Scientific Papers. Series A. Agronomy, Vol. LXIII, No. 1, 2020
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

POTENTIAL OF *Miscanthus giganteus* AT INTRODUCTION IN THE MIDDLE VOLGA REGION

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Abstract

Along with industrial and food crops, energy crops as fast-growing species could form abundant biomass. One of such species of raw materials is Miscanthus giganteus which grows in one place for more than 25 years and annually could produce powerful ground mass even on poor lands since the third year of its life. To study the agrobiological features of Miscanthus giganteus and its introduction in the Middle Volga region, a plantation was laid on the light gray soil of the experimental field near Penza State Agrarian University (Russia) FSBEI HE Penza GAU in 2013. The accumulated snow cover contributed to a good wintering of the culture, and in the second year of life, its productivity increased by 15 t/ha. The next year of research, it was 36 t/ha, despite the arid conditions. Consequently, it should be mentioned that during the introduction of Miscanthus giganteus in zones with unstable moisture on poor soils, it is possible to obtain, if not a stable, but a sufficient high yield of raw materials.

***Key words**: Miscanthus giganteus, introduction, productivity.*

INTRODUCTION

Currently, the world’s energy sector, automobile, marine, rail transport and aviation, housing and communal services and other sectors of the economy are based on such natural mineral resources as oil, gas and coal. But their use is not unlimited, as well as wood. Therefore, humanity must work out all possible options for replacing hydrocarbons. In this regard, along with technical and food crops, energy crops begin to appear, which are combined by the term “biomass”.

The plant world presents unlimited possibilities of choice. As objects are considered woody, reed, grassy plants. But, first of all, researchers pay attention to fast-growing species (Babich et al., 2019), which form abundant biomass subject to environmentally friendly technologies (Gismatulina et al., 2015).

In the coming decades, the use of renewable plant materials as sources of thermal energy will become the main component. *Miscanthus giganteus* could become one of such objects. This is a multi-purpose crop plant (Schroder et al., 2018), growing in one place for 25-30 years and producing annually powerful above-ground raw material mass, starting from the third year of life (Gushchina et al., 2018).

This plant is positioned to produce biofuels (Somerville et al., 2010). Being a group of plants with the mechanism of C4 photosynthesis, *Miscanthus* efficiently accumulates solar energy and produces such an important component of photosynthesis as cellulose (Morandi et al., 2016; Xue et al., 2017), which serves as a base product for many developments with improved physicochemical characteristics.

These include, for example, tissue paper and writing paper, bacterial cellulose with a hemostatic effect, a biodegradable product used to make packaging materials that make up a worthy replacement for plastic. For the production of ballistic powder, the raw materials are cellulose nitrates. *Miscanthus giganteus* short cellulose fiber provides a clear cross in the training targets of shooters and athletes, and in the textile industry its cellulose is used for the production of denim. Therefore, to obtain cellulose with high quality characteristics, it is necessary to grow *Miscanthus giganteus*, whose raw materials can be obtained without prejudice to food crops.

For agricultural producers, while expanding the range of cultural flora of the region, certain risks are assumed. To avoid this, it is necessary to study the agrobiological features of *Miscanthus giganteus* upon its introduction in the Middle Volga (Russia).

MATERIALS AND METHODS

The *Miscanthus giganteus* plantation was laid on the light gray soil of the collection area belonged to the institution of higher education Penza state Agrarian University (Penza, Russia) in the first decade of May, 2013. The precursor of the crop was spring wheat after harvesting which, stubble cultivation and plowing were carried out to a depth of 20- 22 cm. Soil preparation in the spring consisted of harrowing. Planting was carried out with rhizomes to a depth of 10-12 cm with a row spacing of 100 cm and a distance in the row of 50 cm. According to an agrochemical examination, the soil of the site was acidic - close to neutral (pH - 5.7) (Interstate Standard (IS) 26483-75), with a low humus content - 2.7% (IS 26213-91) and easily hydrolyzable nitrogen 102 mg/kg of soil (according to the Kornfield method), high - available to plants phosphorus - 188 mg/kg of soil and exchange potassium - 110 mg/kg of soil (IS 26204-91). All analyzes and surveys were carried out according to the methodology of the State variety testing of agricultural crops.

RESULTS AND DISCUSSIONS

When introducing the culture into the new climatic conditions, it is necessary to establish its response to the factors determining growth, development and productivity. One of the main factors of decisive importance in the conditions of the Middle Volga region (Russia) is the amount of precipitation and their distribution over the growing season.

The annual rainfall from the planting of *Miscanthus giganteus* in 2013 to the second decade of May, 2014 was 664 mm, which is only 36 mm less than the culture requirements established. It should be noted that 58% of the precipitation occurred during the growing season. Hydrothermal Coefficient (HC) was 1.41, that is, the planting year of the plantation was characterized by sufficient moisture with a total of active temperatures of 2643°C (Table 1). The appearance of *Miscanthus giganteus* seedlings observed on May 27, first of all, depended on the quality of planting material, which was not visually infected with diseases and 3-4 regeneration buds were observed on each rhizome. Therefore, insufficient rainfall in May (28 mm at a norm of 43.4 mm) did not affect the germination of *Miscanthus giganteus*, and their almost triple norm in the second half of June contributed to the good development of shoots from 4 to 8 in the bulk of plants, in single plants - one stalk. Optimum humidification conditions at elevated temperatures from the third decade of July to mid-September led to an intensive growth of *Miscanthus giganteus* with a slowdown at the end of the month. With a foliage of 38%, the height of the plants even in the first year of life exceeded 180 cm due to developed leaves.

Table 1. Hydrothermal coefficient of the growing season *Miscanthus giganteus* in years of research

Month	Years						
	2013	2014	2015	2016	2017	2018	2019
May	0.52	1.08	0.25	1.80	0.64	0.54	0.5
June	1.40	0.98	1.14	0.43	1.15	0.39	0.35
July	0.79	0.60	1.40	1.64	1.41	1.08	0.76
August	1.15	0.51	0.14	0.36	0.19	0.25	1.38
September	3.20	1.17	0.15	2.10	3.20	0.72	0.77
For vegetation	1.41	0.87	0.62	1.27	1.32	0.60	0.75

With the decrease in the daily average temperature to 8°C, the growth of plants stopped and with the first frosts of October the leaves lost turgor, which subsequently drooped, remaining on the stems.

Therefore, another factor affecting the productivity of *Miscanthus giganteus* is the length of the frost-free period, which limits the limits of the growing season. In plants of the first year of life, the period from germination to harvest lasted 133 days.

When determining the structure of the bush, it was found that by the end of the growing season, from each rhizome, on average, 11 stems were formed with a height of 85 cm and a thickness of 10 mm at the base. Their total weight was 335 g and with a stem density of 46 pcs/m^2, a high yield of aboveground mass of 14 t/ha was formed (Figure 1).

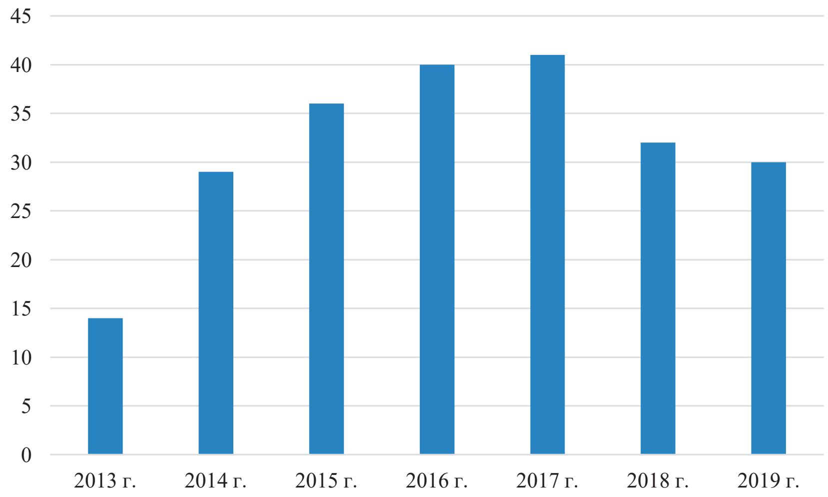

Figure 1. *Miscanthus* productivity by years of research

Important unregulated factors for perennial crops are winter air temperatures, the duration of the snow cover period and its thickness. The increased risk of successful *Miscanthus giganteus* overwintering (2013-2014) is associated with sharp temperature fluctuations and an unstable snow cover.

Precipitation in the form of snow in December fell 1.5 times less than normal at an average daily temperature of minus 3.8°C. Their significant fluctuations from +1.2°C to -31.7°C were observed in January. In the form of rain and snow, precipitation fell 2 times higher than normal.

After a three-day thirty-degree frost in February, by the end of the first decade, the temperature rose to minus 1.9°C with the amount of precipitation exceeding the norm by 37%. In the following decades of the month, as well as in March, sharp fluctuations in temperature and precipitation were observed. However, the remaining stems delayed the snow and the underground organs were not affected.

The moisture that formed on the surface during the thaw in April was gradually absorbed into the still loose soil layer. Therefore, in the spring of 2014, the soaking and milking of the organs of renewal of *Miscanthus giganteus*, which include root offspring with wintering buds, were not noted.

In the third decade of April, the average daily temperature was established plus 10°C at which the *Miscanthus giganteus* continued its ontogenesis and its full regrowth was noted on May 5. With a daily gain of 3.6 cm, already in early June, plants exceeded a meter height. This was also facilitated by moderate hydration during this period.

Elevated temperatures in July and August only contributed to the active process of photosynthesis and the economical consumption of water by *Miscanthus giganteus*. This led to a better development of the assimilation surface, and, consequently, to an increase in biological productivity.

September precipitation and temperature corresponding to the climatic norm did not reduce the intensity of plant development. Their height slightly exceeded 220 cm and the yield of the aerial mass of *Miscanthus giganteus* of the second year of life was 29 t/ha, and the more developed root system began to gradually colonize the soil space.

In the following autumn months, 64% of normal precipitation fell at temperatures below the annual average. However, in winter it was warmer by 1.5-6.6°C, and the amount of precipitation exceeded the climatic norm by 25 mm. This led to an increase in the thickness of the snow cover, an increase in the winter hardiness of the underground organs, and a decrease in the rate of snow melting. In this regard, in 2015, spring growth of *Miscanthus giganteus* was observed a week later than in the previous year. May drought (HC - 0.25) did not affect the growth of the crop, since *Miscanthus giganteus* used winter moisture reserves. And in June and July there were conditions with sufficient moisture, when the HC amounted to 1.14 and 1.40, respectively. It was during this period that there was an intensive increase in the aerial mass with a stem density of 122 pieces/m^2 and a height of 385 cm. Plants of the third year of life showed high resistance to lodging, since the thickness of the stem at the base reached 1.5 cm.

Under very dry conditions in August and September (HC - 0.14), the lower leaves began to dry out, which no longer participated in the photosynthesis process due to their shading. The growth of plants in height also did not occur, but the productivity of the aboveground mass increased by 7 t/ha compared to the previous year.

The next two years of the life of *Miscanthus giganteus* (fourth and fifth) according to moisturizing conditions corresponded to the first year of research. At the same time, in 2016 precipitation fell 67 mm more than normal, and in 2017 - at its level. It should be noted that the greatest number of them was 96 and 126 mm in September, when there was no increase in above-ground mass, as well as in the August drought (HC - 0.36 and 0.19, respectively).

However, at this time, the outflow of lamellar substances into the underground organs, which were responsible for the future crop, was actively passing. During the period of active growth of *Miscanthus giganteus* from May to July, HC for these years of research was 1.29 and 1.10, which affected its productivity, which was almost the same 40 and 41 t/ha with a stem density of 140 pieces/m^2 and height stems without leaves 242-250 cm. It would seem that, under the same conditions of plant growth, the spring of 2017 was cooler than the previous one. This led to a late spring regrowth of *Miscanthus giganteus*, which allowed him to avoid night frosts in mid-May and subsequently not to reduce the productivity of the aerial mass.

Thawing of the soil on the *Miscanthus giganteus* plantation in the spring of 2018 was delayed due to more severe winter conditions and the first spring month, when the average daily temperature was 2°C below normal. The amount of precipitation exceeded the annual average by 37 mm. Despite a sharp increase in temperature in May (up to 17.5°C), soil heating was weak, which led to the growth of *Miscanthus giganteus* only in the third decade, when an almost double rainfall fell.

The June drought (HC - 0.39) reduced the growth rate of *Miscanthus giganteus*, but July rainfall of 71.7 mm and high average daily temperatures (21.9°C at a rate of 19.7°C) led to active assimilation of leaves and plants reached a height of 270 cm with stalk 132 pcs/m^2. This was facilitated by the temperature, which is considered optimal for adequate photosynthesis.

However, in August and September there was no increase in above-ground mass, since dry weather was during this period (HC - 0.48). With good development of the leaves of the upper third of the stem, the lower leaves dried out and crumbled. The hydrothermal coefficient for the growing season was 0.60, which corresponds to insufficient moisture. The yield of the aerial mass of *Miscanthus giganteus* decreased by 9 t/ha compared to the crop of 2017, when the conditions of sufficient hydration of the State Customs Committee -1.32

In the seventh year of life of *Miscanthus giganteus*, i.e. in 2019, in conditions of insufficient moisture (HC - 0.75), the yield of the aboveground mass of *Miscanthus giganteus* at the level of the previous year was 30 t/ha. In April, after the liberation of *Miscanthus giganteus* from snow, a gradual heating of the soil began. The average daily temperatures in May, exceeding the norm by 4.1°C, stimulated the growth of plants, but this month the precipitation was 29% less than the average annual.

During the first two summer months, according to the biology of the culture, the vegetative organs of plants undergo intensive development, but the existing drought (HC - 0.5 and 0.76) caused a steady decrease in the relative growth rate and the daily growth of plants did not exceed 2 cm. Precipitation the first decade of August (70 mm with a climatic norm of 19 mm), increased the viability of the lower leaves, but the number of stems per square meter decreased to 86 pieces against 132 in the previous year. Probably, the aftereffect of the dry 2018 affected the formation of rhizomes with kidney renewal. However, the stems reached a height of 224 cm with a diameter at the base of up to 12 mm. Therefore, its productivity corresponded to the yield obtained in the years with the HC - 0.6, i.e. in the third and sixth year of *Miscanthus giganteus* life.

CONCLUSIONS

Miscanthus giganteus, being a promising renewable raw material in the field of alternative energy and having a number of economic and environmental advantages over other sources, can compete with wood and hydrocarbon raw materials. When introduced into the forest-steppe of the Middle Volga region (Russia), it exhibits high resistance to adverse moisture conditions.

However, as the duration of the drought conditions increases, the ability of plants to adapt decreases, which is clearly manifested when it repeats. At the same time, productivity decreases by 25% compared to years with increased moisture (2016-2017).

Nevertheless, starting from the third year of life, *Miscanthus giganteus* can produce 30- 41 t/ha of aerial mass annually, even on marginal lands.

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