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Seed Productivity Of Millet Cultivars – Switch-Grass (Panicum Virgatum L.) Depending On Their Origin

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Abstract:

The paper contains the results of the research done on seed yield capacity, its germination vigor and emergence of millet cultivars - switch-grass - depending on ploidy and ecotype of the origin. **Methods.** Laboratory, measuring-weighing, mathematic-statistic. **Results.** The studies of the effect of ecotype of switch-grass on seed yield capacity and quality were carried out on four tetraploid and two octaploid cultivars of highland ecotype and two tetrapoid cultivars of lowland ecotypes at the Institute of bio-energy crops and sugar beets of NAAS (Ukraine). It has been found out that yield capacity, germination vigor, emergence and mass of 1000 seeds depend on both the origin of cultivars – their ecotype, and ploidy. Seed yield capacity of highland ecotype, regardless of their ploidy, was reliably higher by 38.6 % or by 37.5 kg/m^2, as compared with lowland ecotype. Cultivars of highland ecotype formed seeds of better quality; their seed yield capacity was reliably higher. Octaploid cultivars of highland ecotype formed reliably higher yield capacity and seed quality, as compared with tetraploid cultivars of both highland and lowland ecotypes. **Conclusions.** Yield capacity and seed quality – germination vigor, emergence and mass of 1000 seeds of highland ecotype were reliably higher, as compared with the cultivars of lowland ecotype both on the average within three years and in the years under study. Octaploid cultivars of highland ecotype showed the highest indicators of seed yield capacity, as compared with tetraploid cultivars of both highland and lowland ecotypes. Germination vigor and seed emergence of tetraploid cultivars of highland ecotype exceeded reliably similar indicators of octaploid cultivars of highland ecotype and tetraploid cultivars of lowland ecotypes.

Keywords: yield capacity, eco-type, germination vigor, emergence, mass of 1000 seeds.

INTRODUCTION

It is important for Ukraine to study new cultivars of bio-energy crops because the intensive use of exhaustive energy sources impulses mankind to attract and apply the alternative to satisfy their needs in energy resources (Kaletnik, 2013). The use of alternative bio-fuel will help solve partially the problem of energy dependence of Ukraine which has a large energy potential of biomass, available labor resources, material and land resources (Doronin, 2013). The cultivation of bio-energy crops, the manufacture and use of bio-fuel create additional employment of rural population and are the source of income, namely in rural areas where the lack of jobs is critical, low production cost of biomass is low (Roik and Yaholnyk, 2015). Switch-grass is one of the promising crops for the production of alternative energy sources. The main advantages of switch-grass as a bio-energy crop are relatively high yield capacity, low need in water and nutrition, reliable productivity in a wide geographical zone, reduced soil erosion, carbon absorption and the improvement of wild nature environment (Yogendra et al., 2012). The crop has low production cost of raw material for the manufacture of bio-fuel and high yield capacity of above-ground mass (Roik et al., 2010), it can be grown in the soil which is not suitable for the cultivation of other agricultural crops (Kenneth P. Vogel et al., 2002), providing high yield capacity of biomass (Parrish et al., 2008). The most important factors in the cultivation technology of switch-grass are the location of its cultivation – the width of cultivar origin, the reduction of seed dormancy, soil moisture, temperature regime, sowing terms (Bransby et al., 1997) and the feasibility to grow it on degraded and low-productive soils (McLaughlim et al., 1996). Which is why, it was important to study seed productivity of millet cultivars – switch-grass – of different origin in the conditions of unstable soil moisture of the Forest steppe of Ukraine.

There are two main ecotypes of switch-grass: lowland and highland. Low land cultivars are grown on moist soils – they have high thick rough stems which grow like bushes. Highland type, adapted to dry climate, has thinner and more numerous stems (Secter, 2008). Highland cultivars are considered to be more resistant to drought but regular drought causes loss of biomass in general which may result in the loss of yield. (Parrish and Fike, 2005). All lowland ecotypes are tetraploid, whereas highland ecotypes can be tetraploid and octaploid (Elbersen et al., 2005, Elmore et al., 1993). The cultivars of lowland ecotype are characterized with higher yield capacity as compared with the cultivars of highland ecotype (Gunderson et al., 2008). The research, carried out in the conditions of unstable moisture of the west

Forest steppe of Ukraine, confirmed that dry biomass yield was changing not only depending on the origin of cultivars but also within one ecotype. Thus, dry mass yield capacity differed reliably between the cultivars of highland ecotype and was the following: Cave-in-Rock – 16 t/ha, Dakota – 7.8 t/ha, Forsberg and Nabroska – 9.3-9.4 t/ha (Mandrovska, 2016). The highest dry mass yield in the fourth year was recorded for the cultivars of lowland ecotype Alamo – 19.1 t/ha, Kanlow – 16.6 t/ha, and it was lower for highland cultivar Cartadge – 15.6 t/ha (Filipas et al., 2012). In scientific literature there is not enough information about the correlation between seed productivity of switch-grass cultivars and their origin. The research, carried out by M. I. Kulyk and I. I. Rozhko (2018), presents the classification of all the cultivars, which were studied as to their seed yield capacity, as low-yielding (80–180 kg/ha), average-yielding (200–300 kg/ha) and high-yielding (over 300 kg/ha) regardless of their ecotype origin. It was stated that by mass of 1000 seeds, switch-grass cultivars had a slight variation in the group of highland cultivars – from 1.42 to 1.98 g, in lowland ecotypes seeds were smaller and the variation ranged within 0.85-0.94 g. The research also proves that emergence of heavier seeds was higher than that of light seeds (Smart and Moser, 1999, Aiken and Springer., 1995). The information concerning seed quality – the intensity of germination and emergence is not available. The research done by American scientists has established that plant ecotype, temperature, moisture and fertilizers are the most important factors which have an impact on switch-grass yield capacity (Ocumpaugh et al., 1997).

The purpose of the research was to study seed productivity of switch-grass cultivars – yield capacity and seed quality – depending on their ploidy and ecotype, and to determine which cultivars are best suited to the conditions of unstable moisture in the west Forest steppe of Ukraine.

MATERIAL AND METHODS

The trials were carried out at the Institute of bio-energy crops and sugar beets of NAAS and in the conditions of Yaltushkivska research-breeding station in 2018-2020 (Coordinates of a field trial: 49°00'140-156 of north latitude; 27°26'592-641 of east longitude). The scheme of the trial envisaged the studies of seed yield capacity and quality of four tetraploid and two octaploid cultivars of highland ecotype and two tetraploid cultivars of lowland ecotypes. Seed yield capacity was determined in the phase of complete maturity by seed weighing from one square meter in 4 replications. Seed germination vigor and emergence were determined according to the technique, namely, seed growing at constant temperature with prior cooling in a moist substrate during 7 days at temperature 10 ^{0}C, which was worked out at the Institute of bio-energy crops and sugar beets (Doronin et al., 2015). Statistic data processing of the experimental findings was done by the method of a disperse analysis (Fisher, 2006) with the use of software Statistica 6.0 from StatSoft.

Soil conditions

The trials aimed at studying the principles of the formation of seed quality and yield capacity of a bio-energy crop – switch-grass – 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.

Weather conditions

In the years under study the weather conditions as to a temperature regime were typical for this area. An average daily air temperature was closer to a long-term meaning and it exceeded a long-term meaning by 2-3 ^{0}C. As to a moisture regime, the years of 2018 and 2020 were characterized by moisture deficit, which amounted to 97 and 47.7 mm, and excessive moisture in a vegetative period was typical for the year of 2019. Precipitations were not evenly distributed by months. In all years under study, the phases of flowering (July-August) and those of seed formation (August) took place in the conditions of serious moisture deficit which facilitated the formation of quality seeds; this was proved by the research of Caddel J. L. et al. (2002) – dry weather in August and September resulted in the formation of good quality seeds. The period of seed harvesting was typical for this zone both by a temperature regime and by moisture supply.

RESULTS AND DISCUSSION

Unlike yield capacity of dry matter in the cultivars of lowland ecotype which was higher in the conditions of unstable moisture in the west Forest steppe of Ukraine, the cultivars of highland ecotype had reliably higher seed yield capacity (Fig. 1).

Within three years on the average seed yield capacity of highland ecotype, regardless of their ploidy, was higher by 38.6% or by 37.5 kg/m^{2}, as compared with lowland ecotype.

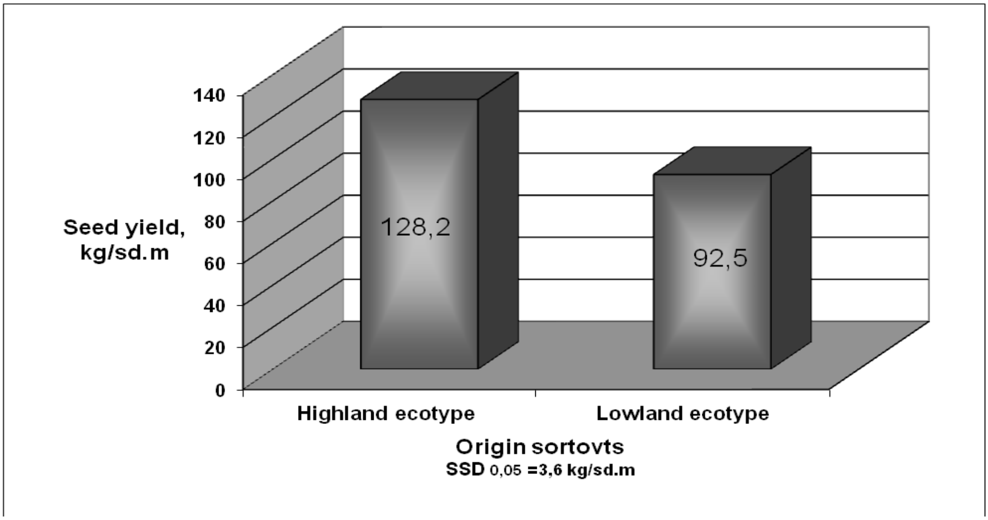

Fig.1. Yield capacity of switch-grass seeds depending on their origin (average in 2018-2020)

The cultivars of highland ecotype formed seeds of better quality. Germination vigor and emergence were reliably higher – by 21% ($HIP_{0,05}$ = 6.4%) and 23% ($HIP_{0,05}$ 8.9%), respectively, than those of the cultivars of lowland ecotype, regardless of their ploidy (Fig. 2).

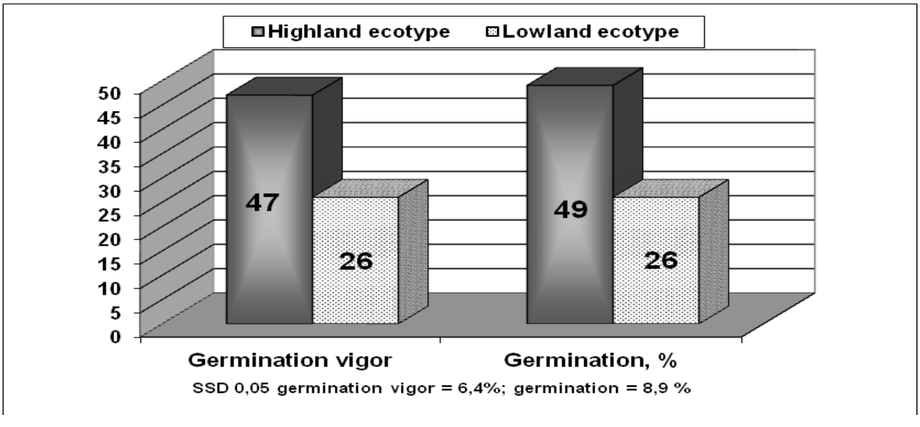

Fig.2. Seed quality of the cultivars depending on their ecotype (average in 2018-2020)

As to the mass of 1000 seeds, our experimental data confirmed the results received earlier by Kulyk M. I. and Rozhko I. I. (2018). The mass of 1000 seeds of switch-grass cultivars of highland ecotype, regardless of their ploidy, was reliably higher – by 0.38 g ($HIP_{0,05}$=0.12 g), namely 1.32 g, and ranged from 1.10 to 1.58 g, as compared with the cultivars of lowland ecotype. On the average, the mass of 1000 seeds of the cultivars of lowland ecotype was 0.94 g with the variation within 0.67 – 1.21 g.

Rather low seed yield capacity and quality of the cultivars of lowland ecotype were caused by unfavorable weather conditions in a vegetative period – a serious moisture deficit.

Similar results were received in the years when the research was carried out. The cultivars of highland ecotype had reliably higher seed yield capacity and quality as compared with those of lowland ecotype (Table 1).

Table 1. Seed productivity of switch-grass cultivars depending on their origin (2018-2020)

Origin, ecotype	Year	Seed yield capacity, kg/m^2	Germination vigor, %	Emergence, %
Highland	2018	137.6	42	46
Lowland		106.0	37	38
$SSD_{0.05\ ecotype}$		1.3	4.4	5.9
Highland	2019	132.0	45	46
Lowland		99.9	22	22
$SSD_{0.05\ ecotype}$		1.0	9.5	10.2
Highland	2020	135.1	52	53
Lowland		103.7	18	18
$SSD_{0.05\ ecotype}$		1.9	5.7	6.6
$HIP_{0.05\ year\ effect}$		0.6	5.3	5.5

Reliably lower seed yield capacity of both ecotypes was recorded in 2019, as compared with the years of 2018 and 2020. The share of the effect of a "year" factor on seed yield capacity was 2.2 %, it amounted to 4.6 and 6.7 % on germination vigor and emergence, respectively. During all years under study seed quality – germination vigor and emergence – were reliably higher in the cultivars of highland ecotype as compared with the cultivars of lowland ecotype. The period of the seed formation for highland ecotype was the most favorable in 2020. An average daily air temperature exceeded its long-term indicator by 3.5 ^{0}C under optimal moisture supply of the plants, the sum of precipitations was the closest to the average long-term amount which helped receive the highest indicators of seed germination vigor (by 7-10 %) and emergence (by 7 %), as compared with the years of 2018 and 2019.

The cultivars of highland ecotype can be both tetraploid and octaploid, and those of lowland ecotype – only tetraploid. Hence, the most objective estimation of seed productivity of switch-grass cultivars, depending on their origin, can be received when they are analyzed separately taking onto consideration their ploidy.

It was found out that octaploid cultivars of highland ecotype had reliably higher seed yield capacity as compared with that of tetraploid ones of both highland and lowland ecotypes (Fig. 3).

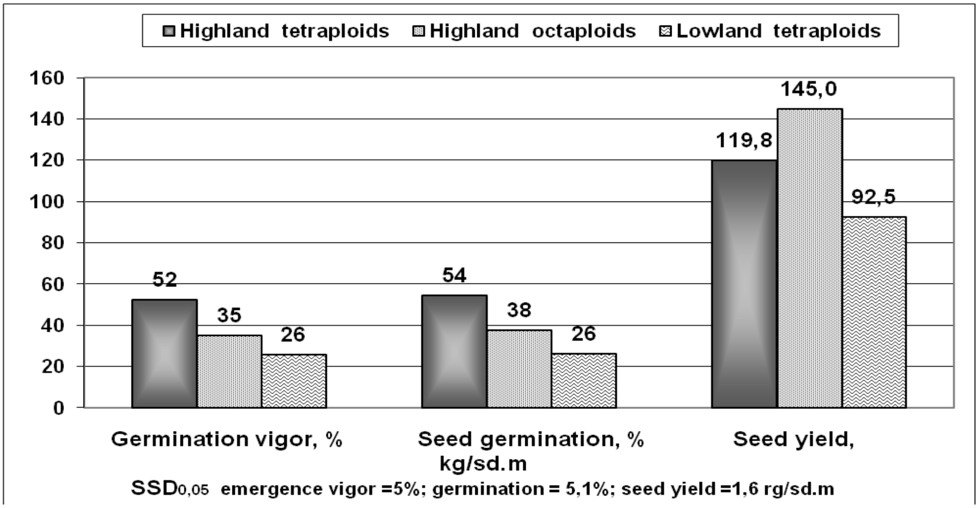

Fig. 3. Seed yield capacity and quality depending on ploidy and ecotype of the cultivars (average in 2018-2020)

Tetraploid cultivars of highland ecotype showed reliably higher seed yield capacity, namely, by 29.5% or by 27.3 kg/m^2, as compared with tetraploids of lowland ecotype. Tetraploid cultivars of highland ecotype showed the highest seed germination vigor (52 %) and emergence (54 %). These indicators of octaploid cultivars of highland ecotype were reliably lower – by 17% and 16%, respectively, as compared with tetraploids of highland ecotype. Tetraploid cultivars of lowland ecotype had the lowest indicators of seed germination vigor (26 %) and emergence (26 %).

A reliably higher mass of 1000 seeds was typical for tetrapolid cultivars of highland ecotype, as compared with both octaploid cultivars of highland ecotype and tetraploid ones of lowland ecotype (Fig. 4).

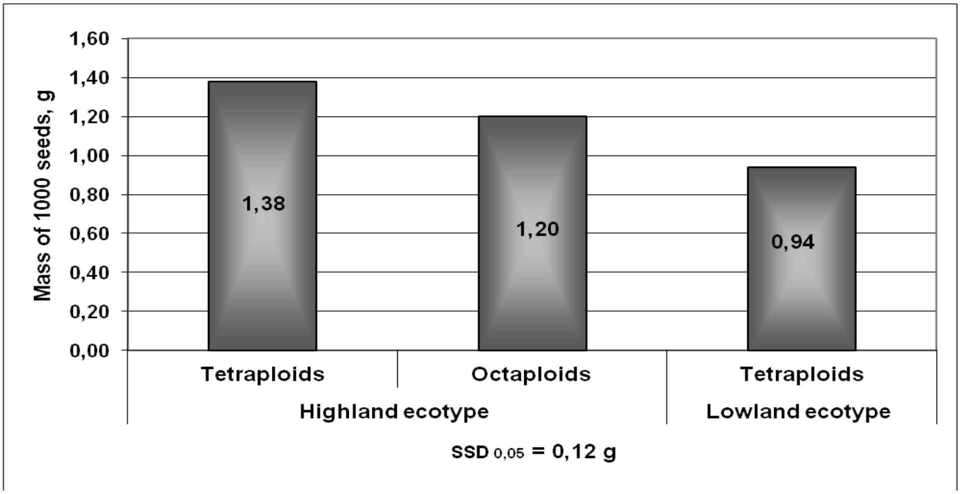

Fig. 4. Mass of 1000 seeds depending on ploidy and ecotype (average in 2018-2020)

Thus, when the mass of 1000 seeds is larger, the indicators of seed germination vigor and emergence are higher which correlates with the results received earlier by Aiken, G. E., & Springer, T. L. [15] and Smart A. J., Moser L. E. A similar correlation was recorded in the years when the research was done.

Octaploid cultivars of highland ecotype gave a reliably higher seed yield capacity, as compared with tetraploid cultivars of highland and lowland ecotypes (Table 2).

Table 2. Seed yield and quality of switch-grass cultivars depending on their ploidy and origin (2018-2020)

Origin, ecotype	Ploidy	Seed yield capacity, kg/m^2	Germination vigor, %	Emergence, %
1	2	3	4	5
2018				
Highland	Tetraploids	129.4	48	52
	Octaploids	145.8	31	35
Lowland	Tetraploids	106.0	37	38
$SSD_{0.05}$		1.3	4.4	5.9
2019				
Continuation of Table 2				
1	2	3	4	5

Highland	Tetraploids	124.6	51	52
	Octaploids	139.5	32	33
Lowland	Tetraploids	99.9	22	22
$SSD_{0.05}$		2.2	6.5	6.2
2020				
Highland	Tetraploids	127.5	57	58
	Octaploids	142.7	42	44
Lowland	Tetraploids	103.7	18	18
$SSD_{0.05}$		1.3	5.7	6.6

Tetraploid cultivars of highland ecotype had significantly higher seed yield capacity than that of the cultivars of lowland ecotype. Reliably higher seed germination vigor and emergence were typical for tetraploid cultivars of highland ecotype. Tetraploid cultivars of lowland ecotype showed the lowest indicators of seed quality.

CONCLUSIONS

Seed yield capacity and quality – germination vigor, emergence and mass of 1000 seeds of the cultivars of highland ecotype were reliably higher, as compared with the cultivars of lowland ecotype both on the average within three years and in the years under study. Octaploid cultivars of highland ecotype had the highest indicators of seed yield capacity, as compared with tetraploids of both highland and lowland ecotypes. Seed germination vigor and emergence of tetraploid cultivars of highland ecotype exceeded reliably these indicators of octaploid cultivars of highland ecotype and tetraploid cultivars of lowland ecotype. Tetraploid cultivars of highland ecotype which guarantee high seed productivity, namely yield capacity and seed quality, are the most suitable for the conditions of the Forest steppe of Ukraine.

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