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Storage Behavior of Pelleted, Tableted, and Taped Lettuce Seed[1]

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Abstract. **Coated and raw (uncoated) lettuce (*Lactuca sativa* L.) seed obtained from commercial sources were subjected to 6 storage conditions (ranging from 21° C, 90% relative humidity (RH) to 5°, 40% RH) for a period of 3 years. Four types of packaging material differing in moisture-barrier properties were used. Samples were removed periodically for moisture and germination tests. Under poor storage conditions, coated seed deteriorated more rapidly than the raw seed controls. Under favorable storage conditions, both coated and raw seed retained full viability for the 3 years.**

The past 5 years have seen a marked increase in the use of coated seed to precision plant vegetable and other crops. The advantages of using coated seed have been discussed elsewhere (11, 13, 16, 17); however, no information has been published on the storage behavior of coated seed. It is known that under poor storage conditions uncoated lettuce seed deteriorate rapidly (8, 14). Also, various seedling abnormalities are produced with increasing storage time (5, 15). The diversity of seed coatings available, particularly in hygroscopic properties, raises the question of how long coated lettuce seed can be stored under various temperature-relative humidity and packaging conditions without a significant decrease in germination percentage.

Materials and Methods

Commercial seed companies provided the 7 lots (5 pellets, 1 tape, and 1 tablet) of coated lettuce seed used. In addition, 4 of the companies also sent raw (uncoated) seed of the lot used for coating their sample (Table 1). The 4 packaging materials, differing in moisture-barrier properties, were obtained from the following commercial sources: paper (20# Kraft paper envelopes), Cupples Hess Co.; cellophane (804 Durafilm [0.0009] 300 cellophane/0.002 polyethylene), The Dobeckman Co.; polyethylene (10 mil Visqueen), The Visking Co.; and paper-foil-polyethylene (foil-PE) (moistite bag 25# Kraft/7# PE/ 0.00035 aluminum foil/15# PE), Crown Zellerback Co.

About 800 coated or raw seed (400 for the tablets) were placed in each packet, heat sealed except for the paper envelopes, and stored in the following temperature-relative humidity (RH) chambers as described by James et al. (7): 21° C, 90%; 21°, 70%; 21°, 50%; 10°, 70%; 10°, 50%; and 5°, 40%. The 5°, 40% condition was a standard long-term storage room at the National Seed Storage Laboratory.

At the predetermined intervals for each storage condition, one packet of each treatment was removed from storage and seed or pellet moisture content (fresh-weight basis) was determined by drying triplicate samples of 20-30 seeds at 103° for 48 hr. Tablet moistures were determined on 10 individual tablets. No moisture determinations were made on taped seed, as the tape melts at this temperature. Moisture percentages on the tablets and pellets include both the seed and the coating material.

Two 100-seed replicates of pelleted and taped seed were germinated in folded blue germination blotter paper. Tablets were planted in peat moss or in folded blotters. In both methods, four 25-seed replicates were used. Raw seed and seed removed from the coating material were germinated (two 100-seed replicates) in plastic boxes (11 x 11 x 2 cm) on top of blotters. All germination tests utilized tap water for moistening and were done at 20°C except that the Royal Sluis pellets were germinated at 15° to overcome a slight dormancy problem at 20°. The seedlings were evaluated according to the AOSA rules (1).

To remove the coating material, pellets and the tape were rinsed in tap water. The rinsed seed were then spread on paper towels and dried in air overnight at room temperature (20°C). Raw seed controls were similarly rinsed and dried before planting. Seeds were removed from the tablets by breaking the tablet to expose the seed and then gently removing the seed with a pair of forceps.

Results

Moisture equilibration. The data from coated and raw seed stored in paper envelopes at 21° C, 90% RH illustrate the moisture absorption (hygroscopic) properties of the various coating materials (Fig. 1). The highest seed moisture contents were obtained at 21°, 90% RH; however, similar absorption data were obtained at the other storage conditions. All of the coated seed except the tablets reached moisture equilibrium in about 4 months. Raw seed also equilibrated in 4 months; however, the absorption curve was sigmoid for raw seed rather than a simple curve as for coated seed. The same relative rankings of the 4 pelleting materials for water absorption rate were reported previously (12).

To illustrate moisture-barrier properties of the 4 packaging materials, moisture content data for the very hygroscopic Germain's pellets stored at 21° C, 90% RH were used (Fig. 2). Pellets stored in paper envelopes reached moisture equilibrium in 4 months, those in cellophane required 8 months, and those in 10 mil polyethylene required 12 to 24 months to reach equilibrium moisture content. The foil-PE packages, if properly sealed, did not allow water vapor to penetrate to the seed. However, some packets were not completely sealed, which permitted some increase in seed moisture content.

A 3-factor analysis of variance of the terminal moisture con-

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[2]Plant physiologist. I wish to thank the technical staff of the National Seed Storage Laboratory and former CSU students for their assistance throughout the course of this study.

[3]Mention of a trademark, proprietory product, or vendor does not constitute a guarantee or warranty of the product by the U. S. Department of Agriculture and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

Table 1. Source of seed lots used for study on storage of coated lettuce.

Coating	Cultivar	Company	Germination (%)	Moisture content (%)
1. Lite-coat II	Parris Island	Asgrow Seed Co.	97	3.3
2. Raw seed of item # 1		Asgrow Seed Co.	98	6.0
3. Filcoat	Calmar	Germain's, Inc.	95	13.2
4. Raw seed of item #3		Germain's, Inc.	98	5.9
5. Morancoat	Calmar	Moran Seeds, Inc.	96	4.4
6. Moran-minicoat	Calmar	Moran Seeds, Inc.	96	4.3
7. Raw seeds of items #5 and 6		Moran Seeds, Inc.	98	5.5
8. Splitkote	Prado	Royal Sluis	95	0.9
9. Tape	Calmar	Creative Agr. Systems (Div. Union Carbide Corp.)	91	–
10. Tablet	Calmar	3 M Company	94	4.6
11. Raw seed of item #10		3 M Company	96	5.5

tent (taken when germination reached zero or after 36 months' storage) of the 4 raw seed lots indicated no significant main effect of seed lot and no significant interaction of seed lot with storage condition or packaging material. Therefore, these data were combined as a single entry in a second analysis including the 6 seed coatings, 6 storage conditions, and 4 packaging materials, with 3 observations per treatment. Foil-PE packages with obvious seal defects were excluded from the analysis. All interaction and main effect F values were significant at the 1% level.

A comparison of main effect treatment means is presented in Table 2. Moisture contents for coating materials followed the pattern shown in Fig. 1, except for the tablet, which was lower than expected due to the longer time needed for equilibration. There was no difference in moisture content for Morancoat and Moran-minicoat. In the various storage conditions terminal moisture content was determined principally by the relative humidity and the time in storage in the cabinet. Although paper, cellophane, and 10 mil polyethylene all permitted water vapor to penetrate to the seeds, significant differences in terminal moisture contents were still observed, because at the more severe storage conditions (21° C, 90% and 21°, 70%), seed death occurred before moisture equilibration was reached.

Interpretation of the 3-way interaction among coatings, storage conditions, and packaging materials was most easily accomplished by examining the three 2-way interactions. An obvious interaction existed between storage condition and packaging material (Fig. 3) as foil-PE maintained initial moisture content under all storage conditions, while paper, cellophane, and polyethylene did not. However, changes in moisture content in these materials paralleled each other in response to storage conditions.

A plot of the interaction means of seed coating x packaging material (Fig. 4) showed that the tablets were one source of variability. The tablet moisture differed significantly from the Asgrow pellet moisture in paper and foil-PE but not in cellophane or 10 mil polyethylene. Additionally, a small but significant difference was obtained between the Morancoat and the Moran-minicoat in the 10 mil polyethylene, but not in the other packaging materials.

The tablet was again a source of variability in the interaction between seed coating and storage condition (Fig. 5). At 10°C, 70% RH the tablet and Asgrow pellet moistures were not significantly different and at 5°, 40% RH the tablet moisture did not differ from that of the Moran pellets. At all other storage conditions the tablet moisture differed significantly from both the Asgrow and Moran pellets.

Germination. When this experiment was initiated, there were no rules adopted by the Association of Official Seed Analysts (1) for testing coated seed. Therefore, in order to compare coated and raw seed under the same germination conditions, the coated seed were germinated intact and after removing the coating material. In order to compare coated and rinsed seed, germination data from the 5° C, 40% storage condition (which showed no decline in viability over the 36 month storage period) was analyzed for each coating. A small but significant difference in germination was found between coated and rinsed seed for all seed coatings except the seed tape (Table 3). In cases where a raw seed control was available, there were no differ-

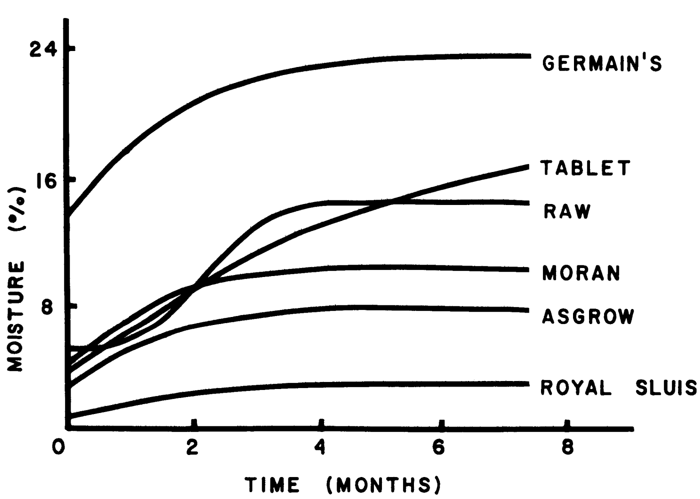

Fig. 1. Cumulative moisture uptake of coated and raw lettuce seed stored in paper envelopes at 21° C, 90% relative humidity.

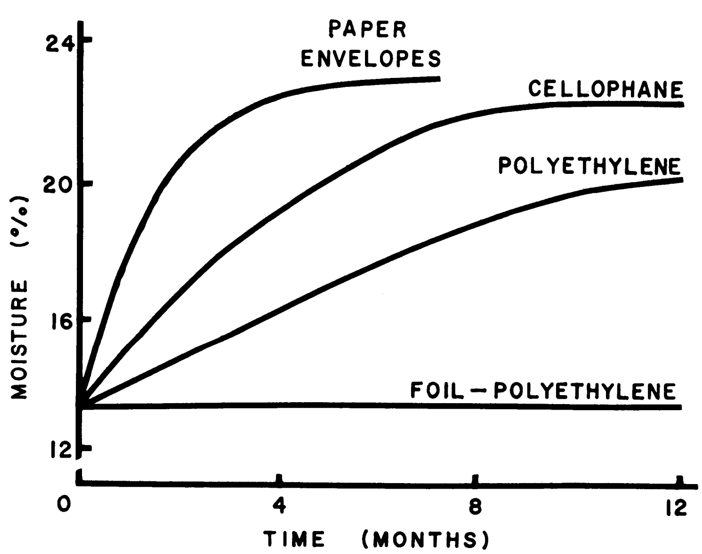

Fig. 2. Cumulative moisture uptake of Germain's coated lettuce seed stored at 21° C, 90% relative humidity in 4 packaging materials.

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Table 2. Effect of seed coating, storage condition, and packaging material on terminal moisture content of lettuce seed.

Coating source	Moisture (%)	Storage condition (°C–%RH)	Moisture (%)	Packaging material	Moisture (%)
Asgrow	4.7E[z]	21–90	9.7A	Paper	7.9A
Germain's	17.0A	21–70	7.4B	Cellophane	7.6B
Morancoat	6.4C	10–70	7.4B	Polyethylene	7.1C
Moran-minicoat	6.5C	10–50	6.2C	Foil-polyethylene	5.7D
Royal Sluis	1.6F	21–50	6.1C		
Tablet	5.3D	5–40	5.6D		
Raw	8.1B				

[z]Mean separation in columns by Duncan's multiple range test, 1% level. Nos. are averages of 72, 84, and 126 observations respectively for coating source, storage condition, and packaging material.

Table 3. Germination (%) of coated, rinsed, and raw lettuce seed stored at 5 C-40% RH. Means are averaged over 4 packaging materials and 6 sampling times (6 to 36 months).

	Seed coating						
	Asgrow	Germain's	Moran-coat	Moran-minicoat	Royal Sluis	Tape	Tablet
Coated	95.0B[z]	93.7B	96.5B	95.4B	54.7B	89.7A	74.7C
Rinsed	99.2A	97.5A	98.1A	98.3A	98.0A	90.8A	90.8B
Raw (uncoated)	99.1A	97.8A	98.3A	98.3A	---	---	95.6A

[z]Means within a column followed by a common letter are not significantly different at the 1% level of probability (LSD test).

ences in germination between rinsed and raw seed, except for the seed from tablets. With the tablets, abnormal roots on excised seeds indicated some mechanical damage during removal.

Seed coatings, storage conditions, and storage time (6 month intervals) were included in a 3-factor analysis of variance for the germination data. Seed stored in paper envelopes and cellophane behaved similarly and were combined as 2 observations in the analysis. Seed stored in polyethylene deteriorated in the same manner as the paper and cellophane, although at a slower rate, while seed in the foil-PE (if properly sealed) showed no deterioration after 36 months in storage. Therefore, these latter 2 packaging materials were not included in the analysis. As all seeds stored in paper and cellophane at 21° C, 90% RH were dead after 6 months, this storage condition as well as 5°, 40% RH (where no deterioration occurred) was also omitted.

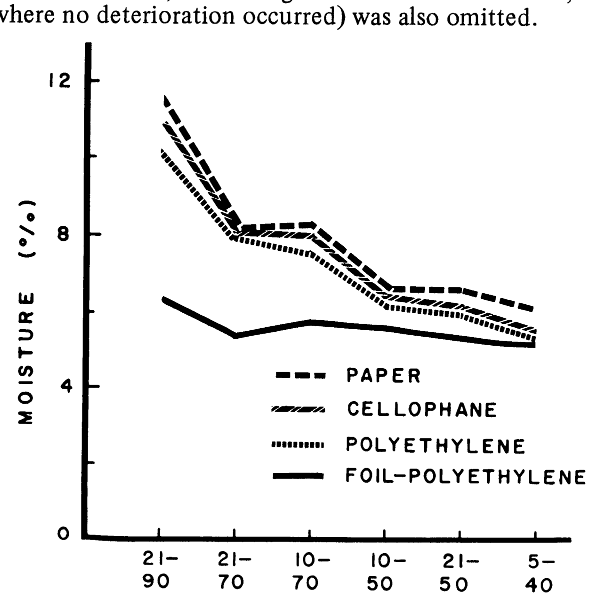

Fig. 3. Terminal moisture content of lettuce seed stored in 4 packaging materials at 6 temperature-relative humidity conditions.

A preliminary analysis of the 4 raw seed lots showed that they could best be combined as a single entry in the overall analysis. Also, the seed tape germination data was included. Generally germination of "rinsed" seed was used to represent the coated seed lot. Occasionally germination of the coated seed was higher than that of the "rinsed" and was used in the analysis of variance.

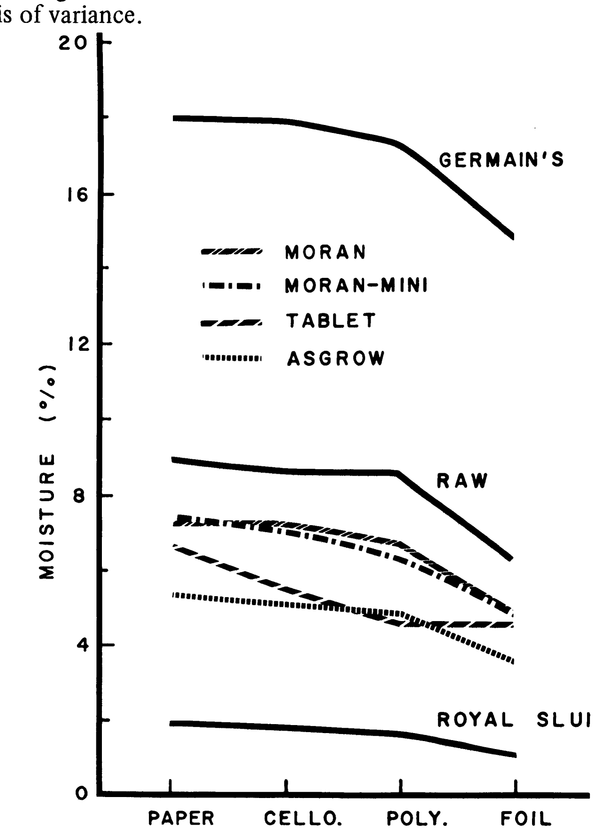

Fig. 4. Terminal moisture content of coated and raw lettuce seed stored in 4 packaging materials.

Table 4. Effect of seed coating, storage time, and storage condition on germination of lettuce seed.

Coating source	Germination (%)	Storage time (months)	Germination (%)	Storage condition	Germination (%)
Asgrow	68.5**^{z}	6	86.2A^{y}	21-70	11.5A^{y}
Germain's	69.4**	12	76.3B	21-50	79.0B
Morancoat	59.4**	18	71.7C	10-70	88.4C
Moran-minicoat	60.8**	24	69.4C	10-50	96.4D
Royal Sluis	75.5*	30	58.7D		
Tablet	74.4**	36	50.5E		
Tape	64.2**				
Raw	78.1				

^{z}*,**Significantly different from raw seed at 5 or 1% level respectively (LSD test). Values are means of 48 observations.
^{y}Means separation within columns by Duncan's multiple range test, 1% level. Values are means of 72 and 96 observations, respectively, for storage time and storage condition.

As with the seed moisture data, all treatment F values including the 2-way and the 3-way interactions were highly significant. For coating source comparisons should only be made between each coating and the raw seed. All coatings were significantly lower than the raw seed (Table 4). Germination decreased with time in storage and all storage conditions were significantly different.

The 3-way interaction of coating source x storage time x storage condition was again most easily examined in terms of the three 2-way interactions. A plot of storage condition x storage time (Fig. 6) showed no loss in germination at 10° C, 50% RH. Deterioration at 10°, 70% RH and 21°, 50% RH accelerated rapidly after 18 months' storage, while at 21°, 70%, significant deterioration had already occurred after 6 months.

The interaction means of coating source with storage time and storage condition are presented in Tables 5 and 6. With 2 exceptions, both the Royal Sluis pellets and the tablets equalled the raw seed germination during the 36 months' storage (Table 5). The other coatings except at 18 and 24 months resulted in lower germination than the raw seed. The Germain's coating also equalled the raw seed at 6 months.

Of the coating materials studied, the Royal Sluis pellet and the tablet stored, the best at the various storage conditions as compared with the raw seed (Table 6). The fact that the tablet germinated less than the raw seed at 10° C, 70% RH and at 10°, 50% RH is more likely the result of mechanical damage in removing the seeds from the tablet than to actual loss in germinability with storage.

Discussion

Lettuce seed is known for its poor storage under adverse conditions (2, 3, 5, 8, 14). Storage below 0 °C appears to be the best solution for long-term preservation (4, 5). For this experiment, an attempt was made to choose conditions normally encountered during handling of coated seed by both growers and seed companies. Long-term storage (10 years or longer) was not an objective of this study. Because of the added expense of coating seed, most seedsmen prefer to custom-coat seed for each customer, with little or no carryover of coated seed. However, with increasing demand for coated seed, carrying coated seed over to the next season could become more prevalent.

Two problems encountered throughout the experiment were mechanical damage to some seeds during rinsing or excising (tablets) and dormancy associated with the coated seed. The problem with rinsed seed was detected when unusually large numbers of seedlings with abnormal roots were obtained.

The problem of dormancy was more difficult to assess, particularly when the coating was left on the seed being germinated. It was impossible to tell a dead from a dormant seed if no radicle or shoot emerged.

Seed coatings, except for the tape, are comprised of 2 substances, the coating material and a binder. The coating materials commonly used are diatomaceous earth, charcoal, clay, and vermiculite (11). For the binder, various compounds have been tried, including methylethyl cellulose, gum arabic (6), polyvinyl alcohol (9), and sugar (10). The nature of the binder and/or the coating material can greatly affect the hygroscopic properties of the coating, and presumably affect seed storage potential. The results of this study showed a relationship between deterioration in storage and hygroscopic properties of seed coatings (i.e., Royal Sluis pellets vs. the other pellets) (Table 5). However, this relationship was not absolute (viz. Germain's pellets vs. Moran pellets). Certainly it would be unwise to allow strongly hygroscopic coatings to be in contact with high humidity for very long before packaging (presumably in a moisture-barrier material). Seed in some coatings such as the Royal Sluis pellets are naturally less susceptible to storage damage under similar circumstances.

Still unanswered is the question of the distribution of moisture between the coating material and the seed. In this study, moisture levels for a given pellet (or the tablet) gave only an indication that water had been taken up under a given storage

Table 5. Germination (%) of coated and raw lettuce seed following storage for various periods of time.

Coating source	Germination (%) Storage time 6 mo.	12 mo.	18 mo.	24 mo.	30 mo.	36 mo.
Asgrow	77.9**^{z}	73.6**	73.9	71.6	59.0**	55.3**
Germain's	92.9	72.8**	71.0	69.8	60.8**	49.3**
Moran coat	74.4**	73.1**	72.1	65.6**	43.1**	27.9**
Moran-minicoat	74.5**	73.1**	71.5	69.9	48.9**	27.0**
Royal Sluis	93.6	74.1**	74.0	73.1	69.1	69.3
Tablet	95.9	84.4	68.8*	69.6	66.9	61.1
Tape	84.1**	70.0**	68.1*	63.3**	51.4**	48.4**
Raw	96.7	89.3	74.0	72.5	70.6	65.9

^{z},*,**Significantly different from raw seed at 5 or 1% respectively (LSD test). Values are means of 12 observations.

Table 6. Germination of coated and raw lettuce seed stored in different temp-relative humidity conditions.

	Germination (%)			
	Storage condition			
Coating source	21°C, 70% RH	21°, 50% RH	10°, 70% RH	10°, 50% RH
Asgrow	2.4**[z]	85.7**	87.3**	98.8
Germain's	13.2**	75.5**	91.5**	97.4
Morancoat	0.4**	62.4**	76.9**	97.8
Moran-minicoat	0.4**	66.2**	78.7**	98.0
Royal Sluis	13.7**	95.5*	94.4	98.6
Tablet	24.5	88.7	92.9**	91.7**
Tape	10.7**	67.0**	88.5**	90.7**
Raw	26.6	91.2	96.8	98.0

[z],*,**Significantly different from raw seed at 5 or 1% respectively (LSD test). Values are means of 12 observations.

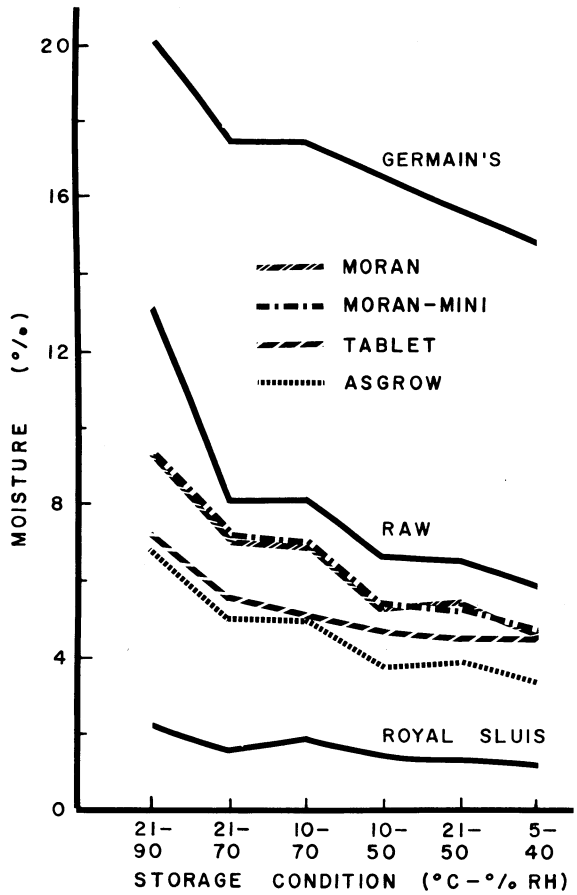

Fig. 5. Terminal moisture content of coated and raw lettuce seed stored under 6 temperature-relative humidity regimes.

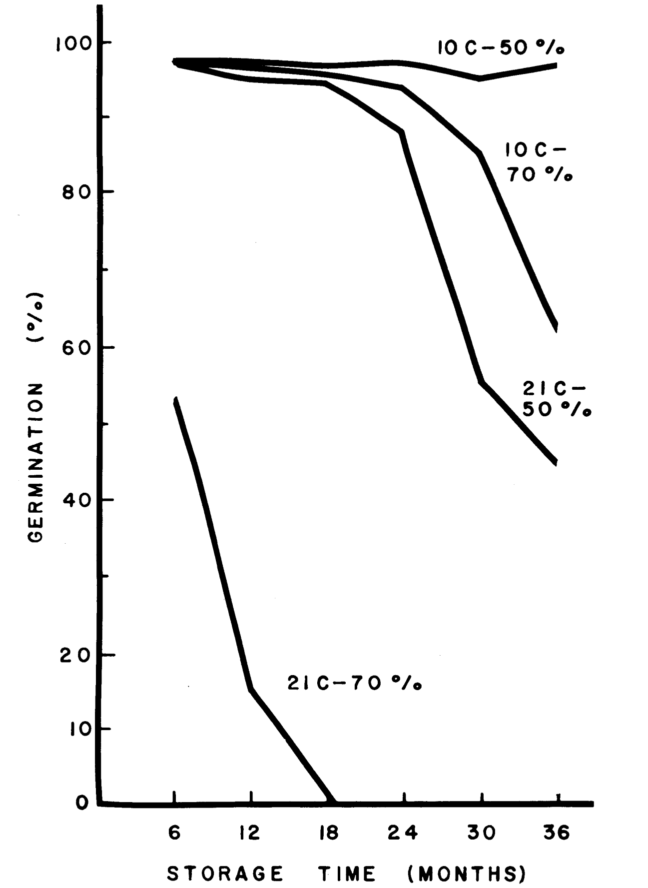

Fig. 6. Effect of storage condition on germination of lettuce seed at 6 month intervals.

condition. For proper seed storage, even for short periods, the actual seed moisture should be known.

Germination of coated seed, with the exception of the Royal Sluis pellet and the tablet, declined more rapidly than did germination of the raw seed. However, at 18 and 24 months this was not apparent (Table 5) because at 6 and 12 months only one storage condition (21° C, 70% RH) produced a significant decline in germination. Only after 24 months did a further large drop in germination occur in 2 other storage conditions (Fig. 6).

One problem frequently encountered in studies involving seed germination is analysis of the data. An analysis of variance is a powerful statistical tool by which germination data can be found to be significant; yet from a seed technologist's point of view the differences may have no practical significance. For example, in Table 3, the differences between coated and rinsed seed, although statistically significant for the Asgrow, Germain's and Moran pellets, have no practical significance for field planting.

General conclusions concerning storage of coated seed include:

1. Coated seed can be stored for up to 3 years if stored in properly sealed moisture-barrier packages at temperatures below 10°C.

2. Coated seed deteriorates more rapidly than raw seed when exposed to relative humidities above 70% and temperatures above 21°C.

3. Seed coating supplies a slight germination stress; hence, care must be taken to assure proper conditions for laboratory germination tests.

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ERRATA

The title and byline of the paper, The Relationship between Vegetative Maturity and the First Stage of Cold Acclimation by P. C. Nissila and L. H. Fuchigami (*J. Amer. Soc. Hort. Sci.* 103(6):710-711. 1978), was inadvertently omitted from the table of contents.

In the paper, Texture Modification of 'Van' Sweet Cherries by Postharvest Calcium Treatments by P. D. Lidster, S. W. Porritt, and M. A. Tung (*J. Amer. Soc. Hort. Sci.* 103(4):527-530. 1978), the caption for Fig. 1 should read: Fig. 1. Ca penetration into 'Van' cherry. Log ppm Ca = 2.920-0.003430 Day + 0.1536 Log Day (P 1%, R^2=0.94). Flesh Ca of undipped control = 545 ppm.

Also under Materials and Methods, in the first paragraph headed *Rate of calcium penetration,* the last sentence of the paragraph should read: Fifty fruits were removed at successive intervals of 1, 2, 4, 7, 14, and 21 days after dipping, and prepared for Ca analysis according to the above procedure.