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Received: 2018-06-05 ; Accepted: 2018-11-19

IMPACT OF THE SOIL AND CLIMATE CONDITIONS ON THE FORMATION OF THE CROP YIELD AND GERMINATING POWER OF THE SWITCHGRASS *(Panicum virgatum* L.*)* SEEDS

Summary

This paper investigates the productivity of the switchgrass seeds (Panicum virgatum L.*) in close interaction with the agro-ecological conditions of the vegetation period. An impact has been established of the storage period on the indicator of the laboratory germination power of the seeds, which has been obtained under different soil conditions. In the future a high-quality seed material of the switchgrass can provide better conditions for the growth and development of plants in the initial stages of organogenesis.*
***Key words**: switchgrass, soil, temperature, seeds, crop yield*

WPŁYW WARUNKÓW GLEBOWYCH I KLIMATYCZNYCH NA WIELKOŚĆ PLONU I ZDOLNOŚĆ KIEŁKOWANIA NASION PROSA RÓZGOWEGO *(Panicum virgatum* L.*)*

Streszczenie

W pracy zbadano produktywność nasion prosa rózgowego (Panicum virgatum L.*) w ścisłym powiązaniu z warunkami rolno-ekologicznymi okresu wegetacji. Ustalono wpływ okresu przechowywania na wskaźnik zdolności kiełkowania nasion przez laboratorium, uzyskany w różnych warunkach glebowych. W przyszłości wysokiej jakości materiał może zapewnić lepsze warunki wzrostu i rozwoju roślin w początkowych etapach organogenezy.*
***Słowa kluczowe**: proso rózgowe, gleba, temperatura, nasiona, plon*

1. Introduction

Switchgrass is a drought-resistant, perennial cereal plant that has a simplified cultivation technology with minimal application of fertilisers and that does not require irrigation. This reduces energy consumption, the cost of production and the amount of the greenhouse gas emissions. Moreover, switchgrass is unpretentious to soils and is not a competitor for the food crops since it is grown on infertile (marginal) lands [2, 6, 20]. The raw materials of switchgrass are used to produce solid biofuel (fuel pellets, briquettes) and liquid biofuel - cellulose ethanol [11].

Like other energy crops, switchgrass is not pretentious to soil; it is grown on marginal lands, so it is not a competitor for the food crops. In soils that are poor in nutrient elements switchgrass can grow normally and form biomass [3].

Switchgrass belongs to the plants with a C4-type photosynthesis, which determines its drought resistance due to increased efficiency of water consumption and reduced evaporation of water [9]. The varieties of switchgrass, based on the ecological approach, are divided into highland and lowland sorts [11. Switchgrass ripens at the end of September - the middle of October. The vegetation period lasts 175-185 days [10].

Under the Ukrainian conditions the crop yield of the overground switchgrass phytomass during the emergence of panicles is 42-64 t ha^{-1}, during the flowering period - 42.73-70.19 tons / ha, the dry mass - 10-15 t ha^{-1}; the seeds - 500-600 (sometimes up to 1000) kg ha^{-1}. The energy efficiency of plants is 40-60 (up to 80) Gcal ha^{-1} [17].

When the plants reach the beginning of the seed-forming stage, the producers should evaluate their crops to determine whether to leave plants till autumn and harvest the seeds or to give up the seeds and harvest the biomass yield, and use it as animal feed or for the production of hay [5].

In case when switchgrass is cut to obtain seeds, it is harvested by combine harvesters or in a two-part manner - by cutting in swaths with following threshing after the panicles are dried. After harvesting the seed material should be conditioned to prepare it for sale, including the removal of residues, the weed seeds, the seeds of agricultural crops and other materials. A typical switchgrass seed test (%): purity: 95+, germination 40, rest: 50 [4, 12].

Switchgrass has a low seed germination power after harvesting. Therefore various methods are applied to increase this indicator: stratification, scarification, sorting by the aerodynamic properties, selection by specific gravity [1]. At the same time domestic publications do not fully reveal the issues concerning the level of the switchgrass seed yield depending on the soil-and-climatic conditions and the dynamics of the germination ability of the seeds stored for a long-term.

The research in the seed yield, taking into account the weather conditions for vegetation, will provide a possibility to determine the most critical periods of organogenesis and develop measures for their optimisation due to the impact of various measures.

2. Materials and methods

The purpose of the work is to study the seed productivity of switchgrass by quantitative indicators of the plants depending on the weather conditions in the vegetation period in the central part of Lesostep (the Forest Area) of Ukraine.

Investigations were carried out by laying out the field and conducting the laboratory experiments with a variety Cave-in-rock of switchgrass under the same conditions in different soils:

Factor A – fertile soils with 4% humus content,

Factor B – low-fertility soils (marginal lands) with 2% humus content.

The area of each accounting plot was 50 m^2, the repetition of the experiment was four times. Replication of the experiment - four-fold. Arrangement of the plots on the area of the field was randomised.

The experiments were carried out by means of the following observations, accounts and analyses: planning and laying out experiments on the methodology of scientific research in agronomy [14] and according to methodological recommendations [16]; the phenological observations on the growth and development of plants were carried out by the methodology of the state varietal testing of agricultural crops [13]; determination of quantitative parameters of switchgrass plants - according to appropriate methodologies [15, 18, 19]; when the phytomass yield was accounted, the seed yield was determined by weighing the seed material with subsequent recalculation to the standard moisture [7]; the mass of 1000 seeds was determined according to Standard GOST 4232-2003; the statistical processing of the research results was executed with the help of the dispersion, correlation-regression analysis using a licensed application computer program Statistica-6.0.

The switchgrass plants are sufficiently sensitive to changes in the weather conditions during their vegetation; therefore, when determining the seed productivity of the crop, the characteristic of the meteorological indicators that were during the research period (the years 2012-2016) is important.

The average value of the average daily air temperature trend in May-September indicates an increase in the value of this indicator during the 2013-2014 vegetation period, and a significant decline in 2012. The amount of precipitations over this period varied within wide limits. A more impartial indicator of the weather conditions is the hydrothermal coefficient (HTC), which varied within the limits from 0.1 (2012) to 1.2 (2015), Fig. 1.

After the analysis of the weather conditions in the vegetation period according to the HTC, it was determined that the years 2012 and 2013 are marked as dry, in 2015 - more wet, and the years 2014 and 2016 are characterised by average precipitations.

3. Results

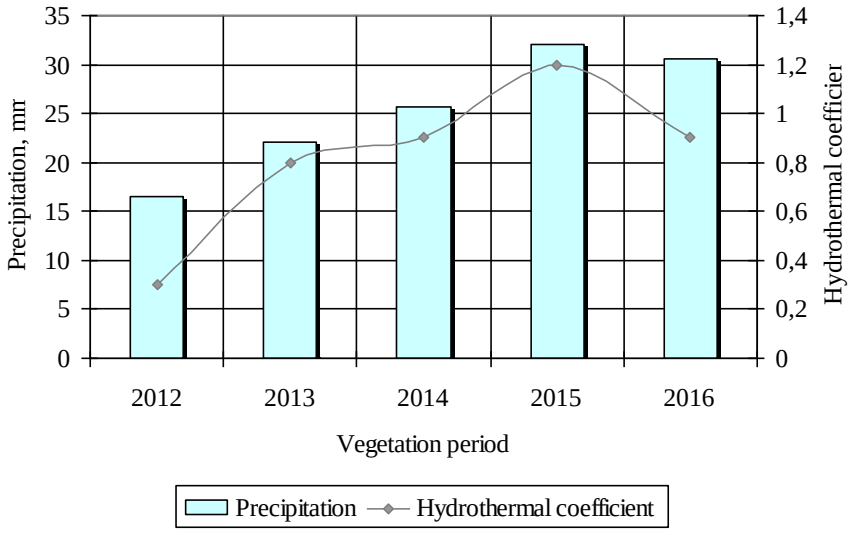
Depending on the soil and weather conditions the quantitative indicators of the switchgrass plants varied in a wide range (Table 1).

During the years of investigations the height of the switchgrass plants varied widely between 138.3 and 182.0 cm in fertile soils, and from 112.5 to 166.8 cm on marginal lands. This indicator was the highest in 2015, essentially less - in 2012-2013, which were respectively determined by the HTC as arid; in 2014 and 2016, under the conditions of insufficient humidity, average values were obtained for this indicator.

The number of the switchgrass plants per unit of area during cultivation, both in fertile soils and on marginal lands, was higher in 2014 and 2016, significantly lower - in 2012-2013, the average value of this indicator was noted in 2015.

The structural analysis of the panicle allowed revealing that the total number of seeds from the panicle branches of different order of the plants grown in fertile soils was within the range of 157.0-320.7 pcs. and it depended on the length of the panicle. The mass of 1000 seeds under these conditions varied in a wide range - from 1.53 g to 1.94 g. The greatest mass of 1000 seeds was formed under the conditions of 2014-2016. (with the HTC close, or more than 1.0), significantly less - in 2012-2013, which had HTC indicators less than 1.0, which characterises this period as arid.

On marginal lands the quantitative indicators of the generative part of the plants were significantly smaller but their tendency to change over the years of research remained unchanged.



Source: own work

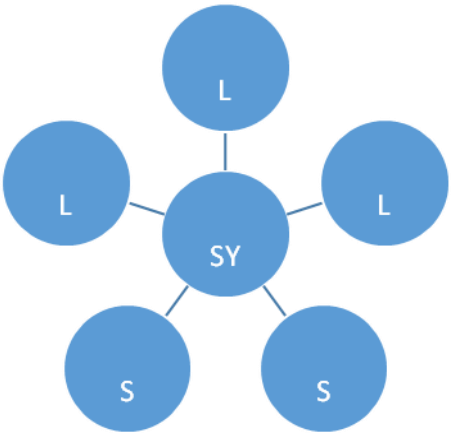
Fig. 1. Hydrothermal coefficient and average amount of precipitations during the 2012-2016 vegetation period of switchgrass

Table 1. Quantitative indicators the switchgrass plants, in the years 2012-2016

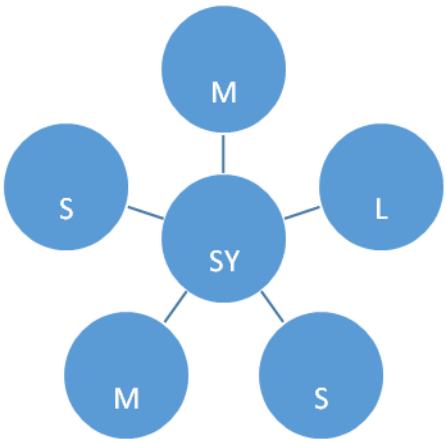
Indicators	Vegetation year					Duncan test, p 0,05
	2012	2013	2014	2015	2016	
The height of plants, cm	138.3 112.5	141.5 127.4	178.0 152.1	182.0 166.8	174.1 162.1	3.2 2.7
The number of stalks, pcs.	198.7 174.2	213.5 182.1	309.6 202.4	303.5 191.3	310.6 204.1	6.5 9.8
The length of the panicle, cm	25.2 24.1	27.4 25.6	52.0 37.7	51.2 33.2	43.4 30.6	2.7 1.4
The number of panicles, pcs	16.3 14.2	18.7 16.4	34.1 24.7	32.0 19.3	30.7 21.9	4.1 1.3
The mass of seeds from one plant, g	157.0 142.3	214.4 194.4	288.0 212.7	320.7 254.1	252.3 218.1	9.8 7.2
The mass of 1000 seeds, g	1.53 1.03	1.62 1.21	1.82 1.45	1.94 1.52	1.79 1.29	0.15 0.06

Note: In the numerator (the number above the line) there are data obtained from fertile soils, in the denominator (the number under the line) - data obtained from marginal lands.

Source: own work



Factor A



Factor B

Note: SY - seed yield, S – strong connectivity, M – middle connectivity, L – limp connectivity

Explanations:

Indicators	Designation
The height of plants, cm	
The number of stalks, pcs	
The length of the panicle, cm	
The number of panicles, pcs	
The mass of 1000 seeds, g	

Source: own work

Fig. 2. The correlation coefficient of the quantitative plant characteristics and the switchgrass seed productivity, 2012-2016

The conducted correlation-regression analysis made it possible to establish correlations between the quantitative indicators of the plants and the switchgrass seed productivity, respectively, in fertile soils and on marginal lands – factor A and factor B (Fig. 2).

The factors that exert the most significant impact on the switchgrass seed productivity in fertile soils are: the length of the panicle (0.60 ... 0.78 cm), in certain years (2014 and 2016), with insufficient moisture supply to the plants, the number of panicles on the plant (0.41 ... 0.39 pcs) and the height of the plants (0.33 ... 0.41 cm); in the years with prolonged drought - the mass of 1000 seeds (0.31 g).

A similar tendency has been observed on marginal lands, yet with an increasing impact of the mass of 1000 seeds on the yield of seeds.

The yield of the switchgrass seeds, which is in close correlation with the seed productivity (0.74 ... 0.80 g), was significantly higher in the years with the HTC, which is close to the moderate moisture content of the plants, or with an indicator of more than 1 (Fig. 3).

The highest yield of the switchgrass seeds in fertile soils was formed in 2014 and 2015 (respectively, 0.93 and 0.86 t ha^{-1}) at LSD05 0.13, which is due to the morphological parameters of the panicle and the weather conditions that occurred during the vegetation of the crop in this period. The average value of this indicator was recorded in 2016 (0.76 t ha^{-1}); significantly lower yield of seeds was in 2012-2013 which resulted from arid conditions (respectively 0.47 and 0.64 t ha^{-1}).

A similar situation, but with lower yield indicators of the seeds, was recorded in infertile soils. The yield of the switchgrass seeds varied from 0.28 to 0.52 t ha^{-1}, with the highest value in the years with HTC close to 1.

During the study of the peculiarities of the post-harvest maturity of the switchgrass seeds, an impact of the storage period on the seed germination (Fig. 4) was established.

Regardless of the conditions for growing maternal plants, it is noted that during the first years of storage there is a gradual increase in seed germination with a sharp increase in the indicator after 3 years of storage (factor A), and a slight increase in the seed germination, which was produced on marginal lands (factor B).

It was established that the seeds grown on marginal lands have a longer post-harvest maturity and low germinating capacity, even in long-term storage (20.2%) in contrast to those grown in fertile soils (35.8%).

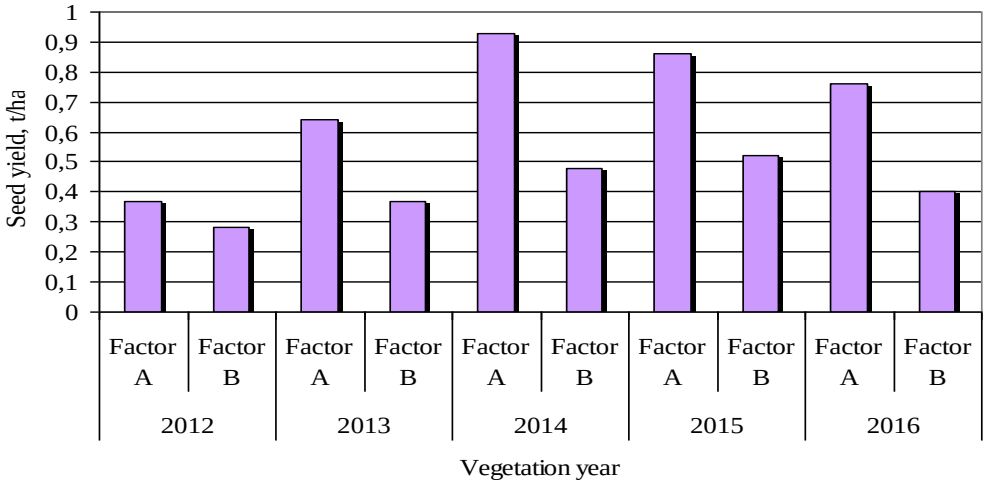


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Fig. 3. Productivity of the switchgears seeds (t / ha), 2012-2016 [LSD $_{05}$ 0,13 (Factor A), LSD$_{05}$ 0,07 (Factor B)]

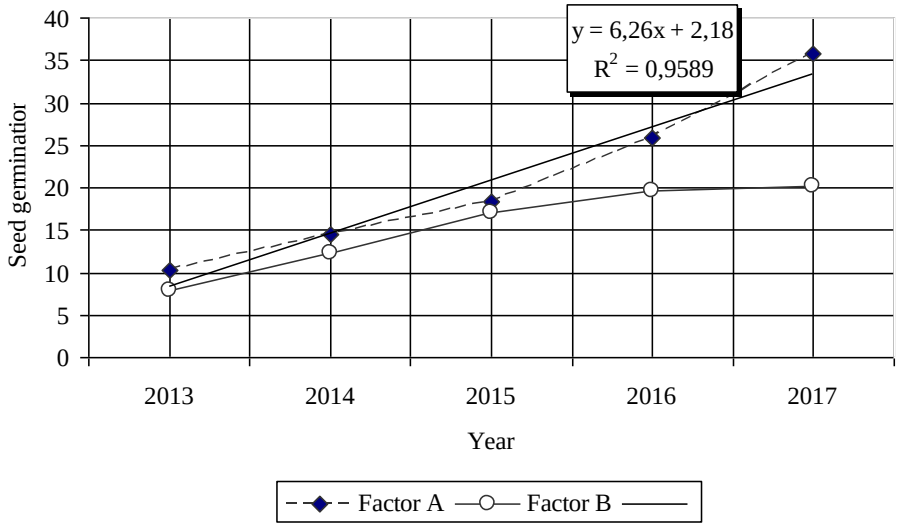

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Fig. 4. Dynamics of the switchgrass seed germination depending on the storage period, 2013-2017.

4. Conclusions

1. An increase in the quantitative indicators of the switchgrass plants (the average height of the plants, length of the panicle, their quantity, the mass of seeds from the plant and its size) was obtained in more humid years with the HTC approximated (equal to) or more than 1.0.
2. A high yield of the switchgrass seeds is formed under the impact of the length and the number of panicles on the plants under the humidification conditions which are close to optimal. Under arid conditions the impact of the plant height the panicle length and the mass of 1000 seeds - the indicators that determine the seed productivity of the crop – increases. This tendency does not depend on the fertility of the plants and is probably related to the specific features of the crop.
3. The yield of seeds is to a greater degree determined by soil-climatic factors.
4. The period of the post-harvest maturity of the switchgrass seeds, grown on marginal lands, is more prolonged than in fertile soils, which is due to the adaptive reactions to unfavourable conditions for the growth of the maternal plants that are inherited by their off springs.

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Acknowledgements
We are grateful to the scientists of the Wageningen University (the Netherlands) who supplied us with original seeds for the research project.