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Winter Storage of Strawberry Plants[1]

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DEVELOPMENT OF PRACTICAL WINTER STORAGE

Strawberries are grown in home gardens and in commercial plantings in all parts of the United States, as they are adapted to a wide range of growing conditions and produce a crop relatively soon after they are set. Strawberry fields last 2 to 5 years, usually 3; consequently, large numbers of plants are required to maintain production and these are generally obtained from nurseries. The digging, trimming, counting, cleaning, packing, and shipping of plants require much hand labor. To get satisfactory growth the general practice is to dig the plants in the spring before active growth has started. In a given locality there is only a relatively short time after digging can begin that the plants remain sufficiently dormant, and, consequently, a peak demand for labor occurs. On the other hand, the demand for plants may extend over a considerable period as southern growers may order plants from more northern nurseries before the soil there can be worked and northern growers may order plants from more southern nurseries after the plants have begun active growth. By digging plants in the late fall or winter and holding them in storage, it would be possible to have plants available to fill very early orders, to keep up with the orders better during the peak demand, and to have relatively dormant plants to fill late orders. The use of stored plants would relieve the demand for labor during the peak period in the spring. It would also remove the plants from the hazard of winter injury in the field.

In 1937 experiments were started with plants grown on the Eastern Shore of Maryland to determine the feasibility of the winter storage

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of strawberry plants and the most suitable conditions for storage. Preliminary results [2] with Howard 17 (Premier) plants dug and stored in shipping crates at monthly intervals throughout the winter, beginning December 21, 1937, indicated that 30° F. at a low humidity and 32° and 36° at either low or high humidity were suitable for storage but that the plants would be killed or severely injured at 17°. Stored plants when set late grew better than plants freshly dug. Gem plants stored over winter in the rough (without bunching or cleaning) made as good growth as freshly dug ones, but those stored in crates did not grow so well. The results are in general agreement with those of Hoffman and Evans,[3] who found that early-dug plants from Maryland held in storage until planting time in New York were better than late-dug plants set at the same time. On the other hand, Aamodt and Brierley [4] reported for several Minnesota nurserymen that "in all cases where the storage temperatures were above freezing, much trouble was experienced with growth of the crowns, mildew or storage rots or drying," but that storage of plants in unheated sheds where the temperature dropped to 15° and 22° F. was successful.

In more extensive experiments strawberry plants of various varieties from two Maryland nurseries were dug at different times in late fall or early winter and stored under different conditions to determine how different factors affect the growth responses.

In these experiments the average growth response of 12 varieties stored over winter in crates at 32° F. for 1, 2, or 3 seasons was at least equal to that of freshly dug plants of the same varieties set at the same time, indicating that such storage is practical. Only 3 varieties grew better when set immediately after digging than when stored. The Gem variety was hardest of all to store; the Dorsett, Klondike, and Mastodon held up better in storage than the other varieties.

Plants, particularly those of the Dorsett variety, stored before they were sufficiently hardened grew poorly. The time when hardness is sufficient varies with locality, season, and cultural conditions, but under the conditions of these experiments storage by the middle of November, and in some seasons by the first of November, was satisfactory.

Plants stored in shipping crates at 32° F. looked better and made better growth response than those stored at 30° or 36°. Plants stored in the rough at 30° seemed somewhat superior to those stored at 32°.

Wetting the plants at intervals during storage was somewhat beneficial at 32° F., but it was of no benefit at 30° and was detrimental at 36°.

Removal of leaves, at the time of storage or when the plants were set, to reduce water loss was of no apparent benefit.

About 24 hours at an air temperature of 32° F. was required to reduce the temperature of the plants packed in the rough in bushel baskets from 60° to 40°. Gradual cooling in the fall was detrimental to growth, but rapid cooling with ice was of no benefit.

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[2] HALLER, M. H. STORAGE OF STRAWBERRY PLANTS. Amer. Soc. Hort. Sci. Proc. (1938) 35: 466–472. 1939.

[3] HOFFMAN, M. B., and EVANS, J. A. HANDLING STRAWBERRY PLANTS TO AVOID LOSSES. N. Y. State Hort. Soc. Proc. 82: 267–270. 1937.

[4] AAMODT, T. L., and BRIERLEY, W. G. WINTER STORAGE OF STRAWBERRY PLANTS. Amer. Soc. Hort. Sci. Proc. (1937) 34: 504–507. 1938.

Storage in the rough seems the most practical method of holding the plants, as plants stored in that way gave somewhat better growth response than those stored in crates and had a better appearance. The labor was also distributed over a longer period. The benefits of storage increased with delay in setting.

Fumigation of plants with methyl bromide after they had been stored had no apparent ill effect.

These results indicate that growers should find the growth response of plants held in cold storage over winter and set in the spring satisfactory. From the standpoint of appearance, however, some of the stored plants have been lacking. This was particularly true of those stored in crates at 36° F., at which temperature there were considerable mold growth, browning of the leaves, and some browning of the roots. Some browning of leaves occurred at 32° also, but it was less severe than at 36° and the plants did not appear as fresh as plants left in the field over winter. At 30° the leaves remained green but became wilted. If strawberry plants are to be stored with the leaves exposed and the roots in sphagnum moss, as when packed in shipping crates, a storage temperature of 32° should be used. This temperature results in as satisfactory growth response as higher or lower temperatures and in less deterioration in appearance.

When the plants were stored in the rough there was considerable browning of the leaves and roots at 36° F. At 32° and 30° there was little or no browning of the roots and many of the leaves remained green and turgid so that when the plants were trimmed and bunched after storage they generally presented an appearance equal to that of those freshly dug. From the standpoints of the appearance of the plants and the distribution of labor the most practical method of storing strawberry plants would be to hold them in the rough at 30° to 32°. The plants could then be trimmed and bunched during the late winter and early spring or just previous to shipping.

EXPERIMENTAL METHODS AND MATERIALS

The strawberry plants for these investigations were obtained from 2 commercial nurseries near Salisbury, Md. They were dug at various times in the late fall or early winter and either were tied in bundles of 25, dipped in water, and packed in shipping crates with moist sphagnum moss around the roots or were packed in the rough (without bunching and cleaning) and shipped to the cold-storage laboratories at Arlington, Va., or Beltsville, Md., where they were stored at constant temperatures of 30°, 32°, and 36° F. When packed in the rough the plants were placed directly in bushel baskets lined with moist burlap or sphagnum moss. These plants were not sorted or cleaned until a few days before being set.

After storage the plants were returned for spring planting to the respective nurseries from which they had been obtained. Freshly dug plants of the same varieties were set at the same time for comparison. For some tests plants were removed from storage at monthly intervals for planting and freshly dug plants were planted at the same time. The check (freshly dug) plants were not necessarily from the same field or part of the field as the stored plants; this may account for some of the inconsistencies in the relation between freshly dug and stored plants of the same varieties.

The plants from each treatment were set 15 to 18 inches apart in rows 40 inches apart. In 1939, 50 plants were set in each plot; in 1940, 25 plants per plot were set at 1 nursery and 50 at the other; and in 1941, 25 plants were used per plot at both nurseries. At both nurseries the field was divided into 2 blocks and the plots were located at random in each block. As the same varieties and treatments were used at both nurseries this gave 4 replications of most treatments in each season.

The most practicable time for taking records appeared to be after runner-series development had occurred but before the runner series became so extensive as to make counts difficult (generally about mid-July). As a measure of growth and vigor the percentage stand of the plants set was determined, and counts were made of the number of leaves and the number of runner series on each of 20 plants in each plot. These determinations were combined into an index of growth by adding the total number of leaves to the total number of runner series on the 20 plants and multiplying by the percentage stand. Within varieties there was generally a close correlation between the numbers of leaves and runner series per plant so that essentially the same conclusions would have been arrived at from either the leaf counts or the runner-series counts as from the combined counts.

The fields were level and of rather uniform sandy loam fertilized in accordance with the commercial practice at the nurseries.

Fairly normal weather conditions suitable for growth prevailed in 1939 until the growth records were taken. In this season the two blocks (3 and 4) at one nursery were in separate fields several miles apart, and the soil of block 3 was considerably less fertile than that of block 4. In 1940 a rather severe drought occurred in the month previous to the time when the records were taken; this caused considerable browning of leaves and killing of plants at one nursery (blocks 3 and 4). At the other nursery (blocks 1 and 2) the plants were set in a somewhat heavier soil and no injury was apparent. In 1941 drought conditions prevailed previous to the time the counts were taken, but growth response did not seem to have been seriously retarded at either nursery.

The data were analyzed for statistical significance by analysis of variance. Rather large differences were frequently found between replicate plots so that rather large differences between treatments are necessary for significance.

RELATION OF GROWTH RESPONSE TO VARIOUS FACTORS

Variety

During all three seasons plants for storage were dug about December 1, packed in shipping crates with moist sphagnum moss around the roots, and stored at 32° F. They and freshly dug plants of the same varieties were planted about the first of April.

Since all varieties were not used in all seasons (table 1), a general statistical analysis was not made but each variety was considered separately. In 3 of the 12 varieties (Gem, Chesapeake, and Dunlap) the growth response averaged greater for the freshly dug than for the stored plants, but the difference was significant only in the case of the

Gem variety. In the other 9 varieties the growth response averaged greater for the stored than for the freshly dug plants. However, only in the case of Mastodon and Dorsett were the stored plants significantly superior.

The mean growth response for all varieties averaged 9 percent greater for the storage lots than for the freshly dug lots. While the

TABLE 1.—*Growth responses of strawberry plants stored at 32° F. over winter and of (field) plants not-stored* [1]

[Growth index=(leaves+runner series on 20 plants)×percentage stand]

Variety and year planted	Growth index of stored plants in block—					Growth index of not-stored plants in block—					Ratio (stored to not-stored)
	1	2	3	4	Mean	1	2	3	4	Mean	
Howard 17:											
1939	237	308	199	256	250	275	312	137	239	241	
1940	165	216	104	186	168	145	242	92	235	179	
1941	53	136	139	187	129	54	178	16	138	96	
Mean					182					172	1.06
Fairfax:											
1939	145	292	90	393	230	203	213	112	215	188	
1940	332	315	97	121	216	383	337	65	167	239	
1941	126	249	179	212	192	41	232	215	153	160	
Mean					213					196	1.09
Blakemore:											
1939	354	309	249	426	335	252	319	261	323	289	
1940	383	369	135	271	290	280	285	191	193	237	
1941	159	222	270	213	216	207	257	300	176	235	
Mean					280					254	1.10
Dorsett:											
1939	227	253	194	489	291	224	276	199	283	246	
1940	332	636	185	98	313	261	443	86	83	218	
1941	146	331	210	104	198	177	317	103	35	158	
Mean					267					207	1.29
Catskill:											
1939	314	238	126	281	240	235	336	125	158	214	
1940	414	227	194	113	237	368	273	105	42	197	
Mean					239					206	1.16
Chesapeake:											
1939	114	208			161	194	296			245	
1940	271	178	58	71	145	171	199	45	54	145	
Mean					150					160	.94
Mastodon:											
1939	262	213	141	318	234	195	196	97	214	176	
1940	169	218	185	149	180	179	213	124	136	163	
Mean					207					170	1.22
Gem:											
1939	55	53	30	93	58	132	150	48	151	120	
1940	191	108	16	23	85	182	132	52	41	102	
Mean					72					111	.65
Missionary:											
1941	134	268	267	175	211	151	214	154	218	184	1.15
Aroma:											
1941	153	153	128	76	128	108	95	154	95	113	1.13
Klondike:											
1941	146	204	184	253	197	207	165	125	144	160	1.23
Dunlap:											
1941	111	18	54	87	68	148	77	118	25	92	.74
Grand mean					199					182	1.09

[1] Stored plants dug about Dec. 1. All plants set about Apr. 1; growth records made about mid-July.

great variability between replicate plots and the inconsistency among the varieties made this difference not statistically significant, the results show that the stored plants of most of the varieties tested grew as well as freshly dug plants, if not better.

Time of Digging

In the preliminary studies by Haller [5] plants were dug for storage at monthly intervals throughout the winter beginning December 21. The results of these studies indicated no differences in the response of the plants to storage when dug at different times during the winter. It seemed likely, however, that plants dug early, before they had become winter-hardened, might not store well or might be injured by the sudden and extended exposure to low temperatures. Consequently subsequent investigations were concerned more with plants dug at early dates. The results for each year of these investigations are presented in table 2. Because both weather conditions and cultural practices influence hardiness, the date at which plants may be sufficiently hardened for storage in one season and locality may not apply to another season or to a different locality.

In 1938 the earliest date at which plants were dug for storage was November 1 (table 2). Although the average growth response of Howard 17 plants dug at this time was less than that of plants dug later, the difference was not statistically significant and no other significant differences due to time of digging or between the stored and the field lots (dug April 4) were found.

In 1939 plants were dug for storage as early as October 20 and 21. Plants of all varieties dug this early produced less average growth than plants dug later. Although no significant varietal difference was indicated, the Dorsett variety appeared to be particularly subject to injury from early digging; the early dug plants of this variety were generally dark brown and decayed throughout when removed from storage. On some of the other varieties the leaves were brown and dead, but the browning generally did not extend into the crown. There was an improvement in the average growth response with delay in digging up to December 1 and 2, but the change after November 14 and 18 was not significant.

In 1940 plants were dug on November 1, November 18 and 19, and December 3 and 5 and were stored in the rough. The plants were trucked to the cold storage, instead of being shipped by express or parcel post as in the previous seasons, and were stored about 24 hours after digging. Plants from all three diggings were stored at both 32° and 30° F. until planting time, when they were removed from storage for cleaning, bunching, and planting. The results for the four varieties used (table 2) do not show any significant differences due to time of digging.

In digging strawberry plants for storage it is essential that digging be delayed until the plants become hardened. At Salisbury, Md., the plants were satisfactory for storage by the first of November in two of the three seasons in which these investigations were conducted and by the middle of November in the third season. It is recognized that the time at which the plants become sufficiently hardened will no doubt vary greatly with climatic and cultural conditions and no satisfactory index to this condition has been developed. On the other

[5] See footnote 2, p. 2.

hand, the plants may suffer some winter injury under some conditions so that it would not be desirable to delay digging until too severe freezing is likely to occur.

TABLE 2.—*Relation of time of digging for storage to growth response of strawberry plants* [1]

[Growth index = (leaves + runner series on 20 plants) × percentage stand]

Year planted and variety	Date dug for blocks—		Storage temperature	Growth index of plants in block—				
	1 and 2	3 and 4		1	2	3	4	Mean
			° F.					
1939:								
Howard 17	Nov. 1, 1938	Nov. 1, 1938	32	113	268	92	195	167
	Dec. 9, 1938	Dec. 19, 1938	32	237	308	199	256	250
	Jan. 11, 1939	Jan. 12, 1939	32	184	341	186	295	252
	Apr. 4, 1939	Apr. 4, 1939		275	312	137	239	241
Fairfax	Nov. 1, 1938	Nov. 1, 1938	32	262	356	42	100	190
	Dec. 9, 1938	Dec. 19, 1938	32	145	292	90	393	230
	Jan. 11, 1939	Jan. 12, 1939	32	228	247	67	292	209
	Apr. 4, 1939	Apr. 4, 1939		203	213	112	215	186
1940:								
Howard 17	Oct. 21, 1939	Oct. 20, 1939	32	142	140	22	67	93
	Nov. 7, 1939	Oct. 28, 1939	32	163	171	53	70	114
	Nov. 18, 1939	Nov. 14, 1939	32	192	157	76	86	128
	Dec. 1, 1939	Dec. 2, 1939	32	165	216	104	186	168
	Apr. 4, 1940	Apr. 5, 1940		145	242	92	235	179
Fairfax	Oct. 21, 1939	Oct. 20, 1939	32	50	69	45	60	56
	Nov. 7, 1939	Oct. 28, 1939	32	215	259	51	79	151
	Nov. 18, 1939	Nov. 14, 1939	32	377	216	103	76	193
	Dec. 1, 1939	Dec. 2, 1939	32	332	315	97	121	216
	Apr. 4, 1940	Apr. 5, 1940		383	337	65	167	238
Blakemore	Oct. 21, 1939	Oct. 20, 1939	32	227	331	7	37	151
	Nov. 7, 1939	Oct. 28, 1939	32	290	237	89	151	192
	Nov. 18, 1939	Nov. 14, 1939	32	385	350	212	264	303
	Dec. 1, 1939	Dec. 2, 1939	32	383	369	135	271	290
	Apr. 4, 1940	Apr. 5, 1940		280	285	191	193	237
Catskill	Oct. 21, 1939	Oct. 20, 1939	32	135	89	56	26	77
	Nov. 7, 1939	Oct. 28, 1939	32	306	158	130	57	163
	Nov. 18, 1939	Nov. 14, 1939	32	293	207	205	129	209
	Dec. 1, 1939	Dec. 2, 1939	32	414	227	194	113	237
	Apr. 4, 1940	Apr. 5, 1940		368	273	105	42	197
Dorsett	Oct. 21, 1939	Oct. 20, 1939	32	19	0	0	0	5
	Nov. 7, 1939	Oct. 28, 1939	32	277	334	0	0	153
	Nov. 18, 1939	Nov. 14, 1939	32	247	354	58	39	175
	Dec. 1, 1939	Dec. 2, 1939	32	332	636	185	98	313
	Apr. 4, 1940	Apr. 5, 1940		261	443	86	83	218
Mastodon	Oct. 21, 1939	Oct. 20, 1939	32	39	75	24	4	36
	Nov. 7, 1939	Oct. 28, 1939	32	71	104	20	47	61
	Nov. 18, 1939	Nov. 14, 1939	32	178	162	114	131	146
	Dec. 1, 1939	Dec. 2, 1939	32	169	218	185	149	180
	Apr. 4, 1940	Apr. 5, 1940		179	213	124	136	163
1941:								
Howard 17	Nov. 1, 1940	Nov. 1, 1940	30	134	215	62	214	156
			32	232	261	139	138	193
	Nov. 18, 1940	Nov. 19, 1940	30	219	91	93	173	144
			32	175	203	67	218	166
	Dec. 3, 1940	Dec. 5, 1940	30	159	160	155	147	155
			32	195	124	63	145	132
	Apr. 1–2, 1941	Apr. 3–4, 1941		54	178	16	138	97
Fairfax	Nov. 1, 1940	Nov. 1, 1940	30	150	185	245	142	181
			32	164	177	202	179	181
	Nov. 18, 1940	Nov. 19, 1940	30	154	269	213	176	203
			32	280	284	190	216	243
	Dec. 3, 1940	Dec. 5, 1940	30	238	137	218	148	185
			32	35	187	181	136	135
	Apr. 1–2, 1941	Apr. 3–4, 1941		41	232	215	153	160
Dorsett	Nov. 1, 1940	Nov. 1, 1940	30	207	151	127	106	148
			32	80	291	243	212	207
	Nov. 18, 1940	Nov. 19, 1940	30	224	198	218	148	197
			32	231	124	248	187	198
	Dec. 3, 1940	Dec. 5, 1940	30	244	277	246	109	219
			32	87	262	294	138	195
	Apr. 1–2, 1941	Apr. 3–4, 1941		177	317	103	35	158
Missionary	Nov. 1, 1940	Nov. 1, 1940	30	216	167	110	106	150
			32	180	185	178	212	189
	Nov. 18, 1940	Nov. 19, 1940	30	214	155	149	270	197
			32	153	214	249	196	203
	Dec. 3, 1940	Dec. 5, 1940	30	133	276	214	223	212
			32	112	165	179	261	179
	Apr. 1–2, 1941	Apr. 3–4, 1941		151	214	154	218	184

[1] Plants set Apr. 1 to 5; growth records made about mid-July.

Storage Temperatures

In all three seasons the responses of strawberry plants stored over winter at 30°, 32°, and 36° F. were compared. The 32° and 36° rooms were held at rather high relative humidities. At below-freezing temperatures it is difficult to maintain high humidities, and consequently the humidity in the 30° room was low. Although the leaves generally remained green on plants stored in shipping crates at 30°, they withered and became dry. In 1938–39 an attempt was made to overcome this by wetting the plants at monthly intervals during storage. At 30° the water froze around the roots in the moss and probably was not available to the plants. Such treatment did not prevent the withering of the leaves. At 36° wetting the plants increased the mold growth and the browning of the leaves and was therefore detrimental from the standpoint of appearance. Plants held in the rough were not directly exposed to the air, and the wilting of leaves at 30° was retarded.

The growth response of the plants for the 1938–39 season are shown in table 3. Plants stored at 30° F. were weaker than those stored at 32° and 36°. However, even though the differences were large, they were not statistically significant.

Table 3.—*Relation of wetting of strawberry plants in storage at different temperatures (°F.) to the growth response of the plants* [1]

[Growth index = (leaves + runner series on 20 plants) × percentage stand]

Variety and treatment	Growth index of plants in indicated block after storage at—									Mean (3 temperatures)
	30°			32°			36°			
	1	2	Mean	1	2	Mean	1	2	Mean	
Howard 17:										
Not wet	265	249	257	237	308	273	380	180	280	270
Wet	200	239	220	297	405	351	259	273	266	279
Fairfax:										
Not wet	150	122	136	145	292	219	207	358	283	212
Wet	169	192	181	269	223	246	224	249	237	221
Mean, 2 varieties:										
Not wet			197			246			281	241
Wet			200			299			251	250
Mean, 2 treatments			199			273			266	

[1] Plants set Apr. 4, 1939; growth records made July 17 to 25, 1939.

For the 1939–40 season (table 4) though there was no appreciable difference in the average growth response of plants from 30° F. and from 32° storage, plants from 36° storage showed a highly significant reduction in growth. This reduction appeared to be greater in the Gem and Chesapeake than in the Howard 17 and Fairfax varieties, but the variety-temperature interaction in the analysis of variance showed this to be not significant. Neither was there a significant difference in the response at the different temperatures due to the method of packing.

In the 1940–41 season eight varieties were stored in crates at 30°, 32°, and 36° F., and four of these were stored both in crates and in the rough at the three temperatures. Their growth responses, together

TABLE 4.—*Relation of storage temperature (F.) and method of packing to growth response of strawberry plants.*[1]

[Growth index=(leaves+runner series on 20 plants)×percentage stand]

Year planted and variety	Method of packing	Growth index of plants in the indicated block after storage at—															Mean, all temperatures	Growth index of check (not-stored) plants in block				
		30°					32°					36°										
		1	2	3	4	Mean	1	2	3	4	Mean	1	2	3	4	Mean		1	2	3	4	Mean
1940																						
Howard 17	Crate	112	266	106	144	157	165	216	104	186	168	200	282	173	137	198		145	242	92	235	179
	Rough	231	237	106	125	175	144	204	92	144	146	165	212	89	195	165						
Fairfax	Crate	228	263	96	58	161	332	315	97	121	216	244	327	99	113	196		383	337	65	167	239
	Rough	305	475	50	94	231	292	240	35	158	181	313	230	42	51	159						
Chesapeake	Crate	195	178	131	26	133	271	178	58	71	145	84	130	20	31	66		171	199	45	54	117
	Rough	264	276	66	39	161	152	237	107	77	143	144	219	59	53	119						
Gem	Crate	80	96	17	17	53	191	108	16	23	85	0	13	2	3	5		182	132	52	41	102
	Rough	253	112	20	34	105	173	202	14	24	103	14	18	0	2	8						
Mean, 4 varieties.	Crate					126					153					116	132					159
	Rough					168					143					113	141					
	Both					147					148					115						
1941																						
Howard 17	Crate	49	72	94	165	95	53	136	139	187	129	51	29	44	231	89		54	178	18	138	97
	Rough	159	160	155	147	155	195	124	63	145	132	154	196	127	199	169						
Fairfax	Crate	45	188	181	129	136	126	249	179	212	192	55	152	151	136	124		41	232	215	153	160
	Rough	238	137	218	148	185	35	187	181	136	135	119	246	202	137	176						
Dorsett	Crate	128	147	205	126	152	146	331	210	104	198	218	178	126	98	155		177	317	103	35	158
	Rough	254	277	246	109	222	109	262	294	138	201	304	199	244	186	233						
Missionary	Crate	226	214	164	204	202	134	268	267	175	211	283	250	232	201	242		151	214	154	218	184
	Rough	133	276	155	223	197	112	165	179	261	179	183	176	178	214	188						
Mean, 4 varieties.	Crate					146					182					152	160					150
	Rough					190					162					192	181					
	Both					168					172					172						
Aroma	Crate	57	50	99	118	81	153	153	128	76	128	37	120	94	103	89		108	95	154	95	113
Klondike	Crate	131	130	235	204	175	146	204	184	253	197	127	145	84	236	148		207	165	125	144	160
Blakemore	Crate	175	252	202	218	212	159	222	270	213	216	75	173	304	205	189		207	257	300	176	235
Dunlap	Crate	193	186	61	38	120	111	18	54	87	68	50	173	61	82	92		148	77	118	25	92
Mean, 8 varieties.	Crate					146					167					141						150

[1] Plants set in early April, growth records made about mid-July.

with those of the check (freshly dug) plants set at the same time as the stored ones, are shown in table 4. The results for the eight varieties in crates indicate a greater average growth response by plants from 32° storage than from the other temperatures, but this was not statistically significant. Neither did the varieties differ significantly in their interaction with storage temperatures. With the four varieties stored both in crates and in the rough there was no appreciable difference in the average growth response at the different temperatures. However, there was a significant interaction between temperatures and method of packing, indicating that, when the plants were packed in crates, 32° was better than 30° and 36°, whereas when they were packed in the rough, 30° and 36° were superior to 32°.

During all three seasons (tables 3 and 4) the growth response of the plants stored in crates was greater (average 17 percent) for the 32° F. storage lots than for 30° lots. Apparently the wilting of the plants at 30° when packed in crates had an adverse effect. On the other hand, in the last two seasons, when plants were stored in the rough and thus protected from wilting, the average growth response of those from 30° storage was superior to that of those from 32°. Storage at 36° adversely affected the appearance of the plants in all seasons and significantly reduced the growth response during one of the three seasons. From the standpoint of appearance and growth response, storage of strawberry plants at 32° seems most desirable, particularly if they are held in shipping crates with the leaves exposed. If they are stored in the rough, a temperature of 30° may be more desirable.

Wetting Plants During Storage

It was thought that injury to the plants during storage might be due to loss of moisture through the leaves and from the drying of the sphagnum moss around the roots. To reduce this loss, water was run into the crates at monthly intervals in the case of plants dug in 1938 and stored at 30°, 32°, and 36° F. (table 3). As stated previously, the water froze at 30° and probably was not available to the plants and, as might be expected, it had no appreciable effect on their growth response. At 36°, on the other hand, the excess moisture was favorable for the growth of mold, and browning of the leaves resulted; the average growth response at 36° was lower with the wet plants than with the ones that were not wet. At 32° the added moisture maintained the turgidity of the plants, little or no mold growth occurred, and there was considerably greater growth response of wet plants than of those that were not wet. However, the differences in growth response to wetting were not statistically significant at either 36° or 32°.

As it appeared that an excessive amount of water was added to the plants dug in 1938 and that wetting the leaves resulted in mold growth and browning of the leaves, water was added to plants dug in 1939 only once, at about the middle of the storage season; it was added by wetting the sphagnum moss only and repacking the moist moss around the roots. In agreement with the results for the previous season at 32° F., the growth response averaged greater in the lots that were moistened during storage than in those that were not moistened (table 5). This difference was statistically significant, and the interaction of wetting with variety and date of digging approached significance, indicating that the beneficial effect of wetting was greater with the second date of digging of Howard 17 and with the early digging of Fairfax.

Additional studies on the effect of moisture during storage were conducted with plants dug in November 1940, and stored at 30° and 32° F. in the rough (table 5). For storage in the rough the plants were placed in bushel baskets lined with sphagnum moss. In the control baskets the moss was moist as in commercial practice, whereas in the wet baskets the moss was soaked in water and only the excess water was allowed to drain off before the moss was used. No determination of the actual amount of moisture under the different conditions was made, and no additional water was added to the wet baskets

during storage. The results in table 5 show that the growth response averaged somewhat greater for the wet plants both at 30° and 32° than for the control plants, but the difference was not significant.

At 32° wetting the moss around the plants resulted in significantly increased growth response in one season and appreciable, though not significant, average increases for the other two seasons. This would seem to justify the addition of water to the moss at packing time for storage at this temperature.

TABLE 5.—*Relation of time of digging and wetting or icing of plants in storage to growth response of strawberry plants*

[Growth index = (leaves + runner series on 20 plants) × percentage stand]

Year planted, variety, and date of digging	Treatment	Growth index of plants in indicated block after storage at—										Mean (2 temperatures)
		30° F.					32° F.					
		1	2	3	4	Mean	1	2	3	4	Mean	
1940: [1]												
Howard 17:												
Oct. 20 and 21, 1939	Not wet	-----	-----	-----	-----	-----	142	140	22	67	93	-----
	Wet	-----	-----	-----	-----	-----	138	131	38	31	85	-----
Nov. 14 and 16, 1939	Not wet	-----	-----	-----	-----	-----	192	157	76	86	128	-----
	Wet	-----	-----	-----	-----	-----	282	291	95	142	203	-----
Fairfax:												
Oct. 20 and 21, 1939	Not wet	-----	-----	-----	-----	-----	50	69	45	60	56	-----
	Wet	-----	-----	-----	-----	-----	253	301	28	25	152	-----
Nov. 14 and 16, 1939	Not wet	-----	-----	-----	-----	-----	377	216	103	76	193	-----
	Wet	-----	-----	-----	-----	-----	287	339	87	144	214	-----
Mean, 2 varieties	Not wet	-----	-----	-----	-----	-----	-----	-----	-----	-----	118	-----
	Wet	-----	-----	-----	-----	-----	-----	-----	-----	-----	164	-----
1941: [1]												
Howard 17:												
Nov. 18 and 19, 1940	Check	219	91	93	173	144	175	203	67	218	166	-----
	Wet	328	151	118	235	208	232	166	66	136	150	-----
	Iced	283	185	148	200	204	98	201	29	146	119	-----
Fairfax:												
Nov. 18 and 19, 1940	Check	154	269	213	176	203	280	284	190	216	243	-----
	Wet	194	267	235	202	225	309	231	226	166	233	-----
	Iced	120	184	241	188	183	342	206	167	124	210	-----
Dorsett:												
Nov. 18 and 19, 1940	Check	224	198	218	148	197	231	124	248	187	198	-----
	Wet	199	339	276	96	228	323	249	227	118	229	-----
	Iced	162	247	254	118	195	200	235	259	208	226	-----
Missionary:												
Nov. 18 and 19, 1940	Check	214	155	149	270	197	153	214	249	196	203	-----
	Wet	250	177	194	180	200	276	236	155	256	231	-----
	Iced	272	260	199	214	236	341	185	171	219	229	-----
Mean, 4 varieties	Check	-----	-----	-----	-----	185	-----	-----	-----	-----	202	194
	Wet	-----	-----	-----	-----	215	-----	-----	-----	-----	211	213
	Iced	-----	-----	-----	-----	205	-----	-----	-----	-----	196	200

[1] Plants stored in shipping crates in 1940 and in the rough in 1941.

Leaf Removal During Storage

To reduce water loss by transpiration the leaves were trimmed from the plants of some lots at the time of storage or setting. The influence of leaf removal on growth is shown in table 6 and indicates that removing the leaves was of no benefit with freshly dug (not-stored) plants. Plants with the leaves removed at the time of storage average greater growth response than those with the leaves left on, but the difference was not significant. The earlier studies by Haller [6] did not indicate any benefit from leaf removal, even with stored plants.

[6] See footnote 2, page 2.

TABLE 6.—*Relation of leaf removal to growth response of strawberry plants* [1]

[Growth index=(leaves + runner series on 20 plants) × percentage stand]

Variety	Treatment	Growth index of plants in indicated block when—					
		Not stored			Stored		
		1	2	Mean	1	2	Mean
Howard 17	Leaves on	275	312	294	237	308	273
	Leaves off	235	243	239	360	381	371
Fairfax	Leaves on	203	213	208	145	292	219
	Leaves off	254	280	267	311	253	282
Mean, 2 varieties	Leaves on	------	------	251	------	------	246
	Leaves off	------	------	253	------	------	326

[1] Plants stored Dec. 9, 1938, and set Apr. 4, 1939; growth records made July 17 to 25, 1939.

RATE OF COOLING

To determine whether the unsatisfactory storage of plants dug relatively early in the fall was due to the sudden cooling of the unhardened plants, certain lots were cooled slowly by holding them at 50° F. for 1 week and then at 40° for 1 week before storing at 32°. The results in table 7 show a significantly detrimental effect of gradual cooling at this season, the growth of gradually cooled plants being 71 percent of that of plants with rapid cooling. The varieties did not differ significantly in their response to rate of cooling.

Since slow cooling was detrimental to the stored plants, it seemed likely that more rapid cooling than immediate storage at 32° F. might be beneficial. More rapid cooling was obtained with plants packed in the rough in bushel baskets by adding about 12 pounds of crushed ice throughout the basket. The temperature in the center of the

TABLE 7.—*Relation of rate of cooling for storage at 32° F. to the growth response of strawberry plants* [1]

[Growth index=(leaves+runner series on 20 plants)×percentage stand]

Variety	Date dug	Rate of cooling [2]	Growth index of plants in block				
			1	2	3	4	Mean
Howard 17	Oct. 20 and 21	Rapid	142	140	22	67	93
		Gradual	103	103	22	0	57
	Oct. 28 and Nov. 7	Rapid	163	171	53	70	114
		Gradual	148	146	35	77	102
Fairfax	Oct. 20 and 21	Rapid	50	69	45	60	56
		Gradual	48	136	14	11	52
	Oct. 28 and Nov. 7	Rapid	215	259	51	79	151
		Gradual	123	77	42	27	67
Blakemore	do	Rapid	290	237	89	151	192
		Gradual	235	276	120	108	185
Catskill	do	Rapid	306	158	130	57	163
		Gradual	187	86	110	33	104
Dorsett	do	Rapid	277	334	0	0	153
		Gradual	217	125	0	0	86
Missionary	do	Rapid	71	104	20	47	61
		Gradual	93	75	13	23	51

[1] Plants set Apr. 4 and 5, 1940; growth records made July 10 to 18, 1940.

[2] Rapid cooling=placed at 32° F. within 24 hours of digging; gradual cooling=50° for 1 week, then 40° for 1 week, and then 32° for rest of storage period.

baskets was determined with electric resistance thermometers. The rate of cooling of the lots dug on November 1 is shown in figure 1. The check plants (not iced) stored at 30° and 32° attained temperatures below 35° in about 40 hours after being placed in storage and nearly 50 hours after the iced plants that were nearly cooled in the center by the time the package was packed and a reading could be taken. Melting of the ice also tended to moisten the plants. If the ice affected the response of the plants to storage there might be some question whether the effect was due to the more rapid cooling or to the wetting of the plants.

In the later digging of November 18 and 19 the plants were stored with ice and with wet sphagnum moss as well as with moist sphagnum moss. When the lots were removed from storage the following April, there was still considerable ice in the lots packed with ice. Although the ice was not weighed on removal there appeared to be at least half of it remaining so that considerably less ice could have been used. The results in table 8 do not show any benefit from package icing compared with storage without ice at either 30° or 32°. Results for the second digging only (table 5) do not show any benefit from package icing compared with packing in either wet or moist sphagnum moss.

Method of Packing During Storage

Comparison of packing in shipping crates with packing in the rough for the 1938–39 storage season is shown in table 9. Although the growth response of plants stored in the rough averaged considerably greater than that of those stored in crates the difference was not significant. Results for the 1939–40 storage season (table 4) also show

Figure 1.—Rate of cooling of strawberry plants in bushel baskets with and without package ice.

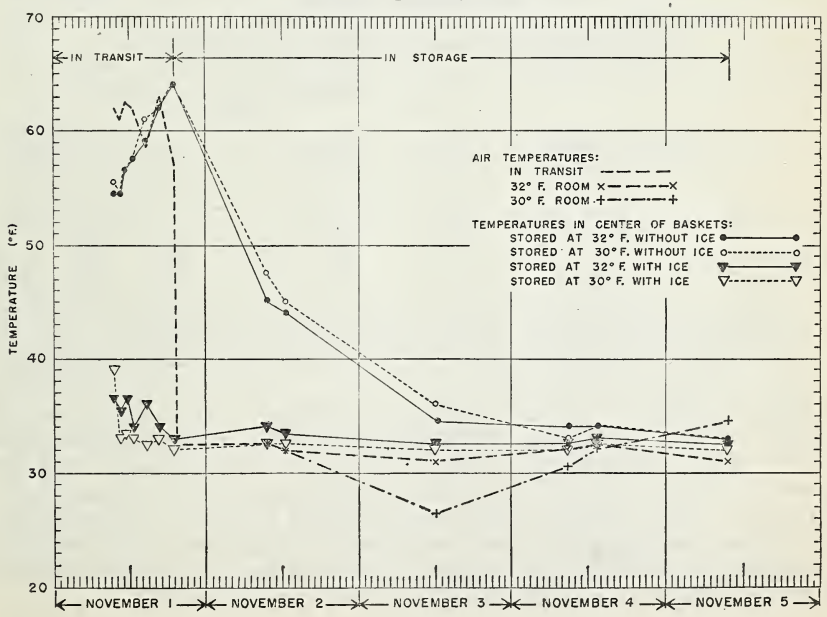

TABLE 8.—*Relation of rate of cooling for 30° and 32° F. storage to growth response of strawberry plants stored in the rough* [1]

[Growth index=(leaves+runner series on 20 plants)×percentage stand]

Variety and date of digging	Rate of cooling [2]	Growth index of plants in indicated block after storage at—									
		30°					32°				
		1	2	3	4	Mean	1	2	3	4	Mean
Howard 17:											
Nov. 1, 1940	Rapid	134	215	62	214	156	232	261	139	138	193
	Immediate	145	149	120	205	155	142	206	80	120	137
Nov. 18–19, 1940	Rapid	219	91	93	173	144	175	203	67	218	166
	Immediate	283	185	148	200	204	98	201	29	146	119
Fairfax:											
Nov. 1, 1940	Rapid	150	185	245	142	181	164	177	202	179	181
	Immediate	171	167	158	110	152	275	250	174	100	200
Nov. 18–19, 1940	Rapid	154	269	213	176	203	280	284	190	216	243
	Immediate	120	184	241	188	183	342	206	167	124	210
Dorsett:											
Nov. 1, 1940	Rapid	207	151	127	106	148	80	291	243	212	207
	Immediate	139	231	162	141	168	168	101	99	106	119
Nov. 18–19, 1940	Rapid	224	198	218	148	197	231	124	248	187	198
	Immediate	162	247	254	118	195	200	235	259	208	226
Missionary:											
Nov. 1, 1940	Rapid	216	167	110	106	150	180	185	178	212	189
	Immediate	86	198	164	191	160	110	243	219	227	200
Nov. 18–19, 1940	Rapid	214	155	149	270	197	153	214	249	196	203
	Immediate	272	260	199	214	236	341	185	171	219	229
All varieties:											
Nov. 1, 1940	Rapid	------	------	------	------	159	------	------	------	------	193
	Immediate	------	------	------	------	159	------	------	------	------	164
Nov. 18–19, 1940	Rapid	------	------	------	------	185	------	------	------	------	202
	Immediate	------	------	------	------	205	------	------	------	------	196

[1] Plants set Apr. 1 to 4, 1941; growth records made July 8 to 15, 1941.
[2] Rapid cooling=placed at 30° or 32° within 24 hours of digging; immediate cooling=packed with crushed ice within 2 hours of digging.

TABLE 9.—*Relation of method of packing to growth response of strawberry plants after storage at 32° F.*[1]

[Growth index=(leaves+runner series on 20 plants)×percentage stand]

Method of packing [2]	Growth index of plants in indicated block				Mean (2 varieties)
	Howard 17		Fairfax		
	1	2	1	2	
Crate	237	308	145	292	246
Rough and crate	354	409	240	200	301
Rough	296	254	308	251	278

[1] Plants dug Dec. 9, 1938, and set Apr. 4, 1939; growth records made July 17 to 25, 1939.
[2] Crate=shipping crate throughout storage period; rough and crate=stored in rough about 1 month, then cleaned, and packed in crate for rest of storage period; rough=stored in rough throughout storage period.

a slight benefit in average growth response for plants stored in the rough, but the benefit was obtained only at 30° F. and was not significant. The results for the 1940–41 season (table 4) show that the growth response of plants stored in the rough again averaged somewhat greater. The analysis of variance indicated that the average difference was not significant but did show a significant interaction of temperature with method of packing, indicating a significant benefit from packing in the rough at 30° and 36° but not at 32°.

Time of Setting

Experiments with late planting were conducted in the 1938–39 and the 1939–40 seasons, and the results are presented in table 10. The results for 1938–39 show a marked reduction in growth of both stored and unstored plants with delay in setting. The late planting (June 1) was followed by dry, hot weather and practically all the Fairfax plants died, both those from storage and those freshly dug. Likewise, most of the freshly dug plants of Howard 17 were killed whereas most of the plants from storage lived and appeared healthy but made little growth during the short period between planting and record taking. The analysis of variance showed no significant difference in the growth response of stored and freshly dug plants to time of setting when the results from both varieties were averaged. The reduction in growth with delay in setting was not so great with the stored plants as with the freshly dug plants in the case of Howard 17 but was greater in the case of Fairfax. That this difference in response of the storage lots of the two varieties to time of planting is significant, is indicated by the significant interaction of variety×storage×time of planting in the analysis of variance of the data.

Table 10.—*Relation of time of setting to growth response of stored (32° F.) and not-stored strawberry plants*

[Growth index=(leaves+runner series on 20 plants)×percentage stand]

Variety and date of setting	Growth index of plants in indicated block when—									
	Not-stored					Stored				
	1	2	3	4	Mean	1	2	3	4	Mean
Howard 17:										
Mar. 8, 1939	307	336			322	225	297			261
Apr. 4, 1939	275	312			294	237	308			273
May 1, 1939	140	136			138	219	148			184
June 1, 1939	8	5			7	28	62			45
Fairfax:										
Mar. 8, 1939	309	333			321	381	458			420
Apr. 4, 1939	203	213			208	145	292			219
May 1, 1939	168	206			187	112	113			113
June 1, 1939	0	0			0	0	4			2
Howard 17:										
Mar. 13–14, 1940	266	321	98	103	200	256	245	70	127	175
Apr. 4–5, 1940	145	242	92	235	179	165	216	104	186	168
May 1–2, 1940	93	48	74	52	67	160	166	22	70	105
Fairfax:										
Mar. 13–14, 1940	389	289	45	103	199	367	363	56	73	215
Apr. 4–5, 1940	383	337	65	167	238	332	315	97	121	216
May 1–2, 1940	133	88	11	9	60	325	269	65	64	181

The spring of 1940 was cold and wet so the first planting could not be made until the middle of March. The second planting made of both stored and freshly dug lots about 3 weeks later showed no significant reduction in growth as compared with the first planting. There was a marked reduction in growth of plants set May 1 and 2 as compared with the earlier planting, and the reduction was significantly greater for the freshly dug plants of both varieties.

Methyl Bromide Fumigation

Methyl bromide fumigation has been used with strawberry plants for the control of Japanese beetle, and it seemed desirable to deter-

mine how it could be used with stored plants. Therefore, fumigation treatment was given March 31; it consisted of exposure to methyl bromide[7] gas at the rate of 2.5 pounds per 1,000 cubic feet of space for 3 hours at 60° to 65° F.

The results for the two varieties Howard 17 and Fairfax are presented in table 11. The growth response of the fumigated plants averaged 26 percent greater than that of the control plants, but because of inconsistencies the difference was not statistically significant. These results confirm those reported earlier by Haller[8] in showing that treatment after storage at the time, temperature, and concentration recommended was not injurious to the plants.

TABLE 11.—*Relation of fumigation with methyl bromide to growth response of strawberry plants* [1]

[Growth index = (leaves + runner series on 20 plants) × percentage stand]

Treatment	Growth index of plants in indicated block				
	Howard 17		Fairfax		Mean (2 varieties)
	1	2	1	2	
Not fumigated	237	308	145	292	246
Fumigated	418	340	275	210	311

[1] Plants stored Dec. 9, 1938, and set Apr. 4, 1939; growth records made July 17 to 25, 1939.

POSSIBLE RELATION OF STORAGE TO RED STELE ROOT DISEASE

In the spring of 1939 the plants in one of the fields from which strawberry plants had been dug the previous December for storage were found to be severely infected with the red stele disease (*Phytophthora fragariae* Hickman). The freshly dug (check) plants were obtained therefore from a different field. It is of particular interest to note, however, that the plants dug the previous December did not show evidence of red stele or develop the disease after planting even though obtained from a field in which red stele was severe by the following spring and presumably was present at the time the plants were dug. This seems to indicate that late-fall and early-winter digging, and possibly the use of runner plants only, might be a desirable precaution in preventing the spread of this disease. The infected field was plowed up, and further studies along this line were not feasible for lack of plants known to be infected with the red stele fungus.

[7] Methyl bromide is poisonous. Persons unfamiliar with its use in fumigation should get advice before attempting to use it.

[8] See footnote 2, page 2.

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