Plant Archives Vol. 18 No. 2, 2018 pp. 1920-1924 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

MISCANTHUS PRODUCTIVITY FORMATION FOR BIOFUEL PRODUCTION THAT DEPENDING OF DIFFERS ON DENSITY OF STANDING PLANTS

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Abstract

Energy plays a leading role in the economic development of Ukraine. We can observe a reduction in consumption of fossil energy resources (gas and oil), and the need of their rational use. Therefore, the creation of its own renewable energy source based on the cultivation and processing of plant bioenergetic raw materials is promising.

In many world countries the basis for bioenergy and the most suitable raw material for the production of solid biofuels are perennial grains.

Specially grown biomass that can be used for biofuel production has a number of characteristics that differ from traditional fossil fuels. The most important fuel and energy characteristic of raw materials is its calorific value, which depends on a number of factors: the genetic characteristics of the crop, the content of cellulose, pectin, polymer and phenolic resins; humidity; conditions of growing and storage of raw materials.

This article presents the results of studies on growth, development, productivity, release of biofuel and energy of miscanthus, depending on the varying density of rhizome planting. It is established that high productivity of dry mass, the greatest release of energy from solid biofuel, obtained from one hectare(ha) of miscanthus plantations, is provided at a density of 20 thousand rhizome / ha. of standing plants and is 16.7 T/ ha dry weight, 18.3 T/ ha solid biofuel and 307.7 GJ / ha of energy.

Key words : Miscanthus, productivity, biofuel, energy.

Introduction

The creation of our own source of raw materials bioenergy for the production of solid biofuels will contribute to strengthening Ukraine's energical security and reduce its dependence on the import of energy resources. In addition, the burning of fossil energy resources is associated with significant emissions of carbon dioxide, which adversely affects the environment. The greatest development in Ukraine has been the production of solid fuels (fuel pellets and briquettes). The raw material for the production of solid fuels is mainly the waste from the woodworking industry, straw from grains and leguminous crops, sunflower husks, etc. Today, special attention should be paid toward the growth of new types of highly productive trees and perennial crops, which will enable us to receive a given amount of biomass of the required quality annually (Hanzhenko *et al.*, 2017; Heaton and Long, 2007).

One of these highly productive perennial crops is the giant miscanthus (Miscanthus Giganteus). Due to the high release of dry biomass, high calorific value, low natural moisture of the stems during harvesting, the miscanthus giant is an effective agricultural crop for biofuel production (Mc Kervey *et al.*, 2008; Frühwirth *et al.*, 2005).

During the burning of the miscanthus giant biomass the amount of carbon dioxide released is less than it was absorbed by the plants during the photosynthesis process.

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Thus, the use of biofuel miscanthus giant will not contribute to the greenhouse effect. In addition, its cultivation positively influences the organic component of the soil, since after 4 years of cultivation 15-20 T / ha of rhizomes accumulate in the soil, which is equivalent to 7.2-9.2 T/ ha of carbon (Zinchenko, 2008).

Therefore, it is urgent to develop the elements of growing technology for giant miscanthus, which will ensure the maximum build-up of the aboveground mass as a result of plants' photosynthetic activity.

Miscanthus is a tall, perennial herbaceous plant with a well-developed root system used for energy production. The genus Miscanthus (Miscanthus Anderss), belongs to the family of grains (Gramineae). Plants miscanthus giant (Miscanthus Giganteus) can reach up to 4,0-5,0 m height. Dark green leaves 40-100 cm long and 2.5 cm wide have a pronounced white middle line. Miscanthus blooms from September to October, depending on the weather conditions. If compared with other C4 cultures, the type of photosynthesis that allows it to carry out photosynthesis at an air temperature of 5°C or more, and use a 2% conversion rate of solar energy, contributes to a better biomass build-up (Kvak, 2014, Mitchell, 2014).

The study on use and development of alternative energy sources from the giant miscanthus biomass is highlighted in the works of many scientists: V. Zinchenka, L. Losya, V. Kvaka, G. Geletukhi, V. Bunetsky, G. Kaletnik and others (Bunetskyi, 2011; Dolynskyi, 2006; Zinchenko, 2008; Zinchenko and Kusailo, 2006; Kaletnyk, 2008; Kvak, 2014; Los *et al.*, 2011, Albaugh *et al*., 2014).

It should be noted that the biological features of miscanthus are successfully combined with a number of valuable economic characteristics - high adaptability, effective use of territory's potential, high productivity and low biomass prime cost. The aboveground mass of this crop is a valuable raw material for the production of high-energy solid biofuel in the form of pellets and briquettes (Kvak, 2014; Parajuli *et al.*, 2015).

The Goal of this research is to increase miscanthus energy productivity by optimizing the density of rhizome planting in the forest-steppe of Ukraine.

Materials and Methods

This research was conducted in 2015-2017 years in a zone of unstable hydration on the research field of Bila Tserkva National Agrarian University. The experience was conducted by the method of systematic replication: in each replication, the variants of the experiment were placed on sections sequentially. The replication of the experiment is fourfold. Phosphate-potassium fertilizers were applied for autumn plowing (background), nitrogen fertilizers were used in the spring. Planting of rhizomes weighing 50-60 g was carried out to a depth of 6-10 cm with a row spacing of 70 cm. The plot area is 50 sq.m, accounting - 25 sq.m. In the experiment, various plant density of plants were studied (10 thousand rhizome / ha, 15 thousand rhizome / ha, 20 thousand rhizome / ha). Field research is conducted according to generally accepted scientific and special agronomic methods.

Results and Discussion

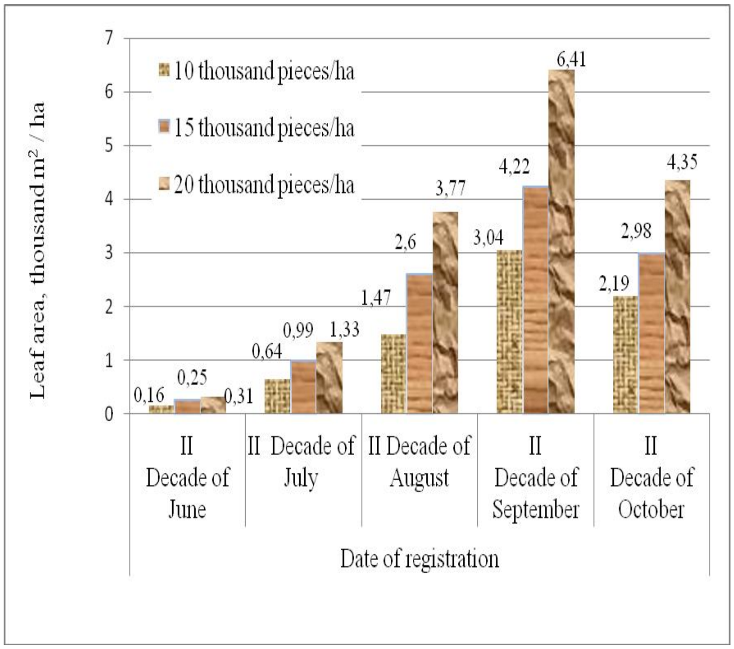
One of the important factors affecting the growth and development of miscanthus plants, is the density of planting rhizomes. The number of plants per unit of area is one of the effective factors that regulate the use of nutrients, moisture, light and the intensity of assimilation process, the formation of the biomass crop. The density of standing plant is an important element in the technology of growing crops. With the optimal placement of plants in terms of area, you can achieve maximum amount of crops while maintaining high quality indicators (Kuperman, 1982).

In the article written by Wiesław Szulczewski, a knowledge about the structure of the plant's density within the plantation makes it possible to estimate the current amount of miscanthus biomass in its area (Szulczewski *et al.*, 2018).

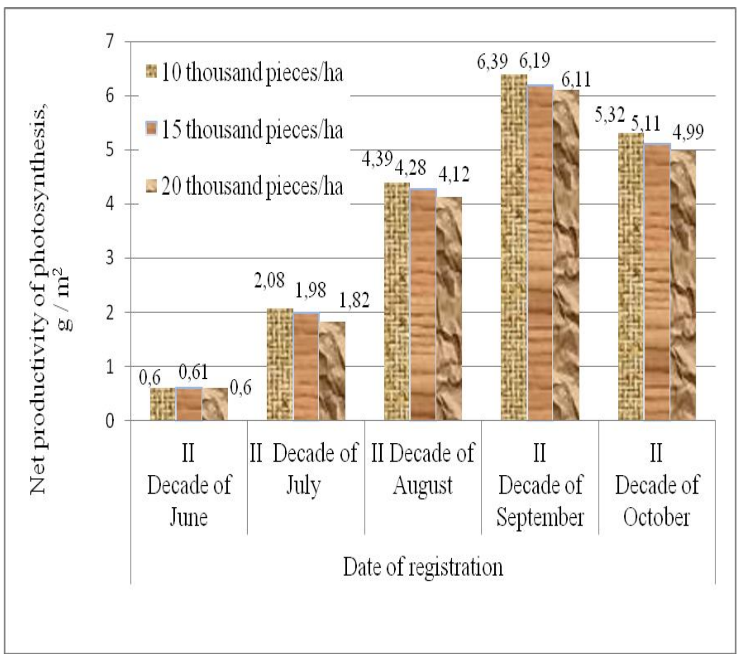
The research results have shown, the density of standing miscanthus plants had a significant impact on their growth and development. With a different density of plant standing, their height, tillering, leaf area, productivity, biofuel release and energy changed.

Young shoots of miscanthus plants are formed from renewal buds, which are placed on the rhizome. In spring, the buds blossom, the shoot escapes from the kidney, lengthens, and the leaves bloom. Extension of the shoot is achieved due to the growth of internodes. The growth of internodes is realized both as a result of the transition of cells into the fission phase, and as a result of the newly formed cells, usually at the base of internodes (Kvak, 2014).

The brooming of miscanthus plants is determined not only by the conditions of soil moisture and fertility, but also by the supply of solar energy to the plant and the conditions of agricultural technology. When planting the rhizomes of the miscanthus with a density of 10, 15, 20, thousand rhizome / ha, the maximum bushiness (11.5 number of stems per plant) was observed at a plant density of 10 thousand rhizome / ha, and the lowest bushiness (9.4 number of stems per plant) at 20 thousand



Pic. 1 : Dynamics of the increase in the leaf area depending on the density of plants standing of the miscanthus, thousand m^2 / ha (average for 2015-2017).



Pic. 2 : Dynamics of net productivity of photosynthesis, depending on the density of planting of miscanthus, g/m^2 (average for 2015-2017).

rhizome / ha. This can be explained by the fact that with an increase in the density of a plant standing from 10 to 20 thousand rhizome / ha the area of plant nutrition decreases, as a result of which plants compete with each other, which adversely affects tillering (table 1). The height of the plants also depends on the density of plant standing and when planting rhizomes with a density of 20 thousand rhizome per hectare for the harvesting period was maximum and was 180 cm. The lowest height of plants is observed with minimal density. However, the dry weight of one plant is the reverse: at the lowest plant density, the mass of one plant was the largest and amounted to 1.22 kg, and at the maximum density of the smallest - 0.84 kg.

It should be noted that, with varying density of standing miscanthus, unequal conditions of nutrition and plant illumination are created in the plantations, which affects the intensity of photosynthetic processes. An increase in the density of standing of plants from 10 to 20 thousand rhizome / ha leads to an increase in the area of the leaf surface from 2.19 to 4.35 thousand m2 / ha. However, with a decrease in plant density, the net productivity of photosynthesis increased, which is associated with an increase in the leaf apparatus due to an increase in the number of shoots in plants.

The specificity of increasing area of a leaf surface during vegetation is also due to the density of rhizome planting (fig. 1). It can be seen from fig. 1 that at the beginning of vegetation the growth of the area of the leaf surface was insignificant - 0.16-0.31 thousand sq.m / ha. In the process of growth and development, it increased and reached a maximum in the second decade of September - 3.04-6.41 thousand sq.m / ha. Somewhat less was the area of a leaf surface during the harvesting period.

Analyzing the net productivity of photosynthesis of miscanthus plants, we observe that its intensity during the growing season first increased and at the end decreased (fig. 2).

In June, the net productivity of photosynthesis was small and for the density of plants standing 10 thousand rhizome/ha was 0.64 g / sq.m per day, for 15 thousand rhizome / ha - 0.61 g / sq.m per day, for 20 thousand .00 / ha - 0.60 g / sq.m per day. In September, these figures were at the maximum and were accordingly: 6.39; 6.19 and 6.11 g / sq.m per day. In October, the net productivity of photosynthesis was less by an average of 1.07-1.12 g / sq.m per day.

The release of miscanthus dry mass is determined by the optimal ratio of individual plant productivity and their quantity per unit area. With increasing density of standing, the mass of one plant decreased (table 1), however, considering the increase in the number of plants per unit area, the release of dry matter was greater.

Table 1 : Biometric indicators of miscanthus depending on the density of plants standing, for the harvesting period (average for 2015-2017).

Density of plants standing, thousand rhizome / ha	Tillering of plants, number of stems per plant	Height of plants, cm	Dry mass of one plant, kg	Leaf area, thousand m^2 / ha	Net productivity of photosynthesis, g / m^2
10	11,5	165	1,22	2,19	5,32
15	10,6	173	1,07	2,98	5,11
20	9,4	180	0,84	4,35	4,99
SSD	0,6	4,3	0,3	0,7	0,2

Table 2 : The yield of dry mass, the yield of biofuel and the energy output, depending on the density of planting of miscanthus, (average for 2015-2017).

Density of plants standing, thousand rhizome / ha	Yield of dry mass, t / ha	Output of biofuel, t / ha	Output of energy, GJ / ha
10	12,2	13,5	228,3
15	16,0	17,6	294,0
20	16,7	18,3	307,7
SSD	0,6	-	-

The maximum yield of miscanthus dry mass of was observed at a density of plants of 20 thousand rhizome / ha and amounted to 16.7 t/ ha. With a decrease in plant density of plants up to 10-15 thousand rhizome / ha, the yield of dry matter decreased and amounted to 12.2 - 16.0 T / ha (table 2).

It is possible to receive 18,3 t / ha of solid biofuel at a plant density of plants of 20 thousand rhizome / hectare. Reducing the density of standing plants of miscanthus to 10-15 thousand rhizome / ha leads to a decrease in the amount of solid biofuel, which can be obtained from a unit area.

The energy released is calculated based on the amount of solid biofuel obtained from 1 hectare of miscanthus plantations. The greatest energy released during the growth of the miscanthus was 307.7 GJ / ha with a plant stand of 20,000 pcs / ha. A slightly lower release of energy was obtained with a plant density of plants of 15 thousand rhizome / ha — 294.0 GJ/ha.

According to Ana Elisabeta Daraban (Daraban *et al.*, 2015), it is known that miscanthus biomass has a very high quality in combustion (same as coal or wood, up to 19.6 MJ/kg of dry matter) and has a positive ecological impact on marginal lands, which makes this plant suitable as bioenergy resources for small heating systems.

Conclusion

Thus, it has been established that the growth and development of miscanthus plants largely depends on the density of plant standing. The highest rates of tillering, dry weight of a single plant and net productivity of photosynthesis of plants were obtained with a density of plantations of rhizomes of 10 thousand rhizome/ha. The height of plants and the area of the leaf surface reached a maximum at a density of rhizomes plantations at 20 thousand rhizome/ha, which significantly affects the productivity of the above-ground miscanthus mass.

It is proved that high productivity of dry mass, the greatest release of energy from solid biofuel obtained from one hectare of miscanthus plantations is provided at a density of standing plants at 20 thousand rhizome / ha.

Further research on the economic feasibility and payback of density of planting miscanthus, as well as the study of new technology elements in the cultivation of miscanthus, is a promising area of research.

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