BIOMASS PRODUCTIVITY OF MISCANTHUS DEPENDING ON THE QUALITY OF PLANTING MATERIAL AND GROWING CONDITIONS IN THE WESTERN FOREST-STEPPE REGION OF UKRAINE

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Summary. The paper presents the research results of the productivity of miscanthus biomass over a three year period, evaluating the dependency between the quality of the rhizomes and growing conditions in western forest-steppe region of Ukraine. The optimal planting density and mass of rhizomes were studied and classified. Factors affecting the yield of dry matter miscanthus were also analyzed.

Key words: miscanthus, biofuel, rhizomes mass, planting density, biomass productivity.

INTRODUCTION

The current condition and development of new markets of solid biofuels in Ukraine is in its infancy. Among the many unsettled problems in this area are improved legislation and the lack of standards for biofuel raw materials. Biomass producers also face the problem of shortage of available raw materials throughout the year. In order to provide a stable capacity of biofuel, factories need a predictable amount of organic raw materials and related logistics[1,2].

PRESENTATION OF THE PROBLEM

This problem can be solved by creating their own high-energy plantation of crops with high yields of biomass with a high content of cellulose and lignin [3]. Miscanthus is among a number of highly promising perennial grass crops for the production of solid biofuels in the form of pellets [4,5,6]. Biological features of this culture successfully combine with a range of valuable economic characteristics such as: high adaptive ability, efficient use of area, high output and low cost. An important feature of miscanthus as perennial crop is the ability to enrich the soil with organic matter. The use of this culture is an innovative way to reduce soil erosion and thus contributing to the improvement of ecological situation, which is important for the western-steppe region of Ukraine.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Miscanthus can be grown on different soils. It is not demanding of moisture and nutrients in the soil; have high resistance to diseases and pests and provides a positive impact on the environment. It is a versatile because this low cost and low risk crop requires minor investments; give high yields of biomass not only on fertile soil but so on low-productive lands. Yields of dry biomass miscanthus increase gradually with 5-6 t/ha the first years to 10-15 t/ha the second year and up to 20-25 t/ha – the third year of cultivation [20,21].

The structure of miscanthus biomass has the typical ingredients for a biofuel raw material with about 50 % cellulose and 30% lignin. Dry biomass has a low ash content – up to 2.4%, compared with straw, and is low in potassium and sodium combined with a high content of calcium and magnesium, which contribute to high combustion temperature and reduce the likelihood slag formation in solid fuel boilers. The cost of miscanthus biomass, in different countries ranges from 20 to 40 euros per ton of dry matter [7,8,16,17,18,19].

With the increased industrial cultivation of miscanthus in Ukraine there is a need to study and implement an efficient manufacturing operations guide in order to optimize the care of the culture and conduct research – based on parameters and methods of cultivation.

The rhizomes mass is the one of the most important quality indexes that influences miscanthus biomass productivity. According to scientific research the optimal rhizomes mass must be between 40-100 g [4]. But other available research seems to suggest that this is not necessarily the case. For example, scientists at the University of Illinois concluded in 2005-2006 that the productivity of dry mass doesn’t depend on planting rhizomes weight being in the range from 20 to 100 g [10].

THE RESEARCH TASK

Thus, the question about the rhizomes mass and the planting norms is actually about the high cost of the planting material.

The aim of the experimental research was to determine the biomass productivity and their standing density under the conditions of western forest-steppes of Ukraine.

THE MATERIALS AND RESEARCH METHODOLOGY

The research was conducted from 2009 to 2011 on the research fields of Intubus Ltd. in Borshchiv, Ternopil region.

The field research was conducted according to the common scientific and special agronomical methodology with the help of electronic computing in the process of working and analyzing the results of the researches [11,12,13].

Research Scheme:

Factor A – the standing density, the plant / ha 25 tsnd (70x55), 20 tsnd (70x70), 15 tsnd (70x105), 10 tsnd (70x140).

Factor B – the rhizomes mass (g): 20 – 30; 30 – 60; 60 – 90; 90 – 120 [14].

The sowing area was 190 m^2, registered area – 98 m^2, repeated four times. The experiments were held according to the method of splited areas, repeat in four tiers.

The soil is light gray with ash, the content of mobile phosphorus (according to the Kirsanov's method) in the layer of soil 0-30 cm is 9.5 mg on 100 g of soil, the content of an exchange potassium (according to the Kirsanov's method) – 6 mg on 100 g of soil, the content of nitrogen (according to Cornfild's method) – 28 mg on 100 g of soil, the acidity of soil (pH) – 6.0 [23].

Borshchiv region is in the temperate area so the climate is mildly continental with insignificant amplitude of fluctuations in temperature, characterized with mild winters, warm and moist summer and a sufficient amount of precipitations [15, 22].

Throughout the full research period the average daily air temperature was 2 – 4°C higher than normal average for the region.

The precipitation during the vegetation period was unevenly distributed. From 2009 till 2011 a few of precipitation measurements fell out – from 250 to 111 mm less than average long-time which caused drought conditions. Especially there was a lack of precipitation in March – April every year. 2010 was wetter than average. The, precipitations in May 2010 was high with 219,3 mm and July with 163,3 mm. This had a positive influence on the growing and development of the miscanthus because the plant thrives on moisture. Over all during the experiment period the weather conditions were favorable for miscanthus planting.

Each year during the cultivation period the phonological, biometrical account and supervisions were conducted.

THE RESULTS OF RESEARCH

Our research results show, (See Chart 1), that different standing density of the plants at the first part of the first year of vegetation has little influence on index of linear increase of stem and the height of the plant in general.

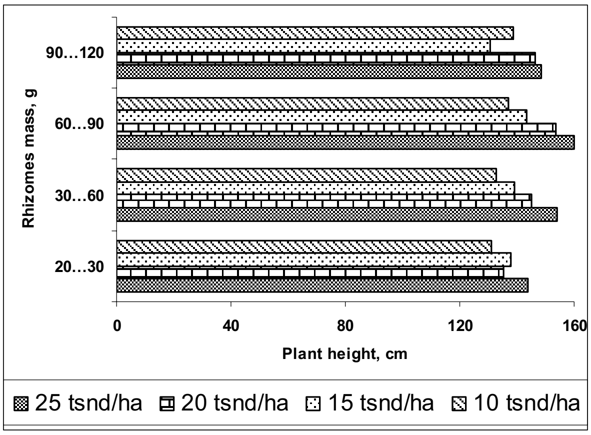

Fig. 1. Dynamic height of the main miscanthus stem

During the second part of growing season, after the considerable formation of vegetative mass there is competition between the plants, as a result of which their height increase proportionally to the planting density. Therefore by the end of the growing season the biggest height of the main stem was 152 cm according to the standing density 25 tsnd/ha, and the smallest height of the main stem was 135 cm according to the standing density 10 tsnd/ha.

Besides, it should be noted, that the rhizomes mass is not the less important growth factor for plant development, because they hold essential nutrients and buds that form shoots in the future. But the height of the main stem doesn't depend on the rhizomes mass and varies from 137 cm to

148 cm. The biggest height of the stem occurs when the rhizomes mass is between 60 – 90 g and 148 cm, and the smallest is then when the rhizomes mass is between 20 – 30 g, 137 cm.

The plant growth and development accompanied by growth puff apparatus, which is the means of accumulating of solids. During all three growing season the number of leaves on the main stems were almost the same (within LCD_{05}) on all test areas with the slight fluctuations within 13,7-14,7 units. Thus, their number doesn't depend on the standing density and rhizomes mass and defined by phases of ontogenesis.

The number of shoots increases in July-August, when the miscanthus is in the tillering phase and stops in ejection phase of panicle. It is known that the number of shoots and productivity of miscanthus increase at the same time. It should be noted that the number of shoots depends on the rhizomes mass.

For example, the mass of rhizomes from 20 – 30 g (Chart 2), the highest number of shoots per bush is 9,6 units, and the mass of rhizomes 90 ... 120 g – 11,3 things.

With increasing standing density, the number of shoots decreases. When the density is 25 tsnd/ha we get on average 8,9 shoots. When the density is 10 tsnd/ha we get on average 11,4 shoots.

At first the biomass harvest increases because the standing density decrease and reaches the maximum value, but it declines further. This is because the same harvest of biomass can be gotten with the help of two different densities.

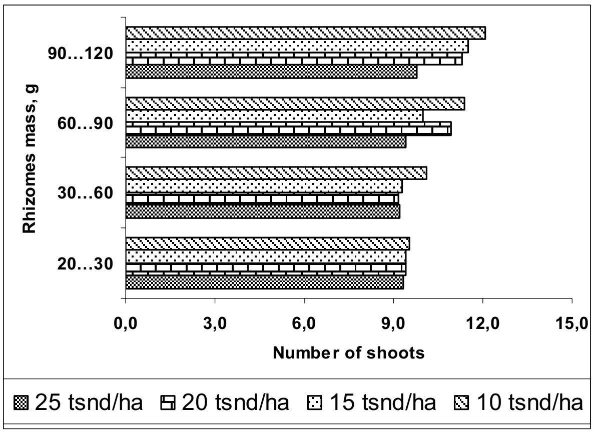

Fig. 2. Dynamic of the shoots number per bush

According to the results the yield of dry biomass of the plant increase when the standing density decreases. So, when the standing density is 25 tsnd/ha then the average mass of one miscanthus is 120,9 g, when the standing density is 15 and 10 tsnd/ha the average mass of one miscanthus is 169,6 g and 180,2 g according to Table 1. This relates to the increasing area of nutrition and lighting conditions and reduction in competitions between plants.

The yield of dry miscanthus mass increase because of the increase of standing density per one unit of area.

For example, (Table 2) when the standing density was 10 tsnd/ha, the yield of dry mass per 1 ha was 1,8 ton/ha, and according to the 25 tsnd/ha density – 3,1 ton/ha during the first year of vegetation

Table 1. **The mass of one dry plant of miscanthus of the first year of vegetation according to the rhizomes mass and their planting density (average within 2009-2011)**

Planting density, tsnd/ha	Rhizomes mass, g			
	20…30	30…60	60…90	90…120
25	120,9	141,2	164,6	183,8
20	135,4	157,5	170,4	196,8
15	169,6	191,2	224,3	231,2
10	180,2	220,2	240,3	244,9
LCD_{05}				3,9

Table 2. **The yield capacity of the miscanthus dry mass according to the rhizomes mass and their planting density for years of vegetation, ton/ha**

Planting density, tsnd/ha	Rhizomes mass, g			
	20…30	30…60	60…90	90…120
The first year of vegetation				
25	2,2	2,8	3,5	4,0
20	2,0	2,5	2,8	3,3
15	1,9	2,4	2,8	3,1
10	1,3	1,7	2,1	2,2
LCD_{05}				0,1
The second year of vegetation				
25	14,0	17,5	20,8	24,9
20	12,9	17,0	17,0	20,6
15	12,7	16,5	16,7	18,2
10	9,6	12,2	13,4	14,1
LCD_{05}				1,0
The third year of vegetation				
25	21,9	27,9	33,0	34,6
20	21,7	27,4	27,5	31,8
15	20,5	26,1	26,2	29,5
10	16,4	19,3	21,3	25,5
LCD_{05}				2,0

According to the standing density of 10 tsnd/ha the yield of dry mass per ha was 12,3 and 20,6 ton/ha, when the standing density was 25 tsnd/ha – 19,3 and 29,4 ton/ha during the second and the third years. It should be noted, that with each successive year the difference between the options is reduced. The difference between the options during the first year was 41 to 45%, the difference during the second and the third year decreased to 31 – 43% and 25 – 26%.

Another very important factor that affects the yield of miscanthus is rhizomes mass, the increasing of which causes the mass increasing of the plants. For example, when the rhizomes mass was 20…30 g – the yield of dry mass was 1,9; 12,3 and 20,1 ton/ha, when the rhizomes mass was 90…120 g – 3,2; 19,5 and 30,4 ton/ha according to the first, second and third years of vegetation.

It happens because the plants produce more shoots during the germination and as a result the vegetative mass increases. After the change-over to the actual root power and photosynthesis those plants better absorb solar radiation, moisture and nutrients from the soil that causes the best productivity, but the plants with less mass of rhizomes become bushes with small stems. They do not have enough vegetative mass and spend energy to make the new shoots.

According to the results of analysis of the variances (Chart 3) it is clear that the greatest influence on miscanthus productivity during the first year of cultivation is the weight factor of rhizomes (15.7%). It is due to the increased uptake of nutrients and the number of potential buds that can sprout from the bigger rhizomes. The standing density of the plant has less of an influence (14.4%).

This is the result of stems height increasing on the dense planting scheme. Because of the weather conditions the year factor influenced only 64.3% on the yield of dry miscanthus weight. The effect of one factor is not dependent on other.

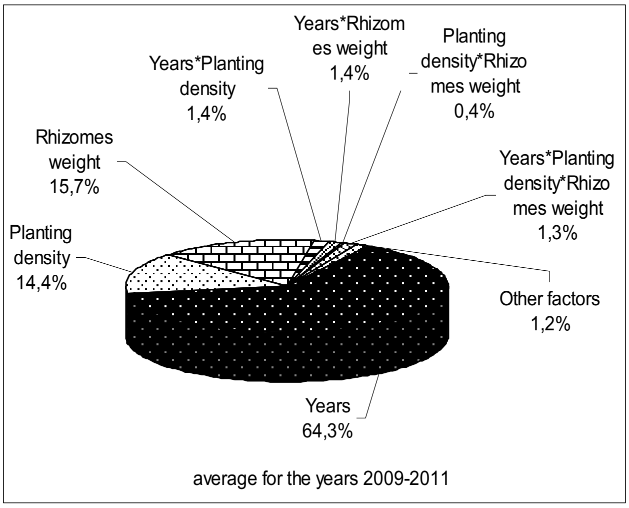

Fig. 3. Part of factors influence on yield of dry miscanthus weight

Because of the fact that miscanthus is long-term, the year-old plantations of this crop is unproductive. Because the plants form strong root systems that help them survive the first winter, the next year they form strong above-ground biomass. During the first year of cultivation the mass of rhizomes is more than green puff-stem mass by 1.8 times. Thus, when the rhizomes mass was set at 20 – 30 g, at the end of the cultivation period the rootstock mass was 471 g, compared to when the rhizomes mass was set at 90 – 120 g it was a much higher 664 g.

It should be noted that the mass of miscanthus rhizomes decreases with increasing total density of standing plants. The smallest values of areas with the maximum density in the experiment (25 tsnd/ha) was measured at 471 g. The measurement for the lowest density planting (10 tsnd/ha) reached a value of 637 g.

Thus, according to the researches was pointed that the optimal standing density of plants is 15 tsnd/ha and with the rhizomes mass 30…60 g.

CONCLUSIONS

1. During the first year of vegetation the plants form rootstock system, which makes them able to survive the first winter, the next years the strong aboveground biomass forms.
2. The increase of the yield of miscanthus depends on the standing density of the plants and rhizomes mass.

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