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PROSPECTS OF USING *MISCANTHUS GIGANTEUS* AS A FUEL CROP IN FOREST-STEPPE OF MIDDLE VOLGA

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ABSTRACT

Currently, wood is used as an ecologically friendly type of fuel. But its supply is limited due to the long period of forest restoration. That's why looking for alternative sources of energy on non-wood origin, which would make a decent competitor to wood in terms of biomass growth speed, is an urgent task. Penza region has great possibilities for organizing plantations for cultivation of energy fast growing herbage plants with high content of cellulose on non-crop lands. One of the promising steps in this direction is the introduction of perennial *Miscanthus giganteus* into agriculture. For its introduction into the yielding, it's necessary to define the productivity and calorific capacity of *Miscanthus*. The peculiarities of plant growth in relation to local climatic conditions were discovered and the correspondence of the culture to the local moisture conditions was defined. In the year of plantation establishment (2013) on the light-grey soil at the excessive moisture, 14t/ha of top was received. A good development of yearlings increased their winter hardiness and the productivity of *Miscanthus* doubled the next year. Despite the arid conditions, in the third year of research, it increased by 7 t/ha as compared to the previous year. The fourth and fifth year of *Miscanthus* life were the most productive (40 and 41 t/ha) because they corresponded to the level of 2013 in terms of moisture conditions. The productivity of plantation in hyper arid 2018 and 2019 decreased to 30 t/ha. According to the main ecological and energy characteristics, chips from the stems of a seven-year-old *Miscanthus* meet European standards.

Keywords : *Miscanthus giganteus,* fuel crop, calorific capacity, ash content, moisture

Introduction

Development of domestic agriculture in recent decades was based on the intensive methods of agricultural production, the ultimate goal of which was obtaining maximal amount of agricultural production, which provides the population with food, and industry with raw materials. Agricultural production has achieved certain success using the created powerful production potential, the concentration of forces and means in the areas providing the greatest return, the widespread development of intensive technologies. With this, the intensification in agriculture is often accompanied by high labor costs, funds and negative environmental consequences (Beljak, 2008).

During the entire historical period, the used land has been always under the anthropogenic influence, the negative consequences of which has increased. With the growth of population and an increase in the need for products and agricultural raw materials, these consequences have become global. Ecological situation continues to aggravate. That's why the necessity to look for the alternative ways to satisfy the society with food and raw materials appeared.

Long, intensive agricultural production, which often ignores the natural laws of ecosystem development, has led to significant changes in landscapes, where there is an irrational ratio of forest, meadow, pasture and plowing land. Herewith, the optimal ration between the plowing land, forage lands and forest is 1 : 1.6 : 3.5. If 1 ha of plowing land is planted with 3.5 ha of forest, then we can assume that it is entirely covered by the forest. That is why these parameters should not only be taken into account in Penza region but the measures shall be taken to achieve this ratio (Beljak *et al.*,1994).

Therefore, it is very important to preserve forests through a relaxed regime of their use, since they reach full ripeness at the age of 80 years or more. This matter was addressed in the Edict of the President of the Russian Federation of 7 May 2018 No. 204, which considers one of the problems on development of national goals and strategic objectives of the Russian Federation development for the period up to 2024 in the field of ecology(Edict of the President of the RF of 07.05.2018 No. 204).

Currently, wood is used as an ecologically friendly type of fuel. However, using the natural forests as a source of biomass is undesirable, because it is an ecosystem where the biodiversity of animals and plants is preserved, pollution of water resources and soil erosion are reduced. Thereby, an urgent task is to look for the alternative source of energy of non-wood origin, which would make a decent competitor to wood in terms of biomass growth speed.

One of the promising steps in this direction is the introduction of perennial *Miscanthus giganteus* into agriculture, which, starting from the third year of life, annually forms a powerful top within 20-30 years (Gushchina *et al.*, 2014, 2018). Biomass of *Miscanthus* may be used for manufacturing of fuel pellets and bricks, and afterward for the construction of bio-factories and for the producing of liquid biofuel (Bulatkin, 2017 and Yastremskaya *et al.*, 2017). When burning plant biomass, carbon dioxide is released in the same way as when burning traditional fuels. But the plants emit as many harmful substances while burning as they consume in the process of growth, thus implementing a complete carbon cycle (Zinchenko, Yashin, 2011).

Manufacturing of pellets in Russia is just beginning to emerge. At present moment, the pellets are manufactured exclusively for industrial purposes, however, due to the lack of domestic demand, production is focused on export to Western Europe. This sector of bioenergy for today is one of the leading regarding the investment volume and the level of practical interest of the business (Sedova, 2015). But for agricultural producers, cultivation of *Miscanthus* involves certain risks, since it is almost impossible to get a crop of top in a year of plantation establishment, especially in risky farming areas where rainfall is a limiting factor. Therefore, in order to introduce this valuable fuel crop into production in the zone of unstable humidification, it is necessary to study the agrobiological features of *Miscanthus,* to determine its productivity and calorific capacity.

Materials and Methods

Miscanthus giganteus was planted in the conditions of the forest-steppe in Middle Volga on the collection plot of FGBOU VO of Penza State Agrarian University on the 6th of May, 2013, on light-gray soil, the arable horizon of which is characterized by the following agrochemical parameters: pH – 5.7 (GOST 26483-85), humus content – 2.7 % (GOST 26213-91), easily hydrolyzable nitrogen – 102 mg/kg of soil(according to the Korn field method), available phosphorus – 188 and exchange potassium – 110 mg/kg of soil (GOST 26204-91).

The fundamental soil treatment was primary tillage after the harvest of summer wheat, which was the preceding crop and plowing to a depth of 22-25 cm. Harrowing was carried out for closing the soil moisture, in 5 days the cultivation and planting of *Miscanthus* was carried out in rhizomes with 2-3 buds on a depth of 8-10 cm according to the 100 × 50 cm pattern. Research and evaluation of experimental results were carried out according to generally accepted methods (Dospekhov, 1985 and Grigoryev *et al.*, 1989). Content of moisture (EN 14774-1), ash (EN 14775), sulfur (EN 15289), the yield of volatile matter (EN 15148) and calorific capacity (EN 14918) of the *Miscanthus* stems was determined in an accredited laboratory of Incolab Services Russia SC (Saint Petersburg).

Results and Discussion

When cultivating *Miscanthus giganteus* during seven years (2013-2019) in the forest-steppe of Middle Volga, various conditions for moistening were developing. At this, the most optimal was the year of plantation establishment, when the annual rainfall was 664 mm, i.e. was at the level of the required amount for the normal growth and development of plants, especially in the initial stages of ontogenesis. Temperature, promoting the active leaves development exceeded the minimum (+5…+10°C) by 7…12° C.Though the temperature necessary for the intensive photosynthesis was lower than the optimal (+28…32° C) and was 20° C on average during the growing season, its sum was sufficient for the formation of a high yield of *Miscanthus* biomass in the first year of life - 14 t/ha.

The effect of unstable winter temperatures was softened by a thick snow cover, which contributed to the successful over wintering of *Miscanthus* and its regrowth on May 5, 2014.Hydrothermic coefficient (HTC) of the growth season made up 0.87(Fig. 1). However, elevated temperatures and shortage of precipitation did not reduce the productivity of the *Miscanthus* top in the second year of life, but on the contrary, it doubled due to the good development of yearlings.

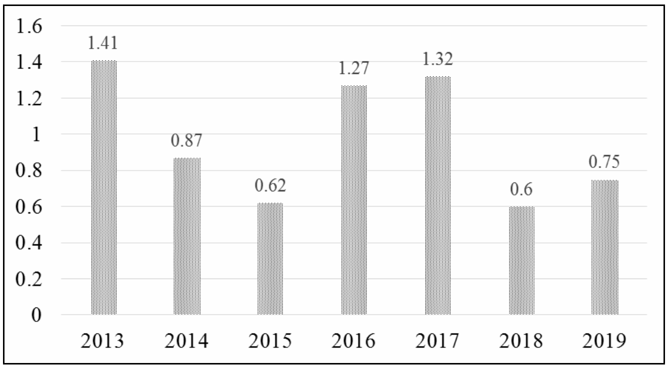

Fig. 1: Hydrothermal coefficient of the vegetative period of giant *Miscanthus* in years of research

Spring regrowth of *Miscanthus* in 2015 happened one week later than in the previous year, since the amount of precipitation in the winter period exceeded the climate norm by 25 mm, and the temperature in the first half of May was 2.2°C lower than the long-term average annual, which led to a delay of snow melting. Winter moisture reserves leveled their deficiency in May, when the HTC made up 0.25. In conditions of sufficient moisture (HTC – 1.28), an intensive growth of top took place in June and July. The absence of precipitation in the next two months did not affect the productivity of *Miscanthus,* and in the third year of research life, it made up 36 t/ha (Fig. 2).

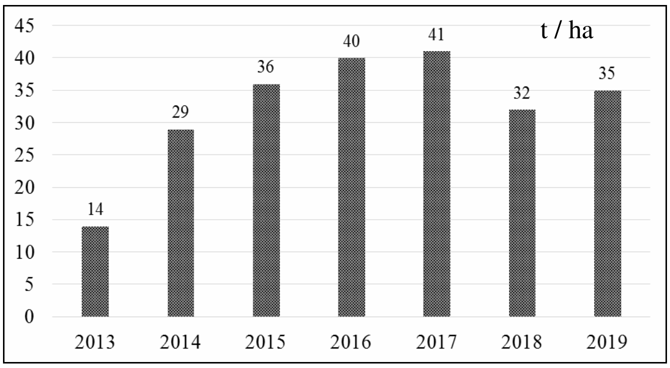

Fig. 2: *Miscanthus* productivity by years of research

Active growth of *Miscanthus* was observed in 2016, when humidification conditions coincided with the level of 2013. At the plant stand of 14 pcs./м^2 and height 3.2 m, the biomass yield made up 40 t/ha, the share of leaves was 35%. On the fifth year *Miscanthus* plantation (2017) the regrowth of plants happened in the middle of May for the average daily temperatures of the spring months were 0.3-3.1°C lower than normal. Moreover, two days before their appearance, night frosts were observed, which didn't affect *Miscanthus*. Lower temperatures in early summer also did not reduce the intensity of plant development.

According to the data of Figala *et al.*, 2015, Miscanthus on old-aged plantations is less sensitive to lower temperatures, where the photosynthesis is as active as at the optimal ones. The amount of precipitation occurred during the growing period of this year was 33 mm more than climate norm, which affected the productivity of *Miscanthus,* which made up 41 t/ha.

In the sixth year of *Miscanthus* life, in 2018, due to low temperatures in April, the spring regrowth of the plants happened only in the third decade of May, when an almost double mean rainfall occurred, which allowed the plants to intensively increase the top despite the June drought (HTC - 0.39). Rainfall in July (70 mm at the norm of 64 mm)and high temperatures (21.9° Cat the norm of 19.7°C) activated photosynthesis, by the following draught decreases the productivity of *Miscanthus* top to 32 t/ha.

2019 was characterized by insufficient moisture (HTC – 0.75) For *Miscanthus* this was the most unfavorable year, since the triple rainfall occurred only in the first ten days of August, when the lower leaves continued to function, but the regrowth of top had already stopped and there was an outflow of plastic substances into the underground organs, responsible for the future yield.

However, the aftereffect of arid conditions in 2019 affected the plant stand of *Miscanthus* in the seventh year of life, because the smaller rhizomes were formed with one – two buds of renewal. That's why there were 1.5 less stems per square meter. i.e. only 86 pieces. Biomass productivity was almost at the level of 2015 and the previous one, when the HTC was 0.6. Consequently, the draught caused a steady decrease in the rate of *Miscanthus* growth. This is especially noticeable at the repeated draught. Possibly that it leads to the suppression of the photosynthesis, which may indicate occurrence of disturbances in the photosynthetic apparatus as well as the increased respiration due to drought. Despite this, *Miscanthus* has high potential productivity in Middle Volga.

The results of seven-years old plant stems analysis show the possibility to use *Miscanthus giganteus* as fuel crop. Obtained data on the main environmental and energy characteristics comply with European standards, as there are still no relevant standards in Russia to date and the production market of these raw materials is poorly developed.

Calorific capacity of any fuel characterizes the amount of heat, emitted at the complete combustion of 1 kg of the fuel. Higher heating value of the sample as received made up 4219 Kcal/kg or 17.6 MJ/kg, the lowest heating value – 3895 Kcal/kg or 16.3 MJ/kg. These indicators exceed the requirements of the European standard (not less than 16 MJ/kg) (Table). The higher is the calorific capacity of the fuel, the lower its consumption. Calorific capacity, in turn, depends on combustible components, moisture content and ash content of the fuel.

The moisture content of chips from the stems of *Miscanthus* did not exceed 8.5%, which exceeded the standard requirements by 1.5%. Ash content of the raw material made up 1.7% (the standard is not more than 3%) (Table). Moreover, the ash from the stems may be used as an eco-friendly potassium fertilizer.

Combustible components include carbon monoxide and sulfur. The volatiles yield in the production sample was 75.3%, which is confirmed by the data of scientists from Bosnia and Herzegovina (Čustović *et al.*, 2016). Their high content indicates that the chips flare up and burn out quickly. And the low content of Sulphur of 0.06% leads to a slight formation of oxides in the combustion process, which accordingly reduces the risk of their transformation into sulfuric acid in the air.

Table 1 : Chemical composition and heat of combustion of wood chips of *Miscanthus giganteus*

Index	European Standard	*Miscanthus giganteus*	European standard requirements
Total moisture, %	EN 14774-1	8,5	<10,0
Ash content, %	EN 14775	1,7	<3,0
Volatile matter, %	EN 15148	75,3	<85
Sulfur, %	EN 15289	0,06	<1,0
Calorific value, gross /net MJ / kg	EN 14918	17,6/16,3	>16,0/13,4

Conclusion

Miscanthus giganteus growing in the zone of unstable moisture on low fertile soils, has a high potential productivity from 29 to 41 t/ha, starting from the third year of life. Notable for its high life expectancy (20–25 years), *Miscanthus* will be able to enrich the assortment of fuel crops both in Middle Volga and in Russia. Eco-friendly fuel in the form of *Miscanthus* chips produced from the harmless to humans and the environment material, corresponds to green technology. The energy value of *Miscanthus* biomass combustion is equal to wood, and wood chips are superior to other types of fuel in calorific capacity.

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