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Influence of Rod-Shaped Millet (*Panicum Virgatum* L.) Seeds Storage Conditions on its Quality

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ABSTRACT

Partial replacement of traditional types of fuel, which in the world and in Ukraine is possible with the use of biomass of plant origin. A perennial cereal plant called switchgrass (*Panicum virgatum* L.) is promising for the production of biofuel, the seeds of which are characterized by a high biological dormancy, which leads to a significant decrease in its germination. Therefore, it is urgent to conduct a study to reduce this state of dormancy, which will ensure an increase in seed germination and contribute to the widespread introduction of the culture into production. In order to find out the effect of conditions and storage time on seed quality, a three-factor experiment was conducted in which two varieties of switchgrass of different maturity groups were stored for 364 days under different conditions that are possible when sowing seeds in the field - variable temperatures and humidity, the time of seed storage in such conditions. It has been found that the conditions of seed storage – temperature, humidity and terms, especially their complex interaction, probably affect the improvement of its quality. At a seed moisture content of 9% and 24–26% at an air temperature of 18–20 °C, during storage for 180 days, a probable increase in the energy of germination of the Cave-in-Rock variety sample by 11–20%, germination – by 13–21%, of the Dakota variety sample, respectively – by 22–19% and 24–31%.

Keywords: similarity, germination energy, seed moisture, pre-cooling.

INTRODUCTION

The lack of fossil energy carriers both in Ukraine and in the world (oil products, gas, coal) and their cost increase is increasingly paying attention to the search and production of alternative energy sources (Doronin et al., 2018), with minimal impact on the environment and the risk of man-made disasters (Gorba et al., 2017). Bioenergy crops can meet the basic need for electricity, which is becoming increasingly important as existing fossil fuel-based thermal capacities are phased out, biofuels can be of high energy density at relatively low cost, which is required for shipping and aviation (Field et al., 2017). In Ukraine, there are already certain developments regarding the use of alternative fuels in such areas as the production of bioethanol on the basis of alcohol and sugar factories, the production of solid biofuel, and the increase of areas for the cultivation of bioenergy crops (Doronin, 2013). To replace traditional types of fuel, the use of biomass of plant origin is more promising – bioenergy. For our country, a significant alternative to traditional fuel today is biofuel (Sinchenko et al., 2014). The soil and climatic conditions of Ukraine are favorable for the cultivation of bioenergy crops, and it has great potential for creating a stable market for energy crops and using their raw materials for biofuel production (Kurylo et al., 2013). Plants such as sugar beet, switchgrass, sugar sorghum, miscanthus (Mozharivska, 2013), willow and poplar (Fuchylo et al., 2009) are of practical interest for the production of biofuel from phytomass. Most bioenergy crops are C3 and C4 type plants (Calabrò et al., 2018). One of the most promising perennial plants for the production of biofuels is the switchgrass (*Panicum virgatum* L.). This crop can be propagated by seeds and rhizomes (Elbersen et al., 2001; Beaty et al., 1978). The state of dormancy can be disturbed in various ways – by exogenous or endogenous factors, most of which are based on the creation of stressful conditions during the period of seed germination or before its germination (Liu et al., 2013). One of the ways to reduce dormancy is the term and conditions of seed storage. Preservation of seeds of their genetic properties, viability, economic and valuable features and quality has always been and remains an important task in seed breeding. Numerous studies on seed storage of various agricultural crops have established that during long-term storage, germination energy and germination decrease, and these processes can occur before harvesting on the mother plant and during seed storage (Podpryatov et al., 2011; Kindruk et al., 1999; Musienko et al., 1994). This is due to the aging of the seed, that is, to a complex of biochemical and physiological changes (Musienko et al., 1994), which over time lead to a partial or complete loss of its ability to germinate. The intensity of the aging process depends on the initial germination, humidity, temperature, purity of the seed, the presence of oxygen and damage to the seed coat (Kropp, 1974).

According to Kulyk et al. (2018) with an increase in the term of storage of millet seeds, its germination increased: during the first two years, there was an increase in the laboratory germination of seeds and a significant increase in it from the third year of storage, especially for larger seeds. Research by Grabowski et al. (2002) proved that storage at room temperature was optimal for breaking seed dormancy: after a month of storage, germination of the Alamo variety increased by 50%. According to Emi Kimura (2014), storage of seeds of the Kanlow cultivar for one month at a temperature of -20 °C provided an increase in the number of seeds that germinated up to 51%, compared to storage conditions at a temperature of -80 °C and room temperature. Kulyk et al. (2022) established that storing the seeds of rod-shaped millet at a temperature of 18 °C significantly increases its germination, but the authors do not indicate how much seed germination increases. State of seed rest decreases and, accordingly, its germination increases during germination at a temperature of 20 °C after its preliminary cooling on a moist substrate at a temperature of 10 °C (Doronin et al., 2019). According to Smith et al. (2012) one of the ways to reduce the dormant state of switchgrass seeds in production conditions is to sow them in the fall - in November or December, it is in cold and wet conditions in winter, which leads to a decrease in the dormant state, but at the same time it is advisable to increase the seed sowing rate, which will ensure increase in field uniformity and uniformity of plant placement. Research objective: was to determine the effect of storage conditions – air temperature and seed moisture – on its germination power and emergence, depending on the varietal features.

MATERIALS AND METHODS

The experiments were conducted in the laboratory facilities in the years of 2021–2022. To test the hypothesis published by Smith et al. (2012) that one of the ways to reduce the dormant state of switchgrass seeds in production conditions is to sow them in the fall - in November or December, it is in cold and wet conditions in winter, which leads to a decrease in the dormant state, but at the same time it is advisable to increase the seed sowing rate. A three-factor experiment was simulated in laboratory conditions (factor A – shelf life, factor B – variety, factor C – storage conditions), the scheme of which provides for the creation of various conditions that occur in field conditions: a). optimal sowing period, the soil is well warmed, the supply of moisture is insufficient and the seeds lie in dry soil (control), to reproduce such conditions, seeds with a moisture content of 9% were stored at a temperature of 18–20 °C, germinated without prior cooling; b). early sowing or late cold spring, when after sowing the temperatures in the field will be lowered (the temperature at the depth of seed placement is 5–7 °C, the optimal supply of moisture and the seeds are on a moist substrate), to reproduce such conditions, seeds with a moisture content of 24–26% were stored at a temperature of 5–7 °C with its preliminary cooling on a wet substrate at a temperature of 10 °C and subsequent germination at a temperature of 20 °C) late or early sowing period, the soil is well warmed, the optimal supply of moisture and the seeds are in moist soil, to reproduce such conditions, the seeds were stored with a humidity of 24–26% at a temperature of 18–20 °C and germinated with preliminary cooling on a moist substrate. The number of germinated seeds was counted after 90 days, provided that the seeds were sown in the field at the beginning of December, and the seedlings appeared in March. In order to determine changes in quality indicators, seeds - germination energy and germination of two variety samples, USA selection, mid-late Cave-in-Rock and very early Dakota, were stored in such conditions for 364 days in sealed polyethylene bags at a temperature of 5–7 °C (in a refrigerator) and 18–20 °C (in the thermostat). Prior to initiating the experiment, the seed germination energy and emergence at temperature 20 °C with pre-cooling were 74% for a mid-season cultivar Cave-in-Rock and 69% for a very early cultivar Dakota. These values for the same cultivars without pre-cooling were 70% and 66%, respectively. Seed quality was determined according to the method of the Institute of Bioenergy Crops and Sugar Beet (Doronin et al., 2015). Statistical processing of experimental data was carried out by the methods of variance analysis according to the Fisher method (Fisher et al., 2006) using the Statistica 6.0 computer program from StatSoft (Website of the StatSoft company) and methodical recommendations (Ermantraut et al., 2007).

RESULTS AND DICSUSSION

It was determined that the seed storage of both cultivars with increased moisture (24–26 %) at temperatures 18–20 °C as well as at temperatures 5–7 °C for a period of 3–6 months while germinating it at a temperature of 20 °C without prior cooling resulted in to a significant decrease in its germination energy compared to the control – the quality of the seeds before the experiment was started (Table 1). When seed of both sample cultivars with moisture of 9% and 24–26% at room temperatures 18–20 °C were stored during 180 days, there was a significant increase in germination energy and emergence as compared with a storage period of 90 days, but it was significantly lower than in the control. The germination energy of cultivar Cave-in-Rock increased by 11–20%, and its emergence increased by 13–21%, while for cultivar Dakota, it increased by 22–19% and 24–31%, respectively. Depending on the varietal features, the seed quality indicators for cultivar Cave-in-Rock were significantly higher than those for cultivar Dakota. Under the storage of seeds for 364 days provided a significant increase in the energy of germination of both variety samples with a humidity of 9 % at a temperature of 19–20 °C, both compared to the control and storage for 180 days. No probable difference was found in the energy of germination of dry seeds - it was the same and amounted to 80% and wet seeds (24–26%) at storage temperatures of 18–20 °C and 5–7 °C, depending on varietal characteristics. Similar results were obtained for seed germination. Depending on the storage conditions, there was no probable increase in germination for 90–180 days, but on the contrary, a significant

Table 1. Seed germination energy depending on the storage term and conditions (seed germination without cooling)

Treatment		Germination energy, %, in days			
Storage conditions	Cultivar	Before trial	90	180	364
Control, moisture 9%, storage at *t* 18–20 °C	Cave-in-Rock	70	49	60	80
Moisture 24–26%, storage at *t* 5–7 °C			33	38	52
Moisture 24–26%, *t* 18–20 °C			43	63	77
Control, moisture 9%, storage at *t* 18–20 °C	Dakota	66	39	61	80
Moisture 24–26%, storage at *t* 5–7 °C			33	35	51
Moisture 24–26%, storage at *t* 18–20 °C			33	52	73
$SSD_{0.05\ tot.}$		6.8			
$SSD_{0.05\ storage\ term}$		2.8			
$SSD_{0.05\ cultivar}$		2.3			
$SSD_{0.05\ storage\ conditions}$		2.8			

decrease was observed, compared to the control – before the experiment was started. Only after 364 days, seed germination probably increased both compared to the control and after storage for 90–180 days. Depending on the varietal characteristics, there was no significant difference in seed germination (Table 2).

For the storage of seed with different moisture levels at air temperatures 18–20 °C and 5–7 °C and subsequent germination without pre-cooling, the "storage period" was the factor which had the most significant impact on germination energy and emergence, namely 55% and 59%, respectively (Fig. 1). The effect of the "storage conditions" factor was also significant, ranging from 26% to 30%. The "cultivar" factor and the interaction between factors were less significant.

In summary, based on the research results, it can be concluded that the storage of both moist (24–26%) and dry (9%) seed at air temperatures 5–7 °C and 18–20 °C for up to 90 days without pre-cooling provided a reliable increase in its germination energy in the Cave-in-Rock variety sample – by 5%, compared to the seed quality before the experiment was started, while at the same time, when storing seeds with a moisture content of 9% at a temperature of 18–20 °C, this indicator increased by 14%, and the variety sample Dakota germination energy was the same as when establishing the experiment. The germination energy of the Cave-in-Rock sample was significantly higher than that of the Dakota sample (Table 3).

In case of the storage of moist seeds at air temperature 5–7 °C, the germination energy and emergence significantly increased for both cultivars. After 364 days of the storage, the seed quality significantly improved for both cultivars, regardless of its moisture level and air temperature, as compared with both the control and the storage term of 90 to 180 days.

Similar results were obtained from seed germination depending on the conditions and period of its storage. A significant increase in germination was obtained by storing both dry and wet seeds for 180 and 364 days (Table 4). An analysis of the factors influencing the seed germination

Table 2. Seed emergence depending on the storage term and conditions (seed germination without cooling)

Treatment		Emergence %, in days			
Storage conditions	Culti-var	Before trial	90	180	364
Control, moisture 9%, storage at t 18–20 °C	Cave-in-Rock	70	51	64	83
Moisture 24–26%, storage at t 5–7 °C			36	49	54
Moisture 24–26%, t 18–20 °C			44	65	79
Control, moisture 9%, storage at t 18–20 °C	Dakota	66	39	63	83
Moisture 24–26%, storage at t 5–7 °C			36	41	53
Moisture 24–26%, storage at t 18–20 °C			36	67	74
$SSD_{0.05\ tot.}$		6.4			
$SSD_{0.05\ storage\ term}$		2.6			
$SSD_{0.05\ cultivar}$		2.1			
$SSD_{0.05\ storage\ conditions}$		2.6			

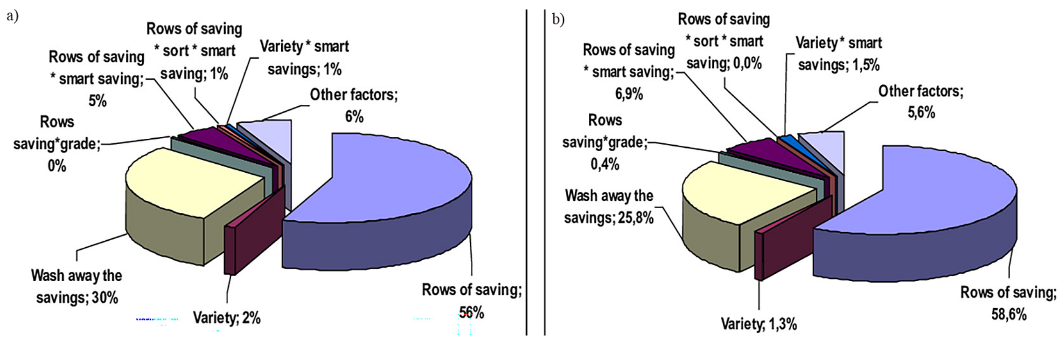

Figure 1. Share of the factor effect on seed quality (without pre-cooling)
a) on germination energy, b) on emergence

Table 3. Seed germination energy depending on the storage term and conditions (seed germination with pre-cooling)

Treatment		Germination energy, %, in days			
Storage conditions	Culti-var	Before trial	90	180	364
Control, moisture 9%, storage at t 18–20 °C	Cave-in-Rock	74	88	80	90
Moisture 24–26%, storage at t 5–7 °C			79	76	85
Moisture 24–26%, t 18–20 °C			77	84	91
Control, moisture 9%, storage at t 18–20 °C	Dakota	69	67	79	88
Moisture 24–26%, storage at t 5–7 °C			69	84	86
Moisture 24–26%, storage at t 18–20 °C			63	88	89
$SSD_{0.05\ tot.}$		6.2			
$SSD_{0.05\ storage\ term}$		2.5			
$SSD_{0.05\ cultivar}$		2.1			
$SSD_{0.05\ storage\ conditions}$		2.5			

Table 4. Seed emergence depending on the storage term and conditions (seed germination with pre-cooling)

Treatment		Emergence, %, in days			
Storage conditions	Cultivar	Before trial	90	180	364
Control, moisture 9%, storage at *t* 18–20 °C	Cave-in-Rock	74	89	81	90
Moisture 24–26%, storage at *t* 5–7 °C			79	78	85
Moisture 24–26%, *t* 18–20 °C			78	84	92
Control, moisture 9%, storage at *t* 18–20 °C	Dakota	69	68	79	90
Moisture 24–26%, storage at *t* 5–7 °C			72	84	89
Moisture 24–26%, storage at *t* 18–20 °C			63	88	91
$SSD_{0.05\ tot.}$		6.0			
$SSD_{0.05\ storage\ term}$		2.5			
$SSD_{0.05\ cultivar}$		2.0			
$SSD_{0.05\ storage\ conditions}$		2.5			

energy and emergence showed that for the storage of seed with different moisture levels at air temperatures 18–20 °C and 5–7 °C, with pre-germination cooling, the most significant factor affecting these quality parameters was the "storage period," which amounted to 43% and 45%, respectively. The effect of the "storage term*cultivar" factor was also significant, ranging from 19% to 20%. The "cultivar" factor and the interaction between factors were less significant (Figure 2). Summarizing the research results, it can be concluded that the storage of both moist (24–26%) and dry (9%) seed at air temperatures 5–7 °C and 18–20 °C for up to 90 days with pre-germination cooling led to a significant increase in their germination energy and emergence. Therefore, in field conditions with early planting and a cooler "sowing-emergence" period, a significant improvement in seed quality and, consequently, field emergence can be expected. To verify the obtained laboratory data, it is advisable to conduct field experiments with the sowing of switchgrass seeds under different conditions. The seeds of rod-shaped millet are characterized by a long biological state of dormancy, which leads to a decrease in its laboratory germination and, accordingly, in field germination, completeness and unevenness of seedlings and, as a result, to a decrease in crop productivity. One of the ways to reduce the biological dormancy is the term and conditions of seed storage. Earlier studies revealed that the quality of seeds increases when they are stored. Contradictory results have been obtained regarding the storage conditions and periods under which seed germination increases.

There is a hypothesis that in field conditions, by sowing seeds in the fall and spring, you can get friendly and uniform seedlings. Therefore, we conducted a model experiment in laboratory conditions, which established that when storing both wet (24–26%) and dry (9%) seeds at air temperatures of 5–7 °C and 18–20 °C for even 90 days

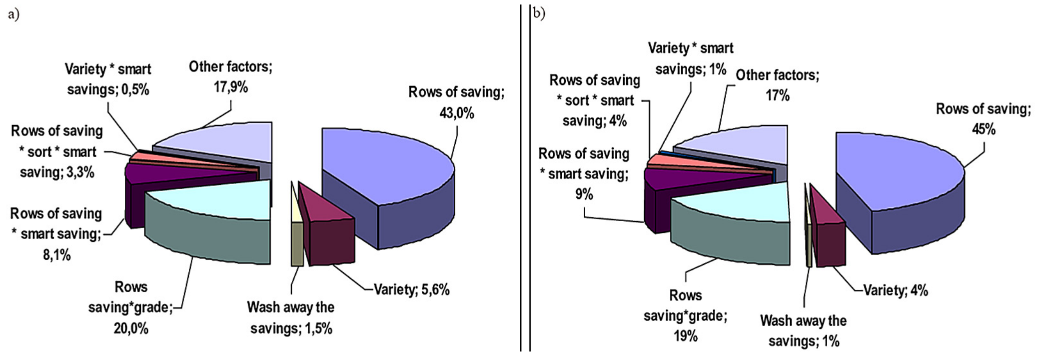

Figure 2. Share of the factor effect on seed quality (with pre-cooling); a) on germination energy, b) on emergence

with pre-cooling provided a probable increase in its energy of germination and germination. That is, in field conditions during early sowing and the cool period of "sowing-seedling production" one can expect a reliable increase in seed quality and, accordingly, its field germination. That is, in field conditions during early sowing and the cool period of "sowing-seedling production" one can expect a reliable increase in seed quality and, accordingly, its field germination.

CONCLUSIONS

It has been established that the storage conditions and terms for switch-grass seed ensure a significant increase in their germination energy and emergence, regardless of varietal features. The storage of both moist (24–26%) and dry (9%) seed at air temperatures 5–7 °C and 18–20 °C for up to 90 days with pre-germination cooling resulted in a significant improvement in the germination energy and emergence. Therefore, under storing such seeds at air temperatures of 5–7 °C and 18–20 °C and germinating them without prior cooling, their quality was reliably lower compared to the control. That is, in field conditions, it is impractical to expect a reliable increase in seed quality during late sowing and a warm period of "sowing-seedling production".

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