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Energy productivity of miscanthus giganteus depending on growing technology elements

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Abstract

Increasing industrial production and global processes in the modern world lead to a significant rising in energy consumption which, as a consequence, causes the environmental damage. The development of unconventional and renewable energy sources should be seen as an important factor in improving energy security and reducing the anthropogenic impact of energy on the environment. In Ukraine, the large-scale use of renewable energy potential is not only of domestic but also of great international importance.It is a significant factor in counteracting global climate change, improving the overall state of Europe's energy security (Heletukha H. H. and Zhelieznaia T. A., 2006). Therefore, scientists around the world are looking for the alternative sources of energy that could provide partial or complete energy independence. The soil and climatic conditions in Ukraine are favorable for the cultivation of crops with a high level of biomass energy accumulation during vegetation. Some unconventional crops capable of accumulating large biomass have significant prospects for bioenergy in Ukraine, in particular due to the fact that photosynthesis occurs over a long period - from early spring to late autumn. The results of studies of miscanthus productivity, biofuel yield and energy depending on the timing of planting rhizomes are highlighted in the article. The maximum yield of dry biomass of miscanthus plants is observed during planting rhizome in the second decade of April and is 15.3 t/ha, which contributes to the increase of yield of solid biofuels (up to 16.8 t/ha) and energy per unit area (up to 285.6 GJ / Ha).

Keywords: miscanthus, yields of biomass, solid biofuels yield, energy yield

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INTRODUCTION

Most of the countries in the world have great achievements in the development and use of biotechnology. Alternative energy sources have been successfully used in other countries (Shevchenko 2015).

European countries (Austria, Denmark, Holland, Norway, Finland and Sweden) use 40-65% of green bioenergy. In Ukraine, green bioenergy is about 3% (Drukovanyi et al. 2011, Poiasniuvalna zapyska do Zakonu Ukrainy … 2006, Taran et al. 2011, Ekonomycheskye aspekty vyrashchyvanyia yvy, miscanthus y trytykale v эnerhetycheskykh tseliakh (Polsha) (2009).

A significant alternative to traditional fuels in Ukraine is biofuel (Koval and Kytaichuk 2013). As a result of combustion, a conventional fuel increases the carbon dioxide content of the atmosphere. Bioenergy crops are more environmentally friendly source of energy. For our country's most promising bioenergetic crops are sugar beet, sugar sorghum, switch grass, miscanthus, which will provide the fuel per hectare, which is an equivalent to 0.72 to 4.1 t/ha of oil (Ivashchenko 2011, Mozharivska 2013).

Miscanthus is one of the most high-energy crops grown as raw materials for the production of solid biofuelsin Ukraine (Doronin et al. 2017).

Miscanthus is perennial bushy herb plant which is propagated by rhizomes, belongs to the family of cereals, the mechanism of photosynthesis C_4 (**Fig. 1**). The height of plantshoots ranges from 1.5 to 5.0 m..The plants are monoecious, of a short day of vegetation, so they bloom from late August to early October. Miscanthus plants are light-requiring and grow mainly on swampy or partially flooded soils, worse in drought conditions, not tolerate drying out (Kvak 2014).

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Fig. 1. Miscanthus (Miscanthus) in the experiments

Many scientists has done researches on cultivation the miscanthus as a raw material for biofuel production (Cerazy-Waliszewska et al. 2019, Krol et al. 2019, Maleski et al. 2019, Morandi et al. 2019, Okeke et al. 2020, Xie et al. 2019). Miscanthus is a high-yielding plant that produces significant biomass every year without transplanting. It has high adaptability to soil and climatic conditions and is characterized by low cost of biomass. Recently, miscanthus has been grown as a valuable raw material for energy purposes (Parajuli et al. 2015).

The purpose of the research is to increase the productivity of miscanthus, depending on the timing of planting rhizomes, as raw material for biofuel production in the conditions of the Right-bank Forest Steppe of Ukraine.

MATERIALS AND METHODS OF RESEARCH

The researches were carried out in 2017-2019 in the conditions of the Bila Tserkva NAU Scientific Center (zone of unstable humidity). The experiment was based on the method of systematic repetitions: in each repetition, the variants of the experiment were placed on the spots consequently. The repetition of the experiment is four times. Phosphorus-potassium fertilizers (background) were introduced during the autumn plowing, nitrogen fertilizers were introduced in the spring. Planting of rhizomes weighing 30-60 g was carried out to a depth of 6-10 cm with a row spacing of 70 cm. The area of the spot is 50 m^2, the accounting area - 25 m^2. The experiment examined different periods of planting rhizomes (I decade of April; II decade of April; III decade of April; I decade of May). Field studies were conducted using conventional and special agronomic methods (Esmaeili et al 2014).

RESULTS OF THE STUDIES AND DISCUSSION

One of the important factors of the research is the optimal period of planting, miscanthus rhizomes. Miscanthus is a heat- and moisture-loving plant and is very responsive to changing planting periods (Kvak 2014). Most scientists believe that the optimal planting time for miscanthus rhizome is when the soil temperature at depth of 5 cm reaches 10 ... 12ºC and the air is 15ºC (III decade of April). Earlier planting is risky due to the possibility of spring frosts, and later is risky because of droughts (Frühwirth et al. 2005).

However, there is some literature suggesting that the recommended optimal planting period is earlier, as rhizomes absorb spring moisture from the soil, providing better plant growth and development. This is an important factor because rapid growth and development leads to a greater accumulation of nutrients in the rhizomes and also allows crops to better tolerate drought and frost (Caslin et al. 2010).

Our results showed that different periods of planting miscanthus rhizomes had a significant impact on their growth and development. At different planting periods, there was a variation of the phenological phases duration of plant growth and development, plant height, field germination, tillering, leaf area, productivity, biofuel yield and energy.

The duration of the phenological phases of plant growth and development and the duration of the growing season varied depending on the period of the rhizome planting (**Table 1**).

The longest growing season (201 days) is observed for planting rhizomes in the first decade of April.During this time the duration of interphase periods is 1-4 days longer than for plantingrhizomes in the second decade of April and 1-11 days longer than for planting in the first decade of May.

For the planting rhizomes in the II and III decade of April, the growing season was 189 and 182 days, respectively. The shortest growing season was observed for planting miscanthus rhizomes in the first decade of May and was 179 days.

The intensity of rhizome germination and the density of miscanthus seedlings are determined by such indicators as soil temperature and humidity. With low temperatures and low soil moisture, the rhizome sprouting period increases, and long-lasting lack of heat and moisture result in the death of the plants. But

Table 1. The duration of the interphase periods of miscanthus plants during the growing season, depending on the period of the rhizome planting, days (average for 2017 – 2019)

Planting period	Duration of interphase periods							duration of the growing season
	planting – emergence of seedlings	emergence of seedlings –3 leaves	3 leaves – tillering	tillering – shooting	shooting – panicle	panicle - blooming	blooming – drying of aboveground mass	
I decade of April	38	4	30	10	29	62	28	201
II decade of April	34	4	28	9	27	60	27	189
III decade of April	29	4	28	9	27	58	27	182
I decade of May	27	4	28	9	27	58	26	179

Table 2. Growth and development of miscanthus plants, depending on the timing of rhizome planting, for the period of harvest,(average for 2017-2019)

Planting time	Rhizome field germination, %	Plant tillering, quantity of stems per plant	Plant height, см	Leaf area, thousand m^2 / ha	Net photosynthesis productivity, g / m^2 / day
I decade of April	76.0	9.1	137.2	4.10	5.78
II decade of April	80.5	12.0	153.4	5.26	6.59
III decade of April	77.3	10.3	146.2	4.81	5.98
I decade of May	65.2	7.2	127.6	3.08	4.19

recently there is a tendency to change weather conditions, in particular, the intensity of soil warming in spring (Scurlock 1999).

In the experiment, the highest field germination was obtained by planting a miscanthus rhizome in the second decade of April (80.5%), which is explained by the sufficient amount of moisture and heat at the depth of the planted rhizomes (**Table 2**). The field germination was somewhat less in case of rhizome planting in the first decade of April, which is explained by the lack of heat, and in the third decade of April, due to the lack of moisture in the soil. During the last term of rhizome planting, the lowest field germination was observed - 65.2%.

With the onset of the tillering phase (early July), the process of active shoot formation begins in miscanthus plants, which lasts until the paniclephase. During the years of research, in average the number of shoots in the bush varied with the change of planting terms, which is associated with the phenological phases in certain soil and climatic conditions. When rhizome planting in the second decade of April, the number of stems in the tuft was the largest - 12 stems on the plant, which is associated with sufficient soil moisture and heat. Changing these parameters according to the sowing time leads to a decrease in the tillering of miscanthus plants from 7.2 to 10.3 stems per plant.

During the period of plant growth and development, morphological features change. One of the most important of these features is the height of the plant. This indicator can be used to evaluate the response of plants to changes in their growing conditions, which depend on agrotechnical measures and weather factors. During the harvesting period, the plant height was maximum at planting in the second decade of April and was 153.4 cm. The lowest plant height is observed during the late sowing period (127.6 cm).

One of the important processes in plant life is the process of photosynthesis. The formation and growth of leaves, life expectancy and intensity of their work depend on both the properties of the plant itself and the conditions of cultivation. The leaf area was in the range from 3.08 to 5.26 thousand m^2 / ha, depending on the sowing time.

Table 3. Dry biomass yield, biofuel and energy outputs according to the rhizome planting periods (average for 2017-2019)

Period of planting	Dry biomass yield, t/ha	Biofuel output, t/ha	Energy output, GJ / ha
I decade of April	14.1	15.5	263.5
II decade of April	15.3	16.8	285.6
III decade of April	13.8	15.2	258.4
I decade of May	12.7	13.9	236.3
Least significant difference	1.2	-	-

The intensity of photosynthesis is determined by the net productivity or the number of grams of dry green weight of top formed on 1 m^2 of leaf area during a certain period of time. Net productivity does not include organic matter consumed by plants for respiration, but only that accumulated during the day. Analyzing the results of studies of the net photosynthesis productivity of miscanthus plants, it is noticeable that its intensity during the growing season initially increased and then decreased. The maximum was reached in September and varied depending on the studied factors. Thus, for the most optimal sowing period (II decade of April), this figure was 6.59 g m^2 / day. For sowing in I and II decade of April this indicator was lower by 1.16 and 0.45 g m^2 / day respectively.

The maximum yield of dry biomass of miscanthus plants is observed for plantingrhizome in the second decade of April and is 15.3 t / ha (**Table 3**). In early sowing, the yield was lower by 1.2 tonnes, and in later sowing periods (in the third decade of April and the first decade of May), the yield was lower by 1.5 and 2.6 t / ha, respectively, for the optimal sowing period.

It should be noted that increasing biomass productivity contributes to increasing of the output of solid biofuels and energy per unit area. For the first planting period (I decade of April), biofuel and energy outputs were 15.5 t / ha and 263.5 GJ / ha, for the optimal second rhizome planting period (II decade of April) it was the highest biofuel and energy outputs, being 16, 8 t / ha and 285.6 GJ / ha, respectively. For the following periods of rhizome planting, these figures decreased to 15.2 t / ha and 258.4 GJ / ha (third decade of April) and 13.9 t / ha and 236.3 GJ / ha for planting in the first decade of May, respectively.

The results of the variance analysis show that the most influential factor in the formation of biomass yield is the timing of planting of miscanthus rhizome – 42.2% (**Fig. 2**).

The impact of the year factor (soil and climatic conditions in the years of research) was slightly smaller and amounted to 35.6%. Factor interaction was 18.4%. Other factors that are not investigated account for 3.8%.

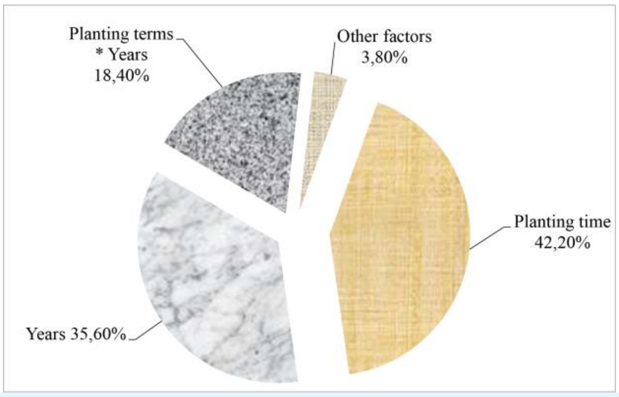

Fig. 2. The share of influence of the studied factors on the yield of biomass depending on the timing of planting miscanthus, % (average for 2017-2019)

CONCLUSION

Thus, it has been proved that the growth, development and productivity of plants depends on the timing of miscanthus rhizome planting. It has been determined that the duration of the growing season decreased with every successive planting period of the rhizome planting from 201 to 179 days. The highest rates of tillering, plant height and photosynthetic activity of the miscanthus leaf apparatus were obtained by planting rhizome in the second decade of April, which has a significant impact on miscanthus biomass productivity.

It has been established that the high productivity of biomass, the output of biofuel and energy from it, received per unit area of miscanthus plantations, is noted for the optimum term of planting rhizome - II decade of April.

In the future, exploring the elements of miscanthus cultivation technology as an energy crop and establishing of its economic and energy value is a promising area of research.

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