	2.2	47.6	0.8	90.0	1.6	73.4
August	18.7	18.0	16.8	16.7	50.8	0.9	90.8	1.6	67.1	1.3	73.7
September	12.8	12.1	13.9	12.0	49.1	1.3	16.0	0.4	48.2	1.2	51.3
October	7.7	8.9	5.2	6.8	48.7	1.0	80.4	1.7	95.4	–	50.2

Results and discussion

Overwinter survival and re-growth in spring of the Miscanthus × giganteus hybrid. Nine days after *Miscanthus* planting, out of the 348 seedlings planted 88% (data not shown) became established. The established plants rapidly grew and intensively developed until the autumn frosts. At the end of October, the stand was covered with a 3 cm-thick winter wheat straw layer to alleviate wintering conditions. After the mild winter of 2007–2008 but early spring with contrasting weather, plant vegetation started late – in the middle of May. The re-growth of the first shoots was rather sluggish because it took long for the soil to warm up, the air temperature at night dropped to 6ºC and in the day time the surface of the straw-mulched soil did not reach a temperature of 10–12ºC, conducive to *Miscanthus* revival (Lewandowski et al., 2000; 2003). Part of the shoots that had started vegetation was frost-killed at the end of May. At the beginning of intensive growth (June 27) there were recorded 219 plants; however, some of the plants that had been considered killed revived and at the end of the season there were 228 plants. Straw mulch remained un-decomposed during the whole vegetation period of the second year. After the second winter of 2008–2009, in spring, the same number of *Miscanthus* plants started vegetation earlier than after the first winter and this number did not change during the whole vegetation season of the third year of growth.

Growth dynamics and development. Nine days after *Miscanthus* planting, the tips of new leaves of established plants emerged and the plants grew rapidly all through the summer and autumn. During the period from August 10 to October 16 (first frosts) plant height increased by 80 cm, or by 1.2 cm per day. At the end of vegetation, the average height of the first-year plants was 112 cm (Table 3). Root system intensively developed, which was indicated by emerging new shoots from rhizome buds. At the end of vegetation, each bunch had on average 6.3 stems, and the bunch diameter was on average 14 cm.

In the second year of growth, in spring *Miscanthus* revived late – mass re-growth of shoots started at the end of the second ten-day period of May. Nitrogen fertilizers applied significantly promoted the growth of plants, which started vegetation late, only in June. Fertilized with 120 kg ha^{-1} *Miscanthus* plants were 85 cm in height, or by 31 cm taller compared with the plants grown without fertilizers (Table 4). Later, when moisture shortage started, the height of the above-ground plant part differed little. In the conditions of high air temperature, unfertilized *Miscanthus* grew very rapidly – more than 2 cm per day during July. Fertilizer effect on plant height did not manifest itself later either. However, positive fertilizer effect on shoot formation started to manifest itself in July, especially for the plants that had received 120 kg ha^{-1} nitrogen. In 2008, the first half of vegetation was dry but *Miscanthus* did not stop growing. During August, *Miscanthus* bunches produced 10–11 shoots. The highest density was recorded for the *Miscanthus* bunches fertilized with 120 kg ha^{-1} nitrogen. At the end of vegetation, there were on average 23.3 stems per bunch, which were 4.3 more compared with the unfertilized treatment. Fertilizers tended to increase stem diameter also.

Table 3. Dynamics of *Miscanthus* growth and development in the first year, 2007

Indicators	Measurement date (day, month)			
	12 07	10 08	06 09	16 10
Mean plant height, cm	32 ± 1.05	54 ± 1.07	91 ± 0.97	112 ± 0.52
Variation of plant height coefficient (V%)	1.82	1.85	1.68	0.89
Mean number of stems per plant				6.3 ± 2.80
Mean stem diameter, mm per plant				14 ± 4.03

Table 4. Dynamics of *Miscanthus* growth and development in the second year, 2008

Measurement date (day, month)	Fertilization			
	N_0	N_{60}	N_{120}	LSD_{05}
Mean plant height, cm				
28 05	17	22	26	12.8
27 06	54	78	85*	25.4
29 07	130	134	125	17.2
01 09	155	155	160	19.5
29 09	185	190	187	16.2
Mean number of stems per plant				
28 05	1.7	1.7	2.0	0.63
27 06	2.0	2.1	2.3	0.81
29 07	3.2	3.5	5.1*	1.30
01 09	13.1	14.9	16.5	7.34
29 09	19.0	20.3	23.3*	1.51
Mean stem diameter, mm				
29 09	10.4	10.5	10.8	2.67

* – statistically significant difference from the control

Literature evidence suggests that *Miscanthus* bunches over the second – sixteenth years become denser with every year: the number of stems varies from 42 to 54 in Central Europe to 80 in the warm climate zone in Portugal (Clifton-Brown et al., 2001). In the spring of the third year of growth, although it was late and cool, vegetation started earlier than in the second year, the first shoots emerged on May 8 and vegetation started another two days later. The plants that had just started vegetation were affected by frost. After frost stress, *Miscanthus* started to grow more intensively only in the last ten-day period of May when the weather became warmer. In summer (July and August) the weather was warm and conducive to *Miscanthus* growth. Significant fertilizer effect on stem growth rate stood out during this period – the height of plants fertilized with N_{120} was 266 cm on August 26 (Table 5).

Plants started to experience moisture shortage in September; the height of plants applied with different nitrogen rates differed little again, although individual plants grew more than 3 metres tall. In the countries of Central and East Europe, the height of *Miscanthus* varies from 2.5 to 4 m (Lewandowski et al., 2000). In the third year of growth *Miscanthus* tillering was weak; the number of shoots per bunch was even slightly lower than in the second-year *Miscanthus* (on average 18.9). Nitrogen fertilizers did not have any effect on tillering intensity; however, they significantly increased stem thickness.

Biomass structure. In the above-ground biomass of the second-year *Miscanthus* cut upon completion of vegetation, leaves dominated and accounted for on average 54.8% (Fig. 1). However, in the third year of growth, the stems grew very tall and the leaves of the bottom part started drying early, therefore their share in the total dry biomass in the autumn dramatically declined and made up on average 28.8%. Some literature findings also indicate that with increasing productive age of *Miscanthus* stand, the share of stems in the total biomass can increase up to 92 % and this has a direct effect on biomass energy value (Christian et al., 2008).

Nitrogen fertilizer effect on biomass structure was noted only in the second-year stands. In the biomass of *Miscanthus* grown without fertilizers leaf share was the highest and made up 61.2%. The higher fertilizer rate N_{120} tended to increase plant leafiness compared with the N_{60} rate.

Biomass. In the first year of growth or planting, *Miscanthus* plants were left uncut over winter to prevent any stress before wintering. Biomass yield of the *Miscanthus* hybrid was established in the autumn after plants had ceased growing. In 2008, the plants were cut on October 15 and in 2009 on October 6. Having weighed the biomass of cut plants, weight per plant and yield per ha were calculated. There were on average 13200 plants per hectare (or 66% from the planted number). Fresh biomass yield of the second-year plants that grew during the dry growing season of 2008 varied from 15.8 to 24.7 t ha^{-1}, dry biomass – from 4.6 to 6.8 t ha^{-1} (Table 6). Nitrogen fertilizers increased biomass yield. Fresh biomass yield was significantly increased by the 120 kg ha^{-1} rate, and that of dry biomass by both rates, however, the differences between different rates were insignificant. In the third year, *Miscanthus* productivity was by on average 82% higher than in the second year and dry biomass yield amounted to 11.5 t ha^{-1}. Nitrogen fertilizers that year only tended to increase yield per plant and total productivity.

Table 5. Dynamics of *Miscanthus* growth and development in the third year, 2009

Measurement date (day, month)	Fertilization			
	N_0	N_{60}	N_{120}	LSD_{05}
Mean plant height, cm				
26 05	50	54	46	9.4
30 06	128	132	133	7.2
23 07	214	223	218	8.9
26 08	234	245	266*	16.9
30 09	288	295	296	32.7
Mean number of stems per plant				
28 05	10.7	16.9	12.9	4.76
30 06	16.3	18.6	14.7	7.21
23 07	17.7	19.7	15.8	4.13
01 09	17.2	19.5	15.3	3.77
29 09	19.4	19.1	18.2	4.30
Mean stem diameter, mm				
29 09	6	6.3	7.3*	1.19

* – statistically significant difference from the control

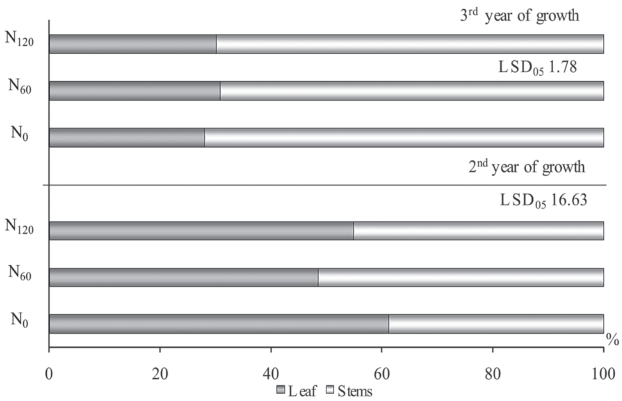

Figure 1. Biomass structure of *Miscanthus* × *giganteus*

In the countries with warmer climate, where snow layer lasts for a short time or no snow layer occurs, *Miscanthus* biomass is cut in the autumn for biofuel and biogas production and early in spring before the resumption of vegetation for the production of granules and briquettes (Lewandowski et al., 2000; Lewandowski, Heinz, 2003; Heaton et al., 2008). In Germany and the Netherlands, biological moisture of spring-cut *Miscanthus* declined to 35.5%, depending on wintering conditions, biomass losses increased to 30% or even 50%, primarily, due to leaf death during wintering.

In the present study, to establish biomass wintering losses, the second-year *Miscanthus* was cut at two terms – at the end of vegetation and in spring, before the start of vegetation.

In spring, the stand was cut during the period of settled, dry, windy and sunny weather, when biomass moisture was 15% (Fig. 2). This shows that biomass losses of spring-cut young *Miscanthus* were very high, ranging from 70 to 76%. Higher losses occurred for more abundantly fertilized *Miscanthus*; however, the differences were insignificant. When estimating this time of cut, one should remember that leaves dominated in the biomass of the second-year *Miscanthus* and their decomposition rate was high due to higher moisture. It is thought that the magnitude of losses was also influenced by the fact that in our climate zone wintering period is long (about half a year) with very changeable weather.

In summary, it can be maintained that persistence of the *Miscanthus* plants introduced to Lithuania from Austria was relatively good over the three growing seasons and two wintering periods. Already in the third year of growth *Miscanthus* biomass yield either compared to or exceeded the yield of other plant species cultivated for biofuel production (Kryževičienė, 2006; Tilvikienė et al., 2009). Yields reported for trials all over Europe are presented along with some information on management conditions (Table 1). Dry matter yields (DM) of up to 25 t ha^{-1} year^{-1} have been obtained from the third year onwards in the spring harvest for *Miscanthus* × *giganteus* crops between the latitudes 37 N (Southern Italy) and 50 N (Central Germany). However, there have been huge differences in biomass yields from 2 to 44 t ha^{-1} (Lewandowski et al., 2000). In the field trials conducted in the United Kingdom, the yield of *Miscanthus* hybrid increased up to the 6th year, the yield of 6 to 14 year-old stands ranged around 5% and made up on average 17.7 t ha^{-1} dry biomass (Christian et al., 2008). The data from *Miscanthus* × *giganteus* productivity research network in European countries indicated that its yield varied depending on the climate zone, temperatures and amount of precipitation, on soil type and soil water availability, as well as on the date and harvesting method.

Table 6. The impact of nitrogen fertilizer on *Miscanthus* yield per plant and total biomass yield in the autumn of the second and third year of growth

Indicators	Green biomass				Dry biomass			
	N_0	N_{60}	N_{120}	LSD_{05}	N_0	N_{60}	N_{120}	LSD_{05}
Second year of growth								
Annual biomass								
t ha^{-1}	15.8	20.0	24.7*	5.63	4.62	6.55*	6.82*	1.85
%	100	127	157	40.5	100	142	148	42.9
Biomass weight per plant								
kg	1.66	2.26*	2.53*	0.627	0.49	0.74*	0.70*	0.208
Third year of growth								
Annual biomass								
t ha^{-1}	27.0	28.5	29.7	5.31	10.5	10.7	11.5	2.47
%	100	105.6	110.1	18.68	100	102.3	110.2	22.61
Biomass weight per plant								
kg	2.05	2.18	2.25	0.396	0.79	0.81	0.87	0.187

* – statistically significant difference from the control

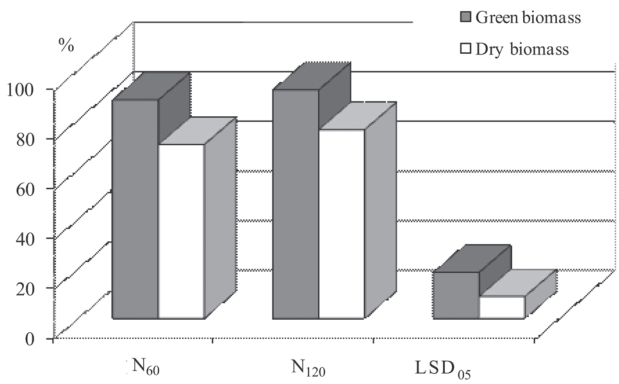

Figure 2. Biomass loss of wintering *Miscanthus*

Biomass chemical composition. Biogas output depends on carbon and nitrogen contents and their ratio in the biomass (Prochnow et al., 2009 a; Tilvikienė et al., 2009); calorific value of biomass of perennial grasses intended for combustion is directly dependent on fibre content (Kryževičienė et al., 2005; Prochnow et al., 2009 b). The share of *Miscanthus* stems in the total biomass has a greater influence than leaves on fibre and carbon contents and determines energy characteristics of biomass (Villaverde et al., 2009). Leaves contain less mineral matter, especially N, P, K, S and Cl, as well as ash (Monti et al., 2006). In the biomass of the second-year *Miscanthus* tested under our conditions, the content of neutral detergent fibre (NDF) was as high as 81% and it further increased in the next year (Table 7). This is more than NDF concentration indicated in literature for the biomass of other grasses type C_4 (78%) and C_3 (75%) (Pappas et al., 2009).

Table 7. Chemical composition of *Miscanthus* × *giganteus* aboveground biomass

Fertilization	Chemical composition %						
	N	C	S	Fibre		Ash	Lignin
				NDF	ADF		
Second year of growth							
N_0	1.032	46.21	0.273	79.3	49.3	5.38	8.47
N_{60}	1.367	47.16	0.178	80.8	47.7	5.19	8.76
N_{120}	1.247	46.35	0.189	79.5	45.4	5.41	7.03
Third year of growth							
N_0	0.681	47.20	0.142	81.7	53.4	3.45	10.9
N_{60}	0.585	47.20	0.137	81.1	51.7	3.41	9.82
N_{120}	0.537	47.80	0.123	83.7	55.8	2.42	11.4

NDF – neutral detergent fibre, ADF – acid detergent fibre

The concentration of major elements in *Miscanthus* biomass was more dependent on the stand age rather than on fertilization. The amount of undesirable ash in the biomass of the third-year *Miscanthus* applied with different nitrogen rates declined by on average 42%, compared with ash content in the biomass of the second-year *Miscanthus*. The concentration of total nitrogen and sulphur in the biomass in dry years was higher in the second-year *Miscanthus*, and the concentration of organic carbon tended to increase with *Miscanthus* age.

Conclusion

Miscanthus × *giganteus* adaptivity after the three years of cultivation was 74 per cent, including tolerance of the weather of two winters and contrasting weather of two springs and shortage of moisture in the summer of the second year of growing. *Miscanthus* biomass yield increased from on average 6 t ha^{-1} dry matters in the second year to 11 t ha^{-1} in the third year. Nitrogen fertilizer increased the yield only in the second year of growing. The *Miscanthus* × *giganteus* hybrid could be used for growing in Lithuania for bioenergy purposes; however further research as well as additional tests on *Miscanthus* would enable expansion of the data base and possibilities of comparison with other imported and indigenous plants from the agronomic, ecological, energy, economic and social viewpoints.

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Drambliažolės hibrido *Miscanthus* × *giganteus* tolerancija Lietuvos klimatui ir auginimas biokurui

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Santrauka

Lietuvos žemdirbystės institute Dotnuvoje 2007–2009 m. lauko sąlygomis tirtas drambliažolės hibrido (*Miscanthus* × *giganteus* Greef et Deu.) auginimas biokurui, siekiant nustatyti augalo toleranciją šalies klimato ir aplinkos sąlygoms: žiemojimą, augimo dinamiką ir vystymosi ypatumus pirmais–trečiais augimo metais, biomasės potencialą ir azoto trąšų įtaką derlingumui.

Drambliažolės hibrido sodinukai (2–4 lapelių) introdukuoti iš Austrijos ir po 2 vnt. m^2 pasodinti pasotintame rudžemiškame smėlžemyje su žvyro bei akmenų priemaiša (SDr-b), *Eutri-Cambic Arenosol* (*ARb-eu*). Kas mėnesį matuotas augalų aukštis ir skaičiuotas stiebų skaičius, vegetacijos pabaigoje matuotas stiebų storis, nustatytas biomasės derlius ir jos cheminė sudėtis. Nuo antrųjų augimo metų tirti trys tręšimo azotu lygiai (N 0, 60 ir 120 kg ha^{-1}).

Nustatyta, kad drambliažolės hibrido augalų įsitvirtinimas po trejų augimo metų buvo 65 %, įskaitant sodinukų prigijimą pirmaisiais augimo metais, dviejų žiemų bei pavasarių kontrastingų orų ir drėgmės stokos toleranciją antrųjų augimo metų vasarą. *Miscanthus* × *giganteus* biomasės derlius pamečiui didėjo nuo vidutiniškai 20 t ha^{-1} žalios biomasės ir 6 t ha^{-1} sausos biomasės antraisiais metais iki atitinkamai 28 ir 11 t ha^{-1} trečiaisiais metais. Azoto trąšos derlių didino tik antraisiais augimo metais. Drambliažolės hibridas *Miscanthus* × *giganteus* gali būti auginamas Lietuvoje bioenergetikos tikslais.

Reikšminiai žodžiai: *Miscanthus* × *giganteus*, tolerancija, biomasė, produktyvumas, tręšimas, biokuras.