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LABORATORY GERMINABILITY AND GERMINATION ENERGY OF SPELT GRAIN DEPENDING ON FERTILIZATION AND STORAGE

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The article presents the results of studying the germinability and germination energy of spelt grain depending on fertilization and storage duration. The pre-storage germination energy of spelt grain was found to be 87–90%, depending on nitrogen fertilizer types, doses and application time. After 30- or 90-day storage, the germination energy was the highest, amounting to 98–99%. Further storage decreased this indicator. The greatest effect was exerted by single application of 120 kg/ha of nitrogen fertilizers once in spring.

Key words: *spelt, germinability, germination energy, fertilization, storage.*

Introduction. Spelt is a promising crop for processing, as valuable micronutrients are evenly distributed in its grain, while in modern wheat bread varieties they are concentrated in the hull, aleurone layer and germ. Its proteins contain more gliadins and fewer glutenins, making gluten weak, but better digestible in the human body. Currently, this crop is insufficiently studied, therefore, studies of germinability and germination energy of spelt depending on fertilization and shelf life are relevant and practically feasible [1–3].

Literature review and problem articulation. In modern agriculture, high-quality seeds are of paramount importance as a means of production. High-quality seeds are one of the main prerequisites for achieving high yields [4]. The germination energy is the ability of seeds to germinate quickly and simultaneously. It is defined as a conventionally accepted period, which is almost twice as short as for the laboratory germinability determination and is calculated as the number of normally germinated seeds expressed as a percentage [5]. Some researchers consider the germination energy as the main indicator of the biological value of seeds. Plants grown from seeds with high germination energy show better performance and are more resistant to adverse environmental factors. The germination energy can be considered a qualitative indicator of the seed viability [6, 7].

The germinability is the ability of seeds to form normally developed seedlings. This indicator is expressed as a percentage of the total number of seeds taken for germination. Studies identified different factors affecting the germination and germinability of seeds. They can be grouped into biological (biotic) and abiotic ones. Knowledge of these factors allows for effective control and management of the germinability of seeds [8, 9].

Grain storage is one of the most important stages that determine the grain quality during processing and the quality of seeds intended for sowing. It can have both a positive effect as a result of post-harvest ripening and negative consequences, leading, under the influence of different factors, to grain deterioration. The temperature of grain mass is a particularly important indicator characterizing the grain mass condition during storage [10, 11]. Ukraine has not developed specific storage conditions for spelt grain. In this case, conventional conditions of wheat grain storage are adhered to (State Standard of Ukraine DSTU 3768: 2019). The quality of both bread wheat and spelt grain also depends on the storage period. Changes in grain during storage depend both on raw material quality and on storage conditions. Given that spelt grain contains more protein (25%) and gluten (up to 50%) than grain of traditional wheat bread varieties, it is necessary to develop appropriate storage conditions for freshly harvested grains lest the grain mass change its quality. High humidity, inadequate temperature or air access in the granary provoke the spread of microorganisms causing diseases of the grain mass [12, 13].

Fertilization is one of the most important measures in growing wheat technologies to increase yields and grain quality [14]. Spelt, as a high-protein crop, responds well to nitrogen fertilizers. The top grain quality is ensured by N_{30} application in spring, N_{30} application at the beginning of leaf-tube formation and N_{30} foliar application during the in milky ripeness phase in combination with $P_{60}K_{60}$ [15]. Other scientists showed [16] that the effect of single application of nitrogen fertilizers on grain quality was similar to that of divided application. Depending on fertilizer, spelt can have a 1000-grain weight of 32.5–44.4 g, test weight of 725–739 g/L and vitreousness of 77.0–83.0%.

Purpose and objectives: to assess the germinability and germination energy of spelt depending on the types, doses and timing of nitrogen fertilization and storage period.

Materials and methods. The experimental site was located in Mankiv natural agricultural area of the Middle Dnipro-Bug Region of the Right-Bank Forest-Steppe (geographical coordinates at 48°46'56.47" north latitude and 30°14'48.51" east longitude). The altitude above the sea level was 245 m. The soil in the experimental field was podzolic chernozem.

The study was conducted in 2014–2015. In general, the climate in this region is favorable for growing most of temperate crops. 2014 had sufficient precipitation. Thus, in April-July, the precipitation amount was 292 mm, which was by 10% more than the multi-year average. However, this year was characterized by lower air and soil temperatures after renewal of vegetation in spring. The precipitation amount for the whole year was the lowest in 2015 (520 mm, which was 1.2 times less than the multi-year average (633 mm). In 2015, a significant amount precipitated during the spring-summer vegetation (271 mm), in April–July. Thus, the weather conditions during the study years were typical for the region. Fluctuations in precipitation, temperature and relative humidity during certain periods of spelt growing did not significantly affect its productive processes and quality.

The study was conducted in the Laboratory of Evaluation of Grain and Grain Product Quality of the Chair of Grain Storage and Processing Technologies of Uman National University of Horticulture. We studied winter spelt variety Yevropa created by hybridization of *Triticum aestivum* L. with *T. spelta* L. Spelt was fertilized, as Table 1 describes. In addition, the germinability and germination energy was assessed depending on the duration of grain storage. Fertilizers were ammonium nitrate, ammonium sulfate, granular superphosphate, and potassium chloride. The experimental plot area was 72 m^2; the record area was 40 m^2. The experiments were carried out in three replications. The plots were arranged inline. The forecrop was vetch-oat mixture grown for on green feed. The field experiments, observations and assessments were conducted by traditional methods.

Table 1

Experiment design

Treatment	Pre-storage	Storage period, days				
		30	90	180	270	360
No fertilizers (control)	+	+	+	+	+	+
P_{60} + N_{120}	+	+	+	+	+	+
K_{60} + N_{120}	+	+	+	+	+	+
$P_{60}K_{60}$ – basic fertilization	+	+	+	+	+	+
Basic fertilization + N_{120}	+	+	+	+	+	+
Basic fertilization + N_{60} + N_{60}	+	+	+	+	+	+
Basic fertilization + N_{60} S_{70} + N_{60}	+	+	+	+	+	+

Dry spelt grain (when packing for storage, water content was 13.0–13.5%) was stored air tight sealed polyethylene tubings at unregulated temperature in a traditional depository. State Standard of Ukraine 4138-2002 "Seeds of Agricultural Crops. Methods of Quality Determination" does not specify analyses of spelt seeds. The International Seed Testing Association (ISTA) has issued requirements and methods for determining the sowing qualities of this crop [17]. It should be noted that the methods of analyzing the germinability and germination energy of bread wheat specified in DSTU 2240-93 coincide with the ISTA's corresponding methods for spelt. The germinability and germination energy were determined as percentages of the total number of seeds taken for germination (mean value, n=4). To determine these indicators, four samples of 100 seeds were taken in quick succession from a pure seed fraction and germinated in Petri dishes between filter paper sheets. Petri dishes were placed in thermostats at about 20°C. The germination was monitored daily for 7 days. The germinability was expressed as the percentage of germinated seeds to the total number of seeds. After three and seven days of germination, the germination energy and laboratory germinability, respectively, were determined.

Result and discussion. The germination energy characterizes the viability of seeds, on which the germination rate depends. Seeds with high germination energy give early and uniform sprouts [4, 7]. We found that the germination energy dynamics of spelt grain depended on the duration of storage and fertilization (Table 2, Fig. 1).

Table 2

Germination energy dynamics of spelt grain depending on fertilization and duration of storage (2014–2015), %

Treatment (A)	Pre-storage	Storage period, days (B)				
		30	90	180	270	360
No fertilizers (control)	87	99	98	96	92	88
$P_{60} + N_{120}$	89	99	99	98	95	90
$K_{60} + N_{120}$	89	99	99	98	95	90
$P_{60}K_{60}$ – basic fertilization	87	99	99	95	92	87
Basic fertilization + N_{120}	90	99	99	98	95	90
Basic fertilization + N_{60} + N_{60}	89	98	99	98	95	90
Basic fertilization + N_{60} S_{70} + N_{60}	89	99	99	98	96	91
LDS_{05}	*A=1, B=3, AB=4*					

Prior to storage, the germination energy was 87–90% depending on fertilizers, the maximum after N_{120} application. Nitrogen fertilizers significantly increased this indicator compared to not fertilized plots. The germination energy varied significantly depending on the duration of storage. After 30- and 90-day storage, the germination energy was the highest and amounted to 98-99%. Further storage significantly decreased this parameter. After $P_{60}K_{60}$ application, it was the lowest: 95%, 92% and 87% when seeds were storage for 180, 270 and 360 days, respectively.

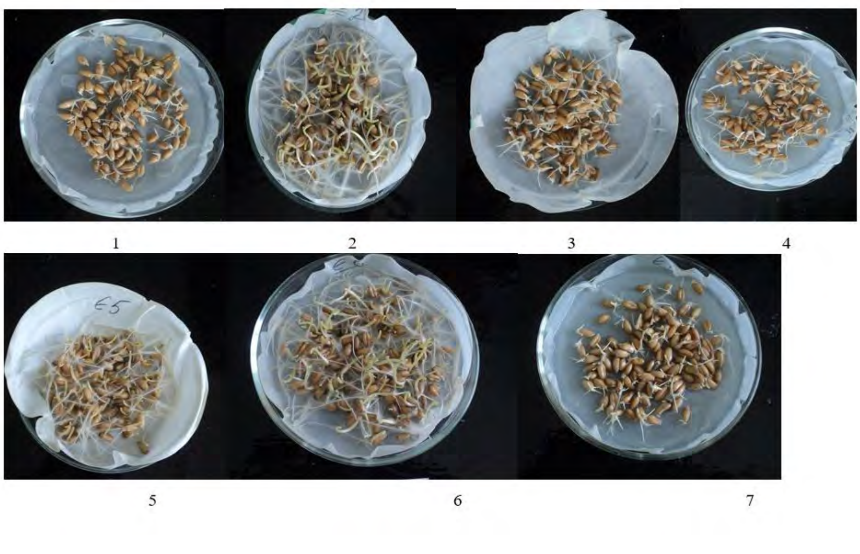

Fig. 1. The germination energy of spelt grain depending on fertilization

1 – No fertilizers (control); 2 – $P_{60} + N_{120}$; 3 – $K_{60} + N_{120}$; 4 – $P_{60}K_{60}$ – basic fertilization; 5 – basic fertilization + N_{120}; 6 – basic fertilization + $N_{60} + N_{60}$; 7 – basic fertilization + $N_{60}S_{70} + N_{60}$.

Other reserchers [18] confirmed the effect of storage duration on the germination energy of seeds. They revealed that this indicator decreased after 1-year storage of grain. In a study [19], the germination energy of wheat grain varied significantly depending on the variety and duration of storage. This indicator was the lowest in the first two months of storage. Afterwards it grew to 85-95% depending on the winter wheat variety. After 1-year storage, this figure did not decrease, but was not significantly higher than that after 9-month storage.

The laboratory germinability is the most important indicator of seed quality; it largely depends on soil, climate, cultivation technology, and fertilization [7, 9]. The sowing quality of seeds depends on their germinability. Appropriate standards are set for all field crops. The germinability of sseds determines the plant density and uniformity of stem distribution. The pre-storage laboratory germinability of spelt grain was found to be excellent regardless of fertilizers (Table 3, Fig. 2). Thus, before storage and after 30- and 90-day storage of spelt grain, this indicator was 99%, and fertilizers did not change it. 180-day storage resulted in a decrease in the laboratory germinability by 1-2%, depending on fertilization. After 270-day storage, this parameter decreased to 88% in the control and 89% in the other experimental variants. The lowest laboratory germinability (81–84%) was observed after 1-year storage, depending on fertilization, which was significant compared to the contral with $LSD_{05} = 3$. The maximum was recorded with $P_{60} + N_{120}$ and amounted to 84%, while the lowest value was noticed without fertilizers or with $N_{60}S_{70} + N_{60}$.

Table 3

Laboratory germinability of spelt grain depending on fertilizers and duration of storage (2014–2015), %

Treatment	Pre-storage	Storage period, days				
		30	90	180	270	360
No fertilizers (control)	99	99	99	97	88	81
$P_{60} + N_{120}$	99	99	99	98	89	84
$K_{60} + N_{120}$	99	99	99	98	89	82
$P_{60}K_{60}$ – basic fertilization	99	99	99	97	89	82
Basic fertilization + N_{120}	99	99	99	98	89	83
Basic fertilization + $N_{60} + N_{60}$	99	99	99	98	89	82
Basic fertilization + N_{60} $S_{70} + N_{60}$	99	99	99	98	89	81
LDS_{05}	*A=1, B=3, AB=4*					

It is known [19] that during storage seeds are dormant and their vital activity almost ceases. However, they remain living organisms, and processes of physiological maturation, structural and biochemical reorganization still occur in themt. These processes can occur before harvesting on parentsl plants or during storage. It explains why the germination energy of spelt in the experiment immediatelty after harvest was lower compared to 30-day storage.

In the study [18], statistical analysis confirmed that the laboratory germinability of grain also strongly depended on the duration of its storage. The reserchers [19] noted that chromatin degeneration in the cell nucleus resulting in division arrest was the most frequent cause of a reduced sowing quality of grain.

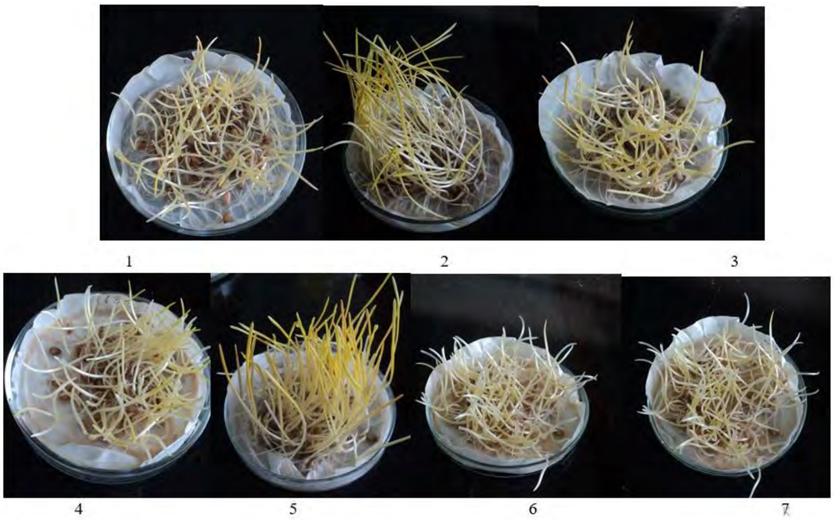

Fig. 2. Laboratory germinability of spelt grain depending on fertilization

1 – No fertilizers (control); 2 – P_{60} + N_{120}; 3 – K_{60} + N_{120}; 4 – $P_{60}K_{60}$ – basic fertilization; 5 – basic fertilization + N_{120}; 6 – basic fertilization + N_{60} + N_{60}; 7 – basic fertilization + $N_{60}S_{70}$ + N_{60}.

Thus, it was established that the highest sowing quality of spelt grain was achieved after 30- to 180-day storage. Longer storage decreased the germination energy by 1-2% and laboratory germinability by 15-18%, depending on the type, doses and timing of nitrogen fertilization.

Conclusions. The germination energy of spelt grain was found to be the highest after 30- to 180-day storage (96-99%). This indicator was most affected by nitrogen fertilizers. After 360-day storage, the germination energy reduced to 87–91% depending on the type and timing of nitrogen fertilization. The laboratory germinability of spelt grain of 97–99% maintained from harvesting to storage day 180. When spelt grain was stored in sealed containers without temperature control, this indicator gradually decreased to 81–84% for 360 days of storage, depending on fertilizers.

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ЛАБОРАТОРНА СХОЖІСТЬ ТА ЕНЕРГІЯ ПРОРОСТАННЯ ЗЕРНА ПШЕНИЦІ СПЕЛЬТИ ЗАЛЕЖНО ВІД УДОБРЕННЯ І ТРИВАЛОСТІ ЗБЕРІГАННЯ

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Пшениця спельта є перспективною культурою для переробки, оскільки цінні мікронутрієнти рівномірно розподілені в зернівці, тоді як у сучасних сортів пшениці м’якої вони знаходяться в оболонці, алейроновому шарі та зародку. Білок її відрізняється вищим вмістом гліадину та нижчим глютеніну, що робить клейковину слабкою, проте вона краще засвоюється організмом людини.

Мета і задачі дослідження: оцінити схожість та енергію проростання зерна пшениці спельти залежно від виду, доз і строків застосування азотних добрив і тривалості зберігання.

Матеріали і методи. Дослідження проводили у лабораторії «Оцінки якості зерна та зернопродуктів» кафедри технології зберігання і переробки зерна Уманського національного університету садівництва. Вивчали сорт пшениці спельти озимої Європа, отриманий гібридизацією *Triticum aestivum* L. / *Triticum spelta* L. Для удобрення використовували аміачну селітру, сульфат амонію, суперфосфат гранульований, калій хлористий.

Обговорення результатів. У результаті дослідження встановлено, що до зберігання енергія проростання зерна становила 87–90 % залежно від варіанту удобрення. Застосування азотних добрив істотно підвищувало цей показник порівняно з ділянками без добрив. При зберіганні впродовж 30 і 90 діб енергія проростання була найбільшою і становила 98–99 %. При подальшому зберіганні цей показник істотно зменшувався. Найменшим був за внесення $P_{60}K_{60}$ і становив 95 % при зберіганні впродовж 180 діб, 92 – 270 діб, 87 % – 360 діб.

До зберігання і впродовж зберігання зерна пшениці спельти впродовж 30 й 90 діб цей показник становив 99 % і не змінювався залежно від удобрення. Найменшими показниками лабораторної схожості характеризувалось зберігання зерна впродовж року 81–84 % залежно від удобрення. Найбільшим цей показник був за внесення $P_{60} + N_{120}$ і становив 84 %, а найменшим у варіанті без добрив та за внесення N_{60} $S_{70} + N_{60}$.

Висновки. Встановлено, що енергія проростання пшениці спельти найвища за зберігання впродовж 30–180 діб (96–99 %). Найбільше на цей показник впливає застосування азотних добрив. Після 360 діб зберігання зерна енергія проростання знижується до 87–91 % залежно від виду і строків застосування азотних добрив. Лабораторна схожість зерна пшениці спельти на рівні 97–99 % зберігається від збирання врожаю до його зберігання впродовж 180 діб. За умови зберігання зерна пшениці спельти у герметичних умовах без контролювання температури цей показник знижується до 81–84 % залежно від удобрення після зберігання впродовж 360 діб.

Ключові слова: *пшениця спельта, схожість, енергія проростання удобрення, зберігання.*

ЛАБОРАТОРНАЯ ВСХОЖЕСТЬ И ЭНЕРГИЯ ПРОРАСТАНИЯ ЗЕРНА ПШЕНИЦЫ СПЕЛЬТЫ В ЗАВИСИМОСТИ ОТ ВАРИАНТА УДОБРЕНИЯ И ПРОДОЛЖИТЕЛЬНОСТИ ХРАНЕНИЯ

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Пшеница спельта является перспективной культурой для переработки, поскольку ценные микронутриенты равномерно распределены в зерновке, тогда как в современных сортов пшеницы мягкой они находятся в оболочке, алейроновом слое и зародыше. Белок ее отличается высоким содержанием глиадина и ниже глютенина, что делает клейковину слабой, однако она лучше усваивается организмом человека.

Цель и задачи исследований. Целью исследования было оценить всхожесть и энергию прорастания зерна пшеницы спельты в зависимости от вида, доз и сроков применения азотных удобрений и продолжительности хранения.

Материал и методика. Исследования проводили в лаборатории «Оценки качества зерна и зернопродуктов» кафедры технологии хранения и переработки зерна Уманского национального университета садоводства. Изучали сорт пшеницы спельты озимой Европа, полученный гибридизацией *Triticum aestivum* L. / *T. spelta* L. Для удобрения использовали аммиачную селитру, сульфат аммония, суперфосфат гранулированный, калий.

Обсуждение результатов. В результате проведенных исследований установлено, что к хранению энергия прорастания зерна составляла 87–90 % в зависимости от варианта удобрения. Применение азотных удобрений существенно повышало этот показатель. При хранении в течение 30 и 90 суток энергия прорастания была самой большой и составляла 98–99 %. При дальнейшем хранении этот показатель существенно уменьшался. Наименьшим он был за внесение $P_{60}K_{60}$ и составил 95 % при хранении в течение 180 суток, 92 – 270 суток, 87 % – 360 суток.

До хранения и в течение хранения зерна пшеницы спельты в течение 30 и 90 суток этот показатель составлял 99 % и не менялся в зависимости от удобрения. Наименьшими показателями лабораторной всхожести характеризовалось хранения зерна в течение года 81–84 % в зависимости от удобрения. Наибольшим этот показатель был при внесении $P_{60}+N_{120}$ и составил 84 %, а наименьшим у варианте без удобрений и при внесении $N_{60}S_{70}$ $+N_{60}$.

Выводы. Установлено, что энергия прорастания пшеницы спельты самая высокая при хранении в течение 30–180 суток (96–99 %). Больше всего на этот показатель влияет применение азотных удобрений. После 360 суток хранения зерна энергия прорастания снижается до 87–91 % в зависимости от вида и сроков применения азотных удобрений. Лабораторная всхожесть зерна пшеницы спельты на уровне 97–99 % сохраняется от сбора урожая до его хранения в течение 180 суток. При хранении зерна пшеницы спельты в герметичных условиях без контроля температуры этот показатель снижается до 81–84 % в зависимости от удобрения после хранения в течение 360 суток.

Ключевые слова: *пшеница спельта, всхожесть, энергия прорастания, удобрения, хранения.*

LABORATORY GERMINABILITY AND GERMINATION ENERGY OF SPELT GRAIN DEPENDING ON FERTILIZATION AND STORAGE

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Spelt is a promising crop for processing, as valuable micronutrients are evenly distributed in its grain, while in modern wheat bread varieties they are concentrated in the hull, aleurone layer and germ. Its proteins contain more gliadins and fewer glutenins, making gluten weak, but better digestible in the human body.

Purpose and objectives: to assess the germinability and germination energy of spelt depending on the types, doses and timing of nitrogen fertilization and storage period.

Materials and methods. The study was conducted in the Laboratory of Evaluation of Grain and Grain Product Quality of the Chair of Grain Storage and Processing Technologies of Uman National University of Horticulture. We studied winter spelt variety Yevropa created by hybridization of *Triticum aestivum* L. with *Triticum spelta* L. Fertilizers were ammonium nitrate, ammonium sulfate, granular superphosphate, and potassium chloride.

Results and discussion. The study found that before storage the germination energy of grain was 87–90% depending on fertilization. Nitrogen fertilizers significantly increased this indicator. When grain was stored for 30 and 90 days, the germination energy was the highest and amounted to 98–99%. Longer storage significantly decreased this parameter. It was the lowest after $P_{60}K_{60}$ application: 95%, 92% and 87% when grain was stored for 180, 270 and 360 days, respectively.

Before and after 30- and 90-days storage of spelt grain, this parameter amounted to 99% and regardless of fertilizers. The lowest laboratory germinability was observed after 1-year storage of grain (81–84% depending on fertilizers). This indicator was the highest with P_{60} + $N_{120,}$ amounting to 84%, and the lowest without fertilizers or with $N_{60}S_{70}$ + N_{60}.

Conclusions. The germination energy of spelt grain was found to be the highest after 30- to 180-day storage (96-99%). This indicator was most affected by nitrogen fertilizers. After 360-day storage, the germination energy reduced to 87–91% depending on the type and timing of nitrogen fertilization. The laboratory germinability of spelt grain of 97–99% maintained from harvesting to storage day 180. When spelt grain was stored in sealed containers without temperature control, this indicator gradually decreased to 81–84% for 360 days of storage, depending on fertilizers.

Key words*: spelt, germinability, germination energy, fertilization, storage*.