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Formation of Seed Quality of Switch-Grass (*Panicum virgatum L.*) Depending on Cultivation Conditions and Varietal Peculiarities

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ABSTRACT

The results of the research concerning the formation of seed quality depending on the cultivation conditions and varietal peculiarities were presented in the paper. Analyzing seed quality in the years under study, it was found out that germination energy and seed emergence depended both on ripeness groups of switch-grass and the sum of effective temperatures in the vegetation period. The highest quality indicators were typical for an early cultivar (Dacotah), an early-ripening cultivar (Forestburg) and average-ripening cultivars (Nebraska, Sunburst); a reliable difference depending on varietal peculiarities was not recorded. Varietal samples of average-late ripening cultivars (Alamo, Cave-in-rock) had reliably lower quality indicators, and a very-late ripening cultivar Kanlow had the lowest ones. In the conditions of the Forest-steppe of Ukraine average-late, late and very late varietal samples do not ripen biologically which affects seed quality – its emergence is very low and amounts to 6–26%. By the years under study, the highest reliable germination energy and emergence of all varietal samples, particularly in a late ripeness group, were recorded in the vegetation year of 2018, and they amounted to 33–66% and 17–25%, respectively, which was predetermined by the sum of effective temperatures – over 3539 °C. Much lower indicators of seed quality were received in 2021, this year was the least favorable for the formation of high-quality seed, and the sum of effective temperatures was only 3080 °C. The conclusion can be made that in the period of vegetation the formation of quality seeds of switch-grass depended on the sum of effective temperatures which was lower than 3300 °C. It has been established that the later a ripeness group is, the larger sum of effective temperatures a varietal sample requires, and accordingly, a longer term for the occurrence of phonological phases of crop growth and development; this has an effect on the peculiarities of the seed formation and ripening and in turn on its quality. It was found out that the factor "the conditions of the year" had the highest effect on seed quality – 48%, and the factor "varietal sample – ripeness group" had the lowest one, namely 29% and 30%, respectively.

Keywords: varietal sample, germination energy, emergence, phonological development phases, ripeness group.

INTRODUCTION

To manufacture alternative energy sources it is important to use bio-energy crops which have several advantages: their cultivation is possible on low-productive and degraded soils which are not suitable for agricultural crops; they stop soil erosion and restore non-productive soils, they reduce deforestation, they decrease the application of traditional fuels – gas and coal (Kenneth P., et al., 2002;. Roik M.V., et al., 2015). Most of bio-energy crops are the ones of C_3 and C_4 types (Calabrò P.S., et al., 2018). The following plants present a practical interest for the production of bio-fuel of phyto-mass: sugar beets, switch-grass, sugar sorghum, miscanthus (Mozharivska I.A., et al., 2013), willow and poplar (Fuchylo Y.D., et al., 2009). In Ukraine, among new energy plants, switch-grass (*Panicum virgatum* L.), a perennial cereal crops, deserves a special attention as it can accumulate large amount of bio-mass due to photo-synthesis (Shcherbakova T.O., et al., 2017). In foreign countries this crop is researched for a comprehensive application – as bio-fuel, in livestock production and in paper industry (Wolf D.D., et al.,). During a vegetation period weather conditions have a serious effect on crop growth and development and, accordingly, on its productivity (Bransby D.I. et al.,1997). Switch-grass is propagated with seeds and rhizome (Elbersen H.W., et al., 2001; Beaty E.R., et al., 1978) and also with an accelerated technique of clone micro-propagation (Patent 85560 Ukraine, 2013). The crop has relatively small seeds with a high level of dormancy state. At a high level of dormancy state, seed emergence can be only 5%, and in field conditions such seeds do not germinate at all (Doronin V.A., et al., 2019). A biological dormancy state can be caused by a decreased activity of embryo (germ) or by various properties of its cover (Adkins S.W., et al., 2002; Li M., et al., 2010). Hence, all the elements of the cultivation technology of switch-grass seeds have to be concentrated on the creation of optimal conditions for going through the physiological processes which determine a high productivity of the plants and seed quality.

The purpose of the research is to identify some peculiarities of the formation of switch-grass seed quality depending on varietal features and cultivation conditions.

CONDITIONS AND METHODS

The research program envisages the regularities of the formation of switch-grass seed quality depending on varietal peculiarities and weather conditions in the years of vegetation. The research was carried out at the Institute of bio-energy crops and sugar beets of NAAS and in the conditions of Yaltushivska research-breeding station in the years of 2018–2021. The research scheme implied the harvesting and studying of the seeds of varietal samples of switch-grass of various ripeness groups – very early, average-early, average-late, late and very late – which were grown in the years under study in the conditions of Yaltushivska research-breeding station, situated in the area of unstable moisture of the Forest steppe of Ukraine.

Seed germination energy and emergence were determined in the laboratory conditions by the methodology of the Institute of bio-energy crops and sugar beets of NAAS (Doronin V.A., et al., 2015). Statistical processing of the experimental data was done by the technique of disperse and correlation analyses by Fisher's method (Fisher R.A., 2006) with the use of software Statistica 6.0 from StatSoft (Site of the company *StatSoft*).

The trials were carried out on low productive, grey opodzolic poorly-washed soils with low humus content which was equal to 1.56 %. The content of liable forms of phosphorus and exchangeable potash (according to Chyrykov) was 170 and 132 mg/kg, respectively, that of nitrogen, which hydrolyzes easily (according to Cornfield) – 59 mg/kg of the soil. Hydrolytic acidity, mg.-equiv. per 100 g of the soil was 2.7, pH – 5.1. Soil density was equal to 1.25 g/cm^3. The content of productive moisture in a 1-m soil layer was 110 mm.

RESULTS AND DISCUSSION

The terms of the appearance of sprout emergence is the beginning of all further phases of plant growth and development. In the conditions of Yaltushivska research-breeding station the appearance of full sprout emergence depended on both ripeness groups of switch-grass and the number of effective temperatures. The sum of effective temperatures is the sum of average temperatures per day, reduced to the value of biological minimumж it is used to determine the process of plant growth and development phases (Agro-forecast). Full emergence of early varietal sample Dacotah and average-early Sunburst was observed on May 15, and the sum of effective temperatures amounted to 406. 5 °C. Full emergence of average-late varietal samples was observed on May 20, 5 days later, and the sum of effective temperatures for them amounted to 474. 0 °C. Full emergence of very late cultivars was received the latest – May 25, the sum of effective temperature being 541.5 °C. A similar tendency of going through other phonological phases was observed. For instance, a phase of plant browning of a very early-ripening varietal sample Dacotah began on September 10 and the sum of effective temperatures was 2615.9 °C. This phase began on September 30 for average late varietal samples; the sum of effective temperatures was 2859.9 °C; the latest browning phase, namely on November 1, was for late varietal samples, and the sum of effective temperatures was 3080.0 °C. So, the more a varietal sample belongs to a late ripeness group, the larger sum of effective temperatures it requires, and in turn – a longer term for the beginning of a phonological phase of plant growth and development.

Seed germination energy and emergence depended on ripeness groups of the cultivars (Table 1). Very early, early-ripening and average-ripening cultivars had the highest quality indicators – germination energy and emergence; no reliable difference in correlation with varietal peculiarities was identified. Average late varietal samples had reliably lower quality indicators; a late cultivar had the lowest quality indicators.

L.E. Moser та K.P.Vogel (Moser L.E. et al., 1995) have stated that the main factors which determine the area of adaptation of a cultivar are the response to the length (duration) of a light day, the amount of precipitation and moisture. Average late, late and very late varietal samples do not ripen biologically which affects seed quality; also its emergence is very low. In our opinion, in this case neither of farm practices can ensure the increase of this indicator. Thus, to solve the problem of receiving high quality seeds of varietal samples of these ripeness groups, it is expedient to concentrate their cultivation in other soil-climatic conditions, the ones which are favorable for the formation of quality seeds of the crop.

Analyzing seed quality by the years under study it was found out that seed germination energy and emergence depended on both ripeness groups of varietal samples (Table 2) and the sum of effective temperatures in the vegetation period (Figure 1).

Reliably highest germination energy and emergence of all varietal samples, and in particular those of a late ripeness group, were in the vegetation year of 2018; they were equal to 33–66% and 17–25%, respectively, which was due to the sum of effective temperatures – over 3539 °C. Significantly lower indicators of seed quality were received in 2021, this year was the least favorable for the formation of quality seeds and the sum of effective temperatures was only 3080

Table 1. Seed quality depending on varietal peculiarities (in 2018–2021)

Treatment		Germination energy, %	Emergence, %
Varietal sample	Ripeness group		
Dacotah	Very early	45	48
Forestburg	Early-ripening	38	40
Nebraska	Average early	39	40
Sunburst	Average early	47	50
Cave-in-rock	Average late	31	32
Alamo	Average late	30	32
Carthage	Late	24	26
Kanlow	Very late	6	6
$SSD_{0.05\ gen.}$		5.9	8.0
$SSD_{0.05\ cultivar}$		2.9	4.0

Table 2. Seed quality depending on varietal peculiarities and vegetation conditions (in 2018–2021)

Varietal sample, ripeness group	Germination energy, %				Emergence, %			
	2018	2019	2020	2021	2018	2019	2020	2021
Dacotah, very early	66	49	43	25	66	51	44	25
Forestburg, early-ripening	57	36	56	-	60	37	58	-
Nebraska, average early	33	62	61	-	35	63	62	-
Sunburst, average early	37	59	67	11	45	59	69	13
Cave-in-rock, average late	42	35	36	7	46	36	38	7
Alamo, average late	58	42	30	0	59	43	31	1
Carthage, late	20	29	48	-	25	30	50	-
Kanlow, very late	17	1	5	0	17	1	6	0
$SSD_{0.05\ gen}$	5.9				8.0			
$SSD_{0.05\ year\ conditions}$	2.1				2.8			
$SSD_{0.05\ cultivar}$	2.9				4.0			

°C. In this year even very early varietal sample Dacotah formed seeds with germination energy and emergence equal to 25%. The seeds of late and very late varietal samples failed to germinate.

The vegetation periods of 2019 and 2020 were less favorable than the year of 2018, but they were more favorable as compared with the year of 2021. In these years the sum of effective temperatures amounted to 3300 °C, which facilitated the formation of quality seeds of all cultivars of switch-grass, except for cultivar Kanlow; this cultivar belonged to a very late ripeness group and its germination energy and emergence were 1–6%. The highest indicators of seed quality were typical for early-ripening cultivar Forestburg (56–58%) and average early cultivars Nebraska (61–63%) and Sunburst (59–69%).

The conclusion can be made that the formation of quality seeds of switch-grass depended on the sum of effective temperatures during the vegetation period which was at least 3300 °C.

The studies of the factors which had an effect on seed quality proved that in the vegetation period the effect of the factor “the conditions of the year” on germination energy and emergence was the highest, namely 47–48%, whereas the effect of the factor “varietal sample – ripeness group” was the lowest – 29% and 30%, respectively (Figure 2).

The research carried out earlier confirmed that the cultivars with a larger number of chromosomes were more productive. It has been established that triploid sugar beet hybrids have higher sugar content and sugar harvest per hectare, namely 17.8% and 9.11 t/ha, whereas these indicators for diploid hybrids are lower – 17.0% and 8.75 t/ha, respectively [4]. It means that hybrids with higher ploidy ensured higher crop productivity. This is the reason why at some time all breeding companies carried out active breeding work aimed at the development of triploid hybrids of sugar beets.

A similar correlation between the yield increase of seeds and ploidy of varietal samples was also recorded for switch-grass. On the average, in the years when the dependence of seed yield of varietal samples on their ploidy was studied, all octaploid varietal samples had reliably higher

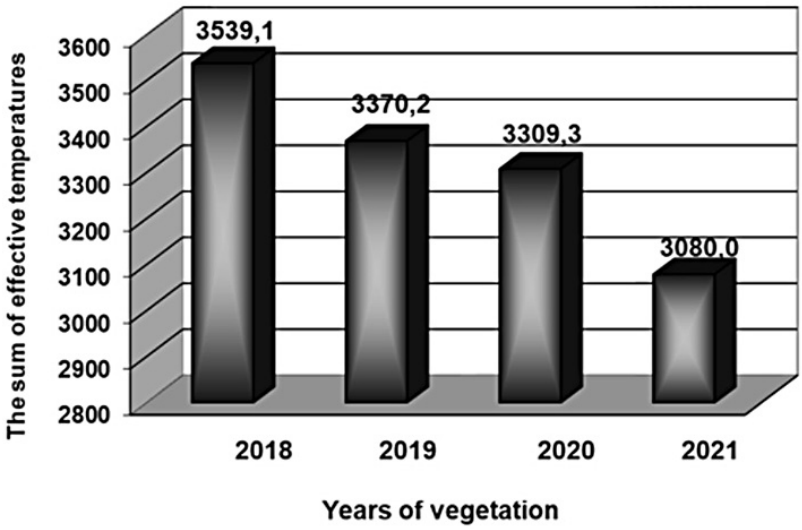

Figure 1. Sum of effective temperatures during the vegetation period

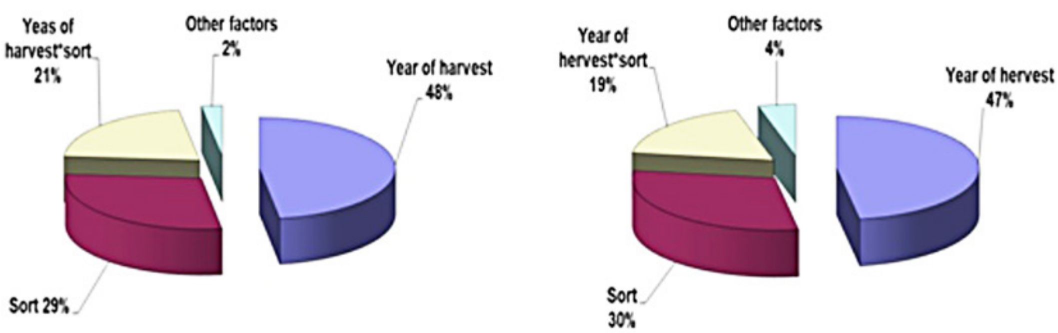

Figure 2. Effect of the factors on seed quality of switch-grass

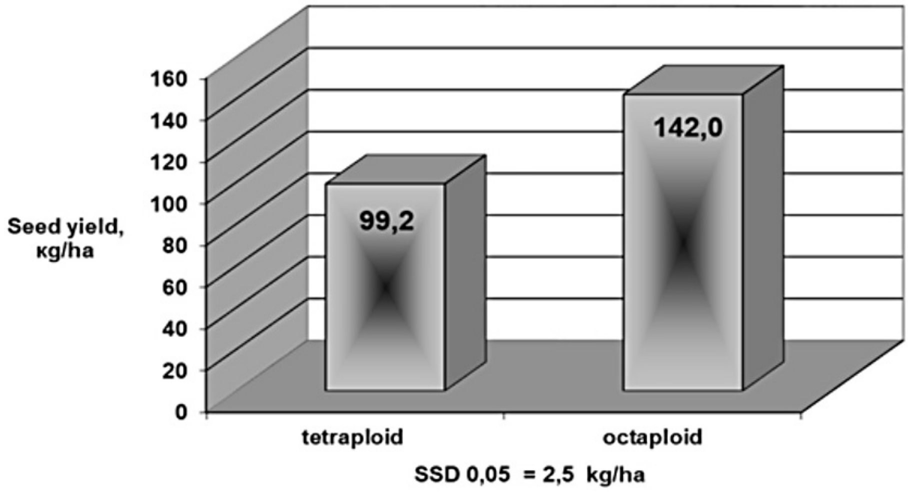

Figure 3. Seed yield capacity depending on ploidy of cultivars (in 2020–2021)

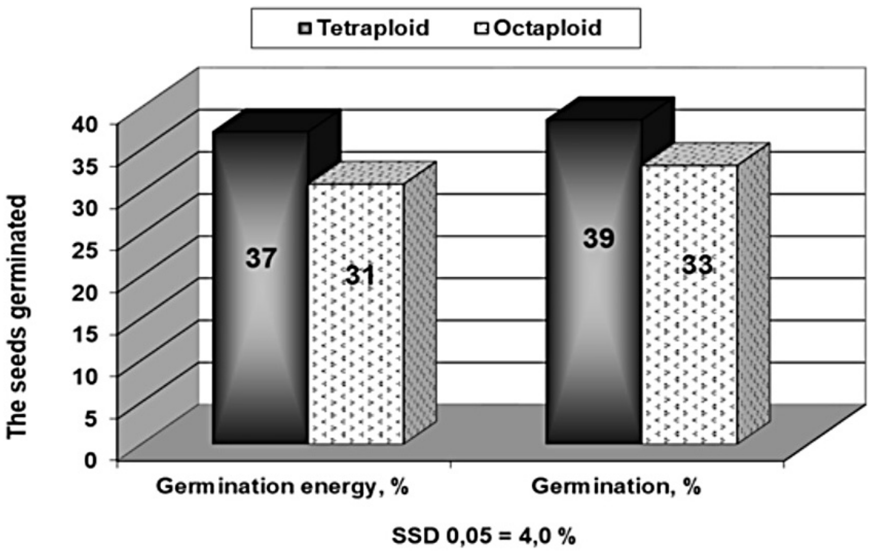

Figure 4. Seed yield capacity depending on ploidy of varietal samples (in 2018–2021)

seed yield capacity which amounted to 142.0 kg/ha, or it was higher by 42.8 kg/ha, as compared with tetraploid samples (Figure 3).

And yet, seed quality – germination energy and emergence of octaploid varietal samples – was reliably lower, namely 31 and 33%, or it was smaller by 6% which was due to their ripeness group (Figure 4).

Octaploid varietal samples belong to late and very late ripeness groups, and in the conditions of the Forest steppe of Ukraine they do not have enough time to form quality seeds and fail to ripen.

CONCLUSIONS

It has been established that the later a ripeness group is, the larger sum of effective temperatures a varietal sample requires, and accordingly, a longer term for the occurrence of phonological phases of crop growth and development; this has an effect on the peculiarities of the seed formation and ripening and in turn on its quality. It was found out that the factor "the conditions of the year" had the highest effect on seed quality – 48%, and the factor "varietal sample – ripeness group" had the lowest one, namely 29% and 30%, respectively.

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