DOI: 10.17707/AgricultForest.64.2.10

***Mykhaylo GUMENTYK, Mykola KHARYTONOV*** [1]

# DEVELOPMENT AND ASSESSMENT OF TECHNOLOGIES OF MISCANTHUS AND SWITCHGRASS GROWING IN FOREST-STEPPE ZONE OF UKRAINE

## SUMMARY

The relation between weather conditions and yield of energy crops in the conditions of forest-Steppe of Ukraine was established. Optimum conditition for *Miscanthus × giganteus* rhizome density and depth, method of sowing of switchgrass seeds, row spacing and terms of conducting maintenance during the first year of vegetation have been established. The yield of *M.×giganteus* increases due to rhizomes planting in the early stages and planting depth - 8-10 cm.

The article presents the results of studies on the effect of cultivation technology for *Miscanthus × giganteus* and switchgrass biomass purposed for the production of solid biofuel. Methods of planting, optimal row width and conditions of care during the first year of vegetation are substantiated. The highest switchgrass yield of dry biomass and the energy output was provided in options with marker crop sowing and the width between rows 30 and 45 cm. The factors under study, namely methods of planting and tillage are essential only in the first year of vegetation. The optimal row width, methods of planting and tending switchgrass sowing were established.

**Keywords:** energy crops, planting dates, row width, planting density, marker crop, productivity.

## INTRODUCTION

The involvenment of alternative sources in energy balance of agricultural sector, reduce energy dependence of Ukraine (Geletukha et al., 2016). Production of fuel pellets and briquettes based on biomass energy crops is economically viable biofuel production (Mitchell et al., 2012, Hodgson et al., 2010; Bouriaud et al., 2015). The main advantage of solid biofuels is renewable, reducing the greenhouse effect, environmentally closed-loop energy system, the potential for growing cellulosic feedstock (Karp. and Sheid, 2008; Heaton et al., 2010). Biomass of Miscanthus (*Miscanthus Anders*) and switchgrass (*Panicum virgatum L.*) has a high content of cellulose and lignin and thus it is high quality raw material for the production of solid biofuels (Butkutė et all, 2013; Cassie et al., 2015). *Miscanthus × giganteus* and switchgrass are perennial grasses with C4-

[1] Mykhaylo Gumentyk, Institute of Energy Crops and Sugar Beet, 03141, Klinichna st. 25, 03141, Kiev, UKRAINE, Mykola Kharytonov, (corresponding author: kharytonov.m.m@dsau.dp.ua), Dnipro State Agrarian and Economic University, S.Yefremova st. 25, 49600, Dnipro, UKRAINE.
Notes: The authors declare that they have no conflicts of interest. Authorship Form signed online.

type photosynthesis. At a certain point these plants had attracted the interest of researchers as a promising source of cellulose containing biomass for chemical industry and bioenergy production (Christian et al., 2008, Dohleman et al., 2009, Brosse et al., 2012; Mitchell et al., 2012). The aboveground plant biomass can be used as renewable raw materials for the production of solid (pellets, briquettes), liquid or gaseous (ethanol, butanol, ethylene) types of fuels (Hodgson et al., 2010, Han et al., 2011, Parrish et al., 2012; Cassie et al., 2015 *)*. Recent researches (Lewandowski and Schmidt, 2005; Milovanovic et al., 2012; Arnoult and Brancourt-Hulmel, 2015; Powlson et al., 2005) have shown that many different factors can influence on Miscanthus and switchgrass biomass production efficiency (geographical location of the cultivation area, climate conditions, water supply, crop management, mineral element availability, genotypic variability). In this connection, thorough studying of productivity parameters under introduction conditions will allow to determine of potential and prospects of this crop cultivation. Meantime, adaptation of the technology of second generation energy crops growing to soil and climatic conditions of Ukraine is still missing. The objective of this study was to develop and evaluate technologies of switchgrass sowing and planting of *Miscanthus* × *giganteus* rhizome in conditions of forest-steppe of Ukraine.

## MATERIAL AND METHODS

Experimental plots located in the western part of forest-steppe zone of Ukraine the Borshchiv district, Ternopyl region. The soil of the experimental plots is turf podzol with acidity (pH) is 6.0. The climate is moderately continental with minor amplitude fluctuations in temperature, the sum of positive temperatures is within 2500 and.2600ºC. Period with average temperature above 10 ° C lasts 160-165 days. There are 370-420 mm of rainfall during this period, the value of hydrothermal factor is from 1.4 to 1.6. Weather conditions prevailing in the study region for 2009-2015 years are shown in tables 1 and 2. Moisture level was limiting factor, since precipitation is distributed unevenly. A small amount of precipitation was registered during the period 2009-2011, which resulted in drought conditions for the studies plants. Weather conditions in 2012 year could be caracterized by warm early growing season.

The average daily air temperature in April was 10.3°. The summer of 2012 year was characterised warm weather conditions. It was enough for energy crops growth and development. Meanwhile, during this time, precipitations were at sufficient level. The less rainy summer of 2012 year, when in May precipitation rate registered at level 21.5 mm, had negatively affected the germination of plants. However, a large amount of precipitation fell in June – 105.5 mm and 77.5 mm – in August. 2012-2014 years weather was hot and humid. Average temperature in 2012-2013 years was 16.4 °C, while in 2014 – only 14.9 °C. In May of 2014 precipitation twice higher than long-term observations average was registered.

Table 1**.**The average long-term values of air temperature in Ternopyl region

| Month | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|
| Apr | 11.1 | 9.4 | 10.4 | 10.3 | 12 | 9.5 | 8 |
| May | 14.5 | 15.3 | 14.9 | 16.0 | 16.4 | 14.9 | 14 |
| June | 17.3 | 17.9 | 18.4 | 19.3 | 18 | 16 | 18 |
| July | 20.9 | 20.3 | 19.7 | 23.0 | 19.5 | 20 | 21.5 |
| Aug | 19.7 | 21.1 | 19.3 | 19.1 | 20 | 18.5 | 22.5 |
| Sept | 16.0 | 12.8 | 17.2 | 15.1 | 13 | 15 | 17.5 |

Table 2**.**The average long-term values of precipitation in Ternopyl region

| Month | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|
| Apr | 3.4 | 26.3 | 37.5 | 83.0 | 93 | 75 | 47 |
| May | 41.0 | 108.6 | 21.2 | 21.5 | 100 | 133 | 113 |
| June | 81.3 | 143.9 | 92.4 | 105.5 | 143 | 38 | 64 |
| July | 27.3 | 122.9 | 66.0 | 82.2 | 44 | 120 | 38 |
| Aug | 49.9 | 42.1 | 63.0 | 77.5 | 52 | 67 | 11 |
| Sept | 3.8 | 134.8 | 13.3 | 19.0 | 115 | 30 | 47 |

The weather was hot during summer of 2015 year. Irregularity of precipitations could be observed during this period. Such weather conditions had adverse impact on growth and development of all types of studied plants and their yields.

All observations could be resulted in following: during 2009-2015 years dry weather was prevailing, temperatures higher of average were registered. As it generally known, optimal conditions for the crop can be supported by certain agronomic measures before and after sowing, if those are variable and timely. The sun radiation level can be optimized by adjusting planting density and direction of rows and the width between rows. Temperature regime has great impact on germinating quality of cereals and the transition from the tillering phase to the next phases of development.

Two factors field experiment were conducted on *Miscanthus × giganteus*. Plants were grown during 2009-2012 years. Factor A – planting dates (I – II decade of Apryl; II–III decade of Apryl; I decade of May). Factor B is planting depth (6 cm; 8cm; 10cm; 12cm).

Field experiments with switchgrass were conducted from 2009 to 2015 years. Two factors were considered as well: factor A - method of seeding (with and without marker plant). Mustard was used as marker crop. Factor B is the width of inter-row spacing. The total area of the experiments was 0.40 ha, repetition - four times.

## RESULTS AND DISCUSSION

The impact the timing and depth of planting rhizomes on the yield of miscanthus are shown in the table 3.

Table 3**.** Yield of *Miscanthus* × *giganteus* biomass depending on the timing and depth of planting rhizomes

| Planting time | Year | | | | |
|---|---|---|---|---|---|
| | 2009 | 2010 | 2011 | 2012 | Average |
| | Planting depth - 6cm | | | | |
| I | 2.2 | 3.7 | 1.8 | 3.2 | 2.7 |
| II | 2.1 | 3.1 | 1.5 | 2.5 | 2.3 |
| III | 1.7 | 2.8 | 1.3 | 2.1 | 2.0 |
| | Planting depth - 8cm | | | | |
| I | 2.8 | 3.7 | 1.9 | 3.3 | 2.9 |
| II | 2.1 | 3.2 | 1.7 | 2.6 | 2.4 |
| III | 1.7 | 2.8 | 1.4 | 2.3 | 2.0 |
| | Planting depth - 10cm | | | | |
| I | 2.9 | 3.9 | 2.2 | 3.6 | 3.2 |
| II | 2.2 | 3.5 | 1.9 | 2.6 | 2.5 |
| III | 1.8 | 2.9 | 1.4 | 2.4 | 2.1 |
| | Planting depth - 12cm | | | | |
| I | 2.9 | 3.9 | 2.0 | 3.1 | 3.0 |
| II | 2.1 | 3.5 | 1.8 | 2.3 | 2.4 |
| III | 1.7 | 2.8 | 1.3 | 2.1 | 2.0 |
| $LSD_{05}$ | 0.4 | 0.4 | 0.3 | 0.3 | |

Weather conditions had a significant effect on the *Miscanthus* × *giganteus* biomass yield. The yield of *Miscanthus* × *giganteus* in the favourable weather conditions of 2010 and 2012 years was 2 times higher compared to 2009 and 2011 years. It is established that the yield of *Miscanthus* × *giganteus* biomass rises with the increase in depth of planting rhizomes. Best result is fixed when Rhizomes are planted 10 cm deep. Depending on the time of planting the rhizome during the four years of studies, yield of biomass ranged: the first period – from 1.8 to 3.9 t/ha, second term: from 1.5 to 3.5 t/ha; the third period –from 1.3 to 2.9 t/ha. These factors influence on the yield was observed in the first year of vegetation. Meanwhile, the trend continued in subsequent years. However, the effect in subsequent years was small. Plants of *Miscanthus* × *giganteus* were in the same conditions. The main shoot regeneration started at the same time regardless of the timing and depth of planting in the previous year. The yield of *Miscanthus* × *giganteus* at different planting dates during four years is shown in Fig.1. The yield of biomass in all options changed from 13.1 to 15.2 t/ha (plants after the second year of vegetation), 21.1-21.8 t/ha after the third year and 24.1-24.8 t/ha after the fourth year. Decreasing harvest of *Miscanthus* × *giganteus* in the second and third planting dates was associated with deficient rainfall in 2009 and 2011years.Seed germination in experiments with switchgrass starts at the temperature of +6 - 8

°C. Amicable germination occurs when soil was warming to +15-16 °C. Seedlings appeared only after 15-18 days.

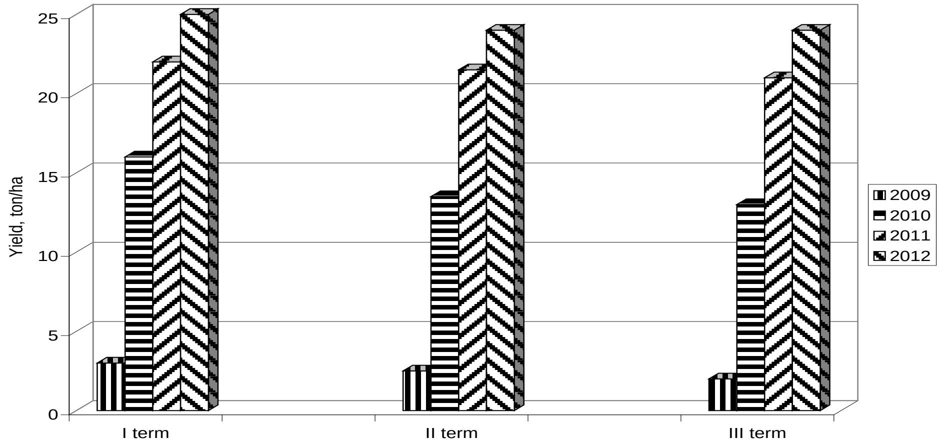


Figure 1. The miscanthus yield in different planting dates during four years

Seedlings can withstand weak frosts to - 2 °C. The sprouts were killed or significantly damaged at the temperature 3-5 °C. Long-term effect of low positive temperatures (+6 -10 °C) and cloudy weather was very harmful for switchgrass seedlings. In the first year of vegetation in the early phase of tillering roots develop poorly, deep into the soil slowly to a depth of 12-15 cm. The increase of the root mass occurs until late autumn. Regrowth of switchgrass started simultaneously and its density depended largely on the degree of tillering of the plants in previous years. The data of number of switchgrass stems before maturation of the seed depending on the width of inter-row spacing and mustard as marker crop are presented in the table 4.

Table 4.The number of stems of switchgrass depending on the width of inter-row spacing and marker crop.

| Width of row spacing, marker crop | Years | | | | | Average |
|---|---|---|---|---|---|---|
| | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Width 15 cm, marker crop sowing | 242 | 250 | 225 | 233 | 240 | 238 |
| Width 30 cm, marker crop sowing | 233 | 276 | 280 | 285 | 288 | 272 |
| Width 45 cm, marker crop sowing | 260 | 284 | 288 | 292 | 290 | 283 |
| Width 15 cm, without marker crop sowing | 236 | 256 | 262 | 269 | 273 | 259 |
| $LSD_{05}$ | 30.3 | 33.3 | 32.9 | 33.7 | 34.1 | 32.8 |

The number of stems was large compared with the row - spacing width of 15 cm in the trials when a width between rows - 30 and 45 cm. The increase in height of stems up to 40 cm was fixed in the same trials (table 5).

Table 5. Height of switchgrass stems depending on the width of inter-row spacing and marker crop, cm

| Width of row spacing, marker crop | Years | | | | | Average |
|---|---|---|---|---|---|---|
| | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Width 15 cm, marker crop sowing | 167 | 174 | 180 | 183 | 185 | 178 |
| Width 30 cm, marker crop sowing | 191 | 212 | 214 | 220 | 224 | 212 |
| Width 45 cm, marker crop sowing | 196 | 218 | 221 | 223 | 219 | 215 |
| Width 15 cm, without marker crop sowing | 169 | 172 | 179 | 181 | 180 | 176 |
| $LSD_{05}$ | 22.6 | 24.3 | 24.8 | 25.2 | 25.3 | 24.4 |

In the variants with a width 30 cm between rows switchgrass yield was 20.3 t/ha, 45 cm – 19,5 t/ha, whereas the width of the row spacing of 15 cm – from 16.5 to 15.8 t/ha (table. 6).

Table. 6.The switchgrass yield depending on the width of inter-row spacing and marker crop, t/ha

| Width of row spacing, marker crop | Years | | | | | Average |
|---|---|---|---|---|---|---|
| | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Width 15 cm, marker crop sowing | 12.5 | 16.1 | 17.2 | 18.1 | 18.2 | 16.5 |
| Width 30 cm, marker crop sowing | 17.1 | 19.7 | 21.6 | 20.9 | 22.2 | 20.3 |
| Width 45 cm, marker crop sowing | 16.3 | 19.7 | 19.1 | 20.3 | 21.6 | 19.5 |
| Width 15 cm, without marker crop sowing | 11.8 | 14.0 | 17.3 | 17.9 | 18.0 | 15.8 |
| $LSD_{05}$ | 1.8 | 2.2 | 2.4 | 2.4 | 2.5 | 2.3 |

Additional biomass in comparison with the fourth embodiment (inter-row spacing of 15 cm, seeding without the marker crop) was 2.9-4.8 t/ha. The lowest yield of dry biomass switchgrass was observed in the variant with the marker crop. An important indicator characterizing the value of switchgrass as bioenergy crop is possible energy output with yield. Calculations of this index are given in table 7. The highest energy output 367,2 GJ/ha was obtained at switchgrass sowing with the 45 cm width between rows with the marker crop, and the lowest

– 304,3 GJ/ha with a width of row spacing of 15 cm without marker crop. The calculations for the five years indicate that the greatest productivity in miscanthus – 25.3 t/ha of dry matter and 516.2 GJ/ha.

Table 7. Energy uptake with switchgrass depending on the method of preparation of soil for sowing, (mean for 2011-2015 years)

| Width of row spacing, marker crop | Yield of raw mass, t/ha | Dry matter, % | Yield of dry biomass, t/ha | The yield of solid fuel, t/ha | Energy output, GJ/ha |
|---|---|---|---|---|---|
| Width 15 cm, marker crop sowing | 21.2 | 80.2 | 16.5 | 18.6 | 316.2 |
| Width 30 cm, marker crop sowing | 25.0 | 79.5 | 18.3 | 20.7 | 351.0 |
| Width 45 cm, marker crop sowing | 24.7 | 79.2 | 19.5 | 21.6 | 367.2 |
| Width 15 cm, without marker crop sowing | 20.6 | 81.2 | 15.8 | 17.9 | 304.3 |
| $LSD_{05}$ | 2.9 | 10.0 | 2.3 | 2.6 | 41.1 |

The switchgrass yield – 18.2 t/ha, energy uptake – 371.5 GJ/ha (Table. 8). The results indicate that the higher effect can be obtained by creating energy chain supply of raw materials to the consumer. Realization of raw biomass for biofuel production on domestic and foreign markets, as well as planting material of miscanthus (ryzoms) and switchgrass (seeds), can bring additional economic benefits and reduce costs during the laying of plantation energy.

Table 8. The energy uptake of perennial bioenergy crops in the third year of vegetation (average over 2012-2016 years)

| Energy crop | Yield of raw mass, t/ha | Dry matter, % | Yield of dry biomass, t/ha | The yield of solid fuel, t/ha | Energy output, GJ/ha |
|---|---|---|---|---|---|
| Miscanthus | 58.8 | 42.6 | 25.3 | 30.3 | 516.2 |
| Switchgrass | 23.2 | 78.5 | 18.2 | 21.8 | 371.5 |

Indexes of energy crops production economic efficiency were evaluated at actual cost realized in the field experiments. In the experiments provided the traditional system of primary tillage, plowing with a wrapping layer. The fertilizers and pesticides responded to the need of plants to produce a crop according to get the 25.3 t/ha of miscanthus dry biomass and 18.2 t/ha of switchgrass. Analysis of the funds structure distribution per 1 ha of sowing such energy crops as miscanthus and switchgrass (table. 9) indicates that the largest part of these items are mineral fertilizers, pesticides and seeds that take up to 50 % of the total cost. A significant portion of energy costs were for planting material, fuel, fertilizer and herbicides.

Table 9. Economic efficiency of energy crops cultivation, euro

| Item of expenditure | Miscanthus | | Switchgrass |
|---|---|---|---|
| | for the 2nd year of vegetation | for the 3rd year and subsequent years | From 2nd year of vegetation |
| Salary | 40.3 | 9.1 | 40.9 |
| Fuel material | 102,06 | 13.7 | 65.6 |
| Amortisation | 26.1 | 9.2 | 19.8 |
| Routine maintenance | 18.3 | 12.8 | 13.9 |
| Seeds, cuttings, rhizome | 500 | - | 16.7 |
| Mineral fertilizer | 112.5 | 22.1 | 23.5 |
| Pesticides | 39,3 | - | 74.8 |
| Other expenses | 19,3 | 6.1 | 6.0 |
| The rent of land | 62.5 | 20.9 | 42.0 |
| Total production costs | 923 | 73.0 | 310 |
| Transport cost | 46.2 | 3.6 | 15.5 |
| Market price raw materials, ton | 31.7 | 31.7 | 30.0 |
| Gross proceeds | 1013 | 633 | 267 |
| Tax income | | | 274.5 |
| Profitability, % | 4,5 | 726,8 | 84.0 |
| Yield, ton/ha | 25,3 | 25 | 18.0 |
| Cost, 1 ton | 38,3 | 3.8 | 16,3 |
| Income, 1 ton | 1,38 | 27.8 | 13.7 |

Therefore it is necessary to implement such technologies of cultivation of bioenergy crops, which could contribute to a reduction in total energy costs. In the system of technology of growing take place a differentiated use of natural resources, anthropogenic factors and adaptive capacity of cultivated species, varieties, weed control etc. The second largest cost item is fuel. The amount of energy expenditure accounted for the total energy on the cultivation of energy crop. Costs the total energy for cultivation of miscanthus and switchgrass was not the same. A special feature of both crops is the low yield in the first three years of vegetation associated with significant costs for the construction of plantations. Considerable expenditure is incurred in laying plantations of miscanthus because of its vegetative propagation by rhizome planting. However, in subsequent years the exploitation of plantation expenses incurred are fully justified. This is with minimal care, mineral fertilizing and harvesting biomass. Switchgrass has a slightly lower economic performance than miscanthus. Switchgrass is indispensable in the arid southern regions of Ukraine, where miscanthus growing is much more difficult. That's why, for the rational use of energy plantations need to consider the advantages and disadvantages of each crop as a whole.

It is known that Giant Miscanthus is a very cold-tolerant warm-season grass.The optimal planting time for rhizomes is from March to April but planting can continue into May and even early June and still be successful(Christian et al., 2008). In our research the early stages (first and second) planting helped to increase yields from 19 to 45% compared to the third planting time. 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 and allow the crop to tolerate drought and frost better We approved also that best depth for *Miscanthus x giganteus* rhizomes is 10 cm deep (Pyter et al., 2010). Results of this study suggest that rhizomes should be 60–75 g, planted to a depth of 10 cm and kept in cold storage for as little time as possible. It is known, that in the first year of growing switchgrass gives up to 30% of its potential, in the second year - up to 70%. 100% of its potential can be reached from the third year of cultivation (Burli et al., 2017). Depending on the cultivation conditions, the switchgrass yield of two-year plants can reach 9 to 18 t/ha (Mitchell et al., 2012). In our experiment, the productivity of three years old plants with inter-row spacing width 30 cm reached 21.6 t/ha.

## CONCLUSIONS

The yield of miscanthus increases due to rhizomes planting in the early stages. Optimum planting depth is 8...10 cm. The effect of date and depth of planting on the yield of biomass was observed only in the first year of vegetation. The trend continues due to the difference of plant density.The greatest difficulty in switchgrass growing technology is the increased sensitivity of plants to the conditions of life support in the first year of vegetation. The highest switchgrass yield of dry biomass and the energy output was provided in options with marker crop sowing and the width between rows 30 and 45 cm. A high yield of solid biofuels (20.7 t/ha) and energy (351.0 GJ/ha) with switchgrass is achieved farming with row-spacing width of 45 cm with the sowing of marker crop. It is proved that miscanthus is the most profitable energy crop. The profitability of growing miscanthus for year 3 and subsequent years is 726 %.

## REFERENCES

Arnoult S.,Brancourt - Hulmel M.2015. A Review on Miscanthus biomass production and composition for bioenergy use: genitipic and environmental variability and implications for breeding. *Bioenerg. Res*., vol. 8, p. 502-526.

Brosse N.,Dufour A., Meng G X., Sun Q.,Ragauskas A. 2012. Miscanthus: a fast-growing crop for biofuels and chemicals production. Review. *Biofuels*, p. 1–19.

Butkutė B., Lemežienė N., Cesevičienė J., Liatukas Z., Dabkevičienė G. 2013. Carbohydrate and lignin partitioning in switchgrass (Panicum virgatum L.) biomass as a bioenergy feedstock. Zemdirbyste-Agriculture, vol. 100, No. 3, p. 251–260

Bouriaud L., Duduman M.L., Danila I.C., Olenici N., Biris I.A., Ciornei I., Barnoaiea I., Maciuca A., Savin A., Grosu L., Mutu M., Nichiforel L., Bouriaud O., Danila G., Avacaritei D., Roibu C. 2015. How to evaluate the sustainability of short-term cultures for biomass production? An application from ne Romania. Agriculture & Forestry, 61(4):7-22. doi: 10.17707/AgricultForest.61.4.01

Burli P. Forgoston E., Lal P., Billings L., Wolde B. 2017. Adoption of switchgrass cultivation for biofuel under uncertainty: A discrete-time modeling approach. Biomass and Bioenergy. Vol.105. P.107–115. http://dx.doi.org/ 10.1016/j.biombioe.2017.06.012

Cassie M.W., Balasubramanian V.K., Petti C., Rai K.M., DeBolt S., Mendu V. 2015. Engineering Plant Biomass Lignin Content and Composition for Biofuels and Bioproducts. Energies. 8, 7654-7676; doi:10.3390/en8087654

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. *Industrial crops and products*, 28, 320–327.

Dohleman F.G., Heaton E.A., Leakey A.D.B., Long S.P. 2009. Does greater leaf-level photosynthesis explain the larger solar energy conversion efficiency of Miscanthus relative to switchgrass? *Plant, Cell and Environment*, vol. 32, p. 1525-1537.

Geletukha G., Zheliezna T., Tryboi O. (2014). Prospects for the growing and use of energy crops in Ukraine. *UABio Position Paper* , 10. – 30p.

Geletukha G., Zheliezna T., Tryboi O., Bashtovyi A. 2016.Analysis of criteria for the sustainable development of bioenergy. *UABio Position Paper*, 17. – 30p.

Han, M., Choi, GW., Kim, Y., Koo, B. 2011 Bioethanol production by Miscanthus as a lignocellulosic biomass: focus on high efficiency conversion to glucose and ethanol. BioResources, vol. 6(2), p. 1939-1953

Heaton E.A., Dohleman F.G., Miguez A.F., Juvik J.A., Lozovaya V., Widholm J., Zabotina 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, 76–137.

Hodgson, EM., Fahmi, R., Barraclough, T., Shield, I., Allison, G., Bridgwater, AV., Donnison, IS. 2010. Miscanthus as feedstock for fast-pyrolysis: does agronomic treatment affect guality? *Bioresour Technol*., vol. 101, p. 6185-9191.

Karp, A., Sheid, I. 2008. Bioenergy from plants and the sustainable yield challenge. *New Phytologist*., vol. 179, Issue 1, p. 15-32.

Lewandowski I., Schmidt U. 2006. Nitrogen, energy and land use efficiencies of miscanthus. reed canary grass and triticale as determined by the boundary line approach. Agriculture, Ecosystems & Environment, vol. 112, p. 335-346

Milovanovic J., Drazic G., Ikanovic J., Jurbekova Z., Rajkovic S. (2012). Sustainable production of biomass through Miscanthus giganteus plantation development. *Annals Faculty Engineering Hunedoara – International Journal of Engineering*, X(1), 79–82.

Mitchell R., Vogel K.P., R. Uden D.R. 2012 The feasibility of switchgrass for biofuel production.Nebraska Cooperative Fish & Wildlife Research Unit -- Staff Publications. 169. Biofuels 3(1): 47–59

Parrish D.J., Casler M.D., Monti A. 2012. The evolution of switchgrass as an energy crops: In book edited Andrea Monti A.:Switchgrass: A Valuable Biomass Crop for Energy. p.1-28

Powlson D.S., Riche A.B., Shield I. (2005). Biofuels and other approaches for decreasing fossil fuel emissions from agriculture. *Annals of Applied Biology*, 146, 193–201.

Pyter RJ, Dohleman FG, Voigt TB. (2010). Effects of rhizome size, depth of planting and cold storage on Miscanthus x giganteus establishment in the midwestern USA. Biomass Bioenergy 34(10), 1466–1470.