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

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].

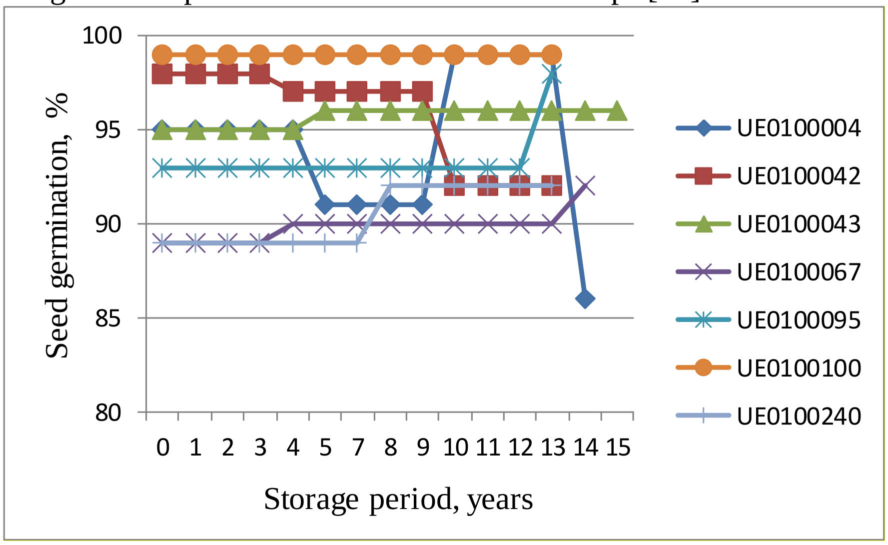

Fig.1. **Post- storage germination capacity of sunflower seeds with the moisture content of 2.3-3.0 %, 1997-2014.**

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,

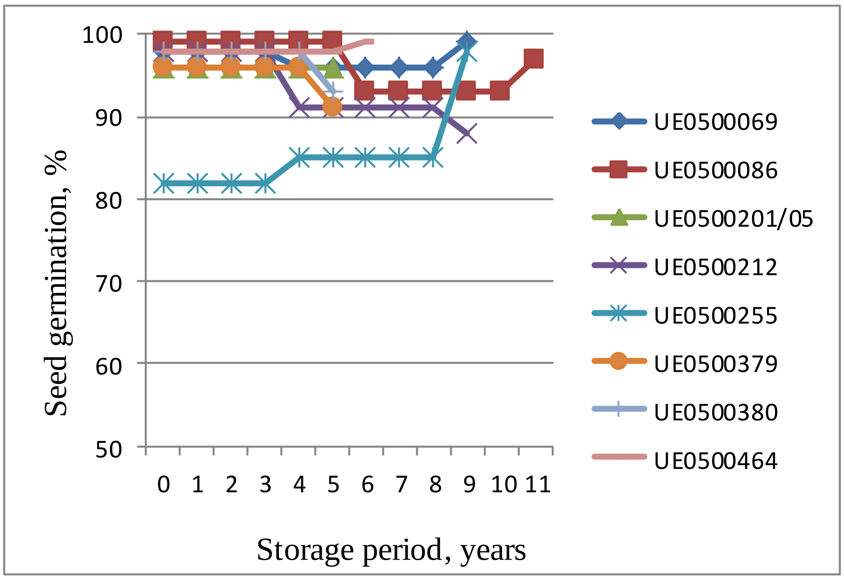

Fig.3. **Post-storage germination capacity of rape seeds with the moisture content of 2.5-3 %, 1997-2014.**

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°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).

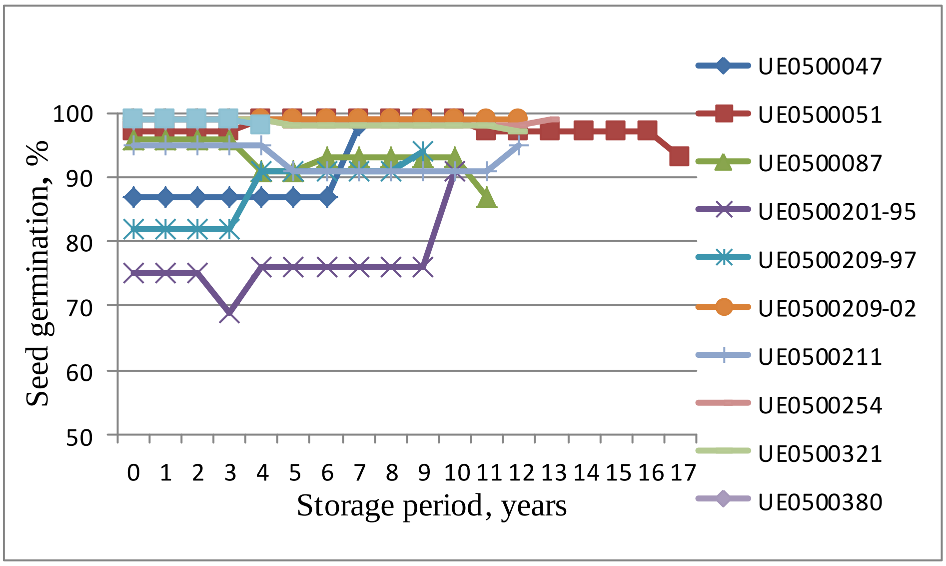

Fig.4. **Post-storage germination capacity of rape seeds with the moisture content of 3.1-3.7 %, 1995-2014.**

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

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).

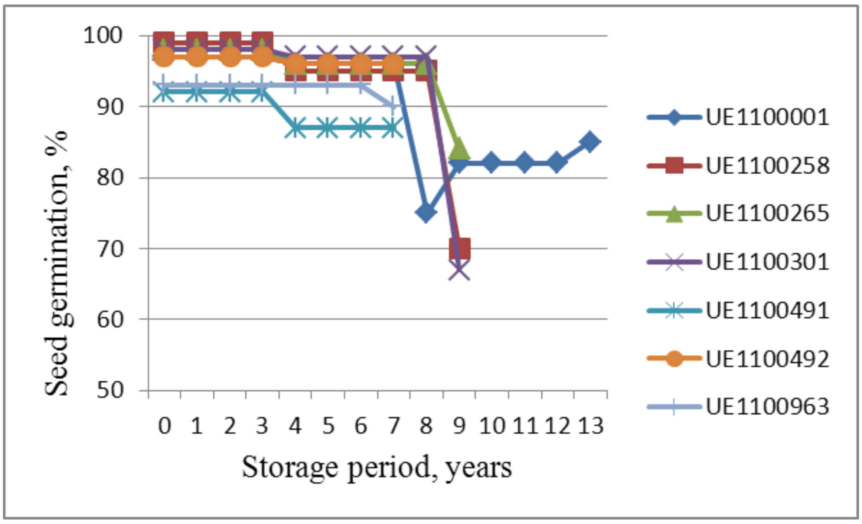

Fig.6. **Post-storage germination capacity of poppy seeds with the moisture content of 2.4-3.0 %, 1997-2010.**

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.

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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°C, or at -20°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°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°C or at 4°C.

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

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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}C или отрицательной температуре минус 20^{o}C, 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}C 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}C.

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