EXPERIMENTAL RESEARCH OF MISCANTHUS PLANTING TECHNOLOGICAL PROCESS BY MEANS OF UPGRADED POTATO PLANTER

/

ЕКСПЕРИМЕНТАЛЬНЕ ДОСЛІДЖЕННЯ ТЕХНОЛОГІЧНОГО ПРОЦЕСУ САДІННЯ МІСКАНТУСА ЗА ДОПОМОГОЮ КАРТОПЛЕСАДЖАЛКИ

Prof. PhD. Adamchuk V. [1)], Prof. PhD. Bulgakov V. [2)], PhD. IvanovsS. [3)], PhD. Prysyazhnyi V. [1)], PhD. Boris A. [2)]

[1)] National Scientific Center "Institute for Agricultural Engineering and Electrification" NAAS of Ukraine, 11 / Ukraine

[2)] National University of Life and Environmental Sciences of Ukraine / Ukraine

[3)] Latvia University of Life Sciences and Technologies / Latvia

Tel.+37129403708, e-mail: semjons@apollo.lv

Keywords: *Miscanthus, upgrading, planting, rhizomes, the planting apparatus.*

ABSTRACT

Miscanthus is a promising energy crop. There are no inexpensive and efficient planting machines in practice as yet for planting on small areas up to 10-20 hectares. In order to plant the Miscanthus rhizomes on such areas, it is appropriate to use potato planters equipped with special replaceable spoons. Research has been carried out to optimize the parameters of a planting machine spoons and the length of the planting material (rhizomes), as well as to test mechanised planting under economic conditions by means of a potato planter equipped with an upgraded planting apparatus.

АНОТАЦІЯ

Міскантус є перспективною енергетичною культурою. Поки що в практиці немає дешевих машин для його садіння на невеликих площах до 10…20 га. Для садіння ризом міскантуса на таких площах доцільно використовувати картоплесаджалки, які оснащені спеціальними змінними ложечками, які є в наявності в господарствах, що вирощують картоплю. Проведенні експериментальні дослідження по оптимізації параметрів ложечек садильного апарату для садіння та довжини садильного матеріалу (ризом), а також проведена перевірка механізованого садіння в господарчих умовах з використанням модернізованого садильного апарату.

INTRODUCTION

The production and use of the plant biomass for energy is an important branch of agriculture in the developed countries *(Arnoult et al., 2015; Richter et al., 2016).* One of the promising energy crops in the areas with limited moisture is Miscanthus *(Bellamy et al., 2007; Quinn et al., 2010; Kalinina et al., 2017).* In a number of Western European countries there takes *place active growing of this crop as an energy plant (for the production of fuel briquettes) (Heaton et al., 2008; Rakhmetov et al., 2015).* Miscanthus is a drought-resistant herbaceous plant that grows up to 4 m tall and produces a large amount of biomass (in Ukraine up to 6.76 t·ha^{-1}), the roots spreading deep into the soil up to 2.5 m *(Kharytonov et al., 2017; Xue et al., 2017).* Such a root system contributes to a very good consumption of the elements and water. The yield of Miscanthus can be harvested up to 30 years; it does not deplete the soil and can grow even in low-productive soils. For the Miscanthus propagation there is applied a method of dividing the rootstock into separate pieces with subsequent planting. Planting of the Miscanthus rhizomes is carried out at a depth of 8...10 cm with a density of 14...8 thousand rhizomes per ha, with an inter-row spacing of 0.7 m and a planting interval (in-the-row spacing) of 0.9 m *(Kurilo et al., 2002).* On the large Miscanthus growing areas, of 50…400 hectares and more, laying of plantations is carried out with the help of special machines. However, on smaller areas the use of these machines is entailed with a high cost, and therefore it is not economical.

Sometimes, when no special equipment is available, the crushed remnants of the Miscanthus rhizomes are scattered by machines for the application of organic fertilizers, followed by ploughing and rolling down with smooth rollers. This way of planting has many shortcomings due to the random scattering of the planting material, low yield and inconvenience of harvesting.

For mechanised planting of the Miscanthus rhizomes a semi-mechanised special machine may also be used, the planting apparatus of which is a vertically installed planting tube through which the planting material is manually fed and supplied to the coulters, covering it with a layer of soil *(Gumentic et al. 2016).*

The disadvantage of this method is low productivity, which is limited by the low speed of manual feeding of the planting material into the planting tube.

For planting of the Miscanthus rhizomes on small areas (up to 10…20 ha) it is economically appropriate to use a potato planter. This method combines the high productivity of a potato planter without manual feeding of the planting material, eliminating the need to purchase a special machine. In this case it is necessary to upgrade the planting apparatus of the potato planter by replacing the spoons for planting potatoes with the corresponding special spoons for planting the Miscanthus rhizomes. The rhizomes must be regular or close to this form and it is purposeful to divide them into pieces with the length of 40…60 mm.

The previously conducted research showed that, under the conditions in Ukraine, planting the Miscanthus rhizomes, 40…60 mm long, with an inter-row spacing of 0.7 m and with increased density of Miscanthus rhizomes in the row (the average planting interval (in-the-row spacing) 0.20…0.3 m), ensures a maximum yield of the stem mass and the output of a quality planting material *(Gumentic et al., 2015).* The purpose of the work is to investigate a possibility to perform the technological process of planting the Miscanthus rhizomes by means of a machine based on a potato planter, to substantiate rational parameters of a spoon of the planting apparatus and to determine the optimum length of the Miscanthus rhizomes corresponding to these spoons length.

MATERIALS AND METHODS

First of all, researches and optimisation of the parameters of the planting apparatus spoon were conducted under laboratory conditions and then an economic testing of its performance was done under field conditions. Processing of the experimental data was carried out by mathematical-statistical methods using standard methods by means of the Matlab program *(Adler, 1971).*

For the research and design upgrading of 4-row potato planter “Hassia”, the most common potato planter in Ukraine, was used with a 2-row arrangement of spoons on the carrier band (there were 4 bands on the planter).

The quality of the planting apparatus work is mainly determined by the size of the gaps (that is, those that have not reached the intended planting points) and the preset distribution uniformity of the rhizomes by length.

To determine the necessary parameters of the spoons, it is necessary to know the basic parameters of the rhizomes – the average thickness and their length.

The average thickness of the Miscanthus rhizomes was determined with a calliper at the place of their greatest thickening. The number of rhizomes was 50 pcs (Fig. 1).

Fig. 1 – Typical forms of Miscanthus rhizomes

The average planting interval (in-the-row spacing) – 24 cm was determined as the arithmetic average of 100 measurements of the distance between the centres of the rhizomes in a row (Fig. 8). The efficiency of planting the Miscanthus rhizomes in the field by an upgraded machine was determined according to a standard methodology *(Kurilo et al., 2002).* The length of the rhizomes is formed during the cutting process and is limited by the need to have no less than 4-5 potential buds on one rhizome. It has been established that to these requirements correspond rhizomes which are more than 40 mm long. The length of the rhizomes more than 100 mm is not practiced.

Accordingly, a planting material was prepared for the experiments from the Miscanthus rhizomes with the length from 40 mm to 100 mm with a 10 mm increment (Fig. 2).

Fig. 2 – The Miscanthus rhizomes and their parts, prepared for planting:
4, 5,...,10 – the length of the Miscanthus rhizomes and their parts – 40, 50,...,100 mm

The rhizomes were divided into parts manually by means of clippers and a ruler. They were selected rectilinear or close to this form. The deviation from the rectilinearity was up to 10%. According to the methodological recommendations *(Kucenko et al., 2002),* such rhizomes are more optimal than the curvilinear ones.

In order to conduct laboratory studies to determine the number of gaps, depending on the length of the rootstock (rhizoma, rhizome) and its parts, the potato planter was installed on a special support (stand). The spoons of the planting apparatus were also able to capture rhizomes, longer than 60 mm. In this case, the rhizomes were placed at an angle to the spoon (one part of the rootstock (rhizoma, rhizome) rested upon the bottom of the spoon, the other on the side wall).

The rhizomes of each typical size (Fig. 3) were alternately filled into the hopper of the potato planter; the planting apparatus was manually turned at the respective working speed by means of a drive wheel until 100 spoons had passed through the top point of the planting apparatus. In order to determine the number of gaps, the number of empty spoons (not occupied by the rhizomes) out of one hundred spoons was calculated. As a result, there was taken as the percentage ratio of the number of identified empty spoons to all the calculated ones. There was triple replication of experiments.

Fig. 3 – Field experiments of the Miscanthus plantations

Practical studies of the operating capacity of mechanised Miscanthus plantation by an upgraded planting apparatus were carried out at the experimental site of the institute in Vasilkovsky District, Kiev region. Before the research, an experimental plot was prepared: ploughing to a depth of 30...32 cm, cultivation to a depth of 14...16 cm. The plantation scheme was with a row spacing of 0.7 m and an increased density of the Miscanthus rhizomes and their parts in the row (with a preset planting interval (in-the-row spacing) of 0.24 m). The planting material was poured into the hopper of the planter and mechanised planting was performed.

The planting interval (in-the-row spacing) was determined by measuring with a tape the distances between the centres of the rhizomes in the row. Triple replication. The work was performed in accordance with the methodological recommendations for conducting research of potatoes *(Standart GOST* 28306-2018*).*

RESULTS

The measurements of the thickness of the planting material (the common Omega variety) showed that it is 14.1 mm with a root-mean-square deviation 1.1 mm. According to the agro-demands, 40…100 mm long rhizomes with a 10 mm planting interval (in-the-row spacing) were used.

On the other hand, the length of the spoon *d* on the band (with a double-row arrangement of the spoons on the band) is limited to 60 mm. In accordance with these initial requirements, a structural scheme of the spoon for planting the Miscanthus rhizomes has been developed (Fig. 4).

The potato planter was upgraded; special spoons of an appropriate size were made and installed – Fig. 5. The maximum width of the spoon in the modernized design may be 60 mm. Taking into account the fact that the average thickness of the Miscanthus rhizomes is 14 mm, the width of the spoon bottom is 15 mm (by 11 mm more than the average thickness of the rootstock (rhizoma, rhizome)), the height of the front wall is *b* = 15 mm, the width of the upper part of the spoon is 20 mm.

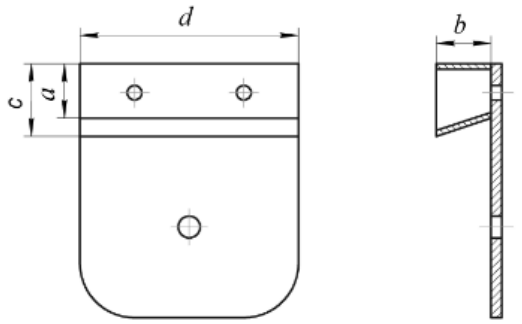

Fig. 4 – The structural scheme of a spoon for planting the Miscanthus rhizomes
a – the width of the spoon bottom; *b – the height of the front wall of the spoon; c – the width of the top of the spoon; d – the length of the spoon*

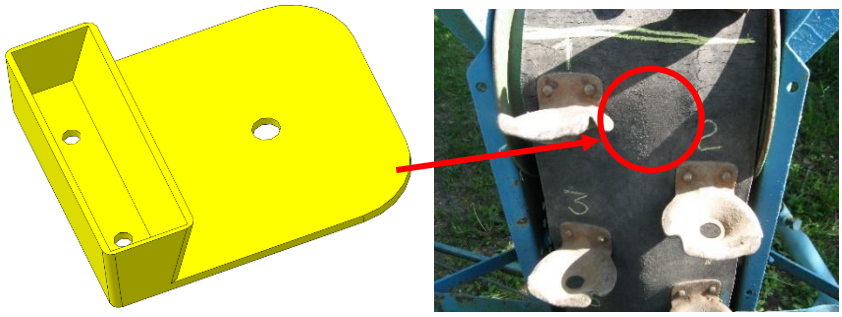

Fig. 5 – An upgraded planting apparatus of the potato planter

In order to determine the optimal length of the work pieces used for planting by means of the spoon with the selected parameters, laboratory experiments were conducted. Dependence (Fig. 6) of the number of the gaps between the Miscanthus rhizomes upon the length of the previously prepared planting material was obtained. It is obvious from the obtained dependence that for mechanised Miscanthus planting by a potato planter the optimum length of the rhizomes and their parts should be 40...60 mm. In this case the number of gaps is from 0.6 to 9%. When the length of the rhizomes is more than 70 mm, the number of gaps increases sharply and reaches 50% and more. According to the agro-requirements the number of gaps is 2%. As a result of field research (Fig. 7) on Miscanthus rhizomes mechanised planting, it was found that the existing number of gaps was generally compensated by twins (that is, it is ensured the required number of plants per fruit). The number of twins, when planting the Miscanthus, rhyzomes 40…60 mm in size, is up to 19% (according to the agrodemands, twins are allowed if the length of the Miscanthus rhyzome is less than 10 cm).

Compared to the gaps, the presence of twins (when the spoon picks up two rootstocks (rhyzomas, rhyzomes) and plants them side by side into the soil) is not a significant shortcoming and, according to the agrodemands, it is allowed if the length of the rhyzome is less than 10 cm. The negative effect of twins presence is mainly only the increased consumption of the planting material.

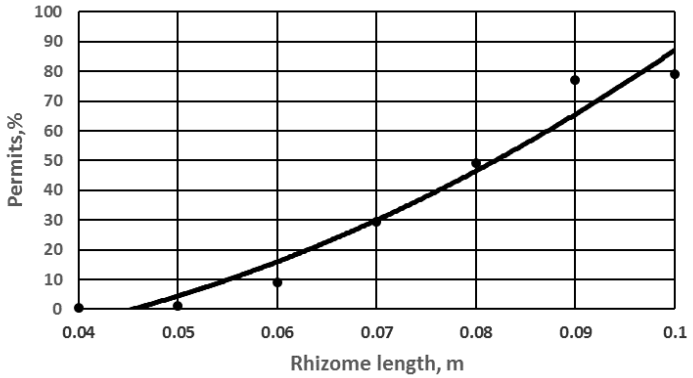

Fig. 6. – Dependence of the number of gaps upon the length of the rhizomes

The maximum distance between the rhizomes in one row is not more than 0.7 m (according to agro-requirements, the maximum distance between the rhizomes in one row is 0.5...0.7 m). The average planting depth was 50…80 mm. Germination of the rhizomes of the size 40…60 mm was 93%.

Fig. 7 – Plantations of Miscanthus rhizomes

According to the testing results of Miscanthus rhizomes mechanised planting by means of a modernized planting apparatus, an average planting interval (in-the-row spacing) was determined – 24 cm with a root-mean-square deviation 3.6 cm (Fig. 8), which was obtained as the arithmetic average of 100 measurements of the distance between the centres of the rhizomes in a row. As it is known *(Gumentic, 2016),* planting of Miscanthus rhizomes and of their parts with their increased density in the row ensures an increase in the yield of the stem mass and output of a high-quality planting material.

Fig. 8 – Determination of the planting interval (in-the-row spacing) of the Miscanthus rhizomes by means of an upgraded planting apparatus of the potato planter

The efficiency of the 4-row potato planter in the experiments was 1.5 ha·h^{-1}, refitting of the planting apparatus of a 4-row potato planter – 300…320 Euro. The cost of a new 4-row potato planter "Hassia" is about 6,000 Euros (it depends on the basic configuration). However, these planters are already on the farms, and the schedule of their use allows one to use them for planting Miscanthus. Therefore no capital investments for the purchase of a special machine are required, and the refitting cost is low. In this case, refitment payback is achieved already in the first year of operation when an area of 5…8 hectares was planted.

CONCLUSIONS

1. For planting the Miscanthus rhizomes on small areas (up to 10 ha) it is economically appropriate to use an upgraded potato planter.

2. The geometrical dimensions of the spoon of the planting apparatus of the Miscanthus rhizomes are substantiated: the width of the spoon bottom – 15 mm, the height of the front wall – 15 mm, the width of the top of the spoon – 20 mm, the length of the planting apparatus spoon – 60 mm.

3. The optimal length of the Miscanthus rhizomes for planting by the proposed spoons is 40…60 mm.

4. The efficiency of the 4-row planter in the experiments was 1.5 ha·h^{-1}.

REFERENCES

[1] Adler J., (1971), *Planning of an experiment when searching for optimal conditions*. Nauka, Moscow / Russia, 283 p.;

[2] Arnoult S., Brancourt-Hulmel M., (2015), A Review on Miscanthus biomass production and composition for bioenergy use: Genotypic and environmental variability and implications for breeding, *Bioenerg. Res.,* Vol. 8, pp. 502-526;

[3] Gumentic M., Kvak V., Zamojsky O., Morozova E., (2015), Impact of the elements of a mechanised technology upon the yield of the Miscanthus biomass. *Collection of scientific papers of the Dnepropetrovsk State Agrarian-Economic Institute*, Vol. 38 (4), Dnepropetrovsk / Ukraine, pp. 50-54;

[4] Gumentic M., (2016), Technology of growing the giant Miscanthus as a raw material for the production of solid biofuel. *Proceedings of the International Scientific and Practical Conference, attached to the 95th Institute of Bioenergetics Crops and Sugar Bee*t. Vinnica / Ukraine, pp.262-265.

[5] Heaton, E.A., Dohleman, F.G., Long, S.P., (2008), Meeting the United States biofuel goals with less land: the potential of Miscanthus. *Global Change Biology Bioenergy* 14, pp. 2000-2014;

[6] Kalinina O., Nunn Ch., Sanderson R., Hastings A.F.S., Weijde T. et al., (2017), Extending Miscanthus cultivation with Novel Germplasm at six contrasting sites. *Frontiers in Plant Science*, Vol. 8, pp. 1-15;

[7] Kharytonov M, Martynova N., Sitnyk S., Naumenko M., Pidlisnuk V., Stefanovska T., (2017), A productive potential estimation of five genotypes of the Miscanthus Anderss genus in the Ukrainian steppe zones conditions. *INMATEH – Agricultural Engineering.* Vol.52, Issue 2, pp. 129-136;

[8] Kucenko V., Osipchuk A., Podgaetsky A., Kononuchenko V., (2002), Methodological recommendations on conducting the research on potatoes. *Institute of Potatoes of the National Academy of Agrarian Sciences of Ukraine*, Nemashaevo, Ukraine, 182 p.;

[9] Kurilo V., Ganzhenko O., Gumentic M., Kvak V., (2002), Methodological recommendations on the pre-plant soil tillage and planting the Miscanthus rhizomes, *Institute of Bioenergy Crops and Sugar Beet*; Kyiv / Ukraine. 56 p.;

[10] Quinn, L.D., D.J. Allen, and R. Stewart. (2010). Invasive potential of Miscanthus sinensis: implications for bioenergy production in the United States. *Global Change Biology Bioenergy* 2, pp.310–320;

[11] Rakhmetov D.B, Shcherbakova T.O, Rakhmetov S.D., (2015), Miscanthus in Ukraine: introduction, biology, bioenergetics (Міскантус в Україні: інтродукція, біологія, біоенергетика), Kiev: *Phytosociocenter*, pp. 158-162;

[12] Richter G. M., Agostini F., Barker A., Costomoris D., Qi A., (2016), Assessment on-farm productivity of Miscanthus crops by combining soil mapping, yield modelling and remote sensing. *Biomass and Bioenergy*, Vol. 85, pp. 252-261;

[13] Standart GOST 28306-2018, (2018), *Agricultural machinery. Machines for planting potatoes. Test methods*. 28 p. Moscow / Russia;

[14] Xue S., Lewandowski I., Kalinina O., (2017), Miscanthus establishment and management on permanent grassland in southwest Germany. *Industrial Crops and Products,* Vol. 108, pp. 572-582;

[15] Adamchuk V., Bulgakov V., (2016), *Small-size agricultural machinery (design, theory and calculation): monograph*. Kyiv: Agrar. Nauka, 2916. 292 p.