EurAsian Journal of BioSciences
Eurasia J Biosci 13, 1101-1108 (2019)

Growing of *Miscantus Giganteus* planting material in the conditions of unstable moistening

V. A. Doronin [1], V. V. Dryha [1], Yu. A. Kravchenko [1], V. P. Mykolaiko [2], L. M. Karpuk [3*], I. V. Krasnoshtan [3]

[1] Institute of Bioenergy Crops and Sugar Beets NAAS, #25 Klinichna Str., Kyiv, 03110, UKRAINE
[2] Pavlo Tychyna Uman State Pedagogical University, 2 Sadova Str. Uman, 20300, UKRAINE
[3] Bila Tserkva National Agrarian University, 8/1 Soborna square, Bila Tserkva, UKRAINE
*Corresponding author: lesna_karpuk@ukr.net

Abstract

The paper covers some specific aspects of the planting material formation of the introduced crop of giant miscanthus in Ukraine. It was found out that in the zone of unstable moistening, the use of MaxiMarin absorbent resulted in a reliable growth of rhizome mass and more buds were formed on it. When planted with rhizome (mass is 20-30 g) and with the use of absorbent at the first planting term the mass growth of rhizome was larger at the end of vegetation as compared with the control, and depending on an absorbent kind it ranged from 78.4 g (the application of absorbent granules into the soil) to 433.6 g (combined application of absorbent granules and gel), more buds were formed on the rhizome – by 14.6-42.6 at the first planting term and by 8.4-42.5 at the second planting term as compared with the control. The increase of rhizome mass and the number of buds on it ensured the output growth of planting material – rhizomes, which depended on both the application of absorbent (granules and gel) and the mass of planted rhizomes and their planting terms. When planted with rhizome (mass is 60-90g) and with combined application of absorbent granules and gel more planting materials (large rhizomes) was received – by 2.1 times at the first planting term, - by 2.2 times at the second planting term, as compared with the control. More rhizomes - by 1.3 times - were received when planted with rhizome with 60-90 g mass than when rhizome mass was 20-30 g at both planting terms.

Keywords: rhizome, rhizome mass, buds, absorbent, gel, granules, planting term

Doronin VA, Dryha VV, Kravchenko YuA, Mykolaiko VP, Karpuk LM, Krasnoshtan IV (2019) Growing of *Miscantus Giganteus* planting material in the conditions of unstable moistening. Eurasia J Biosci 13: 1101-1108.

INTRODUCTION

Ukraine belongs to the energy-dependent countries and can only partially satisfy its own needs in energy resources, which is why it is to import about 65% of mined energy-carriers (Blium et al. 2014, Roik et al. 2011). Traditional fuel as a result of burning increases the carbon dioxide content in the atmosphere. Bioenergy crops are the most environmentally friendly source of energy. The use of biofuels helps to increase the epidemiological situation; implementation of the requirements for reduction of atmospheric emissions, provided by the Kyoto protocol to the UN Framework Convention on Climate Change (Kaletnik, 2008). At the same time, Ukraine has a huge potential of bio-mass, available for energy manufacture – about 29 mln t The main potential component is by-product of agriculture (straw, stems, etc) and energy crops (Heletukha *and* Zheliezna 2017). Taking into consideration favorable soil-climatic conditions for crop cultivation, phyto-energy is the most promising kind of bio-energy which is based on bio-raw material of plant origin (Roik et al., 2015). The most promising bio-energy crops for Ukraine are sugar beets, sugar sorghum, switch-like millet (switch grass), miscanthus (Mozharivska 2013, Panasiuk 2014), willow and poplar (Fuchylo et al. 2009, Khivrych et al. 2011). Miscanthus is one of such crops (Chou 2008, Christian et al. 2008, Rakhmetov 2011). In the greater part of the territory of Ukraine this crop can make a considerable effect as to the amount of biomass and the lowest cost of its cultivation (Kotsar and Bekh 2013). According to its chemical composition, giant miscanthus is closer to the straw of other cereal crops, in particular wheat, and if compared with leafy wood (a birch-tree) it contains more polysaccharides (cellulose and pentosans), which proves the feasibility of its use (except for bio-fuel) for the manufacture of fibrous semi-finished products, the latter are used for making paper and cardboard (Romanchuk et al. 2014).

Received: March 2019
Accepted: June 2019
Printed: August 2019

Species Miscanthus (*Miscanthus Anderss.*) belongs to a sub-family Millet (*Panicoideae*), family Cereal (*Poaceae*) (Griffiths 1994). Miscanthus species are the plants with photosynthesis of C_4-type (Kurylo et al. 2010). It is a strong and hardy plant, and being planted once, its creeping rhizome will give new shoots annually (Humentyk 2011). Miscanthus species includes 17-20 and according to other sources over 40 morphological species (Biofuels 2012, Shumnyi et al. 2010). The most popular species are Chinese miscanthus (*Miscanthus sinensis*), sugar-flower miscanthus *(Miscanthus saccharifiorus*), giant miscanthus (*Miscanthus giganteus*) (Yastremska et al. 2017). All miscanthus species are highly-yielding, frost-resistant and are characterized with intensive growth and development. When planted in the first year, it is possible to annually harvest 10-15 t/ha of dry matter within 15–20 years (Heletukha et al. 2014).

For industrial cultivation of the raw material of this crop, it is important to provide producers with a sufficient quantity of quality planting material. At present there is no technology of the cultivation of miscanthus planting material in the conditions of unstable moistening in the Right-bank Forest-steppe zone of Ukraine, which would guarantee high rhizome engrafting and its maximum output. Thus, it is relevant to study specific aspects of the formation of miscanthus planting material in correlation with a complex use of technology elements, including planting terms, rhizome mass and the application of absorbent into the soil, which is the task of the research.

MATERIALS AND METHODS

The research program consisted in studying the peculiarities of the formation and output of planting material depending on the technology elements of its cultivation.

Field trials with the plants of giant miscanthus (*Miscanthus x giganteus* J.M.Greef & Deuter ex Hodkinson & Renvoize) were carried out in the experimental field of the Institute of bio-energy crops and sugar beets of the National academy of agrarian sciences of Ukraine, which is situated in the central part of the Right-bank Forest-steppe zone of Ukraine, the area of unstable moistening, characterized with a temperate-continental climate during the years of 2015-2017. The trial scheme included a complex use of technology elements: *factor A* – terms of planting with rhizome: first term – first – third decade of April, second term – second decade of April – third decade of May; *factor B* – application of absorbent MaxiMarin: control – without absorbent; soaking of rhizome in absorbent gel; absorbent granules in a hole; absorbent granules in a hole + soaking of rhizome in absorbent gel. Planting terms of miscanthus depended on spring conditions of the years of the research, and they ranged by years.

The preparation for miscanthus planting was carried out step by step: rhizomes were taken from a stocking field and delivered to a laboratory, where planting material was prepared carefully. Intact rhizomes (not frozen) with the mass required by the trial scheme were selected from the rootstock. While performing field studies the only condition was followed, namely one difference and factoriality (one factor), all the trial variants were in typical and identical conditions (soil-climatic conditions, farm practices, etc.), except for the factors which were studied.

All records and observations were done on the plants of the first-year vegetation. To improve water supply of the plants, absorbent granules and gel MaxiMarin were used, which absorb and retain the amount of liquid that exceeds their own weight by hundred times, and during drought they give this moisture to the plants; it creates favorable conditions for engrafting of planting material, growth and development of the plants, and in turn it causes the increase of the planting material output (rhizome). The area of the record plot is 12.25 m^2, replication is quadruplicate. Variants and replications were placed by a randomized method. Planting with rhizome was done by hand, inter-row was 70 cm, spacing in a row was 70 cm, and depth of seeding was 8–10 cm. The following was identified in the field trials: dynamics of the emergence (from the first single ones to the total emergence) by the methodology of the Institute of bio-energy crops and sugar beets of UNAAS, acclimatization of plants (correlation between emerged and planted rhizomes), intensity of plant growth (plant height, tillering – number of sprouts per one rhizome, leaf area, number of leaves) according to the development stages depending on the cultivation conditions (Roik and Hizbullin 2014).

Statistical processing of the experimental data was done with help of disperse and correlation analyses by Fisher’s method (Fisher 2009) with the use of software Statistica 6.0 from StatSoft company.

RESULTS AND DISCUSSIONS

The criterion to estimate the elements of the cultivation technology of planting material is its output, which depends on the quality of planted rhizomes, their ability to germinate, engrafting and farm practices and soil-climatic conditions for its cultivation. High rhizome engrafting together with soil-climatic conditions and farm practices facilitated an intensive increase of both above-ground mass of the plant and rhizome mass, which resulted in higher output of the planting material (Doronin et al. 2018).

On the average during a three-year experiment at the end of the plant vegetation the rhizome mass increase, when absorbent was used at both planting terms, was reliably larger, as compared with the control (**Table 1**).

Table 1. Mass of stocking rhizomes and bud number at the end of the vegetation depending on the elements of the cultivation technology (mean in 2015-2017)

Rhizome mass, g - *factor B*	Variant – application of absorbent MaxiMarin – *factor C*	Stocking rhizome mass, g	Bud number per rhizome, pcs. (pieces)
First planting term (I-III decades of April) – *(factor A)*			
20–30	Control – without absorbent	466.4	101.9
	Soaking in absorbent gel	571.7	116.5
	Absorbent granules in a hole	544.8	127.7
	Absorbent granules in a hole + soaking in absorbent gel	900.0	144.5
60–90	Control – without absorbent	736.1	126.5
	Soaking in absorbent gel	901.0	207.1
	Absorbent granules in a hole	988.7	200.8
	Absorbent granules in a hole + soaking in absorbent gel	1635.5	300.0
Second planting term (III decade of April -II decade of May) – *(factor A)*			
20–30	Control – without absorbent	412.6	108.4
	Soaking in absorbent gel	564.3	116.8
	Absorbent granules in a hole	518.4	121.9
	Absorbent granules in a hole + soaking in absorbent gel	739.9	150.9
60–90	Control – without absorbent	760.5	148.5
	Soaking in absorbent gel	934.5	171.4
	Absorbent granules in a hole	977.8	197.7
	Absorbent granules in a hole + soaking in absorbent gel	1430.9	322.1
$HIP_{0.05}$ total.		100.3	15.2
$HIP_{0.05}$ planting term (factor A)		35.5	5.4
$HIP_{0.05}$ rhizome mass (factor B)		35.5	5.4
$HIP_{0.05}$ absorbent (factor C)		50.2	7.6

The increase of rhizome mass (20-30 g) with absorbent application at the first planting term at the end of the vegetation was considerably higher as compared with the control, and it varied depending on absorbent kind from 78.4 g (absorbent granule application into the soil) to 433.6 g (combined application of absorbent granules and gel). The planting terms of rhizomes and their mass together with absorbent application had a definite effect on rhizome mass.

As the mass of stocking rhizomes increased, more buds were formed on them. More buds were formed in all variants with absorbent application as compared with the control. On the average within three years at rhizome planting (mass is 20-30 g) and absorbent application, much more buds were formed on rhizomes: at the first planting term – by 14.6-42.6, and at the second planting term – by 8.4-42.5, as compared with the control. Similar results were received when rhizomes with mass 60-90 g were planted.

The application of absorbent granules and gel led to the formation of the largest number of buds on rhizomes regardless of the mass of the planted rhizomes and planting terms. On the average within three years at the first planting term (rhizome mass is 20-30 g) the number of buds increased by 42.6, and at the second planting term – by 42.5 pieces ($HIP_{05\ absorbent}$ = 7.6 pcs.), as compared with the control. When rhizomes with mass 60-90 g were planted, and absorbent granules and gel were applied together, the number of buds increased – by 173.5 and 173.6 pcs., respectively, as compared with the control.

The number of buds on rhizome increased reliably depending on the mass of the planted rhizomes. When rhizomes with mass 60-90 g were planted at the first planting term more buds were formed in the control – by 24.6, and at the second planting term – by 40.1 - than when the mass was 20-30 g. A similar increase of the bud number was recorded in the variants with absorbent application.

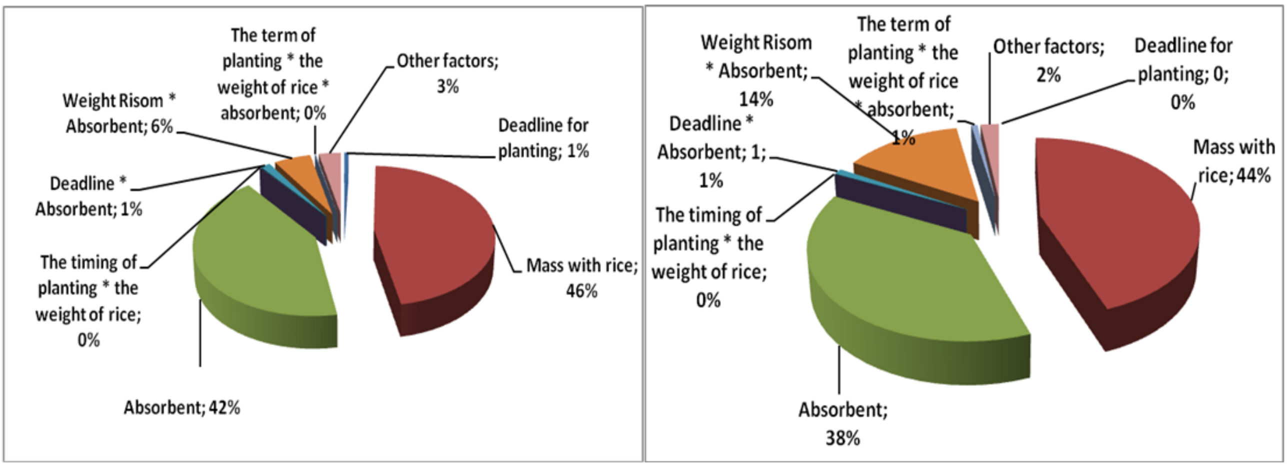
A reliable increase of the bud number on rhizomes was not recorded in correlation with the planting terms, only a tendency to the increase of this indicator was observed.

In the years of the research similar correlations were received between the formation of the bud number depending on absorbent application, mass of the planted rhizomes and their planting terms. The vegetation period of the year of 2016 was not good for emergence and initial growth and development, later the conditions were favorable, and as a result the plants formed larger above-ground and rhizome mass. In 2016 more buds were formed on larger rhizomes than in 2015 and 2017.

The research of the factors which had an impact on the formation of rhizome mass and bud number on them proved that on the average within a three-year period the effect share of factor “absorbent” was important and equal to 42% and 38%, that of factor “rhizome mass” – 46 and 44.0% (**Fig. 1**).

In the years of the research the effect of factors “absorbent” and “rhizome mass” was similar to the fluctuation in different years. The effect of other factors and their interconnection was not significant both on the average within three years and in the years of the research.

The increase of the above-ground mass facilitated the increase of rhizome mass, and in turn – the output of the planting material – rhizomes. It was established that the output of the planting material – large rhizomes – depended on both the application of absorbent (granules and gel) and the mass of the planted rhizomes and their planting terms (**Table 2**).



a) rhizome mass b) bud number on them

Fig. 1. The factor effect on the formation of stocking rhizome mass and buds on them depending on a complex use of technology elements (mean in 2015-2017)

Table 2. The output of the planting material – rhizomes – at the end of the vegetation depending on the elements of its cultivation technology (mean in 2015-2017)

Rhizome mass, g - *factor B*	Variant – application of absorbent MaxiMarin – *factor C*	Rhizome output, pcs.	
		large (4-8 buds)	small (1-3 buds)
First planting term (I-III decades of April) – *(factor A)*			
20–30	Control – without absorbent	21.4	33.3
	Soaking in absorbent gel	29.4	38.9
	Absorbent granules in a hole	28.5	40.1
	Absorbent granules in a hole + soaking in absorbent gel	37.1	45.6
60–90	Control – without absorbent	24.3	41.5
	Soaking in absorbent gel	32.4	58.7
	Absorbent granules in a hole	34.7	55.0
	Absorbent granules in a hole + soaking in absorbent gel	51.9	71.3
Second planting term (III decade of April -II decade f May) – *(factor A)*			
20–30	Control – without absorbent	18.0	29.5
	Soaking in absorbent gel	21.3	34.9
	Absorbent granules in a hole	20.7	35.7
	Absorbent granules in a hole + soaking in absorbent gel	24.8	42.1
60–90	Control – without absorbent	21.8	39.4
	Soaking in absorbent gel	27.0	46.9
	Absorbent granules in a hole	28.4	46.8
	Absorbent granules in a hole + soaking in absorbent gel	48.6	70.2

It was found out that under combined application of absorbent granules and gel at the first and second planting terms much more rhizomes were received as compared with the control and other variants. On the average within three years at the first planting term, rhizome mass was 60-90 g, under combined application of absorbent granules and gel, more planting material was received, namely by 27.6 pcs. or by 2.1 times, as compared with the control, at the second planting term these indicators were 26.8 pcs. and 2.2 times, respectively.

Similar results were received when rhizomes with mass 20-30 g were planted, but the amount of planting material was much smaller as compared with planting rhizomes with mass 60-90 g at both planting terms.

The application of absorbent granules and gel ensured a reliable increase of planting material but in a smaller amount than under combined application of these preparations. In the years of the research similar correlations were recorded as to the output of the planting material depending on absorbent application.

The output of the planting material depended on both absorbent application and planting terms and the mass of the planted rhizomes. When large rhizomes were planted more planting material was received than when small rhizomes were used. On the average in a three-year period when large rhizomes were planted, more rhizomes were received – by 1.3 times - than when small rhizomes were sued.

A similar increase of the planting material depending on the mass of the planted rhizomes was received in the variant with absorbent application. Thus, under combined application of absorbent granules and gel and when large rhizomes (mass was 60-90 g) were planted, at the first planting term the increase of the output of large rhizomes was by 1.6 times larger, and at the second planting terms – by 1.7 times larger than when small rhizomes (20-30 g) were planted. A similar increase of the output of the planting material was

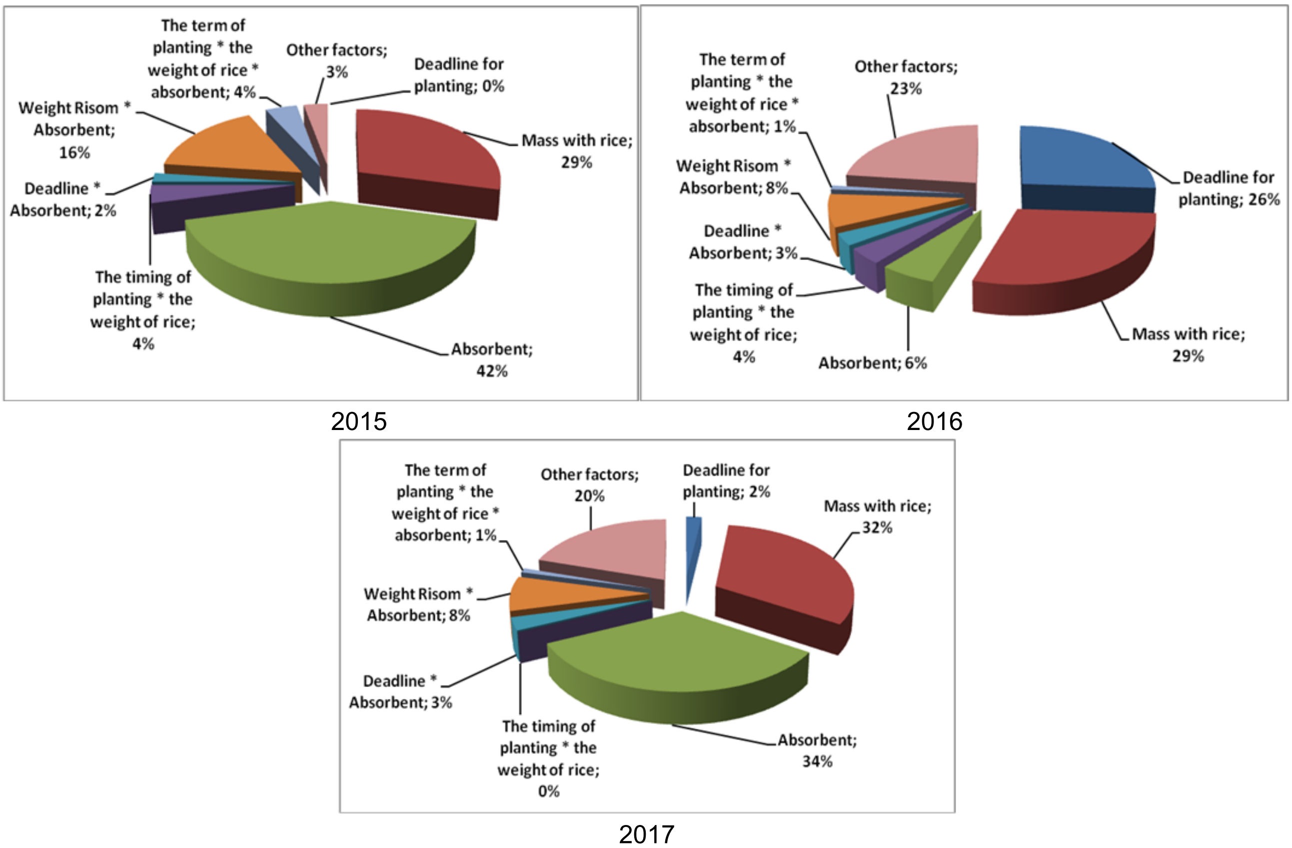


Fig. 2. The effect of the factors on the formation of the planting material – large rhizomes – depending on a complex use of the technology elements

received in the variants when absorbent granules or gel were applied.

Depending on the planting terms, a similar increase of the planting material was received. Regardless of the mass of the planted rhizomes and absorbent application at the first planting term, the output of the planting material was considerably larger than at the second planting term. In the control when small rhizomes were planted at the first planting term, on the average within three years, 33.3 large rhizomes were received, and at the second planting term – by 3.8 pieces fewer; at the second planting term these indicators were 41.5 pcs. and 2.1 pcs, respectively. At the first planting term and combined application of absorbent granules and gel, when small rhizomes were planted, 45.6 large rhizomes, or by 3.5 pcs. more, were received, as compared with the second planting term; similar results were received when large rhizomes were planted. Similar results were received by the years of the research.

The research of the factors which had an impact on the formation of the planting material – large rhizomes – confirmed that the share of the effect of factor "absorbent" was significant – 42.0% in 2015, only 6% in 2016, and 34% in 2017; that of factor "rhizome mass" ranged from 29 to 32% by years (**Fig. 2**).

In 2016 the efficiency of absorbent was much smaller than in 2015 and 2017, which was due to excessive moistening and large reserves of productive moisture, and, in particular in the planting period, re-growth, initial growth and development of the plants. The effect of factor "planting term" was different by years, namely, in 2015 and 2017, good years of a vegetative period for growth and development, it was insignificant, and in 2016, a less favorable year, it was 26%. The interaction of the factors was not significant in all the years of the research.

A complex use of the technology elements ensured the increase in the planting material amount, both large and small rhizomes. The output of small rhizomes depended on the application of absorbent, the mass of the planted rhizomes and their planting terms.

When small rhizomes were planted at the first planting term, on the average in three years, and under combined application of absorbent granules and gel, more planting material – small rhizomes – was received, namely by 1.4 times, and when large rhizomes were planted - by 1.7 times more than in the control. Similar results were received at the second planting term. When small rhizomes were planted the output of the planting material increased by 1.4 times, and when large rhizomes were planted – by 1.8 times, as compared with the control. A separate application of absorbent granules or gel at both planting terms and when both large and small rhizomes were planted, all this led to a

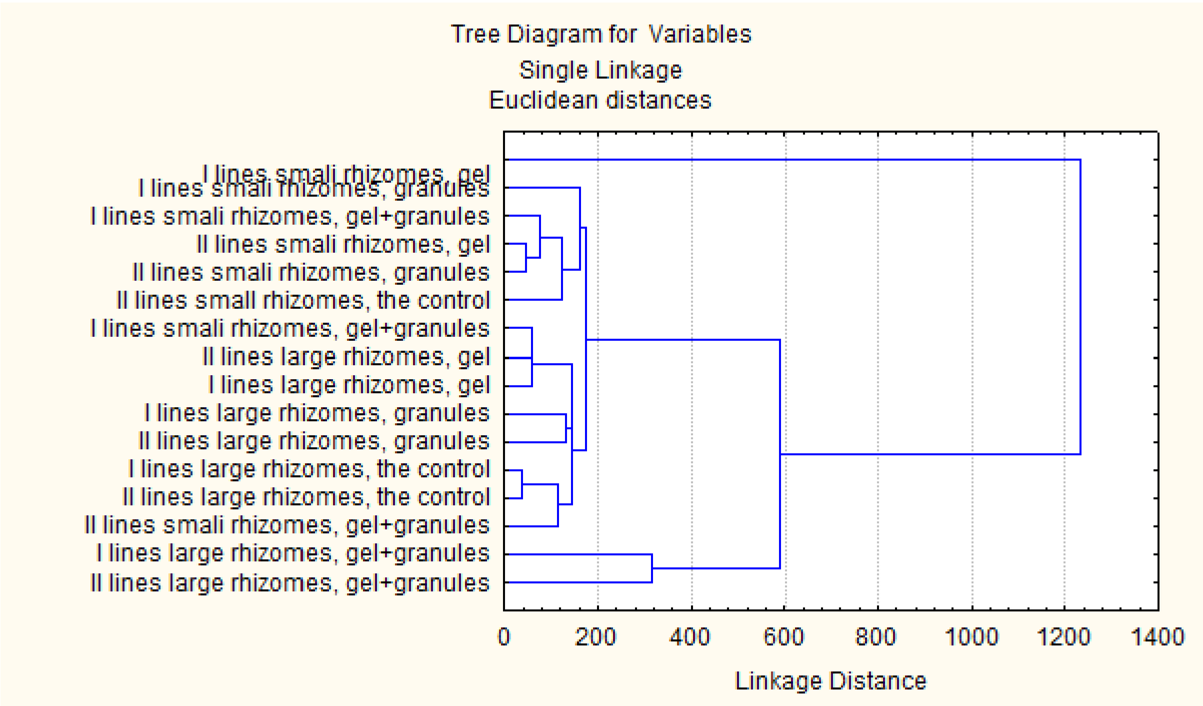


Fig. 3. Cluster analysis of the similarity distribution of the technology elements of the cultivation of miscanthus planting material

considerable increase of the planting material, as compared with the control. Similar results were received by the years of the research. A reliably larger amount of the planting material – small rhizomes – was received depending on the mass of the planted rhizomes at both planting terms. At the second planting term the output of small rhizomes was much higher than at the first planting term.

With the aim of a comprehensive evaluation of the efficiency of the technology elements – planting terms, rhizome mass and absorbent application, a cluster analysis for feature similarity was made (**Fig. 3**).

According to a comprehensive evaluation of the effect of the studied variants of planting terms, the mass of the planted rhizomes and absorbent application, the most similar as to the structure were, on the one side, the variants when small rhizomes were planted at two planting terms without absorbent application, combined in one cluster, and on the other side – the variants when small rhizomes were planted and absorbent gel or granules were applied at both planting terms, combined in another cluster.

In another cluster the variants, where large rhizomes were planted at the first planting term with the application of absorbent gel, were combined, and the variants with large rhizome planting at two planting terms with absorbent granule application, combined in one cluster. As to the complex of features, the variants, where small rhizomes were planted at the first planting term with combined application of absorbent gel and granules and when large rhizomes were planted at the second planting term with the application of absorbent gel, come organically closer to this cluster.

The third cluster combined the variants where large rhizomes were planted at both planting terms with the application of granules and gel and the variant where large rhizomes were planted at the first planting term with the application of absorbent gel. Similar results were received when large rhizomes were planted at two planting terms without the application of absorbent (the control), which were combined in one cluster. The results of large rhizome planting at two planting terms and combined application of absorbent gel and granules were included in a separate cluster.

Such classification of the variants into clusters confirms the conclusion that the application of absorbent gel and granules results in the increase of biometric indicators of above-ground mass, rhizome mass and the output of small rhizomes both at the first and the second planting terms.

CONCLUSIONS

1. The mass increase of miscanthus stocking rhizomes depended on both absorbent application and rhizome planting terms and their mass.
2. As the mass of stocking rhizomes increased, more buds were formed on them, and in turn the output of the planting material increased.
3. When small rhizomes were planted at the first planting term and under combined application of absorbent granules and gel, more planting material – small rhizomes – was received, namely by 1.4 times,

and when large rhizomes were planted - by 1.7 times more than in the control, and at the second planting terms - by 1.4 times and 1.8 times, respectively, as compared with the control. A separate application of absorbent granules or gel at both planting terms and when both large and small rhizomes were planted, all this led to a considerable increase of the planting material, as compared with the control.

4. Regardless of the mass of the planted rhizomes and absorbent application at the first planting term, the output of the planting material was much larger than at the second planting term.

5. Under combined application of absorbent granules and gel and when large rhizomes (mass was 60-90 g) were planted at the first planting term the increase of the output of large rhizomes was by 1.6 times larger, and at the second planting term – by 1.7 times larger than when small rhizomes (20-30 g) were planted.

6. The integration of both planting terms for large rhizomes at combined application of absorbent gel and granules, which led to receiving similar biometric indicators, rhizome mass and the output of small rhizomes, into one cluster proves the expediency of using these technology elements.

REFERENCES

Blium YaB, Hryhoriuk IP, Dmytruk KV (2014) The system of using bio-resources in the latest bio-technologies of alternative fuel manufacture. Kyi: Agrar Media Group, 360 p. (in Ukrainian)

Brosse N, Dufour A, Meng X, et al. (2012) Miscanthus: a fast-growing crop for biofuels and chemicals production. Biofuels, Bioprod. Bioref, 6(5): 580-598. https://doi.org/10.1002/bbb.1353

Chou CH (2009) Miscanthus plants used as an alternative biofuel material: the basic studies on ecology and molecular evolution. Renewable Energy, 34(8): 1908–1912. https://doi.org/10.1016/j.renene.2008.12.027

Christian DG, Riche AB, Yates NE (2008) Growth, yield and mineral content of Miscanthus × giganteus grown as a biofuel for 14 successive harvests. Industr. Crops Prod.. 28(3): 320–327. https://doi.org/10.1016/j.indcrop.2008.02.009

Doronin VA, Dryha VV, Karpuk LM, Vachniy SP, Pavlichenko AA, Mykolaiko VP, Polishchuk VV (2018) Specific aspects of the formation of Miscanthus planting material depending on cultivation conditions. EurAsian Journal Biosci, 12(2): 325-331.

Fisher RA (2006) Statistical methods for research workers. New Delhi: Cosmo Publications, 354 p.

Fuchylo YaD, Sbytna MV, Fuchylo OYa, Litvin VM (2009) Experience and prospects of growing poplar (Populus sp.l.) in the southern steppe of Ukraine. Scientific works of Forest academy of sciences of Ukraine: proceedings, 7: 66–69 (in Ukrainian)

Griffiths M (1994) Index of Garden Plant. Oregon: Timber Press, 1234 p.

Heletukha HH, Zhelezna TA (2017) Current state and trends in the development of bio-energy in Ukraine. Promyslova teplotekhnika (industrial heat engineering), 39(2): 60-64. (in Ukrainian) https://doi.org/10.31472/ihe.2.2017.09

Heletukha HH, Zhelezna TA, Tryboi OV (2014) Prospects of cultivation and use of energy crops in Ukraine. Analytical note BAU, 10, 33 p. Available at: http://uabio.org/img/files/docs/position-paper-uabio-10-ua.pdf (in Ukrainian)

Hivrych OB, Kvak VM, Kaskiv VV, et al. (2011) Energy plants as an alternative for traditional fuels. Agrobiology, 6: 153–157. (in Ukrainian).

Humentyk MYa (2011) Emergence of miscanthus depending on various depths of rhizome planting. Scientific works of the Institute of bioenergy crops and sugar beets: proceedings. Kyiv: 12: 55–61. (in Ukrainian)

Kaletnyk HM (2008) Rozvytok rynku biopalyv v Ukraini. Kyiv. p. 422.

Kotsar MO, Beh NS (2013) Monitoring of miscanthus species as to drought-resistance using biotechnological techniques. Scientific works of the Institute of bioenergy crops and sugar beets: proceedings. Kyiv, Iss. 17(2): 233–236. (in Ukrainian)

Kurylo VL, Humentyk MYa, Kvak VM (2010) Miscanthus – a promising energy crop for biofuel manufacture. Agrobiology: Proceedings. Bila Tserkva, 4: 62–66. (in Ukrainian)

Mozharivska I (2013) The technology of growing of such energy crops for the production of different types of biofuel. Proceedings of IBECandSB, Kyiv, 19: 85–89. (in Ukrainian)

Panasiuk BYa (2014) A pilot program “alternative energy sources of Vinnytsia region”. Bioenergetyka (bio-engineering), 2(4): 18. (in Ukrainian)

Rahmetov DB (2011) Theoretical and applied aspects of plant introduction in Ukraine: a monograph. Kyiv: Agrar Media Group, 398 p. (in Ukrainian)

Roik MV, Hanzhenko OM, Tymoshchuk VL (2015) The concept of production and use of solid bio-fuel kinds in Ukraine. Bioenergetyka (bio-engineering), 1(5): 5–8. (in Ukrainian)

Romanchuk LD, Zinchenko VO, Vasyliuk TP (2014) Peculiarities of growing energy crops in the conditions of Ukraine's Polissia: from the book. Development trends alternative energy in Ukraine's Polissia. K.: Center of teaching literature: 81–111. (in Ukrainian)

Royik MV, Hizbullin NG, Sinchenko VM, Prysyazhnyuk OI (2014) Methods of research in beet. Kyiv: Korzun, 374 p.

Royik MV, Kurylo VL, Hanzhenko OM, Humentyk Mya (2012) Prospect for the development of bioenergy in Ukraine. Tsukrovi buriaky [Sugar Beet], 2–3: 6–8. (in Ukrainian)

Shumnyi VK, Veprev SG, Nechiporenko NN, et al. (2010) New form of Chinese miscanthus (Veiernika Chinese miscanthus Miscantus sinensis Anders.) as a promising source of cellulose-containing raw material, 14(1): 122–126.

Yastremska LS, Pryshliak RI, Fedoniuk YuV (2017) Miscanthus – energy crop for bio-fuel manufacture. Problems of ecological biotechnology, 1. Available at: http://nbuv.gov.ua/UJRN/peb_2017_1_3 (in Ukrainian)