

SEED SOWING VALUE AND RESPONSE TO DROUGHT STRESS OF ORGANIC AND CONVENTIONAL OAT (*Avena sativa* L.) SEEDS DURING 5 YEARS OF STORAGE

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Abstract. Due to progress of ecological farming the breeders and farmers need to know how to store ecological cereal seed material. Investigations on the seed storage value of ecological and conventional seeds were performed on naked and hulled oat during 5 years of storage in a granary and long-term store. There were analysed germination capacity, mean germination time, vigour by the growth test according to ISTA method and response to drought stress. It was found that germination capacity and vigour were lowest for the organic seeds of cv. Polar stored in a granary. In the hulled cv. Krezus degradation process was delayed. In case of long-term storage, seed value was retained irrespective of the cultivar or method of cultivation. The highest response to drought stress occurred in organic seeds of cv. Polar taken from a granary. The response to drought stress of the hulled cv. Krezus was lower irrespective of method of cultivation.

Key words: hulled oat, long-term store, naked oat, storage conditions, vigour of seeds

INTRODUCTION

In recent years the area of ecological farmland in Poland has increased and according to the data of the Ministry of Agriculture and Rural Development covers approx. 675,000 ha [<http://www.minrol.gov.pl>]. According to legal acts, in organic farming seed or vegetative sowing material should be produced with organic methods [Ustawa z dnia 25 czerwca 2009 r. o rolnictwie ekologicznym and Ustawa z dnia 5 grudnia 2014 r. o zmianie ustawy o rolnictwie ekologicznym]. Moreover, the seed material applied in organic agriculture has to meet all the requirements concerning production, quality and trading defined in the Act of 9th November 2012 on seed [Dz.U. z dnia 28.12 2012 r., poz. 1512]. An important trait of seed quality is storage value, to

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which contributes high germination capacity, good vigour, low moisture content and lack of pathogens. Seeds during storage are subjected to the effect of internal factors (i.e. genetic and physiological ones) as well as external factors, i.e. environmental ones. Internal factors include level of seed vigour during harvest or their age when they are placed in a storage. Evaluation of seed value both with regard to germination and vigour allows for predicting more accurately the response of seeds to varied, often unfavorable, environmental conditions during storage and germination [TeKrony and Egli 1991]. Even ideal storage conditions of seeds cannot improve their poor condition, and only inhibit degradation processes, which progress along with seed age [Lityński 1982]. Oat, compared with other cereals, requires the highest moisture of bedding for germination [Moś *et al.* 2006]. Water deficiency delays and reduces germination. According to Gawrońska and Grzelak [1991], applying polyethylene glycol in laboratory studies allows for simulating water deficiency, that is drought stress during seed germination. Currently, in the list of the available organic seed material there are only two cultivars of hulled oat, however, no naked cultivars have been observed yet [<https://piorin.gov.pl/rolnictwo-ekologiczne/wykaz-materialu-ekologicznego>]. Every year, there is lack of qualified, organic oat seed material, therefore some studies have been undertaken concerning storage of this species.

The aim of the research, during 5 years of storage, was evaluation of the seed value and response of the seed material of hulled and naked oat produced under organic and conventional conditions, to drought stress.

MATERIAL AND METHODS

The research material were seeds of the naked oat cv. Polar and the hulled cv. Krezus from an organic and conventional cultivation of the harvest in 2008. The conventional material of both cultivars came from Strzelce Plant Breeding, while the organic material from organic seed plantations from the Kuyavian region. It was impossible to obtain research material from the same cultivation conditions. In the first variant, the seed material was stored in linen bags at a variable temperature and humidity in a granary. As for the second variant, closed jars were used in a store with a stable temperature of 0°C. The studied material was stored and assessed over 5 years, in terms of germination capacity and various traits of seed vigour. In the 5th year, the material kept in a granary, was assessed only in terms of its germination ability

Before placing, in the two storage variants, evaluation of the initial material was conducted in terms of moisture content, 1000 kernels weight and germination capacity in accordance with ISTA methods [International Seed Testing Association 2008]. During storage, research methods included annual evaluation of germination and the vigour measured by various traits, as well as response to drought stress during germination. For the evaluation of germination capacity, 50 seeds were sown in a cuvette on paper in 3 replications. In order to calculate an average time of germination of one seed according to Ellis and Roberts [1981], 3 × 50 seeds were sown on Petri dishes of a diameter of 100 mm, and every day germinating kernels were taken out. While evaluating vigour, also study of seedling growth was conducted measuring length of the first leaf (shoot part) and length of the primary root as well as dry matter of the seedling (as the total of normal seedlings) compared to the number of sown seeds. To evaluate these parameters, 3 × 25 kernels were sown on germination paper rolls

according to ISTA Handbook of Vigour Test Methods [1995]. Response to drought stress was determined while sowing in cuvettes 3×50 seeds on paper bedding soaked in polyethylene glycol solution PEG 6000, which simulated three levels of drought: -0.2 MPa (S1), -0.4 MPa (S2) and -0.6 MPa (S3) [Gawrońska and Grzelak 1990]. Before sowing, the seeds had been moisturized up to 15%, and they were disinfected in 1% sodium hypochlorite solution. For every drought level, evaluation of germinating capacity was conducted after 15 days, (seedlings developed slowly, and ISTA Rules [2008] allow for prolonging the time of assessment). All analyses were conducted in a thermostat with a stable temperature of 20°C . Because of the character of data (distribution and variations), statistical analysis was limited to mean values, standard variations and graphic presentation of the results.

RESULTS AND DISCUSSION

Preliminary characteristic of the initial material indicates that there was a low moisture content while 1000 kernels weight of conventional material in both cultivars was at least by 10% lower than in the organic material (Table 1).

Table 1. Seed quality of the initial material in 2008

Variant	Moisture content %	TKW g	Results of germination analysis, %			
			normal seedlings	abnormal seedlings	fresh, ungerminated seeds	dead seeds
Krezus conventional	9.2	34.5	93	4	0	3
Krezus organic	9.8	37.8	89	2	0	9
Polar conventional	9.3	21.0	97	2	0	1
Polar organic	9.9	23.2	83	5	0	12

The initial material, both organic and conventional, met requirements for the qualified seed material, as for hulled oat cultivars the minimal germination capacity is 85%, and for the naked cultivars it is 75% [Rozporządzenie Ministra Rolnictwa i Rozwoju Wsi z dnia 18 kwietnia 2013 r.]. In the present study, while keeping oat in a granary, irrespective of the cultivation method, there occurred a decline in germination capacity. Analysis of the results indicated that organic material of cv. Polar after two years in a granary its germination capacity significantly decreased (Fig. 1A). Next year, value of this parameter further decreased, and in the consecutive years the seeds did not germinate. On the other hand, conventional material of this cultivar had a slower rate of losing germination, as after two years of storage it was 81%, and in the following year it was only half of this value. The hulled cv. Krezus responded differently to staying in a granary. In the conventional material there occurred a decrease in its germination capacity only in the third year of storage, while a really significant decrease in the value of this trait occurred only in the 5th year. Seeds of cv. Krezus from an organic cultivation in the second year of storage had a germination capacity slightly lower than the initial one, and in the following year only half of the seeds germinated. In the 4th year of storage in a granary, no symptoms of germination were observed. Comparison

of both cultivars from conventional cultivation indicates that the naked cv. Polar lost its germination capacity quicker while staying in granary than the hulled cv. Krezus, which even after 5 years germinated on the level of several percent. Under conditions of long-term storage, germination capacity of the conventional material of both cultivars was retained until the end of the experiment (Fig. 1B). In cv. Krezus after 5 years of storage, organic material germinated on the same level as the initial one.

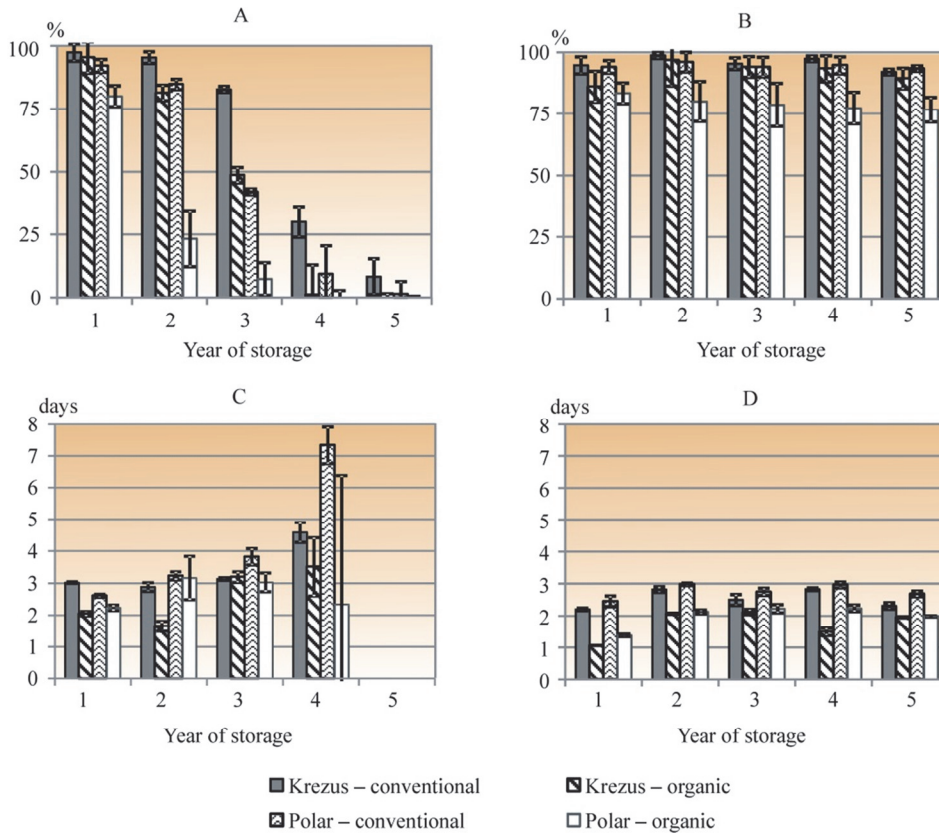


Fig. 1. Germination capacity and germination rate of the seeds depending on storage conditions: A – germination capacity of the seeds in a granary, B – germination capacity of the seeds in long-term storage, C – germination rate of the seeds in a granary, D – germination rate of the seeds in long-term storage.

Germination capacity of spring cereals studied by Kolasińska [2008] produced on organic qualified seed plantations was for half of the samples lower than quality standards of the seed material. From the present study it follows that organic seed material quickly lost its germination capacity. This especially concerned cv. Polar, whose seed material had a visibly lower germination capacity even after 2 years of storage in a granary. The reason for the decrease in germination capacity under these storage conditions may be seed infestation. Wiewióra [2009] conducted mycological analysis of cereal seeds from the organic cultivation and found heavy infestation with fungi, both saprotrophic, i.e. storage fungi and pathogenic ones from the genus

Fusarium and *Bipolaris sorokiniana*. In the present study, the reason for worse storage of the organic material than conventional one, might have been fungi occurring on kernels from the organic cultivation, especially in the naked cv. Polar. From the literature data it follows that naked seeds are to a higher degree prone to mechanical damage during harvest and threshing, as well as to infection with fungal diseases and pests [Moś and Zieliński 2003]. This may be the cause of a decreased germination capacity and vigour, and a quicker decrease in the value of these parameters may be also expected during storage.

One of the traits of seed vigour is the rate of germination. In the conducted experiment after a year of storing the material, an average rate of germination of one seed was from 2 to 3 days, while after 4 years it was over 7 days in cv. Polar from conventional cultivation (Fig. 1C). In both cultivars, the conventional material germinated longer than organic material. Lower variation was observed in the material from storage where after a year of storing, the average rate of germination was from 1 to 2.5 days, while in the 5th year from 2 to 2.7 days (Fig. 1D). Probably, the low temperature at which it was stored caused breaking of seed dormancy, and activated the germination process. According to Moś *et al.* [2008], average germination time in naked oat forms is lower than in the hulled ones, which was not confirmed in the present study. However, numerical values given by authors were higher, probably because of the applied various temperature for the evaluation of this parameter. Willenborg *et al.* [2005] found differences in terms of germination capacity and average germination time between oat genotypes, seed size and osmotic potential of the bedding.

Vigour of the seeds from the material from a granary assessed with a growth test for seedlings indicated that the average length of the shoot part of the seedling was lower at the end of the research period than at the beginning. This was especially visible in the 3rd year in cv. Polar from the organic cultivation, while in the material from storage, value of this trait was quite stable (Fig. 2A, B). Slightly different results were obtained while studying vigour based on the length of the root part of the seedling. It was as early as in the 3rd year of storage that the organic material of both cultivars had the lowest value of this trait. Moreover, the average length of the root part of the seedling in cv. Krezus was by 130 mm higher than the shoot part (Fig. 2A, B, C, D). Measurements of the dry weight of seedlings indicated higher values of this trait in conventional material of both cultivars which was kept in a granary for the first 2 years (Fig. 2E). Later, there occurred a decrease in vigour, especially in cv. Polar. However, this cultivar in the long-term storage after 5 years had a slightly higher average dry weight of seedlings than after a year because of a higher length of their root part (Fig. 2D, F).

In each research year, organic material of both cultivars had a lower dry weight of seedlings than conventional material, both the one kept in a long-term store and in a granary (Fig. 2E, F). However, in the samples from the long-term storage, variation in this trait remained on a similar level.

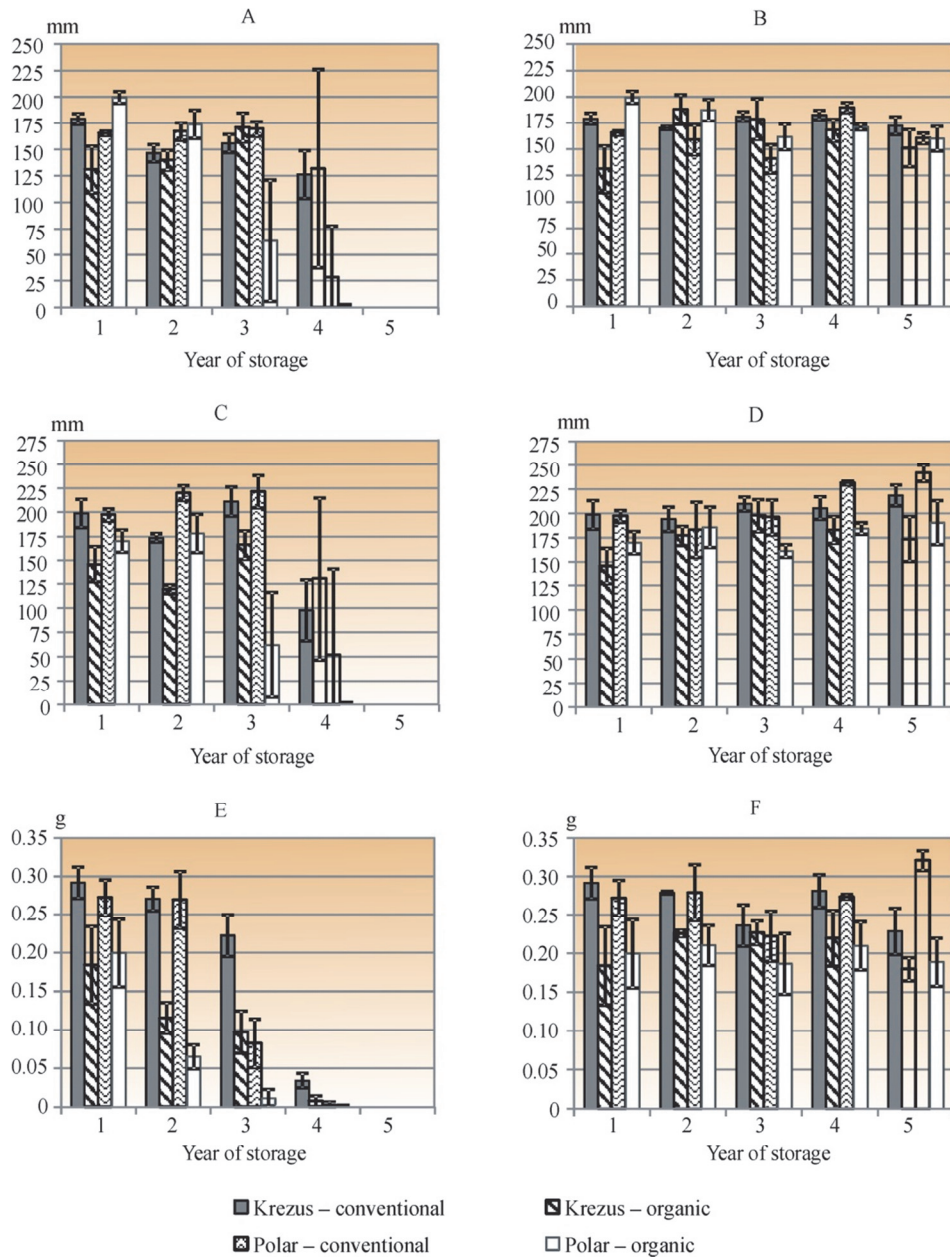


Fig. 2. Vigour of the seeds depending on storage conditions: A – shoot length of seedlings of the seeds in a granary, B – shoot length of seedlings of the seeds in long-term storage, C – root length of seedlings of the seeds in a granary, D – root length of seedlings of the seeds in long-term storage, E – dry weight of seedlings of the seeds in a granary, F – dry weight of seedlings of the seeds in long-term storage

Evaluation of germination under conditions of drought stress S1 indicated that organic material of cv. Polar kept in a granary had a lower proportion of viable seeds (Fig. 3A). In the following years it distinguished itself with a quick decrease in the value of this parameter, almost to a zero in the 4th year of research. However, conventional material of this cultivar indicated a lower seed vitality as early as in the 3rd year of storage. The hulled cv. Krezus showed a higher tolerance to water deficiency, as even after 4 years of storing conventional material in a granary, half of the seeds were found to be viable. Seed material of both cultivars from the long-term storage responded similarly in each year of research, although in cv. Polar from organic cultivation even in the 2nd year of storage there occurred lower germination (Fig. 3B). In the drought stress S2, seeds of cv. Krezus from the organic cultivation had a decreased vitality in the second year of storage, while from conventional cultivation as early as in the 4th year (Fig. 3C). Seeds of both cultivars stored in the long-term storage retained vitality in drought stress S2 (Fig. 3D). Standard deviations indicate that variation between research variants in consecutive years remained on the same level. In the highest drought stress S3 in cv. Polar from organic cultivation stored in a granary, germination was only 25% in the 2nd year of research and reached values being by over half lower than the initial ones, similarly as with other concentrations of polyethylene glycol (Fig. 3E). Material in the long-term storage in all variants of drought stress showed a similar response of kernels to water deficiency in all cultivars. However, in the 2nd and 5th year of research in cv. Polar from organic cultivation there a lower average seed vitality was observed in drought stress S3 (Fig. 3F). Mut and Akay [2010] studied naked cultivars of oat under conditions of water deficiency during germination and found that the higher the osmotic potential of the bedding the lower the germination capacity, the higher the average time of germination, and the lower length of plumula and root part of the seedling. In the present study, in each variant of drought stress, organic material of cv. Polar from the granary responded stronger, i.e. it produced fewer seedlings than the hulled cv. Krezus. This does not confirm research results of Zieliński *et al.* [2009] with a higher resistance of naked form of oat to water deficiency in the initial stage of germination. The comparison of organic and conventional material in terms of the proportion of viable seeds indicates that irrespective of the osmotic potential of the bedding, material from the long-term storage retained vitality above 50%.

From the research conducted by Kolasińska [2009] concerning cereals from organic plantations it follows that response of kernels to drought during germination was diverse, however seeds of cv. Polar were less sensitive than hulled cv. Chwat, as well as wheat and barley. Also Moś *et al.* [2006] indicated that under drought stress, higher sensitivity was indicated in the hulled cultivars than in naked cultivars, which does not correspond with the results of the present research. All mentioned authors studied seeds over a short time after harvest. Moś and Zieliński [2003] studied storage potential of oat under conditions of an accelerated ageing test, and found a lower suitability of seeds of naked cultivars for storage. In the present study, the hulled cv. Krezus from conventional cultivation reached highest vitality in all years of storage, both in a long term store and granary, which confirms the results of these authors.

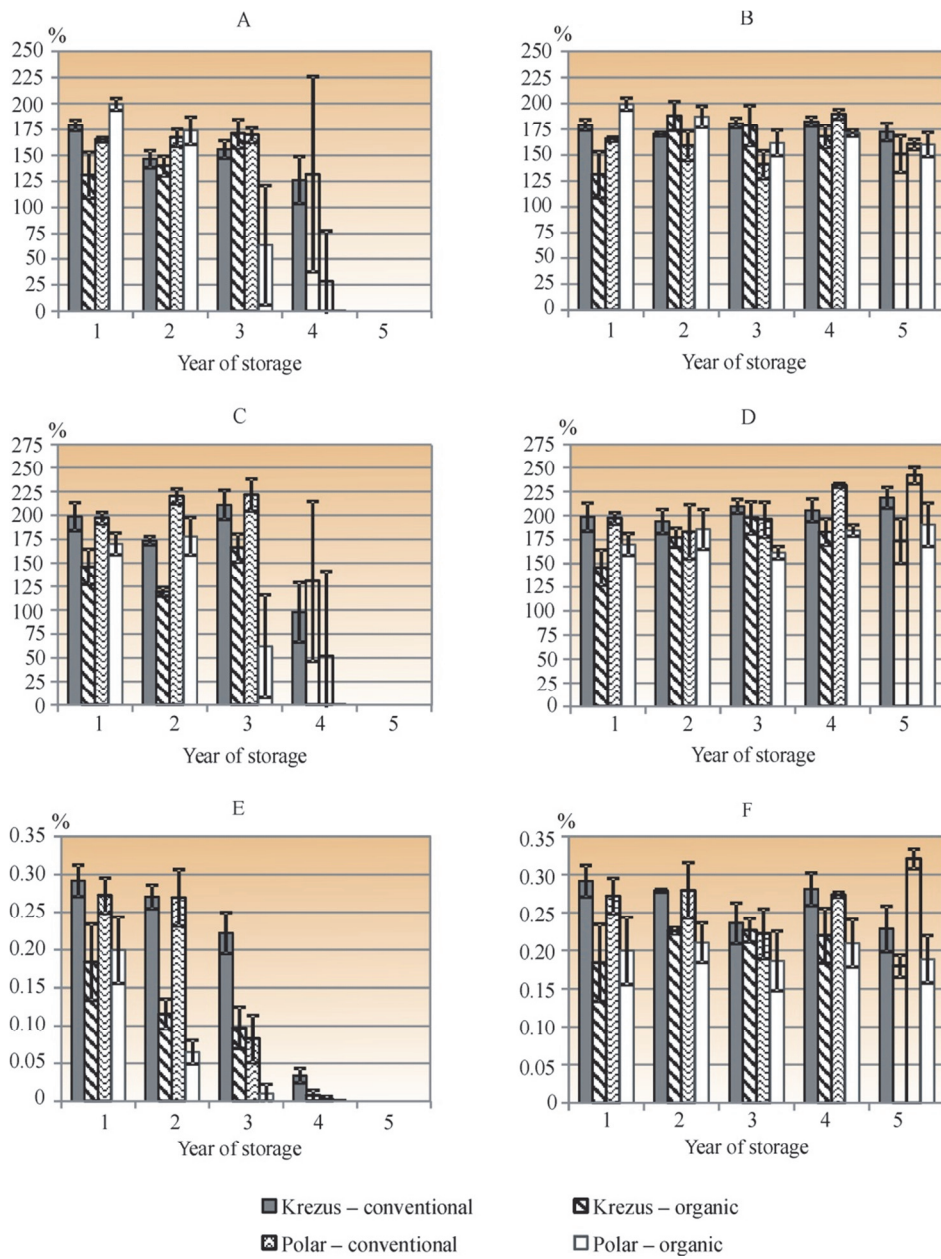


Fig. 3. Vitality of the seeds depending on the level of drought stress: A – in a granary in drought stress S1, B – in long-term storage in drought stress S1, C – in a granary in drought stress S2, D – in long-term storage in drought stress S2, E – in a granary in drought stress S3, F – in long-term storage in drought stress S3

CONCLUSIONS

Based on the conducted research, it was found that during 5 years of storage the highest loss of germination capacity and vigour was observed in the organic material of the naked cv. Polar kept in a granary. In the hulled cv. Krezus stored under the same conditions, a decrease in the seed value occurred more slowly. In both cultivars stored in a granary, organic material had lower values of the assessed parameters than the conventional material. In the long-term storage, sowing value was retained irrespective of the cultivar or cultivation method. Response to drought stress was the highest in the organic material of cv. Polar stored in a granary. The hulled cv. Krezus indicated weaker response to water deficiency during germination, irrespective of the cultivation method.

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WARTOŚĆ SIEWNA ORAZ REAKCJA NA STRES SUSZY EKOLOGICZNEGO I KONWENCJONALNEGO MATERIAŁU SIEWNEGO OWSA (*Avena sativa* L.) PODCZAS 5 LAT PRZECHOWYWANIA

Streszczenie. W związku z rozwojem ekologicznej produkcji roślinnej zarówno hodowcom, jak i rolnikom potrzebna jest wiedza na temat przechowywania ekologicznego materiału siewnego zbóż. Z tego powodu podjęto badania dotyczące wartości przechowalniczej owsa o ziarnie oplewionym i nieoplewionym podczas 5 lat przechowywania. Przedmiotem analizy była wartość siewna i reakcja na stres suszy konwencjonalnego i ekologicznego materiału siewnego owsa, składowanego w magazynie oraz przechowalni długoterminowej. Oceniano zdolność kiełkowania, szybkość kiełkowania, wigor testem wzrostowym siewki zgodnie z metodyką ISTA oraz kiełkowanie w stresie suszy. Stwierdzono, że najszybciej zdolność kiełkowania i wigor tracił materiał ekologiczny odmiany nieoplewionej Polar przechowywany w magazynie. U odmiany oplewionej Krezus proces degradacji następował wolniej. W warunkach przechowalni długoterminowej wartość siewna została zachowana niezależnie od odmiany i sposobu uprawy. Materiał ekologiczny odmiany Polar, przechowywany w magazynie, reagował najsilniej na stres suszy. Odmiana oplewiona Krezus wykazała słabszą reakcję na niedobór wody podczas kiełkowania, niezależnie od sposobu uprawy.

Słowa kluczowe: owies nieoplewiony, owies oplewiony, przechowalnia długoterminowa, warunki magazynowe, wigor

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