Long-Term Storage for Vegetable Seeds – Part I

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Abstract

Seeds of three origins of *Brassica pekinensis* and *Foeniculum vulgare* var. *azori-cum* were stored at +10/30, +5 and –20°C for 20 years, seeds of *Solanum melongena* for 16 years air-tight in 2 x 100 µ PE bags. Seed moisture content ranged from 5,1 to 8,3 %. Germination tests took place at temperatures from 10 to 30°C (steps of 5°C). High germination results were found after 20 years for all *B. pekinensis* seeds at 10 to 30°C in variant –20°C and for one origin in variant +5°C. *F.* var. *azoricum* seeds of two origins germinated after 20 years at 10 to 25°C in variant +5 and –20°C also to a high percentage. *S. melongena* seeds of one origin showed at the beginning a relative dormancy (after ripening). For seeds of all origins a temporary dormancy was found after seven years depending on the storage variant. Experiments after 16 years indicated a complete breakdown of this dormancy. Seeds of all origins germinated to a high percentage in variant –20°C after 20 years, too.

INTRODUCTION

The change from nomads to settlers was only possible by collecting and storing seeds for the next sowing season. Excavations showed that first silos were built in the Mesolithicum (middle stone age) as Gonen (1979) wrote. These silos indicated rather a slow evolution of man than a “Neolithic Revolution” as Childe (1936) presumed. The storage of most seeds is possible because they are orthodox and they can be dried to a low moisture content without damage (Roberts, 1981). Orthodox seed offer not only the possibility of storage but also the opportunity of transportation. Many stored seeds are able to germinate all over the world. Consequently new vegetables could be introduced in northern Europe like *Brassica pekinensis*, *Foeniculum vulgare* var. *azoricum* and *Solanum melongena* during the seventies. However, the required conditions for seed storage of these minor vegetables are often unknown. Therefore experiments were carried out in order to find optimal conditions for long-term storage (10 to 20 years and more) and also for the gene resources conservation of these vegetable seeds.

MATERIAL AND METHODS

Seeds of *B. pekinensis* and *F. vulgare* var. *azoricum* (*F.* var. *azoricum*) of different origins (I, II, III) were stored for 20 years and seeds of *S. melongena* (I, II, III) for 16 years, in some cases for 20 years, air-tight welded at +10/30°C (room, variant +10/30), +5°C (fridge, variant +5) and –20°C (freezer, variant –20). As packing 100 µ PE-bags where chosen and some seed portions were packed with the same material. Between the PE-films silica gel was given for humidity control. The experiments started in the beginning of 1978 with seeds harvested in 1977. First the seed moisture content (smc) was determined following ISTA’s rules with three replicates. Germination tests (ISTA rules) were carried out in 1978 and from 1980 to 1985, also in 1994, 1996 and in 1998 at germination temperatures ranging from 10 to 30°C (steps of 5°C). The average of the first germination results at all temperatures are indicated as basic germination. A germination limit for the storage time was fixed depending on first germination results. All data were subjected to analysis of variance – ANOVA – (P = 5 %).

RESULTS

The smc of *B. pekinensis* seeds of three origins was between 5,12 and 6,09 % and the basic germination was 99 and 100 % (Table 1). The results showed that germination in variant +10/30 extended from 34 to 61 %, in variant +5 from 54 to 89 % and in variant –20 it was 90 % and more. Although the basic germination at the beginning for all seeds was very high the storage temperatures revealed an origin specific germination pattern. Only seeds III in variant +5 and –20 germinated to a high percentage. Also direct information about storage time could be obtained by the experiments (Table 2). The duration of high germination results extended at temperatures from 10 to 30°C for seeds in variant +10/30 from 3 to 6 and for seeds in variant +5 from 3 to 20 years. All seeds in variant –20 germinated after 20 years without any decrease. Furthermore seeds III showed in variant +10/30 and +5 a longer period with high germination than seeds I and II.

The smc of *F.* var. *azoricum* seeds extended from 7,63 to 8,33 % and the basic germination from 70 to 78 % (Table 3). Seeds I and II germinated at temperatures from 10 to 25°C between 76 and 84 % respectively. Germination at 30°C was 30 % for seeds I and 74 % for seeds II. Seeds III germinated at 10°C to 62 % at temperatures from 15 to 25°C to 74 and at 30°C to 66 %. Although the basic germination for seeds I and III was 70 % the single germination results at 5 temperatures showed a higher quality for seeds I. The ANOVA results revealed further indications to the storage experiments (Table 3). In variant +10/30 seeds germinates to an average of 27 to 45 %, in variant +5 of 52 to 68 % and in variant –20 of 54 to 67 %. The highest results of between 64 and 68 % were found in variant +5 and –20 for seeds I and II, whereas seed III germinates to 52 respectively 54 %. From a practical point of view a compilation of the achieved storage time in dependency on storage temperature, germination temperature and seed origin is useful. In variant 10/30 a storage time from 3 to 5 years was found for seeds I and II at 10 to 30°C (Table 4). In variant +5 and –20 the germination limit was largely preserved for 18 respectively 20 years at 10 to 25°C. Seeds III could only reach the germination limit of 3 years in variant –20 at temperatures ranging from 10 to 20°C. The attainable storage time demonstrates clearly the differences of seed quality in dependency on seed origin.

The smc of *S. melongena* seeds ranged from 6,48 to 7,79 % and the basic germination from 18 to 92 % (Table 5). This span of germination results is on the first view completely inexplicable. Seeds I germinated at 15 to 30°C from 87 to 95 and seeds III from 94 to 99 %. At 10°C the germination of seeds I was 17 and of seeds III 74 %. The very low basic germination of seeds II increased in the second testing year at 15 to 30°C in all variants considerably to an average of 73 %. 10°C suppressed germination. This increase at higher temperatures clearly indicates a relative dormancy (after ripening). This could be confirmed by the ANOVA in all variants. The ANOVA showed results in variant +10/30 ranging from 28 to 71 %, in variant +5 from 44 to 71 % and in variant –20 from 52 to 71 %. For seeds III there were no differences between the results of the three variants, whereas for seeds I only in variant +5 and –20 no differences were found out. In the average of all storage variants seeds III germinated at 15 to 30°C after 7 years with 46 % lower than after 6 years with 83 % (Table 6). In contrast further tests after 16 years showed an increase to 94 %. This germination pattern was also found for seeds I in variant +5 and –20 and for seeds II in variant –20 at most of the germination temperatures. Thus, the seeds showed a temporary dormancy depending on seed origin. But no dormancy was found for seeds I and III at 20°C in variant +5 (Table 7). Germination tests after 20 years with remaining seeds of all origins in variant –20 showed an average germination of 90 %. Detailed information about storage time is not possible due to the temporary dormancy. Table 7 demonstrates that germination results of more than 80 % for seeds I and seeds III were preserved for 2 to 6 years in variant +10/30 at 15 to 30°C. Seeds of all origins germinated to a high percentage in variant +5 and –20 at 15 to 30°C mostly between 3 and 6 years. Furthermore seeds I and III showed no dormancy in variant +5 at 20°C and germination remained unchanged for 16 years.

Estimation-values of the ANOVA were also shown in tables 1, 3 and 5. For *B. pekinensis* seeds the factor storage temperature (A) influenced the germination between 26 and 32 % (Table 1). A high influence of 42 and 45 % was found for the factor storage time (C) for seeds I and II, for seeds III it was only 26 %. The ANOVA results for seeds of *F*. var. *azoricum* (Table 3) marked out an influence ranging from 12 to 30 % for the factor storage temperature (A). The factor storage time (C) ranged from 20 to 32 %. The interaction storage temperature x storage time (A x C) showed an influence of 28 for seeds II respectively 34 % for seeds I, whereas for seeds III it only was 17 %. Completely other results were obtained for *S. melongena* seeds (Table 5). The ANOVA showed a high influence of the factor germination temperature (B) on seeds I and III with 68 respectively 69 % due to the mentioned temporary dormancy. The lower influence of 36 % for seeds II was caused by the germination constricting relative dormancy at the beginning. Altogether the ANOVA revealed high significant differences for the single factors as well as for the interactions.

DISCUSSION

The smc of the studied seeds was between 5,12 and 8,33 %. It was not changed during storage by the packing as could be proved by experiments with vegetable seeds stored for 15 years at –20°C (Kretschmer, 2001). The high germination results in variant –20 indicate that there were no freezing injuries and therefore, the smc was sufficient low enough. Furthermore *F*. var. *azoricum* seeds I with a smc of 8,33 % showed a longer period of high germination results than seeds II with a lower smc of 7,63 %. For the long-term storage of small-sized and more fatty seeds a smc below 10 % was sufficient. Even higher moisture contents of 10 to 12 % did not result in reduced germination after 20 years of storage at –4°C (Barton, 1961). On the other side Roberts and Ellis (1977) as well as Roos (1986) recommend a smc of 5 % for the storage at sub-zero temperatures. The influence of seed origin was a decisive factor. For instance *B. pekinensis* seeds of three origins germinated to 99 and 100 % at the beginning. But during storage considerable differences in variant +10/30 and +5 could be demonstrated. Therefore high basic germination is not able to predict the storage potential. The developed seed viability equation by Ellis and Roberts (1981) is apparently not sufficient to predict the storage time as Stumpf et al. detected. By analysing 154 different onion seed lots they found out that there is only in the first 3 years a high correlation between observed and estimated germination. The authors wrote that the history of each seed lot is essential to predict the storage potential. Another point of discussion is the appeared dormancy of *S. melongena* seeds. At the beginning of the experiments seeds II germinated to 18 % on the average of all temperatures. In the second testing year the average germination of all storage variants varied from 40 to 69 %. This is an indication of relative dormancy (after ripening). Absolutely surprising was the temporary dormancy. This dormancy was exceptionally marked for seeds III in all storage variants and stronger at the germination temperatures 10 and 30 than at 20 and 25°C. Seeds I showed in variant +5 and –20 and seeds II in variant –20 this kind of dormancy, too. But no dormancy was found for seeds I and III in variant +5 at 20°C. The decrease in germination after seven years and partly earlier indicated at first a gradual loss of viability. Therefore there was no apparent reason for application of the tetrazolium test. In the present literature no indications of this dormancy pattern in *S. melongena* seeds could be found and therefore consequently no indications about the detected influence of seed origin on this dormancy.

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Tables

Table 1. Influence of storage temperature and origin on germination of *Brassica pekinensis* seeds.

origin	smc (%) 1978	basic germ. (%) 1978	storage temperature (°C) +10/30	+ 5	–20
			germination (%)		
I	6,09	99	49c	72b	93a
II	5,46	100	34c	54b	90a
III	5,12	99	61c	89b	92a

Estimation of components of variance	Factor	A stor. temp.	B germ. temp.	C stor. time	AxB	AxC	BxC	AxBxC	Error
	I	27	1	42	0	15	1	3	1
	II	32	1	45	0	18	1	2	1
	III	26	1	26	0	44	1	1	1

ANOVA

Table 2. Influence of storage temperature, germination temperature and origin on the storage time of *Brassica pekinensis* seeds.

storage temperature (°C)	+10/30			+5			–20		
Origin	I	II	III	I	II	III	I	II	III
germin. temp. (°C)				storage time (year)					
10	4	3	6	6	3	20			
15	4	3	6	7	3	18			
20	4	3	6	7	3	20		20	
25	4	3	5	5	3	20			
30	3	3	3	4	3	20			

germination limit: 80 %

Table 3. Influence of storage temperature and origin on germination of *Foeniculum vulgare* var. *azoricum* seeds

origin	smc (%) 1978	basic germ. (%) 1978	storage temperature (°C) +10/30	+5	–20
			germination (%)		
I	8,33	70	43c	64b	65a
II	7,63	78	45c	68a	67b
III	7,69	70	27c	52b	54a

Estimation of components of variance	Factor	A stor. temp.	B germ. temp.	C stor. time	AxB	AxC	BxC	AxBxC	Error
	I	19	14	20	1	34	7	2	3
	II	12	10	32	1	28	6	3	8
	III	30	7	30	1	17	5	6	4

ANOVA

Table 4. Influence of storage temperature, germination temperature and origin on the storage time of *Foeniculum vulgare* var. *azoricum* seeds

storage temperature (°C)	+ 10/30			+5			–20		
Origin	I	II	III	I	II	III	I	II	III
germin. temp. (°C)	storage time (year)								
10	4	3	0	5	20	0	20	18	3
15	4	5	0	20	20	0	20	18	3
20	5	5	0	20	20	0	20	20	3
25	3	4	0	20	20	0	20	20	0
30	3	3	0	0	3	0	0	0	0

germination limit: 65 %

Table 5. Influence of storage temperature and origin on germination of *Solanum melongena* seeds.

origin	smc (%) 1978	basic germ. (%) 1978	storage temperature (°C) +10/30	+ 5	–20
			germination (%)		
I	7,65	76	56b	67a	67a
II	7,79	18	28c	44b	52a
III	6,48	92	71a	71a	71a

Estimation of components of variance	Factor	Astor. temp.	Bgerm. temp.	Cstor. time	AxB	AxC	BxC	AxBxC	Error
	I	2	68	11	0	8	7	3	1
	II	9	36	21	4	9	14	5	2
	III	1	69	16	0	0	12	1	1

ANOVA

Table 6. Influence of storage time and germination temperature on germination* of *Solanum melongena* seeds III.

storage time (year)	6	7	16
germin. temperature (°C)	germination (%)		
15	72	41	87
20	89	75	96
25	87	65	97
30	93	2	95
average	82,8a	45,8b	93,8a

ANOVA; *average of three storage variants

Table 7. Influence of storage temperature, germination temperature and origin on the storage time of *Solanum melongena* seeds

storage temperature (°C)	+10/30			+5			–20		
origin	I	II	III	I	II	III	I	II	III
germin. temp. (°C)	storage time (year)								
10	0	0	0	0	0	0	0	0	0
15	2	0	5*	5	3	5	3*	5*	6*
20	6	0	6*	16	4	16	6*	3*	6*
25	4	0	6*	6*	4	6*	6*	3*	6*
30	5	0	6*	6*	4	6*	6*	3*	4*

germination limit: 80 %; *after 16 years: 87 til >90 % germination