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OILSEED STORAGE UNDER CONTROLLED CONDITIONS

Monitoring results of oilseeds (common sunflower, winter and spring rape, brown and black mustard, opium poppy, false flax, upland cotton, peanut, castor bean, Indian sesame, arugula, perilla, chufa sedge, lallemantia, oil radish, turnip rape, safflower), which were stored in hermetically sealed containers at uncontrolled temperature and low temperature of 4^{o}C or -20^{o}C, were analyzed. The following values of moisture content provided high seed viability: for common sunflower 2-4.5 % during 9-15 storage years; for winter and spring rape 2/5-3.7 % during 5-18 years; for brown and black mustard 2.5-3.7 % during 4-12 years; for opium poppy 2.4-3.6 % during 4 years; for safflower 2.4-2.9% during 5-10 years. At -20oC the viability of seeds remain unchanged for at least five years at the following values of moisture content: for false flax 2-4 %; lallemantia 2.6 %; peanut – 3.1 %; castor bean 3.8%; for arugula, chufa sedge, Indian sesame, oil radish, perilla, and land cress - below 4 %. It was established that in a depository with uncontrolled temperature the germination of sunflower seeds with 2.5-3.7 % moisture content only remained unchanged for 4 years. Then a gradual reduction was observed. The research results on oilseed storage at controlled temperature and moisture content revealed the optimum conditions for long-term seed storage under controlled conditions at 4^{o}C or -20°C.

Keywords: *oil crops, seeds, storage, moisture content, temperature, genebank*

INTRODUCTION

There is a need for oilseed storage both for production and for scientific purposes. At the same time, oilseeds quickly lose viability under uncontrolled conditions [1]. This is due to lipid peroxidation (lipids are abundant in seeds) and other biochemical processes, which leads to destruction of membranes, including mitochondrial ones [2]. There is a relationship between changes in lipid peroxidation, enzyme activity in sunflower seeds, high content of malondialdehyde, a marker of lipid peroxidation, and glutathione, which has antioxidant properties, and loss in seed viability, resulting from long-term storage [3]. It is known that during the storage of seeds peroxidase activity reduces, and tocopherol content increases. Ascorbate peroxidase and catalase activities considerably vary, depending on seed moisture and temperature of storage, respectively [4]. In addition, during the storage of oilseeds, the composition of phenolic compounds changes. In particular, significantly higher chlorogenic acid content and total phenolic acid content are observed in sunflower seeds with high oil content than in sunflower seeds with a lower oil content [5]. During the storage of seeds, the total oil content also decreases with increasing amounts of fatty acids, especially unsaturated ones [6, 7]. Hence, a more rapid oxidation of oil in crops that contain more unsaturated fatty acids is expected [8]. It is known that the storage of false flax seeds in tissue bags at the average temperature of 17.5^{o}C and seed moisture of 11 % induced changes in biochemical composition. In particular, after the first storage year the oil content increased by 0.9 %. During the further storage for five years a reduction in oil content by 3% was recorded. Polyunsaturated fatty acids underwent the biggest changes. Thus, during the five-year storage the level of linoleic acid decreased by 6 %, of linolenic acid– by 4 %, but the content of oleic acid increased by 3 %, of palmitic acid - approximately by 1 %, and of stearic acid – by 0.23 %. Minor changes in the amounts of these acids did not significantly impact the quality of oil [9].

Under these conditions, varietal characteristics were preserved. The study results demonstrate that the initial moisture content of oilseeds, seed storage conditions, seed quality, and antioxidant enzyme activity determine the type of biochemical changes during the storage [10].

To predict loss in seed viability, there are different methods. Recently appropriate molecular markers associated with the ability of seeds to be stored were established [11]. To analyze different processes that occur during seed aging, seed aging conditions are simulated ("accelerated aging of seeds"). During the accelerated aging of soybean seeds the germination vigor declined, early respiratory activity reduced, conductivity enhanced, 10% of cotyledon dry weight was lost, ability to swell dropped. The authors believe that each of these changes is an outcome of impairment in membrane structure [12]. There was a strong correlation between the total phenol content in exudate and percentage of abnormal seedlings during accelerated aging, indicating a possibility of assessing seed quality by measuring of the total phenol content in seed exudates [13]. Under controlled conditions of accelerated aging, the adenylic pool, ATP level and seed viability reduced. Loss in seed viability is associated with accumulation of peroxide, malondialdehyde, and it is believed that lipid peroxidation is not the only cause of seed viability loss. Reduction in activities of enzymes involved in cell detoxification - superoxide dismutase, catalase, glutathione reductase as well as accumulation of active oxygen species was described [14].

We also know that under accelerated aging of seeds the spin-spin relaxation time shortens, and protein and starch contents reduce. Simultaneously the electrical conductivity and soluble sugar content increase [15].

Some researchers believe that the nature of changes in the NMR spin-spin relaxation time in aging seed suggests that the loss in seed viability attributed to high temperature and high moisture content are closely related to an irreversible loss of membrane integrity and some cellular structures. These facts are confirmed by the simulation results. It is also believed that the difference between the longevity of seeds, in particular in tomato and onion, is due to the differences in the structure of membrane surface [16].

To prevent loss in oilseed viability, there are protocols to create special conditions, which shoould be followed when seeds being collected [17]. According to the technical standards, upon placement, storage and transportation of oilseeds, such as mustard and opium poppy, moisture content up to 10 % is allowed; for safflower, false flax, land cress seeds up to 9 %; for linseed, sesame, rape seeds up to 8 %; and for sunflower seeds up to 7 % [18-20]. In industrial seed production these standards are adhered to. Even primitive methods of drying improve the ability of seeds to be stored. For example, the advantage of peanut seed storing under low humidity conditions (in jute bags with supplementary $CaCl_2$) is known [21]. The advantage of peanut seed storage in the gas atmosphere with different ratios of carbon dioxide, oxygen and nitrogen over vacuum storage was proven [22].

Due to special conditions it is possible to significantly extend the seed shelf life without loss in the seed viability. For example, it is known that the viability of sunflower seeds with the moisture content of 6.4 % stored in hermetically sealed containers at 11-20^{o}C was 24 % lower after 18 storage years than the baseline value; the viability of hemp seeds with the moisture content of 3.5 % reduced by 21 % after 16 years; the viability of perilla seeds with the moisture content of 2.6 % - by 14 % after 17 years; the viability of castor bean seeds with the moisture content of 5.6 % was 10 % lower after 18 years. At the same time the germination capacity of sesame seeds with the moisture content of 2.4 % only dropped by 3% after 23 storage years. Seeds of these crops, which were stored with higher moisture content in unsealed containers, lost viability during this storage period [23, 24].

Optimum storage conditions for seed specimens are created in genebanks. There are recommendations for a long-term storage of seeds under these conditions [25]. To better preserve the viability of seeds of crops that are reproduced by seeds, one should maintain the relative humidity of 15 % ± 3 % and the temperature of -18 ± 3° C in special depositories. Recommended conditions for seed storage are general, therefore, it is advisable to take into account the possibility of varying optimality values these parameters for each crop.

The aim of this study was to determine optimum storage conditions for oilseeds of: common sunflower, winter and spring rape, brown and black mustard, opium poppy, false flax, upland cotton, peanut, castor bean, Indian sesame, arugula, perilla, chufa sedge, lallemantia, oil radish, turnip rape, safflower by the monitoring results on oilseed status under controlled conditions of storage .

MATERIAL, CONDITIONS AND RESEARCH METHODS

The test materials were seed specimens of sunflower (*Helianthus annuus* L.) cv. Foton (UE0100004), Zaporizskyy Kondyterskyy (UE0100042), Kripysh Polipshenyy (UE0100043), Epmak (UE0100100), Omskyy Skorospelyy (UE0100240), VNYYMK 1646 (UE0100078), Voronezhskyy 151 (UE0100121), Mistsevyy 6 (UE0100031), inbred lines Kh 840 V (UE0100067), Kh 480 V (UE0100095), Kh 711 V (UE0100123), Kh 08 T (UE0100958); winter rape (*Brassica napus* L. f. *oleifera biennis* Metzger Koch) cv. Tysmenytskyy (UE0500047), Fedorivskyy (UE0500051), Wotan (UE0500069), Chornyy Veleten (UE0500087), Danhal (UE0500209), Svyeta (UE0500254), Dembo (UE0500379), Atlant (UE0500380), Vinnytskyy (UE0500464); spring rape *Brassica napus* L. *f. oleifera annua* Metzger cv. Ranok Podillya (UE0500086), Mykytynetskyy (UE0500201), Mariya (UE0500211), Oksamyt (UE0500212), UE0500321, Arion (UE0500255); brown mustard (*Brassica juncea* (L.) Czern) cv. Commercial Brown (UE0400002), UE0400005, Roksolana (UE0400006), Rosava (UE0400007), UE0400167, UE0400178; black mustard (*Brassica nigra* (L.) Koch) cv. (UE0400184) and wild form (UE0400004); opium poppy (*Papaver somniferum* L.) cv. UE1100001, Novynka 198 (UE1100193), UE1100258, Sharlachkonig (UE1100491), Laciniatum (UE1100492), UE1100511, UE1100513, UE1100587, UE1100609, E 7-П-13-Н-1 (UE1100963), breeding accessions В-35-К-2 (UE1100265), Start M-3 (UE1100301); false flax (*Camelina sativa* L. Crantz), cv. UE0600001, 31A-6 (UE0600002), Isylkulets (UE0600003), Hirskyy (UE0600008), (UE0600028) and local cultivar (UE0600028); upland cotton (*Gossypium hirsutum* L.) cv. Dniprovskyy 5 (UF0800001), Pidozerskyy 4 (UF08000310); peanut (*Arachis hypogaea* L.) cv. Klynskyy (UE0200001); castor bean (*Ricinus communis* L.) cv. Khortytska 7 (UE0300001); Indian sesame (*Sesamum indicum* L.) cv. Nadezhda (UE1000001); arugula (*Eruca sativa* Mill.) cv. UE1500001; perilla *(Perilla frutescens (L.) Britton var. japonica Hara)* cv. UE0700003; chufa sedge (*Cyperus esculentus* L.) cv. Mestnyy 2 (UE1400003); lallemantia (*Lallemantia iberica* (Stev.) Fisch. et Mey) cv. UE0800002; oil radish (*Raphanus sativus* L.var. *oleiformis* Pars.) cv. Zhuravka UE1600001 and local cultivar UL0800003; turnip rape (*Brassica rapa* L. *var.silvestris* (Lam.) Briggs.) cv. g 97 (UE1700012); safflower (*Carthamus tinctorius* L.) local cultivars UE0900002, UE0900004, cv. Mylyutynskyy 114 (UE0900016).

Seeds were cultivated on the experimental base *Elitne* of the Plant Production Institute nd. a. V.Ya. Yuryev of NAAS, at Ustymivka Experiment Station of the Plant Production Institute nd. a. V.Ya. Yuryev of NAAS, at the Experimental Station of Medicinal Plants of the Institute of Agroecology and Environmental Management of NAAS, at MM Gryshko National Botanic Garden, Vinnytsya State Agricultural Experiment Station (forest steppe zone), at the Carpathian State Agricultural Research Station of the Institute of Agriculture of Carpathian Region of NAAS in accordance with the agronomic requirements (zone of mixed forests), at the Institute of Oil Crops, at the Southern State Agricultural Research Station of the Institute of Water Problems and Meliaration of NAAS(steppe zone) [26].

Seeds were stored in hermetically sealed packages of multilayer foil in the National Depository of Plant Gene Pool for 4-13 years (1995-2014) under controlled conditions at the low temperatures of 4^{o}C or -20^{o}C.

Seeds of some accessions were initially in stored hermetically sealed glass containers at uncontrolled temperature. The average annual temperature in the depository with uncontrolled temperature was 9°C, varying from -18°C to 25°C. After 5 to 10 years of storage under these conditions, accessions with high seed viability were transferred to packages of multilayer foil and placed into a camera at -20°C.

Before storage seeds were air-dried to the recommended moisture content of 2-5 %. Drying was performed at the relative humidity of 25% at ≤25°C with a dehumidifier *Munters* (Sweden). Then seeds were placed in hermetically sealed containers.

Seed viability was tested by ISTA methods between filter paper immediately prior to storage and during storage on average once every 5 years. To determine seed viability, seeds were couched between filter paper sheets at 20-30°C [27, 28]. The data were processed using the methods of variation statistics [29]. To compare two sampling, the sampling rate test was used.

RESULTS AND DISCUSSION

Most of sunflower accessions with the moisture content of <3% (Fig. 1) were stored at 4° C. Storage under these conditions for 9-14 years did not affect the germination capacity of Kripysh Polipshenyy (UE0100043) (t = -0.05), Ermak (UE0100100) (t = 0.0), Omsk Skorospelyy (UE0100240) (t = -1.2), and inbred line Kh 840 V (UE0100067) (t = -1.2) (Figure 1). The initial germination capacity for these accessions was 89 % or higher. Line Kh 480 V (UE0100095) had the initial germinability of 93 %, and after four-year storage this index did not changed (t = 0.0). After 12 storage years the germination capacity of this accession increased by 5 % (t = 5.0). The germination capacity of accessions Kh 840 V (UE0100067) and Omskyy Skorospelyy (UE0100240) showed an upward tendency in comparison with the baseline value: it increased by 3 % (t =-1.2). We suppose that the germinability increase is explained by gradual cleavage of abscisic acid and other inhibitors because of prolonged exposure of seeds to positive low temperature [30]. It is believed that abscisic acid and sugars prevent reserve fat mobilization during germination [31]. Similar findings concerning rise in the seed germination capacity under the influence of negative temperatures are known for other crops [32].

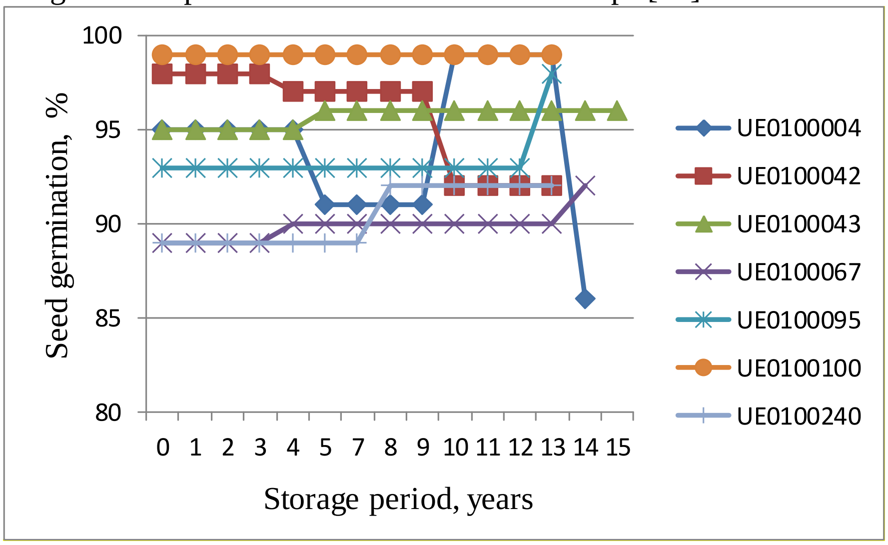

Fig.1. **Post- storage germination capacity of sunflower seeds with the moisture content of 2.3-3.0 %, 1997-2014.**

Seeds of Zaporizskyy Kondyterskyy (UE0100042) did not changed the germination capacity (t = -0,05) after after four-year storage at low positive temperature, but this index reduced by 5 % (t = 3) after nine years. The germination capacity of Photon (UE0100004) decreased by 9 % (t = 3.8) after 13 years of storage at uncontrolled temperature.

Mistsevyy 6 (UE0100031) and Kripysh Polipshenyy (UE0100043) with the seed moisture content of 3.1-4.5 % (Fig.2) were stored at uncontrolled temperature for 7 years. After this period, the germination capacity decreased by 16% (t = 7). After seeds of these accessions had been transferred to the freezer, their germination capacity was monitored two years later. It increased by 6 (t = -2.3) and 13 % (t = -5.1), respectively.

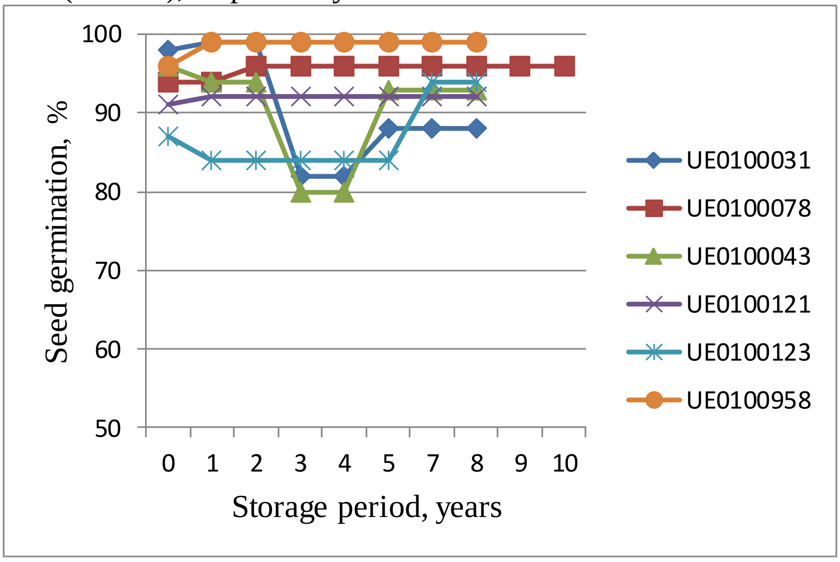

Fig.2. **Post- storage germination capacity of sunflower seeds with the moisture content of 3.1-4.5 %, 1997-2014.**

The other accessions with this moisture content were stored at 4°C. VNYYMK 1646 (UE0100078), Voronezhskyy 151 (UE0100121), and line Kh 08 T (UE0100958) did not change the germination capacity during 11-13 years under these storage conditions, and line Kh 711 V (UE0100123) showed even the increase in this parameter by 10 % (t = -2.9) after ten-year storage.

According to the findings, seeds of cultivars were able to be stored not better than seeds of lines. The test arrived mainly from the Plant Production Institute nd. a. V. Ya. Yuryev (Forest-Steppe) and the Institute of Oil Crops (Steppe). It is known [3] that comparative cultivation of sunflower cultivars in different geographical areas shows differences in the quality of oil and protein, but the varietal features in terms of the total contents of these substances are preserved in all climatic zones. Therefore, one could expect that seeds from close regions would have a similar quality of oil and protein, which determined similar capacity for storage in different accessions. It is also expected that accessions with a greater content of oleic acid (C18: 1) will be better stored than conventional accessions that contain more linoleic (C18: 2) and linolenic (C18: 3) acid [33].

Thus, the storage of sunflower seeds with the moisture content of 2-4 % during 7 years leads to a reduction of their germination capacity in most cases at uncontrolled temperature only. The storage of sunflower seeds with the same moisture content at 4°C or at -20°C does not affect the germination capacity during 9-14 years of storage or causes an increase. In other words, storage of sunflower seeds with the moisture content of 2-4.5% at 4°C or at - 20°C can maintain a high viability of sunflower seeds.

The germination capacity of rape seeds with the moisture content of 2.5-3 % was sufficient during 9-11 years of storage. The other authors' findings prove that rape seeds should be stored with the moisture content < 6 % at the temperature <10°C [10]. Rape accessions Wotan (UE0500069), Ranok Podillya (UE0500086), Oksamyt (UE0500212), Arion (UE0500255) were stored at the low positive temperature for 9-11 years (Figure 3). The germination capacity of Wotan (UE0500069), Ranok Podillya (UE0500086) accessions remained unchanged during this period. Seeds of Arion accession (UE0500255) after the first nine years of storage increased the germination capacity by 16 % (t = -7.7). At the same time, the germination capacity of Oksamyt (UE0500212) accession was 7 % (t = 3.4) and 10 % (t = 4.6) lower than the initial value after 5 and 9 years of storage, respectively.

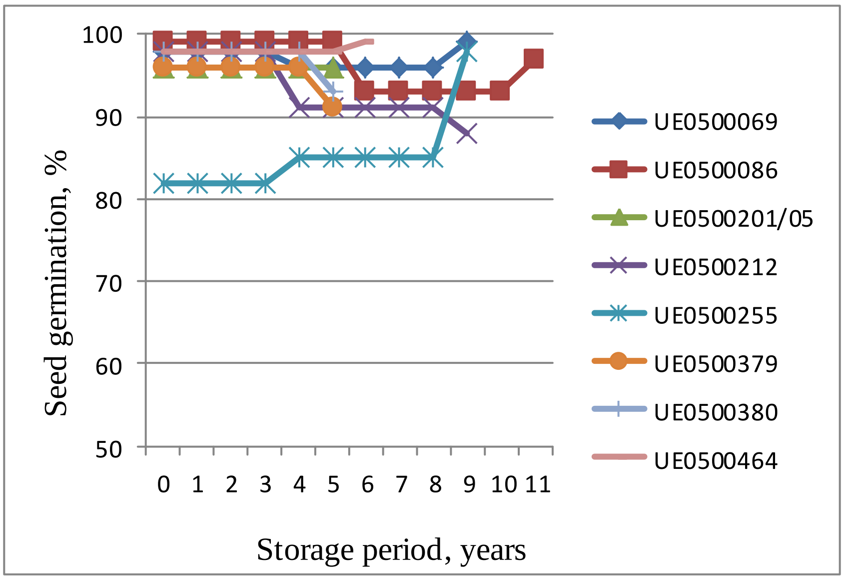

Fig.3. **Post-storage germination capacity of rape seeds with the moisture content of 2.5-3 %, 1997-2014.**

Perhaps, this is due to the conditions of seed couching, because this accession comes from Vinnytsya Experiment Station, and the others - from the Carpathian State Agricultural Experiment Station of the Institute of Agriculture of Carpathian region of NAAS. The germinability of rape seeds with the same moisture content, which were stored at -20^{o}C, was unchanged after 5 years of storage in Mykytynetskyy (UE0500201) (2005 reproduction), Atlanta (UE0500380), Vinnytskyy (UE0500464) accessions and decreased by 5 % (t = 2.3) by in Dembo (UE0500379) accession.

Rape seed accessions with the moisture content of 3.1-3.7 %, which were stored at 4°C, did not changed the germination capacity after 12 - 13 years of storage (Danhal (UE0500209), 2002 reproduction; Maria (UE0500211); UE0500321; Svyeta (UE0500254)) or after 18 years (Fedorivskyy (UE0500051) accession) (Fig. 4).

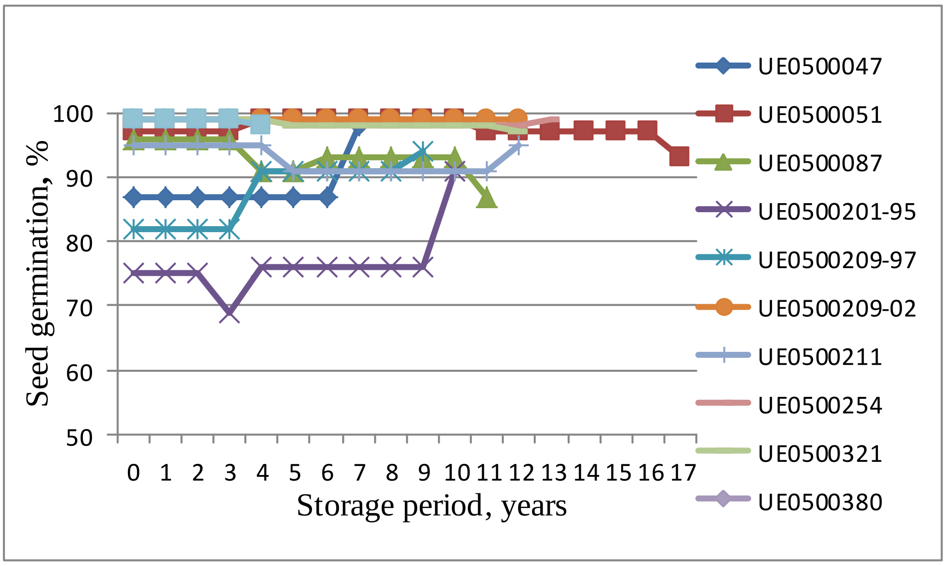

Fig.4. **Post-storage germination capacity of rape seeds with the moisture content of 3.1-3.7 %, 1995-2014.**

The germination capacity of Chornyy Veleten (UE0500087) after 6 years of such storage did not change, and after eleven years it decreased by 9 % (t = 3.9). It should be noted that seeds of this accession come from Vinnytsya Agricultural Research Station - a zone characterized by increased amount of precipitation during the ripening of rape seeds. Perhaps, such drop in the germination capacity is due to unfavorable growing conditions for seeds, as in the above case.

Mykytynetskyy (UE0500201) (1995 reproduction), Danhal (UE0500209) (1997 reproduction) accessions with the same seed moisture content, which were stored without alteration in the germinability at uncontrolled temperature, after transferring to the freezer showed an increase in the germination capacity approximately by 10 % related to the initial value. Tysmenytskyy (UE0500047) accession after seven-year storage at -20°C showed 11 % (t = -5.0) increase in the germination capacity. This is probably induced by changes in phytohormone composition during storage of seeds under these conditions. Similar trends were observed during storage of seeds of other crops at low positive and negative temperatures [32].

Thus, rape seeds with the moisture content of 2.5-3.7 % after 5-18 years of storage demonstrated a high germination capacity during storage both at 4°C and at -20°C (Fig. 5).

Mustard seeds with the moisture content of 2.9-4.2% in general showed a high germination capacity after 5-12 years of storage. After 7 years of storage at uncontrolled temperature brown mustard accession Commercial Brown (UE0400002) did not changed its germination capacity, in cultivar UE0400005 it decreased by 9 % (t = 4.5) during the same period. After 8 years of storage in the depository at uncontrolled temperature black mustard seeds reduced the germination capacity by 41 % (t = 13.2). After transferring this accession to the camera with the temperature of -20°C, the germinability of seeds increased by 20 % (t = -5.7) after 1 year. After storing this accession for 3 years at -20°C, there was a decrease in the germination capacity by 11 % (t = 3.5). In other words, negative temperatures could retard the germination drop, but unfortunately failed to stop it.

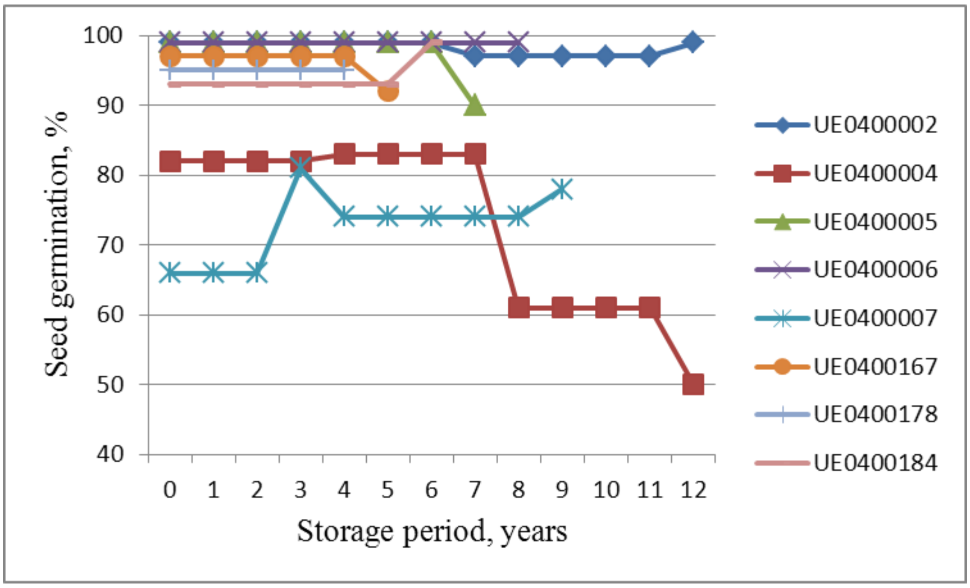

Fig.5. **Post-storage germination capacity of brown and black mustard seeds with the moisture content of 3.1-3.7 %, 1995-2008.**

The germination capacity of brown mustard seeds with the moisture content of 3-4 % of Commercial Brown (UE0400002), Roksolana (UE0400006), Rosava (UE0400007), UE0400178 accessions, which were stored at 4°C or at -20°C for 5-9 years, did nit change. UE0400005 and UE0400167 accessions decreased the germinability by 9 % (t = 4.5) and 5 % (t = 2.4) after 7 and 5 years of storage under these conditions, respectively. The germination capacity of black mustard cv. UE0400184 increased by 6 % (t = -3.2) after 7 years of storage at -20°C. The germination capacity of the wild form UE0400004 of the same species was unchanged during the first 8 years and then experienced a gradual decrease. After 12 years of storage the germination capacity of this accession was 50 %, which was 32 % lower than the initial value (t = 10.8). Perhaps, this is due to different ability of Brassica spp. for storage, since we know that turnip (*Brassica rapa*) and brown mustard seeds with the optimal moisture content of 3 % can be stored with better results than rape seeds. [34] Thus, under controlled storage conditions the germination capacity of mustard seeds in the majority of accessions with the moisture content of 2.5-3.7% remains unchanged during 4-12 years.

The germination capacity seeds of opium poppy cv. UE1100001 with the moisture content of 2.9 % decreased by 22 % (t = 9.0) during eight-year storage under uncontrolled conditions. After one-year storage in the freezer the germinability in this accession increased by 7 % (t = -2.4) (Fig. 6).

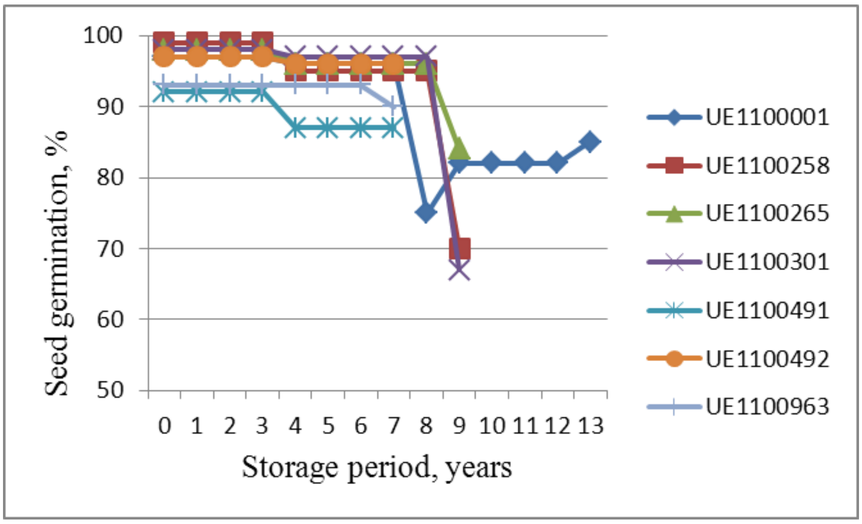

Fig.6. **Post-storage germination capacity of poppy seeds with the moisture content of 2.4-3.0 %, 1997-2010.**

The germination capacity of poppy seeds with the moisture content of 2.4-3.0 %, which were stored at 4°C, did not change after 4-7 years of storage in cv. Laciniatum (UE1100492) and breeding accession UE1100963, but decreased by 5% in cv. Sharlachkonig (UE1100491). Seeds with the same moisture content of cv. UE1100258 and breeding accessions UE1100265 and UE1100301, which were stored at the negative temperature did not change the germination capacity after 4 years of storage, but after 9 years it decreased by 29 % (t = 12.3), 14 % (t = 6.2), and 30 % (t = 12.5), respectively.

The germinability of poppy seeds of cv. UE1100193 with the moisture content of 3.1 % decreased by 42 % (t = 9.8) after six-year storage in the depository at uncontrolled temperature. The initial germination capacity of this accession was lowered – 60 %, perhaps this explains a significant decrease in the seed germinability after long-term storage (Fig. 7).

Thus, poppy seed storage with the moisture content of 2.4-3.6 % for 4 years at 4°C -20°C in most cases did not lead to a decrease in the germination capacity. Further storage under these conditions caused a gradual reduction in the germination capacity of seeds.

The germinability of cotton seeds of cv. Dniprovskyy 5 (UF0800001) with the moisture content of 3.6 % was unchanged – 90 % after 4 years of storage. The germination capacity of the accession of the same genotype, but another year of reproduction and with the moisture content of 4.4 %, increased by 15 % (t = -6.9) under similar storage conditions after 5 years of storage. The germination capacity of Pidozerskyy 4 accession (UF08000310) with the moisture content of 3.6 % decreased by 8% (t = 3.0) after 4 years of storage under these conditions. It is difficult to characterize optimal storage conditions because of small numbers of cotton accessions, but the results enable recommending long-term storage of cotton seeds with the moisture content of about 4 % and the germinability monitoring at least once every three years.

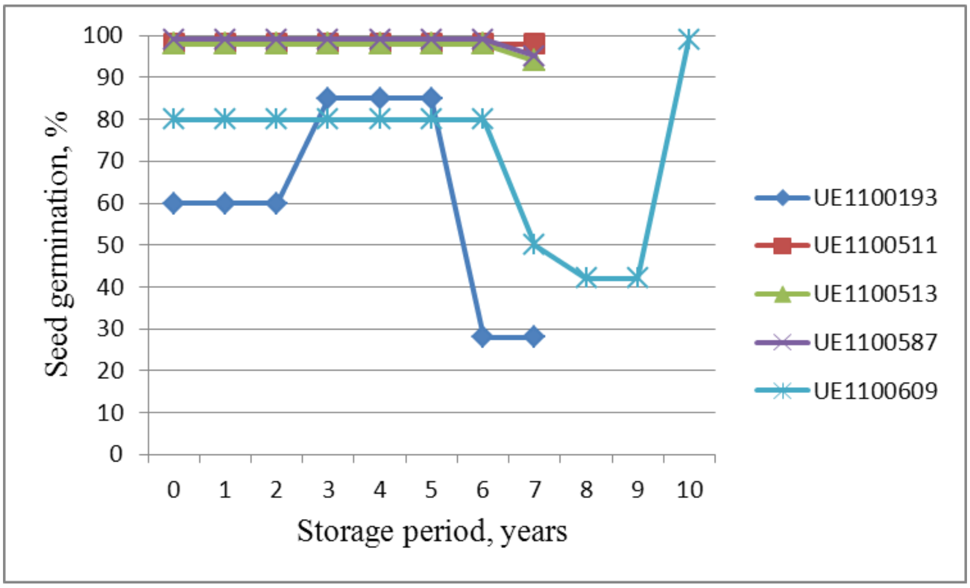

Fig.7. **Post-storage germination capacity of opium poppy seeds with the moisture content og 3.1-3.6 %, 1999-2012.**

The false flax accessions with the moisture content of 2-4 % and lallemantia accessions with the moisture content of 2.6 % were stored at -20°C. False flax contains up to 90 % of unsaturated fatty acids, half of which – polyunsaturated ones [8]. Because of higher (38 %) linolenic acid content than that in rape (10 %), we could expect worse indexes of seed viability after storage [36]. However, owing to the optimal storage conditions (moisture content of 2-3 % in seeds and temperature -20°C) no changes in the germinability were observed during 4-7 years of storage.

No changes in the germination capacity conditions were observed under similar storage conditions for peanut and castor been seeds with the moisture content of 3.1 and 3.8 %, respectively, after 10 years of storage; for arugula and chufa sedge seeds – after 6 years of storage; for seeds of sesame, oil radish and turnip rape accessions with the moisture content of 2.1 %, 2.8 % and 4 %, respectively, after 4 years of storage. These are relatively high indexes, because sesame seeds demonstrated biochemical changes as early as after one-year storage under uncontrolled conditions [37].

Besides, oil radish accession UL0800003 with the moisture content of 4.98 % stored at -20°C increased the germination capacity by 15 % (t = -5.7) after 4 years. Perilla seeds with the moisture content of 2.8 % increased the germinability from 65 % to 95 % (t = 2.6) after 9 years of storage

Seeds of safflower accession UE0900002 with 2.9 % moisture content after 10 years of storage at 4°C increased the germinability by 9 % (t = -3.1). The germination capacity of safflower cv. Mylyutynskyy 114 (UE0900016) increased by 10 %/ Seeds of this accession were stored with 2.9 % moisture content at -20°C. The germination capacity of safflower seeds of accession UE0900004 with the seed moisture content of 4.1 % decreased by 6% (t = 2.4) after 5 years of storage. It is known that seeds of this crop have a high level of unsaturated fatty acids [35]. We believe that the optimum moisture content for safflower seed storage should not exceed 3 %.

CONCLUSIONS

Based on to the monitoring results on the status of oil crop seeds, which were stored under controlled conditions - 12 sunflower accessions, 15 winter and spring rape accessions, seven brown and black mustard accessions, 12 opium poppy accessions, 6 false flax accessions, 3 safflower accessions, 2 accessions of oil radish, 2 upland cotton accessions, 1 accession of each of the following plants: peanut, castor bean, Indian sesame, arugula, perilla, chufa sedge, lallemantia, and turnip rape - optimum regimens of long-term storage of the crop seeds were determined.

To maintain the viability of seeds during storage at 4°C or at -20^{o}C on high levels, the moisture content in seeds should be: for common sunflower – 2-4.5 % during 9-15 years; for winter and spring rape – 2.5-3.7 % during 5-18 years; for brown and black mustard – 2.5-3.7 % during 4-12 years.

Opium poppy seeds stored with the moisture content of 2.4-3.6 % at 4^{o}C or at -20^{o}C during 4 years in most cases didn't change the germination capacity. Further storage under these conditions caused a gradual decrease in the germination capacity. Seeds of safflower did not reduce the germinability after 5-10 years of storage at 4^{o}C or at -20^{o}C and with the moisture content of about 3%.

Seeds of the following crops can be stored without change in the germination capacity at -20^{o}C for at least 5 years with the moisture content of: 2-4 % for false flax seed; 2.6 % for lallemantia; 3.1 % for peanut; 3.8% for castor bean; ≤ 4% for arugula, chufa sedge, Indian sesame, oil radish, perilla and turnip rape.

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OILSEEDS STORAGE UNDER CONTROLLED CONDITIONS

Goal. To determine optimal regimens for storage of the following oil crop accessions on the basis of the monitoring results on the seed status under controlled storage conditions: common sunflower, winter and spring rape, brown and black mustard, opium poppy, false flax, upland cotton, peanut, castor bean, Indian sesame, arugula, perilla, chufa sedge, lallemantia, oil radish, turnip rape, safflower.

Results and Discussion. Based on to the monitoring results on oilseeds- 12 sunflower accessions, 15 winter and spring rape accessions, seven brown and black mustard accessions, 12 opium poppy accessions, 6 false flax accessions, 3 safflower accessions, 2 accessions of oil radish, 2 upland cotton accessions, 1 accession of each of the following plants: peanut, castor bean, Indian sesame, arugula, perilla, chufa sedge, lallemantia, and turnip rape, which were stored in hermitically sealed containers under controlled conditions, at 4^{o}C, or at -20^{o}C - optimum moisture levels in seeds were determined. To maintain the viability of seeds on high levels, the moisture content in seeds should be: for common sunflower 2-4.5 % during 9-15 years; for winter and spring rape 2.5-3.7 % during 5-18 years; for brown and black mustard 2.5-3.7 % during 4-12 years; for opium poppy 2.4-3.6 % during 4 years; and for safflower 2.4-2.9%, during 5-10 years. At -20^{o}C the germination capacity of seeds remains unchanged for at least 5 years with the following values of moisture content: for false flax 2-4 %, for lallemantia 2.6 %; for peanut 3.1 %; for castor bean 3.8%; for arugula, chufa sedge, Indian sesame, oil radish, perilla, turnip rape below - <4 %. It was established that in the depository with non-regulated temperature the germination capacity of common sunflower seeds with 2.5-3.7 % moisture content remained unchanged for only 4 years. Then we observed a gradual reduction in it. Seeds of the oil crop cultivars studied had no advantages upon storage in comparison with seeds of lines of the same crops. Seeds of accessions grown in places with heavier precipitation had worse indexes of germination after long-term storage.

Conclusions. Based on to the monitoring results on the status of oilseeds after long-term storage under controlled conditions, optimal regimens for storage of a number of oil crops were determined. High levels of the viability of oilseeds were preserved, when seeds were stored with the moisture content of < 4.5 % at -20^{o}C or at 4^{o}C.

Keywords: *oil crops, seeds, storage, moisture content, temperature, genebank*

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ХРАНЕНИЕ СЕМЯН МАСЛИЧНЫХ КУЛЬТУР В КОНТРОЛИРУЕМЫХ УСЛОВИЯХ

Цель. Определить по результатам мониторинга состояния семян масличных культур в контролируемых условиях хранения оптимальные режимы для семян образцов масличных культур: подсолнечника, рапса озимого и ярового, горчицы сарапетской и черной, мака снотворного, рыжика посевного, хлопчатника обыкновенного, арахиса подземного, клещевины обыкновенной, кунжута индийского, индау посевного, периллы,

смикавцю съедобного (чуфы) ляллеманции иберийской, редьки масличной, сурепки, сафлора красильного.

Результаты и обсуждение. По результатам мониторинга хранения семян масличных культур: 12 образцов подсолнечника однолетнего, 15 – рапса озимого и ярового, 7 – горчицы сарапетской и черной, 12 – мака снотворного, шести – рыжика посевного, трех – сафлора красильного, двух – хлопчатника обычкновенного, редьки масличной по одному – арахиса подземного, клещевины обыкновенной, кунжута индийского, индау посевного, периллы, сыти съедобной (чуфы), ляллеманции иберийской, сурепки, которые сохранялись в герметичной таре при нерегулируемых условиях температуры, при низкой положительной 4^{o}С или отрицательной температуре минус 20^{o}С, выявлены оптимальне режимы влажности семян. Поддерживать на высоком уровне жизнеспособность семян позволили следующие уровни влажности семян: для подсолнечника однолетнего 2-4,5 % в течение 9-15 лет; для рапса озимого и ярового 2,5-3,7 % в течение 5-18 лет хранения; для горчицы сарапетской и черной 2,5-3,7 % в течение 4-12 лет; мака снотворного 2,4-3,6 % в течение 4 лет; сафлора красильного 2,4-2,9 %, в течение 5-10 лет. При отрицательной температуре минус 20^{o}С семена сохраняют всхожесть без изменений не менее пяти лет с такими уровнями влажности: рыжика посевного 2-4 %, ляллеманции иберийской 2,6 %, арахиса подземного 3,1 %, клещевины обыкновенной 3,8 %, индау посевного, сыти съедобной, кунжута индийского, редьки масличной, периллы и сурепицы до 4 %. Установлено, что в хранилище с нерегулируемой температурой всхожесть семян подсолнечника однолетнего с влажностью 2,5-3,7% сохранялась без изменений только четыре года. Затем наблюдали постепенное ее снижение. Семена сортов изученных масличных культур не обладали преимуществами при хранении по сравнению с семенами линий этих же культур. Худшие показатели всхожести после длительного хранения показывали семена образцов, выращенных в местах произрастания с большим количеством осадков.

Выводы. По результатам мониторинга состояния семян, после длительного хранения в контролируемых условиях установленны оптимальные режимы хранения семян образцов ряда масличных культур. Высокие показатели жизнеспособности семян масличных культур сохраняются при хранении семян с влажностью ниже 4,5 % и температуре минус 20 ^{o}С.

Ключевые слова: *масличные культуры, семена, хранение, влажность, температура*