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Some agricultural aspects of seed longevity (literature review)

ROMAN HOŁUBOWICZ[1], MARIA MOROZOWSKA[2], TOMASZ W. BRALEWSKI[1]

1) Department of Seed Science and Technology, August Cieszkowski Poznań Agricultural University, Baranowo, 62-081 Przeźmierowo, Poland
e-mail: rhseed@owl.au.poznan.pl
e-mail: twbseed@owl.au.poznan.pl
2) Department of Botany, August Cieszkowski Poznań Agricultural University, 60-625 Poznań, Wojska Polskiego 71 C, Poland
e-mail: mariamor@owl.au.poznan.pl

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Summary

There has been a vast and numerous literature concerning seed longevity. Most of these works however has focused solely on theoretical and biological aspects of this problem. Some works although deal with practical problems of seed storage, vigour or deterioration, have had relatively little connection with agricultural crops, practical farming or gardening. Therefore, there has been a need to look at this problem from the seedman's and farmer's point of view. The paper comments on how long seeds of agricultural crops species can keep their longevity, how long it is economically reasonable to store them, the effect of the seeds chemical composition on their longevity, how seeds storage conditions can be modified in order to eventually improve their longevity and environment circumstances influence on the final seed longevity. The paper contains a synthetic summary of expected seed longevity of the most important agricultural species and many examples of long longevity of agricultural species.

Key words: seed, seed longevity, seed deterioration

MAXIMUM SPAN OF AGRICULTURAL SEEDS LIFE

Because of the ability to persist in the soil, seeds represent the longest living propagules of higher plants, and possibly the oldest living organisms on earth (Burnside et al., 1996).

Since many years people were interested in learning how long seeds can keep their ability to germinate. There are reports of germination of many seeds of various genera taken from the mud of the Thames in 1843, after having been placed (for a short time) in boiling water (Cambage, 1928).

The longevity of seeds is a specific for species, genetically inherited trait. The maximum longevity of seed can not be approximated before the adequate methods for storage and methods for germination are known specifically. The only way to determine today reliably the age of seeds are tests for radiocarbon content and the direct dating of the germinated seed *per se* (Shen-Miller et al., 1995). With recently improved dating by accelerator mass spectroscopy (AMS) technique radiocarbon can be assayed using a very small amount of tissue (less than 10 mg). Use of this technique though permits dating only of pericarp, sparing the germinated seed for studies of growth and development (Davis et al., 1990). Practical agriculture is less interested in detailed information about an age of seed's pericarp. The most important part of any seed, in terms of agriculture, has always been its embryo. In practice though, only seeds of very precious breeding materials are stored longer than 10 years (Tab. 1).

The oldest demonstrably viable and directly dated are seed of the sacred lotus (*Nelumbo nucifera* Gaertner; *Nelumbonaceae*) from the Pulantein deposit in China (Ohga, 1926). One of them had a mean physical age, based on radiocarbon dating, of 1,288+271 years. The morphophysiological characteristics of fruit of the sacred lotus-their impervious and mechanically strong fruit walls, chlorophyllous plumules, robust proteins including the MT protein-repair enzyme, high level of reducing compounds in embryonic axes, and maintenance of membrane fluidity-coupled with the highly reducing anoxic environment of the sedimentary strata in which the Pulantien fruits have been preserved, have all significantly contributed to the exceptional longevity of the seeds (Shen-Miller et al., 1995; Shen-Miller et al., 2002). The oldest viable seeds from herbarium specimens are reported to be 90 years in age (Bewley, Black, 1982). Roos and Davidson (1992) reported that among many vegetable seeds, the oldest seed lot tested was a tomato cultivar, Marmon, that still germinated after 60 years of storage. Longevity of more than 50 years were also reported for sugar beet (*Beta vulgaris* L.), corn (*Zea mays* L.), cucumber (*Cucumis sativus* L.), eggplant (*Solanum melongena* L.) and muskmelon (*Cucumis melo* L.). Thus, seeds of the species from *Chenopodiaceae* and *Cucurbitaceae* botanical families, in terms of agricultural and horticultural crops, have had the biggest potential for longevity and practical farming use, i. e. they will keep their viability, germination and ability for field emergence for over 50 years.

Seeds of many species retain their viability longer when buried in the moist soil than when kept dry. There is a certain biological system in seeds to overcome some viability disturbances and abnormalities. The existence of this repair and viability maintenance system in seeds is supposed to correct some seed damage as and when it occurs (Villiers, 1973; Shen-Miller et al., 2002). One of the first such buried studies was initiated by W. J. Beal in East Lansing, Michigan (USA) in 1879. His well documented controlled experiment on the longevity of seed viability showed that of 23 species of seeds subjected to 100 years of burial (1880–1980), the three species: mallow (*Malva rotundifolia, Malvaceae*), mullein (*Verbascum blattaria* and *V. thapsus, Scrophulariaceae*) had remained capable for germination (Kivilaan, Bandurski, 1981). Duvel in his experiment from 1902 showed that the average life

Table 1
Mean time of keeping high germination (in optimal storing conditions) for selected species of agricultural and horticultural importance (Heit, 1944; Roberts, 1973; Lewis, 1958; Nagamine, Miyashita, Nishikawa 2000; Panayotov, Stoeva, 2000; changed)

Species	Number of years	Species	Number of years
Allium cepa	1-3	*Phlox drummondii*	1-2
Althaca officinalis	3-4	*Pisum sativum*	2-5
Amaranthus caudatus	4-5	*Poa pratensis*	1-3
Anethum graveolens	2-3	*Portulaca grandiflora*	3-4
Apium graveolens	3-6	*Primula vulgaris*	2
Capsicum annuum	2-4	*Raphanus sativus*	3-5
Dactylis glomerata	2-4	*Reseda odorata*	2-4
Festuca rubra	2-4	*Rudbeckia spp.*	3-5
F. pratensis	2-4	*Salvia splendens*	1-2
Lycopersicum esculentum	4-6	*Secale cereale*	1-3
Lolium perenne	2-4	*Solanum spp.*	4-5
L. italicum	2-4	*Solanum melongena*	5-6
Medicago sativa	3-5	*Spinacia oleracea*	5-8
Melilotus alba	3-4	*Tagetes spp.*	3-4
Mesembryanthemum crystallinum	3-5	*Trifolium arvensis*	3-4
Nemesia strumosa	2-3	*T. repens*	2-4
Nicotiana tabacum	3-5	*T. pratense*	2-4
Nigella damascena	2-4	*Triticum aestivum*	2-4
Oenothera biennis	2-4	*Triticum vulgare*	2-4
Paeonia suffruticosa	3-4	*Verbena x hybrida*	2-3
Papaver orientale	3-5	*Vicia faba*	7-8
Petroselinum crispum	1-3	*Viola tricolor*	1-3
Petunia x hybrida	2-5	*Zea mays*	1-3
Perilla frutescens	up to 50	*Zinnia elegans*	3-7
Phaseolus vulgaris	3-4		
Phleum pratense	2-4		

of seeds varied greatly with the different botanical families, genera and species. After 39 years seeds of 36 out of the 107 plant species tested, amongst them such genera as e.g. tobacco (*Nicotiana*), clover (*Trifolium*), celery (*Apium*) or meadow-grass (*Poa*), were still viable (Toole, Brown, 1946). The highest percent of germination represented seeds of the plant species from the two botanical families: *Solanaceae* and *Fabaceae* (Chepil, 1946). Peterson and Prasad (1998) found out that weed seeds of Scotch broom (*Cytisus scoparius* [L.] Link., *Fabaceae*) could lay in the soil for over 30 years and still germinate. They have thick pericarp and high multiplication coefficient.

Genetic and physiological factors important in seed longevity include the species, seed lot and/or cultivar and the original seed quality. The lifetime of seeds depends as well on the soil environment, in which they live during the dormancy. Soil treatment is also very important (Demo, 1999; James, Rahman, 2000). The differences in life history and dispersal strategy of different plants may result on seed longevity too. For some species, the extreme longevity and persistence in the soil seed bank is a strategy for exploiting newly distributed sites, while the alternative way of propagation of other agricultural weeds depends more on dispersing the seeds widely in space and in contrast less on extreme seed longevity (Conn, Deck, 1995; Leck, Parker and Simpson, 1989). Knowledge of seed survival is essential to understanding weed population dynamics and for making management decisions in day-to-day farming. In Agriculture, there is a term of the minimal percentage of germinating seeds of agricultural crops, which is of interest to a farmer or horticulturalist. This value depends upon a species. For example, commercial seeds of sugar beet should keep their germination between 95 and 100%, whereas for *Verbena* seeds – 40% would be enough. Therefore, the longevity expectations towards the seeds are different. With the mentioned sugar beet seeds one expects them to be able to germinate and emerge in the field for 1–2 years, for seeds of some flowers – 4–5 years. This results in practical guarantee given by commercial seed companies for their sown seeds being for sugar beets and flower seeds 1–2 and up 5 years, respectively.

SEED LONGEVITY AS A RESULT OF CHANGES IN THEIR ORGANS, TISSUES AND CELLS

Damage to cellular membranes during the seed ageing process is manifested as an increase of solute and electrolyte leakage from seeds during imbibition and as biochemical and physical changes in phospholipids, the major membrane components. These deteriorative changes include: abnormalities of mitochondrial and plastid inner and outer membranes, lobbing of the nuclear envelope, fragmentation or loss of endoplasmic reticulum and the Golgi bodies, dissolution of the bounding membrane of vacuoles and protein bodies, fusion of lipid droplets to form larger bodies or irregular pools, discounties in the plasmalemma and its withdrawal from the cell wall and the occasional appearance of floccular material in the extrapropiastic space (Smith, Berjak, 1995). The extent and leakage rate of intracellular substances depends on several factors including amongst others the plant species, seed quality, specific chemical compound, membrane condition and presence or absence of morphological barriers, e.g. seed coat integrity (Bereśniewicz et al., 1995; Lee et al., 1995; Sung, Chiu, 1995; Taylor et al., 1995). In sunflower osmoprimed seeds no increase in electrolyte leakage was observed during ageing (Chojnowski et al., 1997).

The ability of seeds to survive the withdrawal of water during prolonged storage must result in existence of a mechanism for protecting the integrity of the seed cellular membranes. Sucrose can alter the physical characteristics of a membrane phospholipid, causing it to retain characteristics of hydrated lipid even when water is absent. This mechanism is strengthened by the presence of an oligosaccharide such as raffinose, which restricts or prevents the crystallization of sucrose. A similar *in vivo* reaction between phopholipids and sugars may have direct relevance to the viability of seeds (Caffrey et al., 1988). On the other hand, it is unlikely that changes in oligosaccharides alone are responsible for the reduction in seed longevity (Sunitha, Bradford, 2001).

In aged seeds, the decrease in phospholipid level is noticed (Basavarajappa et. al., 1991; Pukacka, 1991). Autoxidation and enzymatic oxidation of lipids generate changes in unsaturated fatty acids in the phospholipid fractions, which are in turn a free radical chain reaction. These biochemical reactions are assumed to be the primary mechanism by which free radical injury is imposed on plant membranes (Bewley, 1986; Hailstones, Smith, 1988 and 1989; Trawatha et al., 1995; Michalczyk et al., 1998; Shan et al., 2000). The evidence about the relationship between the loss of viability and free radical processes in seeds are often conflicting. For example, for soybean (*Glycine max* L.) seeds the positive relationship between loss of seed viability and lipid peroxidation was found but, on the other hand, lack of relationship between loss of viability and changes in fatty acid composition together with changes to antioxidants was also reported (Priestley, Leopold, 1979; Priestley et al., 1980; Hailstones, Smith, 1988). This might be a result of linking two quite different measurements: damage and viability. For a given tissue damage, the evidence for free radical processes is rather good, but in case of many other seeds, no relationship was found between the loss of seed viability and free radical accumulation. The explanation of this phenomenon may partly come from the differences in treatment of the biological material before analysis and lack of the information about the time that had elapsed between death of the seed and the free radical level determination (Hendry, 1993; Michalczyk et al., 1998).

Loss of viability by seeds during prolonged storage is accompanied by decline amounts and reduced levels of enzymatic activities of different enzymes. Changes in profiles as well as the loss of some forms of izoenzymes such as peroxidase, acid phosphatase, dehydrogenase, esterase and aminopeptidase are associated with the age of seeds. For example, the acid phosphatase activity declined stronger in embryos than in endosperms. Similarly, decreased amylase activity and the reduced rate of its synthesis had been reported in the aged wheat seeds (Petruzelli, Taranto, 1990; Livesley, Bray, 1991). Loss of activity of detoxifying enzymes, mainly catalase, glutathione reductase and lipoxygenase, whereas superoxide dismutase was the least affected and was probably not involved in seed deterioration during ageing, were also present in aged seeds. The marked decrease of lipid-soluble antioxidants levels was another symptom of seed ageing (Pukacka, 1991; Sung, Chiu, 1995; Bailly et al., 1996). This disappearing activity of the enzymes is related to following, during the deterioration of seeds, processes of proteins degradation and denaturation (Roberts, 1972; Harrington, 1973; Aquila, 1994; Bailly et al., 1996). These, in turn, result in damaging the seed's protein synthesis system. Free radicals, toxic and mutagenic compounds, as well as activity of the carboxinucleases may eventually affect the properties of DNA. The loss of DNA integrity is probably the source of chromosomal aberrations and impaired transcription observed when seeds of low viability germinate (Cheah, Osborne, 1978; Grzesiuk, Kulka, 1981; Osborne, Boubriak, 2000; Chwedorzewska et al., 2001). When the seed storage time is prolonged, the frequency of anaphase chromosomal aberrations was increasing (Sawicka, Sadowska, 1990). Other theory (Hendry, 1993) suggests that damage to nucleic acids and membranes involves the action of activated oxygen, which might be playing a crucial role in a loss of viability in seeds.

Seeds rich in lipids have a slight tendency to live shorter (Villiers, 1973). Seeds of dicotyledonous species under soil conditions remain viability and longevity longer than the monocotyledonous ones (Lewis, 1958). A study of the relationship between lipid stability and longevity in legumes and tomato seeds showed no statistically significant correlation between longevity and total lipid unsaturation, tocopherol levels or other protection and vulnerability factors. A significant negative correlation between linolenic acid levels per a unit of total tocopherols and longevity were found when only leguminous seeds were examined. This may point to possible structural or genetic components affecting longevity (Ponquet et al., 1992). Dao et al., (1999) have found that longevity in soybean is a simple, qualitatively-inherited trait conditioned by a few major genes. They also suggested that the seed longevity could be improved by individual plant selection in the early segregating generations.

Changes in the lipid components of seeds, like some differences in the glass-forming tendencies and in the first-order melting behaviour of lipids, are associated with the seed deterioration. The progressive decrease in the energy of the melting endotherm occurred at a similar rate as the loss of vigour and suggests that changes in lipids occur during the process of seed ageing and are not a result of seed mortality. The mechanism, by which the physical properties of storage lipids changed in the process, has been still unknown. Nevertheless, two hypotheses on this matter are suggested: the chemical composition of lipids is altered during storage and/or the physical arrangement of the lipids changes during storage (Vertucci, 1992).

Dry seeds may exist in the glassy state, an amorphous, non-equilibrium condition, in which a liquid achieves such a high viscosity that it resembles a solid. This transition to the glassy state depends upon the increasing concentration of sugars as water is withdrawn, and also upon the temperature. Few beneficial functions of the glassy state in seeds have been suggested: it serves to suppress the deterioration reactions, it has been found to protect macromolecules such as enzymes from being denatured, it may play a role in the protection of membrane integrity by sugars, it can suppress the tissue collapse as water is withdrawn, it helps to avoid the crystalization of cytoplasmic components and increases resistance to water loss (Koster, 1991;

Leopold et al., 1994). In maize seeds, it was found that raffinose serves to amplify substantially the magnitude of the glass signal and this, in turn, is correlated with enhanced stability of the seed under conditions of accelerated ageing (Bernal-Lugo, Leopold, 1995).

Buitink et al. (1998a, b) stated that longevity of seeds is evidently related to the molecular mobility in the cytoplasm. They found out a linear relationship between the logarithm of the rotational motion in the cytoplasm of the seeds and the half-viability time in relation to water content (Buitink et al., 2000). The same authors assumed that oligosaccharides do not play an important role in the stabilisation of the cytoplasmic matrix in seeds by decreasing the molecular mobility of intracellular glass as a result of increasing glass-to-liquid transition temperature.

Seed priming in all its forms, commercially done in seed companies in recent years, to increase their field emergence rate and to make field plants establishment more even, has negative effects on seed longevity. Primed seeds, although, get better price in trade, are poorer in terms of their potential for storage. Such seeds lose their longevity quicker and are much more difficult to store than the check seeds. The mechanism of this phenomenon is not yet completely cleared out. Bruggink et al., (1999) discovered that reduced longevity of seeds after priming can be partially restored by a combined heat shock and dehydration treatment. On the other hand, Powell et al. (2000) found that priming of the cauliflower (*Brassica oleracea* var. *botrytis*) low vigour seeds had improved their longevity. The problem has had a practical importance and is a matter of an intensive seed companies studies. Their results though may not be published as financed by private breeders.

IMPORTANCE OF THE NATURAL CONDITIONS

The seed longevity is affected by its genetic properties, especially those which determine their structure and by the environment conditions (Passam, Lambropoulos and Khan, 1997; Tang et al., 1999; Górski, 1999; Bakker et al., 2000; Dixit et al., 2001; Yogendra, Ram 2001). The nature affects development, growth and structure of the seed. The most important natural factors affecting seed longevity are: temperature, humidity, light conditions and presence of micoflora in the environment, in which the seed had developed and matured and the others e.g. passage through birds (McKee, Musil, 1948; Grzesiuk, 1967; Heydecker, 1973; Grzesiuk, Kulka, 1981; Lityński, 1982; Bochenek et al., 2000; Renne et al., 2001; Witkowski, Wilson, 2001).

High temperature, solarity and low moisture of the environment are causing a slowing-down of the metabolic processes and in most cases stimulate seed longevity (Grzesiuk, 1967; Ellis, Pieta Filho, 1992). In case of the higher relative humidity, low temperature may slow down the process of seed ageing. The approach to the problem of seed longevity must be then different when seeds are stored than when seeds are sown. In the field condition, from the farmer's point of view, more important than seed moisture content is the physiological maturity of the seeds. Seeds sown to the soil will germinate according to theirs own rhythm. That is an important aspect in the strategy of a species (Roberts, Chancellor, 1979; Gutterman, 1980/81). If the seeds are dormant, they will not germinate despite their higher moisture content (Villiers, 1973). In rice plants, seeds showed bigger longevity, if they came from the mother plants, which were grown at lower temperatures (Ellis, Hong and Jackson, 1993). In more wet years, there is bigger occurrence of fungi, bacteria and viruses on seeds, which infest and attack seeds shortening their longevity. High temperature and insolation, in this aspect, lower the number of organisms infecting seeds and prolong the seed longevity (Grzesiuk, 1967; Grzesiuk, Kulka, 1981; Bochenek et al., 2000). Insolation has also effect on dormancy of seeds of some species. It can be broken though (in photophilic species) or initiated (in photophobic species). Primary dormancy of seeds is guaranteeing their longevity (Grzesiuk, Kulka, 1981).

Both temperature and an air relative humidity have also an effect on the final seed testa structure, which in turn affects the seed viability (Crocker, 1909; Bochenek et al., 2000). A good example here are hard seeds of the *Leguminosae* species. They can stay in a dormancy stage longer than the seeds of other species. The best development of these species is when the weather is dry and warm. Temperature and air relative humidity have effect on dry matter content in seeds, and they in turn affect the seed longevity (Bochenek et al., 2000; Rao et al., 2002). In the seeds of some species, however, it has been found out that the biggest seed longevity is not equal to the moment of seed harvesting stage i. e, when their dry matter content is the highest. The seeds may possess the highest longevity and viability also when there is a delay in relation to the point of their maximum dry matter content (Fig.1) (Kameswara et al., 1991; Pieta Filho, Ellis, 1991; Ellis, Pieta Filho 1992; Demir, Ellis 1993; Ellis et al.,1993).

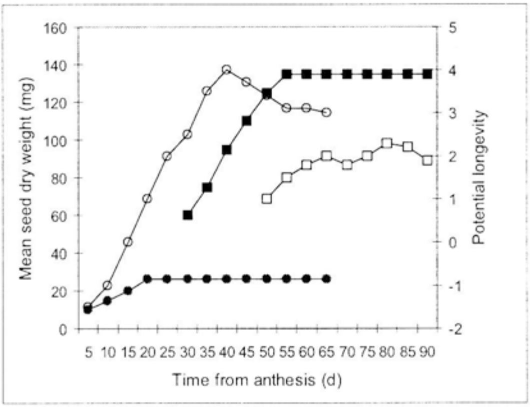

Fig. 1

The mean dry weight (-■-■-) and potential seed longevity (-□-□-) in marrow (*Cucurbita pepo* L.) cv. Long Green Bush (Demir, Ellis, 1993, changed) and the mean seed dry weight (-●-●-) and potential seed longevity (-○-○-) in rice (*Oryza sativa* L.) cv. Ketan Amnera (Ellis et al., 1993, changed)

THE IMPORTANCE OF THE SEED STORAGE CONDITIONS

Seeds of the majority of species from the *orthodox* group are stored in practice from a few months up to a few years, and in incidental cases – till several years (Bewley, Black, 1994). Their seed moisture content is 6–15%. Only in unusual cases their moisture content goes below 4–6% (Murdoch, Ellis, 1992; Hong et al., 2001). Further lowering of moisture content of these seeds only to certain level means prolonging their viability. These minimal levels for seeds of goose-foot (*Chenopodium* ssp.), sun flower (*Helianthus annuus* L.) and flax (*Linum* ssp.), when stored in hermetic bags at 65°C are 4.1%, 2.04% and 2.7%, respectively (Ellis et al., 1988). When lowering seed moisture content from 4.5% (rape) to 6.5% (vetch), further lowering of seed moisture content does not improve their longevity (Ellis et al., 1989). Lowering of seed moisture of bean seed below 3.26% did not improve their longevity when storing them at 65°C (Ellis et al., 1990; Kwong et al., 2001). For the pepper seeds though storing seeds with 10% moisture content had better effect on their germinability than when seeds had 5.8% water (Sundstrom, 1990). For tomato seeds, storing seeds with 5% moisture content in polylaminated aluminium foil pouches let them keep their viability above the certification standard (70%) for 8 months longer than for seeds with 4% moisture content (Sahoo et al., 1999). Seed moisture content is a crucial parameter in storing cereal grains. This is the easiest way to improve their longevity. The study of the moisture relations of seed longevity in *Astronium urundeuva* (Fr. All.) Engl. showed the negative logarithmic relationship between seed moisture content and longevity (Medeiros et al., 1998). Pelleting of tomato seeds had a significant importance on their storability and resulted in lower germination (Sirimathi et al., 2000). Seeds of many species from the subtropical and tropical area and only few from a temperate zone belong to the group *recalcitrant* (Pammenter et al., 2000; Probert, Hay, 2000). Their seeds keep their germination capacity only, if their moisture content is more than 30%. In both cases however, standard conditions do not guarantee keeping their longevity, though it is known that seeds of some tropical trees considered to belong to the *recalcitrant* group, when lowering their moisture content, surprisingly – increase their longevity (Nayal et al., 2000). Storing temperature as well as the type of the container also can affect the viability of seeds from the *recalcitrant* group (Nayal et al., 2001). Neem (*Azadirachta indica* A. Juss) seeds are desiccation-tolerant to intermediate moisture level (11.8%) and thus can be categorized under intermediate storage behaviour (Varghese, Naithani, 2000). The problem of seed longevity in commercial agriculture is met only in few cases, because it is troublesome and expensive (Lityński, 1970; Thomson, 1978; Lityński, 1982; Panday, 1989). This concerns extremely precious and valuable breeding materials and materials of plant collections or gene banks (Hołubowicz, 2000). The conditions of storing such seeds are than described by the same three parameters which are checked in the short-term storage. These are: seed moisture content, temperature of the environment of storing seeds and its relative humidity. The differences are dealing with the level of these factors. For example for Welsh onion (*Allium fistulosum* L.) seeds the increase of seed moisture content resulted in the significant decrease of seed vigour (Yanping et al., 2000). Seeds, which we want to store for long time and eventually to have a long longevity must have the highest possible germination capacity. This could be reached through, among other factors, a proper harvest time. They should also have seed moisture content from 4 to 6% and be packed into hermetic bags, i. e. impermeable for moist (Demir, 1994; Zheng et al., 2001). A low temperature is also an important factor helping to prolong seed's longevity. The best, if it ranges from -20°C to 12°C. It is also possible to keep seeds for this purpose in lower temperatures, e. g. in liquid nitrogen. The relative humidity of the air, in which the seeds are stored hesitates from 35 to 40% (Moss, 1938; Justice, Bass, 1978; Bewley, Black, 1994; Hay, Probert, 1995; Hay et al., 1997; Podlaski, 2000). It is also possible to calculate seed longevity theoretically based it on equilibrated seed moisture content and temperature (Chen, Jays, 2000). In the future, in seed quality testing, seed longevity measurements may become one of the routinely tested parameters the same way as seed vigour, viability or health. They will provide a farmer with additional, essential information about actual value of a given seed lot. It is quite probable that the measurement will be based on a non-destructive determination method (Klein et al., 2002).

Today we can not exclude a possibility of storing seeds in space, in the future. We know, that when keeping the same conditions, the seeds storage capacity exceed the one of the seeds kept on the Earth (Musgrave, 2002).

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Niektóre rolnicze aspekty długowieczności nasion (przegląd literatury)

Streszczenie

Istnieje bardzo wiele danych literaturowych dotyczących długowieczności nasion. Większość z tych prac koncentrowała się jednak wyłącznie na teoretycznych i biologicznych aspektach zagadnienia. Pomimo tego, że część badań dotyczyła praktycznych problemów przechowywania nasion, wigoru czy degeneracji, miały one relatywnie mały związek z nasionami roślin rolniczych, praktyczną uprawą lub ogrodnictwem. Dlatego też wystąpiła potrzeba spojrzenia na ten problem z punktu widzenia producentów nasion i rolników.

Prezentowana praca wypowiada się na temat tego jak długo nasiona roślin rolniczych mogą zachować długowieczność, jak długo ich przechowywanie jest uzasadnione ekonomicznie, jaki jest wpływ składu chemicznego nasion na ich długowieczność, jak mogą być modyfikowane warunki przechowywania nasion w celu ewentualnego zwiększenia ich długowieczności i jaki jest wpływ czynników środowiskowych na końcową długowieczność nasion. Praca zawiera syntetyczne streszczenie na temat najbardziej znaczących gatunków roślin uprawnych i wiele przykładów długowieczności nasion roślin rolniczych.