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Specific aspects of the formation of Miscanthus planting material depending on cultivation conditions

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Abstract

The results of studying some peculiar features of the formation of planting materials depending on the application of a set of technology elements – planting terms and absorbent granules and gel – are presented in the paper. It was found out that emergence terms depended on weather conditions in the years of the research. The higher the average circadian air temperature was the more intensive miscanthus emergence. It was established that the engrafting with rhizome, the intensity of sprout formation, the increase of rhizome mass, and in turn, the output of planting materials depended on planting terms, use of absorbent and weather conditions in the years of the research.

Keywords: engrafting with rhizome, absorbent, planting term, sprouts, rhizome mass

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INTRODUCTION

In Ukraine traditional kinds of fuel are the products of oil refining, coal, gas, hydro and nuclear energy. As the quantity of these energy-carriers is not sufficient and the price of them goes up, more attention is paid to the search and manufacture of alternative energy sources, which will be help reduce the dependence of the country on the traditional kinds of fuel. The world industrialized countries have made great achievements in the development and use of bio-fuel. Nowadays European countries (Austria, Denmark, the Netherlands, Norway, Finland and Sweden) use 40-65% of ecologically clean bio-energy (Drukovanyi et al. 2011). In Ukraine ecologically clean bio-energy constitutes only 3% (Explanatory memorandum to Ukraine's Law 2006).

At present a valid alternative to traditional fuel in Ukraine is bio-fuel which is produced from plant bio-energy raw material, grown on low-productive and degraded soils excluded from crop rotation and not used for the cultivation of agricultural crops. According to the statistics of the Institute of real estate development, there are over 1.1 mln ha of such land (the Institute of real estate development).

The most promising source of energy for Ukraine is bio-power, namely: phyto-power. The following plants present a practical interest for bio-fuel manufacture from phyto-mass: switch-grass, miscanthus, sorghum, sugar beets, corn and some other bio-energy crops (Bashniak 2010, Doronin 2013, Humentyk 2012). An introduced plant such as miscanthus takes a special place in the production of solid kinds of bio-fuel. By its energy value, a ton of miscanthus dry mass is equal to 400 kg of crude oil. Plants of this crop can exist/grow on the same plot for 15-20 years; they can be as high as 3.5 m and produce up to 12-18 t/ha of dry matter. It requires 2-3 times less expenses as compared with wheat (Kuptsov and Popov 2015). Miscanthus belongs to angiosperms *(Angispermal*) species *Anderssons* (Taran, Mahomedov and Ponomarenko 2011) as well as to C_4-plants (Kurylo et al. 2010, Williams and Douglas 2011).

Analysis of the latest research and publications. It was known from foreign sources that some research was carried out concerning the use of miscanthus to manufacture solid bio-fuel in the U.S.A. (Williams and Douglas 2011), the response of giant miscanthus to moisture, the temperature regime, the resistance to herbicides and to nitrogen nutrition (Pyter et al. 2006). In England miscanthus is propagated in two ways – rhizomes, there are to be at least 2-3 buds on them, and micro-cloning. To control over the amount of weeds on

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miscanthus plantations, it is recommended to apply the same herbicides as under grain and corn crops. In England miscanthus yielded 13 t/raha of dry mass on an experimental plot (Nixon and Bullard 2001). Winter resistance of miscanthus was studied in the conditions of Michigan state university of the U.S.A. It has been recorded that miscanthus can die at soil temperature below 26 ° F and at soil depth 2.5 cm (Thelen et al. 2005).

In Ukraine the following was studied: the issue of miscanthus emergence in relation to the depth planting with rhizome (Humentyk 2011) and planting terms (Kvak 2012), rates of mineral fertilizer application (Kvak 2012), use of growth regulators aimed at increasing crop productivity (Zinchenko 2013), efficiency of herbicide usage in miscanthus fields (Makukh 2016).

All the trials conducted earlier and presently are aimed at the development of technology elements which will ensure the yield increase of miscanthus and, in turn, the increase of the power potential of the crop.

To widely use miscanthus for the manufacture of solid bio-fuel, it is required to have enough quality planting material. At present, in Ukraine, there is no growing technology of miscanthus planting material in the conditions of unstable moistening which will guarantee high engrafting with rhizome and its maximum output. Which is why, it is relevant to study specific aspects of the mass formation of miscanthus rhizome and engrafting with rhizome depending on the cultivation conditions; this was the aim of the research.

MATERIALS AND METHODS

The research program envisaged the studying of the formation peculiarities of miscanthus rhizome depending on its cultivation conditions.

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 includes 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.

We connected rhizome planting terms with weather conditions in a planting season rather than with certain dates. The first term – planting with rhizome was done in early spring, when it was possible to begin planting, and according to the years of the research those were the first – third decades of April. In this period the soil was warmed up and there was enough moisture. Taking into account that miscanthus is a warmth- and moisture-loving crop and to get higher efficiency of the absorbent usage, the second term of planting was done 21 days later, in the period when average circadian air temperature was 10 ^{0}C, the soil was warmed up well, and moisture content was lower than at the first planting term. Actual dates of planting with rhizome were different by the years of the research.

To create favorable conditions for engrafting with rhizome and for the growth and development of miscanthus, and respectively, to increase the output of planting material, it was envisaged to use absorbent granules and gel MaxiMarin, which absorb and retain the amount of liquid that exceeds their own weight by hundreds times, and during drought they give this moisture to the plants.

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 (mass – 60-90 g) 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 (Roik et al. 2014), acclimatization of plants (correlation between emerged and planted rhizomes) (Kovalchuk et al. 2010), dynamics of tillering, increase of rhizome mass and output of planting material (rhizome) according to the development stages depending on the cultivation conditions (Fisher 2006).

Statistical processing of the experimental data was done with help of disperse and correlation analyses by Fisher's method (2006) with the use of software Statistica 6.0 from StatSoft company.

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.

RESULTS AND DISCUSSION

The terms of having total emergence, which depended on weather conditions of the years of the research, are the beginning of all the proceeding stages

Table 1. Dynamics of miscanthus emergence (%) depending on its cultivation conditions, average in 2015-2017

Variant – absorbent application MaxiMarin – *factor B*	Record term after planting, weeks						
	3	4	5	6	7	8	9
First planting term (I-III decade of April) – *factor A*							
Control – without absorbent	21.1	39.8	74.5	80.7	84.5	82.0	100
Soaking in absorbent gel	25.3	42.9	67.6	79.4	78.2	82.4	100
Absorbent granules in a hole	24.2	42.7	64.0	68.0	75.8	80.3	100
Absorbent granules in a hole + soaking in absorbent gel	27.8	42.8	61.0	66.8	71.1	79.7	100
Second planting term (III decade of April -II decade of May) – *factor A*							
Control – without absorbent	17.9	26.1	48.5	54.5	65.7	100	0
Soaking in absorbent gel	18.0	30.5	47.3	55.1	73.1	100	0
Absorbent granules in a hole	16.5	26.5	49.4	60.0	75.3	100	0
Absorbent granules in a hole + soaking in absorbent gel	22.4	34.5	40.0	62.4	75.8	100	0

of plant growth and development. At the first planting term shoots began to appear on the 21st day in 2015, on the 28th day in 2016 and on the 35th in 2017 from the beginning of planting; and at the second planting term sprouts began to appear earlier by the years of the research, respectively, – on the 14th, 19th and 21st day from the beginning of planting, which was due to weather conditions in the years of the research.

In 2017 planting with rhizome at both terms was carried out earlier than in 2015 and 2016, but in 2015 first sprouts appeared earlier, in particular at the first planting term, which resulted from temperature regime and moisture supply in the period of planting and sprout appearance. An average circadian air temperature in April (first term) was 9.3 ^{0}C (2015) and 12.4 ^{0}C (2016), at the second planting term (May) an average circadian air temperature was higher – by 6.9 and 2.2 ^{0}C and was 16.2 ^{0}C and 14.6 ^{0}C, respectively. A conclusion can be made that the higher average circadian air temperature is the more intensively miscanthus sprouts appear. In 2017 the period of planting and sprout appearance by a temperature regime was similar to an average and long-standing regime and it was characterized with moisture deficit, namely 47.0 mm, whereas an average and long-standing indicator is 47.0 mm. These conditions resulted in a considerable delay of sprout emergence.

Based on the studying of emergence in dynamics as to cultivation conditions – weather conditions, planting terms and absorbent application, it was established that three weeks later after the beginning of planting at the first planting term there were more sprouts by 3.2-7.7% than at the second planting term, depending on trial variants. A similar increase of the sprout number was recorded on other record dates. The use of MaxiMarin absorbent also facilitated the increase of emergence intensity three weeks after planting with rhizome, as compared with the control – without absorbent (**Table 1**).

So, after three weeks at the first planting term there was 21.1% of emergence from the total amount in the control, then, when absorbent was applied depending on the form it ranged from 24.2% (application of granules in a hole) to 27.8% (application of absorbent granules and gel). At the second term similar correlation was recorded.

At the first planting term total emergence was seen nine weeks later after planting, whereas at the second planting term – after eight weeks, however plant density was higher at the first planting term than at the second planting term. After seven weeks at the first planting term 84.5% of emergence was recorded in the control, and at the second planting term – 65.7%.

Weather conditions had a considerable effect on engrafting with rhizome. In 2015 and 2017 the period of planting and emergence was dry, precipitation deficit was 27 and 47 mm, respectively, which affected engrafting with rhizome. And even in such conditions, when absorbent was applied, engrafting with rhizome was indeed higher, as compared with the control (**Fig. 1**)

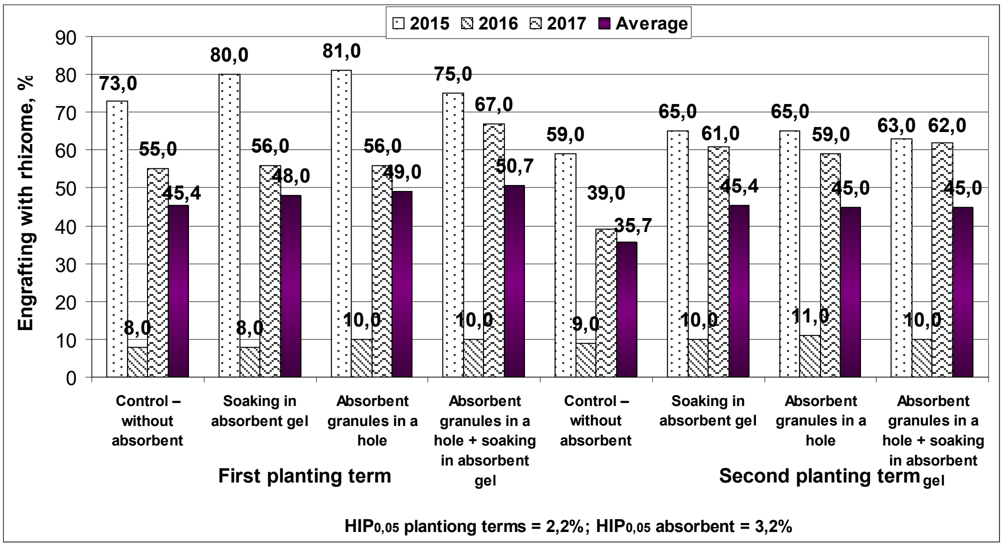

Fig. 1. Engrafting with rhizome depending on miscanthus cultivation conditions, average in 2015-2017

Table 2. Dynamics of tillering by development stages depending on technology elements of miscanthus cultivation, average, average in 2015-2017

Variant – application of MaxiMarin absorbent – *factor B*	Growth and development stages			
	regrowth	tillering	shooting	end of vegetation
First planting term (I-III decade of April) – *factor A*				
Control – without absorbent	3.8	8.0	16.1	26.1
Soaking in absorbent gel	3.5	8.7	18.8	28.8
Absorbent granules in a hole	3,7	8.8	15.2	29.8
Absorbent granules in a hole+ soaking in absorbent gel	4.5	9,2	16.6	33.9
Second planting term (III decade of April - II decade of May) – *factor A*				
Control – without absorbent	3.5	7.5	16.4	24.9
Soaking in absorbent gel	3.6	7.7	18.9	27.9
Absorbent granules in a hole	3.2	6.5	15.5	29.0
Absorbent granules in a hole+ soaking in absorbent gel	3.0	7.2	16.7	30.1
$HIP_{0,05\ total}$	0.6	1.0	2.3	3.0
$HIP_{0,05\ planting\ terms}$	0.2	0.3	0.7	0.9
$HIP_{0,05\ absorbent}$	0.3	0.4	0.9	1.2

The period of planting and emergence in a vegetation stage of the year of 2016 was characterized with excessive moistening – in April the amount of precipitation was 139%, and in May – 137% of the annual average indicator – and with large reserves of productive moisture in a 1-m soil layer – 115-153 mm. Such conditions caused the formation of water saucers, damping-off and decay of those crops planted with rhizome and, in turn, the decrease of engrafting with rhizome.

To get a well-developed above-ground mass (crop yield) as well as a ramified root system, and in turn, the output of planting material, the number of formed miscanthus shoots is very important (tillering). On the average, within three years at both planting terms and at all stages of plant growth and development, the largest number of shoots was formed when absorbent was applied and, particularly when granules and gel were used. Thus, at the first planting term when absorbent granules and gel were sued at the end of the vegetation, 33.9 shoots were formed and 26.1 shoots – in the control (**Table 2**).

Similar results were received at the second planting term. At both terms of planting with rhizome and joint use of absorbent granules and gel at the end of the vegetation period on the average within three years, much more shoots were formed both in the control and when granules and absorbent gel were used separately. A real increase of the shoot number was recorded when only absorbent gel or granules were used at both rhizome planting terms. A direct and strong correlation was established between the number of shoots and the mass of rootstock, a correlation coefficient was 0.93-0.94.

An evaluation criterion of technology elements of planting material cultivation was its output which depends on the quality of those planted with rhizome, their ability to sprout, engrafting and agro-technical and soil-climatic conditions of planting material cultivation. High engrafting with rhizome together with soil-climatic and ago-technical conditions facilitated an intensive growth of both above-ground plant mass and rootstock mass which made it possible to increase the output of planting materials (rhizome).

On the average in the years of the research at all plant growth and development stages, the increase of the rootstock mass was more intensive when absorbent

Table 3. Dynamics of the increase of rootstock mass depending on technology elements of miscanthus cultivation, average in 2015-2017

Variant – application of MaxiMarin absorbent – *factor C*	Growth and development stages			
	regrowth	tillering	shooting	end of vegetation
First planting term (I-III decade of April) – *factor A*				
Control – without absorbent	16.3	39.8	129.2	736.1
Soaking in absorbent gel	18.7	38.5	170.8	901.0
Absorbent granules in a hole	20.2	42.7	178.4	988.7
Absorbent granules in a hole + soaking in absorbent gel	21.9	51.0	258.4	1635.5
Second planting term (III decade of April - II decade of May) – *factor A*				
Control – without absorbent	13.9	52,4	192.7	760.5
Soaking in absorbent gel	17.1	63,8	245.1	934.5
Absorbent granules in a hole	16.7	74,2	277.7	977.8
Absorbent granules in a hole + soaking in absorbent gel	20.3	81.4	626.1	1430.9
$HIP_{0,05\ total}$	6.3	10.6	110.5	143.4
$HIP_{0,05\ planting\ terms}$	3.1	5.3	55.3	71.7
$HIP_{0,05\ absorbent}$	4.4	7.5	78.1	101.4

Control Usage of gel and granules

Fig. 2. Rootstock, grown in the control and with joint use of granules and gel (2016) absorbent

was used at both terms of planting with rhizome, as compared with the control (**Table 3**).

At the end of vegetation the rootstock mass, when planted with rhizome at the first planting term, was larger as compared with the control, and it varied depending on the kind of absorbent – from 901.0 g (rhizome soaking in absorbent gel) to 1635.5 g (joint use of absorbent granules and gel). Similar results were received at the second term of planting with rhizome.

Dug-out miscanthus rootstock, received in the control and when absorbent granules and gel were used together, is shown in **Fig. 2**.

The output of planting material depended on the use of absorbent and terms of planting with rhizome. On the average within three years at the first planting term and joint use of absorbent granules and gel, 51.9 pieces (pcs.) of planting material (large rhizomes) were received, at the second term – 48.6 pieces or more than twice as much, as compared with the control (**Table 4**).

Table 4. Output of miscanthus planting material at the end of a vegetation period depending on technology elements of its cultivation, average in 2015-2017

Variant – application of MaxiMarin absorbent – *factor B*	Rhizome output from rootstock, pcs.	
	large (4-8 buds)	small (1-3 buds)
First planting term (I-III decades of April) – *(factor A)*		
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 of May) – *(factor A)*		
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
$HIP_{0,05\ planting\ terms}$	2.3	1.8
$HIP_{0,05\ absorbent}$	4.2	4.5

The use of absorbent granules and gel separately also resulted in a credible increase of planting material, as compared with the control, but to a lesser quantity than when these preparation were used together. No significant difference in the output of planting material as to the use of absorbent gel or granules was recorded.

Planting terms had some effect on the output of planting material. At the first planting term the output of rhizomes was larger both in the control and when absorbent was used, as compared with the control.

CONCLUSION

1. It was found out that emergence terms depended on weather conditions in the years of the research. The higher the average circadian air temperature was the higher intensity of miscanthus emergence.
2. It has been established that engrafting with rhizome depends on planting terms, the use of absorbent and the average circadian air temperature and the amount of precipitation. When absorbent was applied in all the variants, it was rather high, as compared with the control at both planting terms.
3. All studied factors influenced shoot formation. When granules, gel and absorbent granules+gel together were used in the period of rhizome planting, the intensity of shoot formation was higher at all plant growth and development stages, as compared with the control. A direct and strong correlation was recorded between the number of shoots and the mass of rootstock, a correlation coefficient was 0.93-0.94.
4. The intensity of the mass increase of the rootstock and the output of planting material – miscanthus rhizome – depended on the use of absorbent and planting terms. At all plant growth and development stages, the increase of the rootstock mass was more intensive when absorbent was used at both terms of planting with rhizome, as compared with the control. On the average within three years at the first planting term and joint use of absorbent granules and gel, 51.9 pieces (pcs.) of planting material (large rhizomes) were received, at the second term – 48.6 pieces or more than twice as much, as compared with the control.
5. The use of absorbent granules or gel separately resulted in a credible increase of planting material, as compared with the control, but to a lesser number than when these preparation were used together. No significant difference in the output of planting material as to the use of absorbent gel or granules was recorded.

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