Vol. 62 MARCH 15, 1941 No. 6

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CONTENTS

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EFFECT OF COOL STORAGE OF EASTER LILY BULBS ON SUBSEQUENT FORCING PERFORMANCE [1]

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INTRODUCTION

Easter lily bulbs produced in the Southern States usually are ready to dig before the florist is ready to receive them for forcing. Some storage period is therefore necessary. The present study conducted at the United States Horticultural Station, Beltsville, Md., was begun in the fall of 1935 with the purpose of finding a storage practice that would maintain the forcing quality of the bulbs and reduce to a minimum the occurrence of rot, shriveling, and premature sprouting. Short exposures to cool temperature kept the bulbs in good condition and showed a marked effect in accelerating bloom. This latter effect was examined in further detail, and the present paper summarizes 3 years' trials showing that specific preplanting storage treatments are a convenient means of controlling the time of flowering in Easter lilies.

MATERIAL AND METHODS

The horticultural varieties of *Lilium longiflorum* Thunb. included in these studies and the sources of the experimental material were Creole from Louisiana, Croft from Oregon, Erabu and Giganteum from Japan, and Harrisii from Bermuda. The name "Croft" has been applied for convenience to a commercial type grown in Oregon without varietal designation and purchased direct from growers each year. One of the 1936–37 stocks of Creole and the 1937–38 stock of Harrisii were also bought direct from growers. All others were purchased through dealers. Attempts were made to obtain each stock promptly after digging to avoid the complication of undesired storage practices before the bulbs were received for the experiments. In general these attempts were not successful, and the resulting discrepancies will be discussed herein.

Bulbs 7 to 9 inches in circumference were specified in all purchases. The mean circumference was determined from 50 random bulbs of each variety and ranged from 7.20 to 8.19 inches, with the exception of one Creole lot (C_1 37 in table 2) in which the circumference averaged only 5.57 inches. The last-named lot was supplied after standard sizes had been sold. The *Lilium longiflorum* seedlings included in one trial were random samples of open-pollinated progenies of the Croft variety. These had been grown in the greenhouse approximately 1 year from seed when the trials were begun.

[1] Received for publication November 25, 1940.

The number of bulbs per unit trial was 25, but if one or more failed to grow or to flower, the means were computed for the number flowering. This was considered sound practice, since the factors responsible for failure to grow or to bloom were apparently independent of the factors under test. Two packing materials, moistened peat moss and dry sand (or soil), were used. Throughout the 1935–36 and 1936–37 studies the individual test lots were repacked for storage tests in peat moss which had been thoroughly wet and from which the excess water was pressed out with the hands. In 1937–38 this moist-peat pack was compared with the original dry sand (Bermuda) or sandy loam (Louisiana) in which the bulbs were shipped.

Storage facilities were provided by the storage and transportation project of this Division at the Arlington Experiment Farm, Arlington, Va. Temperatures were controlled within a range of approximately ±1° F. from the values stated, and relative humidity was maintained at a level of approximately 80 percent. Bulbs subjected to coldframe treatment were potted as for greenhouse planting and plunged in an open unheated frame, where they were exposed to the outdoor temperatures of Beltsville, Md., for the stated intervals. At the close of these intervals the pots were moved to the greenhouse.

In the greenhouse the bulbs were grown singly in 6-inch clay pots in a composted soil with which a liberal amount of bonemeal had been well mixed. The soil for each year's series of trials was prepared and mixed in advance. All trials were conducted in the same section of a greenhouse, the temperature of which was manually controlled, as far as practicable, to 65° F. in the daytime and 60° at night. These temperatures, however, were often far exceeded during the summer months.

1935–36 EXPERIMENT

The data for 3 varieties included in the first year's trials (1935-36) are shown in table 1. Since these varieties were received at different dates, the storage exposures and corresponding control plantings were made independently for each variety. It is apparent from table 1 that cool storage accelerates blooming, the difference in number of days to bloom between stored and control lots always proving highly significant. The height of flowers above the soil line also shows significant decreases in the stored lots as compared with the nonstored lots in the Croft variety. The number of flowers per bulb is decreased in stored lots of Croft and Erabu but not in Creole. The actual date of bloom is shifted less strikingly by storage treatment than is the number of days to bloom, since the stored lots were planted (and the coldframe lots moved to the greenhouse) 37 to 41 days later than the control lots. Data in table 1 from unselected seedlings exposed for two different intervals in the coldframe and those without such exposure to a cool period show similar trends.

Although the general trends toward earlier blooming, shorter stems, and fewer flowers were similar in the three varieties and in one group of seedlings tested, these responses were most striking in the Croft variety. In actual flowering dates the stored lots of Croft were far in advance of the controls, while the stored lots of Erabu bloomed slightly later but within 6 days of the controls. Accordingly the 1936–37 trials were planned to compare the response of different Easter lily varieties to similar storage treatments.

TABLE 1.—*Effect of storage treatment on time of blooming and quality of flowers of 4 varieties of Easter lily in 1935–36*

Variety and source	Circumference of bulbs on arrival [1]	Preplanting treatment	Date planted in greenhouse	Date of blooming	Days to blooming [1,2]	Height [1]	Flowers per bulb [1]
	Inches		*1935*	*1936*	*Number*	*Inches*	*Number*
Croft, from Oregon.	7.92±0.07	None	Oct. 8	June 2	238.3±1.98	20.0±1.00	7.4±0.37
		Coldframe 41 days	Nov. 15	May 21	188.3±1.26	13.6± .35	6.4± .21
		Stored at 50° F. 41 days.	do	Apr. 26	162.9± .82	11.6± .31	3.4± .14
		Stored at 36° F. 41 days.	do	Apr. 21	158.2± .99	13.3± .33	3.4± .13
Creole, from Louisiana.	7.49± .06	None	Oct. 25	Apr. 26	184.4±1.10	26.3± .38	4.3± .16
		Coldframe 40 days	Dec. 4	Apr. 17	135.6± .56	24.0± .44	4.2± .16
		Stored at 50° F. 40 days.	do	Apr. 21	139.0±1.08	23.8± .40	3.7± .24
		Stored at 36° F. 40 days.	do	Apr. 24	142.6± .74	23.0± .47	4.2± .16
Erabu, from Japan.	7.87± .10	None	Nov. 12	do	164.5±1.44	19.6± .80	7.2± .42
		Coldframe 37 days	Dec. 19	Apr. 25	128.0±1.01	17.2± .81	5.6± .40
		Stored at 50° F. 37 days.	do	Apr. 28	131.8±1.16	20.7± .67	4.7± .43
		Stored at 36° F. 37 days.	do	Apr. 30	133.2± .94	18.8± .82	5.3± .26
L. longiflorum (seedling).		None	Jan. 8 [3]	June 3	[4] 144.7±3.43	23.6±1.35	5.4± .29
			1936				
		Coldframe 81 days	Jan. 10	May 5	116.6± .74	17.8± .56	6.0± .44
		Coldframe 182 days	Apr. 20	June 13	54.1± .76	15.6± .49	2.6± .29

[1] Mean and standard error.
[2] From date of planting in greenhouse.
[3] Date on which seed was planted.
[4] Computed as days after Jan. 10, 1936.

1936–37 EXPERIMENT

In the experiment of 1936–37 the varieties Giganteum and Harrisii were added to those previously tested. Two lots of Erabu, designated by the dealer as "Black Stem Regular" (E_237 in table 2) and "Improved Early Flowering" (E_137 in table 2), were included. The dealer did not state whether the early type was genetically or physiologically early, but the results obtained by the writer suggest that its difference from the Black Stem Regular is attributable to handling rather than to selection. Two stocks of Creole were used; one of regular commercial size obtained from a dealer after considerable delay, and one of smaller bulbs obtained direct from the producers. The Croft variety was delayed in arrival because of forest fires in Oregon.

Since it was planned to start storage trials on all varieties simultaneously to minimize differences in the conditions encountered during forcing, the early arrivals were held in their original packing until the later arrivals were received. The prolonged delay of Croft and Creole (C_237) introduced an error that had not been anticipated. The early-arriving varieties stood for 5 to 7 weeks in the original cases in a room at 50° F., which constituted a cool storage treatment in the controls. The effect of this storage is shown in differences that appear between lots 1A, planted on arrival, and lots 1, planted November 2, after all lots (except Croft) were on hand. The duration of this unplanned storage interval may be computed from the differences between planting dates of lots 1A and 1 in table 2. Where no lot 1A appears, the variety was received just in time for the tests proper.

TABLE 2.—*Effect of storage treatment on time of blooming and quality of flowers in 1936–37*

Lot No.	Storage treatment: Temperature	Storage treatment: Interval	Date planted in greenhouse	Average date of blooming	Days to blooming [1, 2]	Days to emergence [1, 2]	Height [2]	Flowers per plant [2]	Size of flower [2] (length by diameter)
	°*F.*	*Weeks*	*1936*	*1937*			*Inches*	*Number*	*Index number*
CREOLE $C_1$37 (MEAN CIRCUMFERENCE OF BULBS, 5.57±0.5 INCHES)									
1A	[3]	-------	Sept. 12	Apr. 14	214.0±0.70	69.1±0.80	27.1±0.57	3.5±0.21	28.5±0.47
1	[4]	-------	Nov. 2	Apr. 10	158.7± .58	35.7± .91	31.1± .53	3.0± .18	29.1± .38
2	50	5	Dec. 7	Apr. 12	125.8± .90	18.1±1.36	30.7± .89	2.7± .53	29.1± .60
3	40	5	---do-----	Apr. 16	129.8± .68	28.7± .90	29.4± .49	3.1± .10	28.8± .41
4	32	5	---do-----	Apr. 22	135.6± .82	34.2± .73	27.8± .47	3.4± .16	29.6± .51
9	[5]	5	---do-----	Apr. 18	131.9± .70	26.2± .75	27.4± .64	3.4± .15	29.8± .59
			1937						
6	50	10	Jan. 11	Apr. 22	101.0± .97	.6± .56	24.4± .49	1.3± .11	30.1± .69
7	40	10	---do-----	May 6	115.0±1.36	28.3±1.68	18.3± .74	2.4± .54	27.6± .66
10	32	17	Mar. 5	May 23	78.6±1.05	17.9±1.00	13.9± .55	2.4± .39	25.1± .46
CREOLE $C_2$37 (MEAN CIRCUMFERENCE OF BULBS, 7.55±0.15 INCHES)									
			1936						
1	[4]	-------	Nov. 2	Mar. 16	134.4±1.62	22.4±1.02	32.3±1.30	3.7±0.56	28.9±0.33
2	50	5	Dec. 7	Apr. 6	120.2±1.13	20.0±1.24	31.4± .90	2.9± .34	27.9± .47
3	40	5	---do-----	Apr. 14	128.0±1.31	28.7±1.41	30.9± .82	4.0± .43	28.5± .56
4	32	5	---do-----	Apr. 16	130.5±1.25	29.0± .81	33.1± .71	4.0± .39	28.1± .72
9	[5]	5	---do-----	Apr. 10	124.2±1.60	19.5±1.23	29.9±1.04	4.4± .48	28.1±1.22
			1937						
6	50	10	Jan. 11	Apr. 27	105.6±1.52	5.6±1.53	22.7± .87	1.7± .20	29.5± .66
7	40	10	---do-----	May 9	117.8±1.67	28.1±1.79	18.1±1.01	3.2± .39	27.5± .68
CROFT CT 37 (MEAN CIRCUMFERENCE OF BULBS, 7.28±0.08 INCHES)									
			1936						
1	[4]	-------	Nov. 5	Apr. 22	167.9±4.18	35.7±1.02	14.0±0.65	5.8±0.35	29.4±0.89
2	50	5	Dec. 7	Apr. 29	142.6±2.37	25.4±1.35	13.1± .31	5.8± .20	29.6± .89
3	40	5	---do-----	May 2	145.5±2.29	35.8±1.73	13.9± .65	4.6± .28	30.9± .72
4	32	5	---do-----	Apr. 30	143.9±1.84	37.0±1.26	11.2± .51	5.0± .33	29.2± .68
9	[5]	5	---do-----	May 2	145.8±1.71	33.6±1.11	11.3± .53	4.5± .29	29.8± .54
			1937						
6	50	10	Jan. 11	May 12	121.4±1.75	15.6±2.62	10.9± .38	3.2± .28	30.4± .71
7	40	10	---do-----	May 13	122.3±1.21	30.2± .92	10.3± .21	4.7± .35	28.2±1.93
10	32	17	Mar. 5	May 24	79.8± .85	17.4± .47	12.5± .36	5.4± .58	28.0± .53
EARLY ERABU $E_1$37 (MEAN CIRCUMFERENCE OF BULBS, 8.19±0.11 INCHES)									
			1936						
1A----	[3]	-------	Sept. 26	Feb. 24	150.7±6.39	47.2±3.55	20.5±1.12	3.4±0.23	23.5±1.08
1------	[4]	-------	Nov. 2	Mar. 12	129.5±2.44	28.4± .84	25.9± .87	4.5± .33	24.5± .67
2------	50	5	Dec. 7	Mar. 30	113.4±1.12	12.8± .88	26.5±1.15	4.2± .27	23.0± .50
3------	40	5	---do-----	Apr. 8	122.1±2.10	26.5±1.16	20.0± .85	2.8± .72	23.2± .90
4------	32	5	---do-----	Apr. 11	124.8±1.67	30.5±1.09	22.8±1.07	4.0± .34	23.8±1.76
9------	[5]	5	---do-----	Apr. 4	118.5±1.56	19.9± .77	23.7±1.32	4.7± .35	24.2± .94
			1937						
6------	50	10	Jan. 11	Apr. 21	99.6±1.32	9.7±2.46	14.2± .63	2.5± .23	22.2±.79
7------	40	10	---do-----	Apr. 30	109.2±1.67	18.8±1.48	15.7± .75	2.4± .13	22.3±.82
ERABU $E_2$37 (MEAN CIRCUMFERENCE OF BULBS, 7.64±0.10 INCHES)									
			1936						
1A---	[3]	-------	Sept. 26	Mar. 14	169.0±2.47	45.3±1.80	20.6±0.92	3.7±0.41	21.6±0.63
1-----	[4]	-------	Nov. 2	Apr. 1	149.5±1.75	34.2±1.65	28.0± .94	5.4± .41	23.5± .75
2-----	50	5	Dec. 7	Apr. 12	125.7±1.48	16.1± .79	28.1± .82	4.6± .34	24.2± .74
3-----	40	5	---do-----	Apr. 18	132.1±1.20	26.8± .87	25.1± .84	4.4± .26	22.9± .60
4-----	32	5	---do-----	Apr. 19	133.3±1.48	30.6±.78	21.6± .81	5.7± .33	22.6± .56
9-----	[5]	5	---do-----	Apr. 24	138.5±1.58	27.4± .87	23.3± .99	5.1± .33	24.2± .61
			1937						
6-----	50	10	Jan. 11	May 5	114.4±2.23	10.4±2.41	18.1± .87	2.9± .25	22.3±1.11
7-----	40	10	---do-----	May 9	117.9±1.50	25.2±1.39	16.2± .85	3.0± .78	22.6± .53
10-----	32	17	Mar. 5	June 1	88.3±1.67	25.5±1.55	19.8± .70	3.1± .53	22.9± .91

Footnotes at end oi table.

TABLE 2.—*Effect of storage treatment on time of blooming and quality of flowers in 1936-37*—Continued

GIGANTEUM (MEAN CIRCUMFERENCE OF BULBS, 7.20±0.07 inches)

Lot No.	Storage treatment		Date planted in greenhouse	Average date of blooming	Days to blooming	Days to emergence [1] [2]	Height	Flowers per plant [2]	Size of flower (length by diameter)
	Temperature	Interval							
	°F.	*Weeks*	*1936*	*1937*			*Inches*	*Number*	*Index number*
1A	(3)		Oct. 20	May 5	197.0±1.00	33.5±0.73	15.2±0.55	5.5±0.21	24.4±0.43
1	(4)		Nov. 2	May 4	182.6± .96	37.1±1.09	14.0± .56	5.8± .43	24.1± .84
2	50	5	Dec. 7	do	148.1±1.32	20.3±1.11	13.7± .57	4.7± .34	24.4± .56
3	40	5	do	May 9	153.0±1.28	33.1±1.20	12.1± .48	4.4± .23	24.2± .41
4	32	5	do	May 11	155.2±1.44	36.4±1.44	9.0± .44	5.0± .32	22.2± .66
9	(5)	5	do	May 4	148.2± .99	31.3±1.77	10.1± .41	5.0± .29	24.2± .61
			1937						
6	50	10	Jan. 11	May 14	122.8±1.40	11.0±3.16	9.1± .46	2.6± .22	23.5± .98
7	40	10	do	do	122.8± .96	29.7±2.74	9.3± .35	3.1± .19	24.5± .48
10	32	17	Mar. 5	June 2	89.2±2.13	24.6±1.34	13.2± .96	2.7± .22	24.3±2.34

HARRISII (MEAN CIRCUMFERENCE OF BULBS, 7.97±0.10 inches)

Lot No.	Temperature	Interval	Date planted in greenhouse	Average date of blooming	Days to blooming	Days to emergence	Height	Flowers per plant	Size of flower
			1936						
1A	(3)		Sept. 26	May 1	217.3±2.33	86.0±2.21	20.5±0.90	2.7±0.30	30.7±2.18
1	(4)		Nov. 2	May 3	181.8±3.23	55.2±3.72	21.6± .78	3.2± .25	32.0±1.46
2	50	5	Dec. 7	May 16	160.2±2.80	40.7±2.54	18.5± .90	2.7± .24	31.6± .85
3	40	5	do	May 14	157.6±3.04	39.9±1.07	18.6± .82	2.9 ±.25	34.0± .58
			1937						
6	50	10	Jan. 11	May 24	133.4±3.56	25.6±5.57	16.8± .84	2.5± .23	32.5± .85
7	40	10	do	May 28	137.2±2.51	33.2±2.51	17.5± .89	2.9± .16	33.2± .90

[1] From date of planting in greenhouse.
[2] Mean and standard error.
[3] Bulbs planted in greenhouse on arrival.
[4] Bulbs planted in greenhouse Nov. 2 (except Croft).
[5] Unheated coldframe.

The storage temperatures and intervals and the forcing data are detailed in table 2. An index of the size of flower, that is, the product of the length by the diameter of the flower when approximately prime, is also presented in table 2. This index is believed to be a more reliable measure than length or diameter alone, since these measures change as the flower opens and fades but tend to equalize each other in the index. The difference between any two means is treated as significant (5-percent level) when found to be twice its standard error.

Bulbs kept in cool storage bloomed in a shorter time from date of planting than the controls in all cases, the differences proving highly significant with rare exceptions ($C_2$37, lot 4). However, the actual dates of blooming were never significantly earlier than those of the untreated lots. The maximum effects of storage treatments appear in Creole $C_1$37, the stock shipped to Beltsville direct from Louisiana. Significant shortening of the number of days required for flowering of stored lots appeared in all the varieties tested, indicating that the accelerating effect of low temperature is not peculiar to any one type of Easter lily. The degree of acceleration of flowering brought about by cool storage again varied among varieties, but the variety most influenced by treatment in 1935–36 (Croft) was relatively unresponsive in 1936–37. Moreover, the control lots of the two stocks of Creole included in the 1936–37 trials showed a striking difference in blooming time. This is most probably attributable to handling before these two stocks reached Beltsville, since all commercial Creoles are grown and harvested under rather closely comparable conditions. The effect of cool storage is cumulative, and Creole $C_2$37 apparently had undergone some cooling before it was received. Additional cool storage applied to a commercial lot already exposed to some similar treatment still shows a significant shortening of the time required for blooming, but the full effect of the treatment is obscured by the failure of the control lot to show the expected delay in flowering. It seems futile, therefore, to attempt to determine varietal differences in response to these treatments by using material so diverse in origin and prior handling. Genetic differences in capacity to respond presumably occur, but they are hopelessly confounded with physiological differences due to different sites of production and methods of handling.

Storage at 50° F. was in general more effective in inducing earliness than either 40° or 32° for comparable intervals, but the differences are not consistently significant. This point is suggested in the data in table 2, but will be shown more clearly later. Storage at 50° or 40° for 10 weeks induced more prompt blooming for all lots than 5 weeks' storage at the same temperature. The lots stored 17 weeks at 32° all bloomed much more promptly than comparable lots stored for shorter periods. These lots (No. 10) of course received the additional stimulus of higher greenhouse temperature, which rises beyond control in May at Beltsville, Md.

The time required for the plant to emerge from the soil shows great irregularity. Some stocks (Creole $C_1$37, Early Erabu, Erabu, and Harrisii) emerged more promptly after storage treatment. This was a material advantage in Harrisii, which was slow to emerge when not placed in cool storage. Apparently cool storage reduces the importance of the common practice of starting bulbs at a low temperature, which is raised after growth has started. Storage at 50° F. for 10 weeks was followed by prompt emergence of all varieties except Harrisii. Both shoot and root growth occurred at this temperature, but the resulting plants were not salable because the etiolated shoots developed in storage never expanded to normal size. Moist storage at 50° should not be practiced except for short intervals, such as 4 to 6 weeks, as a means of inducing extreme earliness.

That cool storage has a tendency to induce flowering while the plants are short is shown in table 2 by significant shortness of plants in all lots stored 10 weeks or more at 32°, 40°, or 50° F. The 5-week storage intervals in general showed no significant reduction in height. There was also a tendency for cool-stored bulbs to produce fewer flowers than the controls. This point is illustrated in table 2 by the number of flowers in lots stored 10 weeks or more, which is usually, but not always, significantly lower than the number for the corresponding control lot. The effects of cool storage on both height and number of flowers are better illustrated in data to be discussed in a later section (p. 328).

The interval between the first and last flowers on a single plant, which was visualized as an index of duration of attractiveness of a lily as a pot plant, was also measured. The data have not proved very helpful, however, so they are not included. They appear to be dependent on the number of flowers per plant as well as on the lasting qualities of individual flowers and on other factors. Low values obtained for the lots stored for 10 weeks at 50° F. are largely a reflection of a reduced number of flowers in these lots.

The mean size of flower is a very stable characteristic of the variety as compared with other characteristics shown in table 2. Very few differences in this column show evidence of significance.

1937–38 EXPERIMENT

CREOLE VARIETY

Since comparisons of varietal response had not proved enlightening, the 1937–38 experiments were confined chiefly to the Creole variety, which could be obtained shortly after digging, with the addition of a simple interval test with Harrisii designed to extend the bloom of this variety over 2 or 3 months. Both varieties were received on August 26 direct from producing areas with no exposure to cool storage before shipment. Storage trials were set up immediately on receipt of the stocks.

The experiments were intended to provide comparisons between moistened-peat and dry-soil storage and also to afford an opportunity to examine further the effect of the length of the storage interval. The 40° and 50° F. storage trials were not carried beyond 15 weeks' duration, since the 1936–37 results had shown that these temperatures, if long continued, were likely to produce unfavorable effects. The 32° storage was continued up to 60 weeks to determine the tolerance of the Creole variety to this temperature, which in previous trials had appeared least deleterious in its effects on forcing quality. It was hoped that the bloom of the Creole variety could be extended throughout an entire calendar year by suitable storage manipulation. This result was indeed attained, but the average forcing quality of the 7- to 9-inch bulbs was poor after 60 weeks' storage at 32°.

The 1937–38 trials with the Creole variety are summarized in table 3. It will be noted at once that the number of days required to bloom is very greatly reduced by all storage practices included in these trials. In fact, all 5 weeks' treatments, all 10 weeks' treatments, and 2 of the 15 weeks' treatments were significantly earlier in actual date of blooming than the control lot, which flowered during Easter week. These differences are readily visualized by reference to figure 1. These clear-cut differences, which contrast with the less satisfactory results of the previous year, are attributed to the fact that this Creole stock was received before it had been subjected to previous storage.

The earliest bloom was produced by lot 4, which was stored 5 weeks at 50° F. in moist peat. The flowers were of satisfactory size and quality but sharply reduced in number (3.6 per plant), and the plants were significantly shorter than the controls; however, they were very acceptable Easter lilies for February. Lot 7, stored dry at 50° for 5 weeks, bloomed about 14 days later, with no significant improvement in the number of flowers. Longer storage at 50° (10 weeks and 15 weeks, dry) reduced the number of flowers to about two per plant. It seems clear that long storage at 50° is undesirable, and that this temperature is useful only in inducing extreme earliness of bloom.

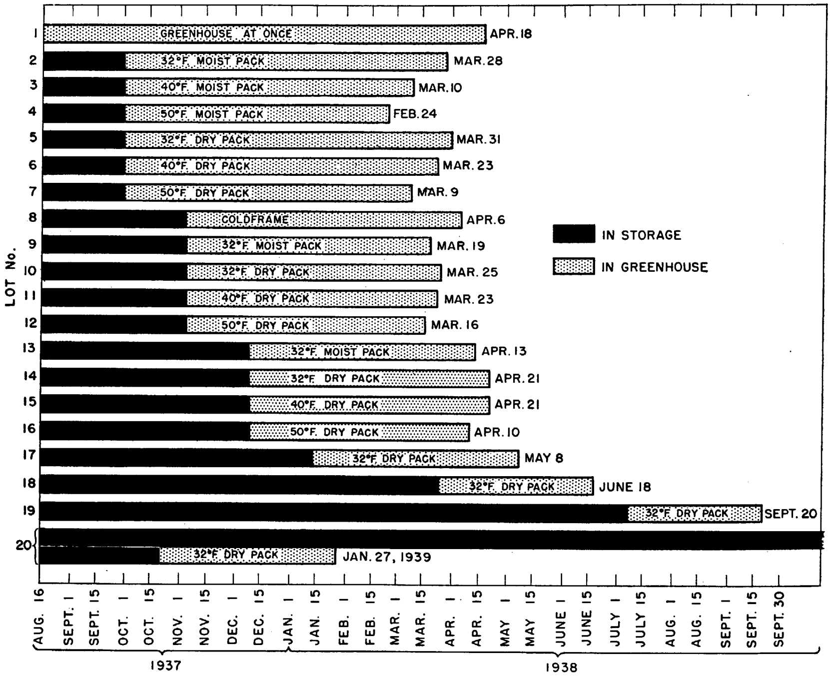

FIGURE 1.—Chart of 20 storage trials with Creole Easter lilies in 1937–38, showing relative length of time in storage and in the greenhouse and mean flowering data.

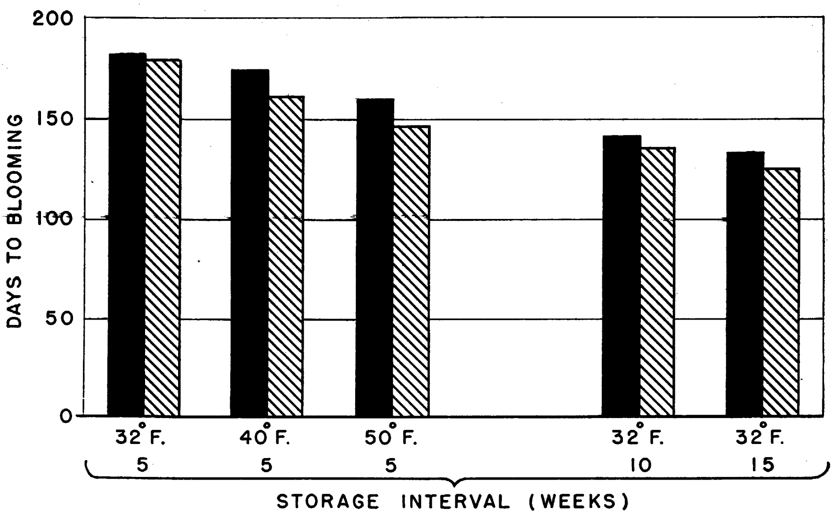

FIGURE 2.—Charts showing comparative effects of storage in dry pack and in moist pack (shaded) on days to blooming in Creole Easter lilies in the 1937–38 trials.

TABLE 3.—*Effect of storage treatment on time of blooming and quality of flowers of the varieties Creole and Harrisii in 1937–38*

CREOLE C138 (MEAN CIRCUMFERENCE OF BULBS, 7.64±0.05 INCHES)

Lot No.[1]	Storage treatment: Temperature	Storage treatment: Interval	Storage treatment: Pack	Date planted in greenhouse	Average date of blooming	Days to blooming [2] [3]	Days to emergence [2] [3]	Height [3]	Flowers per plant [3]	Leaves per plant [3]	Size of flower [3] (length by diameter)
	°F.	Weeks		1937	1938	Number	Number	Inches	Number	Number	Index number
1 [4]	----	----	----	Aug. 26	Apr. 18	235.3±0.65	42.0±0.57	24.6±0.83	8.5±0.19	162.7±3.19	25.5±0.54
2	32	5	Moist	Sept. 30	Mar. 28	179.1± .93	31.9± .87	21.1± .55	5.1± .16	102.5±1.51	25.5± .48
3	40	5	do	do	Mar. 10	160.9± .78	25.6± .55	20.5± .55	4.7± .11	84.9±1.21	25.2± .68
4	50	5	do	do	Feb. 24	146.8±1.00	16.0± .55	19.1± .46	3.6± .17	69.5±1.42	25.6± .59
5	32	5	Dry	do	Mar. 31	182.0± .91	33.9± .75	22.6± .74	5.2± .10	101.5±1.18	25.0± .59
6	40	5	do	do	Mar. 23	174.2± .72	35.5± .95	20.0± .57	4.2± .19	78.9±1.63	25.8± .49
7	50	5	do	do	Mar. 9	160.4±1.07	26.6± .70	19.2± .44	3.6± .19	73.8±1.40	25.1± .52
8	([5])	10		Nov. 4	Apr. 6	153.2± .96	([6])	19.3± .60	6.0± .18	99.6±2.58	25.2± .48
9	32	10	Moist	do	Mar. 19	135.2±1.06	25.4± .49	24.1± .56	4.8± .14	70.9±1.51	26.5± .48
10	32	10	Dry	do	Mar. 25	141.4± .65	30.1± .60	26.0± .65	4.5± .17	63.6± .89	26.4± .46
11	40	10	do	do	Mar. 23	139.1± .95	31.5± .98	24.8± .44	4.2± .19	52.4± .70	26.9± .45
12	50	10	do	do	Mar. 16	131.7±1.05	29.4±1.50	18.9± .57	2.2± .22	46.9± .72	27.6± .67
13	32	15	Moist	Dec. 9	Apr. 13	125.5± .40	26.2± .61	28.2± .52	5.2± .11	49.0±1.05	27.5± .25
14	32	15	Dry	do	Apr. 21	132.8± .74	32.2± .85	24.4± .48	4.8± .12	50.3± .77	27.2± .18
15	40	15	do	do	do	133.3± .78	38.5±1.04	20.2± .56	3.0± .14	41.1± .79	26.8± .37
16	50	15	do	do	Apr. 10	121.8±1.09	26.9±1.27	15.8± .50	1.8± .13	44.3± .66	27.0± .48
				1938							
17	32	20	do	Jan. 13	May 8	115.1± .47	34.4± .81	20.0± .50	4.3± .13	41.3± .72	27.8± .17
18	32	30	do	Mar. 24	June 18	86.5± .73	26.5± .68	18.4± .46	3.9± .19	32.8±1.37	25.1± .30
19	32	45	do	July 7	Sept. 20	74.6±1.42	15.8± .62	20.2± .32	2.6± .13	40.5± .95	23.6± .14
					1939						
20	32	60	do	Oct. 20	Jan. 27	99.2±5.80	21.1± .99	17.0± .61	2.0± .17	24.2± .72	24.4± .96

HARRISII H38 (MEAN CIRCUMFERENCE OF BULBS, 7.98±0.23 INCHES)

Lot No.[1]	Temperature	Interval	Pack	Date planted in greenhouse	Average date of blooming	Days to blooming [2] [3]	Days to emergence [2] [3]	Height [3]	Flowers per plant [3]	Leaves per plant [3]	Size of flower [3] (length by diameter)
				1937	1938						
1 [4]	----	----	----	Aug. 26	Mar. 15	201.0±1.39	48.1±0.57	17.8±0.43	6.2±0.24	----	30.3±0.44
2	40	5	Dry	Sept. 30	Apr. 4	186.2±1.01	43.3± .79	21.2± .48	5.4± .13	----	30.8± .33
3	40	10	do	Nov. 4	Apr. 11	158.3± .76	36.6± .76	25.0± .34	4.7± .20	----	32.8± .38
4	40	15	do	Dec. 9	May 7	149.7± .75	43.8± .87	22.1± .35	3.7± .19	----	34.3± .27

[1] 25 plants in each lot of Creole and 40 plants in each lot of Harrisii.
[2] From date of planting in greenhouse.
[3] Mean and standard error.
[4] Bulbs planted in greenhouse on arrival.
[5] Unheated coldframe.
[6] All bulbs up when brought into greenhouse.

A comparison of five pairs of lots stored in moistened peat and dry-soil pack at the same temperatures and intervals (fig. 2) shows that the moist pack induced earlier bloom. From these five pairs the mean difference in time of blooming is 8.66 days, and the odds exceed the 5-percent level and approach the 1-percent level of significance. The individual differences in time of blooming are each statistically significant, but are too small to assume any practical significance except where maximum earliness is desired. These differences in general could have been made up more conveniently by raising the forcing temperature, which is considerably less trouble (although possibly more expensive) than repacking in moist peat. Where maximum earliness is required the two methods could be combined. All the writer's trials thus far have been run at a comparatively cool forcing temperature. An increase of 10° F. during January presumably would have advanced the earliest flowering date (February 24) still further.

Further consideration of the mean dates of bloom in table 3 reveals that lots stored at 32° F. in dry pack, i. e., in original containers, were the last, or among the last, to bloom in each storage-interval group. The differences between storage at 32° dry and that at 50° dry are always significant, but storage at 32° does not always differ significantly in effect from that at 40°. Similar comparison of the data for the number of flowers from these lots shows that 32° storage was always followed by more flowers per plant than 50° storage. The differences between 32° and 40° storage are smaller and not all are significant, but when real differences appear they show more flowers from lots stored at 32°. When *t* tests are applied to four available pairs of measurements, lots stored at 32° and 40° are found to flower significantly later than those at 50°, and lots at 32° exceed those at 50° in number of flowers by a highly significant difference. These data show 32° to be the best of the temperatures tested for holding Easter lilies for long periods with minimum deterioration of forcing quality.

The effect of progressively longer intervals of storage at 32° F. in dry-soil pack is shown in the bar charts in figure 3, plotted from data included in table 3. It appears from the chart that the effect of continued storage in stimulating early bloom is cumulative. The form of the chart suggests a curvilinear relation, in which additional increments of storage have a reduced effect in stimulating earliness. The fact that the suggested curve is obviously not a smooth one is perhaps explainable as due to temperature differences during forcing. The decline in number of flowers shows a similar trend but is less smoothly expressed. The effect of storage at 32° on height is not uniform in trend, but reference to table 3 will show a rather consistent decline in height with progressively increasing periods of 50° dry storage.

The data for days to emergence are also presented in figure 3, *B*, and table 3. All stored lots emerged more promptly than the control lot, and the differences are significant though not large. The mean difference in time of emergence between moist and dry storage at the same temperature and storage duration is 6.63 days, a significant value. The five individual differences are always in favor of moist storage but are not always individually significant. Longer periods of

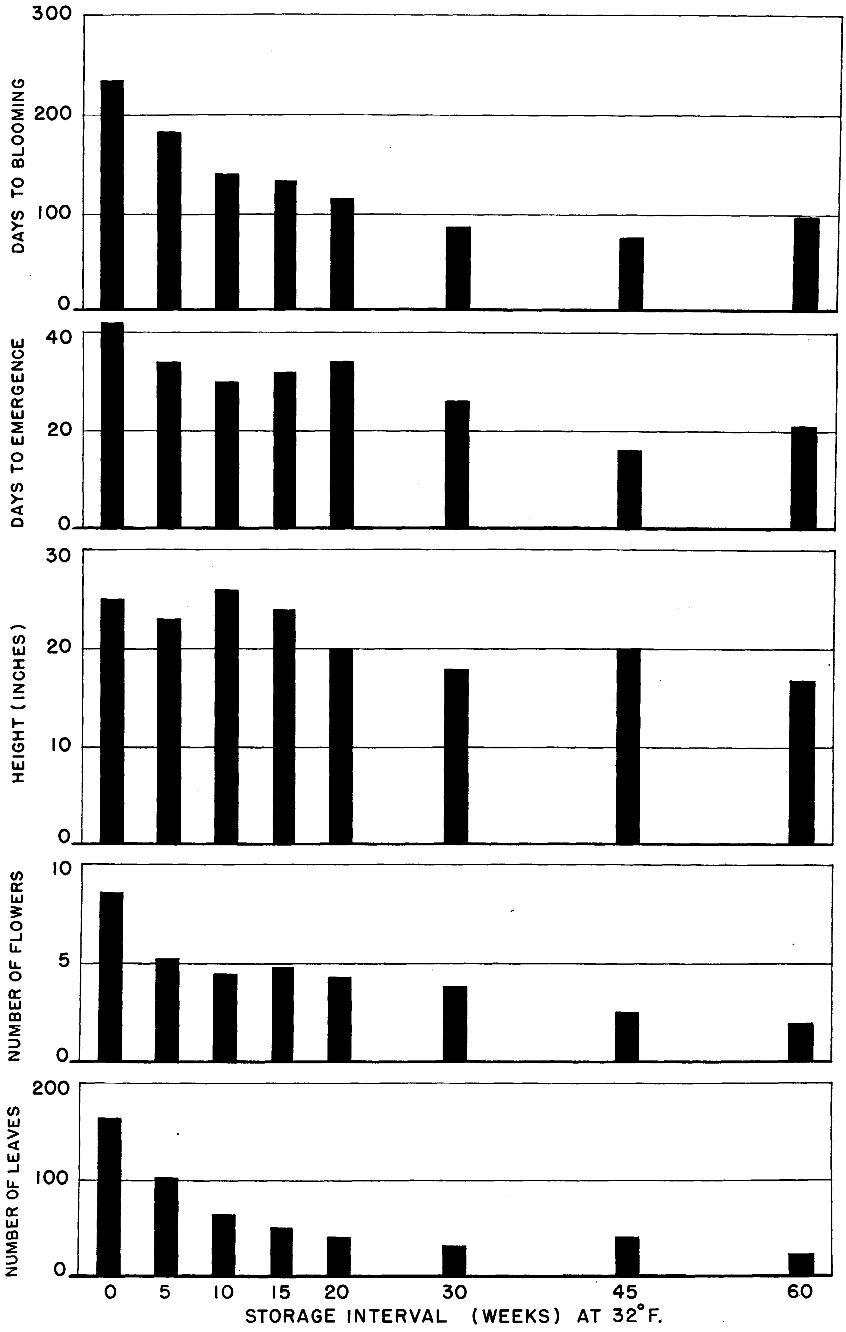

FIGURE 3.—Charts showing effect of duration of storage of the bulbs in dry sandy loam at 32° F. on days to blooming (*A*), days to emergence (*B*), height (*C*), number of flowers (*D*), number of leaves (*E*), and relative size of bloom (*F*). in the Creole Easter lily in the 1937–38 trials.

dry storage at 40° F. show slower emergence than comparable lots stored similarly at 32° or 50°, but these differences are significant only in the 15-week interval. The *t* test shows no significant differences in days to emerge between 32° and 40°, 40° and 50°, nor 32° and 50° storage when the four available compaiisons are grouped. In general, the Creole variety is not difficult to get up, but cool storage and the presence of moisture hasten its emergence.

Decline in height of the plants after storage treatment is notable chiefly in the longer storage intervals at 50° F., but it is also evident after very long storage at 32°.

The number of flowers per plant drops sharply from the control value in all stored lots, the nearest approach to the control appearing in the coldframe lot. This drop in number is more rapid at 40° F. than at 32°, and more rapid at 50° than at 40°, in all comparisons available. A highly significant *t* value is found for the four comparisons between 32° and 50°, but other comparisons, 32° as compared with 40°, and 40° as compared with 50° yield nonsignificant values. Even in 32° storage the decline in number of flowers is the chief limiting factor determining the length of time that bulbs of the 7- to 9-inch size may be held (fig. 3, *D*) without too serious effects in forcing quality.

The number of leaves developed per plant shows a close parallel in decline to the number of days required to bloom and to the number of flowers developed per plant (fig. 3, *A*, *D*, *E*). Again the decline is greater at 50° F. storage than at 32°, greater at 40° than at 32°, and greater with progressive intervals at the same storage. Not all the individual differences are significant, but general trends are evident. Applying *t* tests to four available comparisons, lots stored at 32° show a significantly higher leaf count than lots stored at either 40° or 50°. In addition to the decline in number of leaves, a decline in size of the lower leaves becomes more and more evident with increasing storage intervals.

No measurements of leaf size have been made, but the effect is evident in figures 4 and 5. Bulbs stored 15 weeks or more have incompletely developed lower leaves. Some of those stored for 60 weeks developed leaves irregularly; the lowermost leaves were reduced to scales, and some midway up the stem also remained rudimentary in form.

Size of flower again appears as a relatively stable characteristic, with very few differences approaching the 5-percent level of significance, and no lot differing significantly from the control lot.

The Creole lot which was stored dry for 60 weeks at 32° F. was scattered in the greenhouse, five plants at each of five situations (blocks), to afford a measure of place effects in this particular house. Two lots were placed near the inner end of the house, nearest the steam pipes most frequently used, two lots at the opposite end of the house nearest the outside door, and the fifth lot in the center. On analysis of variance, no significant differences were found between blocks for any of the six characteristics measured. The two blocks nearest the inside door bloomed earlier, but not significantly earlier, than the remaining three blocks. Although there appeared to be a temperature gradient from the inner to the outer end of the greenhouse, the writer failed to demonstrate a significant difference due to position in this trial. It is thought that the place effects measured

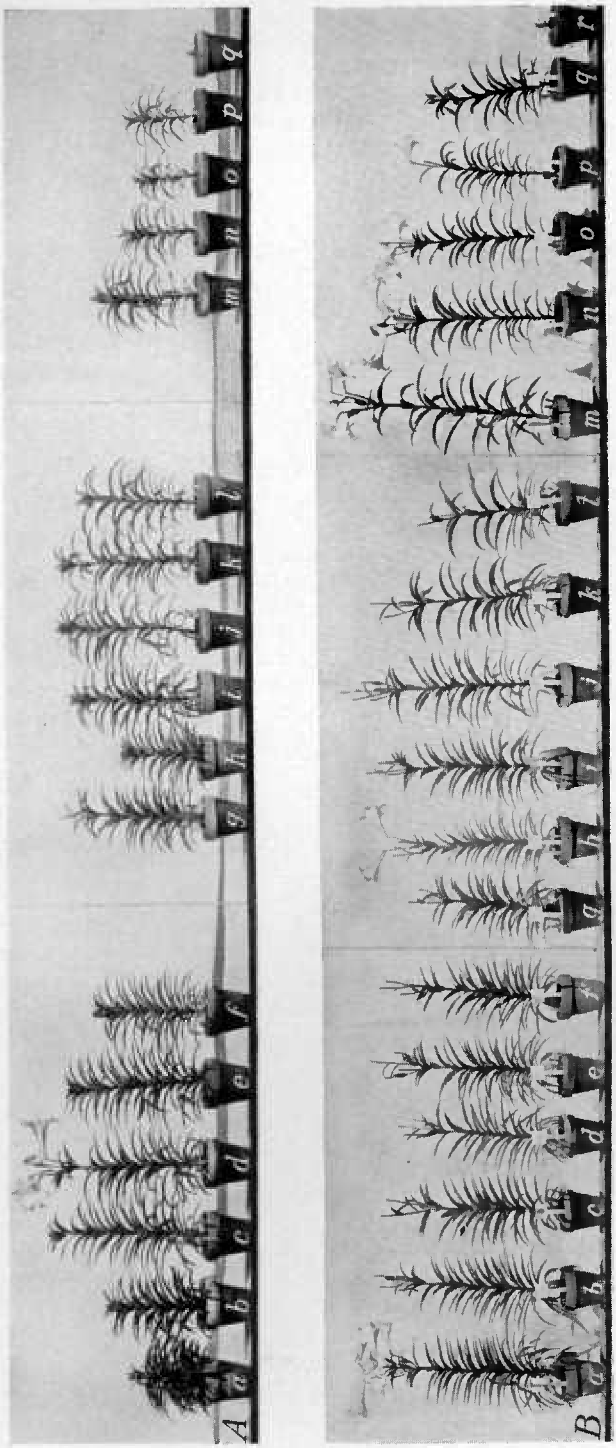

FIGURE 4.—Representative plants from storage experiments with Creole Easter lilies in 1937–38, photographed February 12 (*A*) and April 23 (*B*), 1938. Storage treatments in each row: (*a*) None; (*b*) 5 weeks in moist pack at 32° F.; (*c*) 5 weeks in moist pack at 40°; (*d*) 5 weeks in moist pack at 50°; (*e*) 5 weeks in dry pack at 32°; (*f*) 5 weeks in dry pack at 40°; (*g*) 5 weeks in dry pack at 50°; (*h*) 10 weeks in coldframe; (*i*) 10 weeks in moist pack at 32°; (*j*) 10 weeks in dry pack at 32°; (*k*) 10 weeks in dry pack at 40°; (*l*) 10 weeks in dry pack at 50°; (*m*) 15 weeks in moist pack at 32°; (*n*) 15 weeks in dry pack at 32°; (*o*) 15 weeks in dry pack at 40°; (*p*) 15 weeks in dry pack at 50°; (*q*) 20 weeks in dry pack at 32°; (*r*) 30 weeks in dry pack at 32° (planted March 24). Note the trend toward fewer leaves and fewer flowers from the longer storage intervals.

here represent a maximum, since the plants were grown October 20 to February 22, when steam was used regularly and loss of heat through the outside door was greatest, and the lots were so distributed as to include maximum temperature differences in the house. Although the treatments were not randomized through the greenhouse, place effects probably do not seriously affect the general conclusions presented in this paper, but they may account for some of the irregularity in trends shown in figure 3.

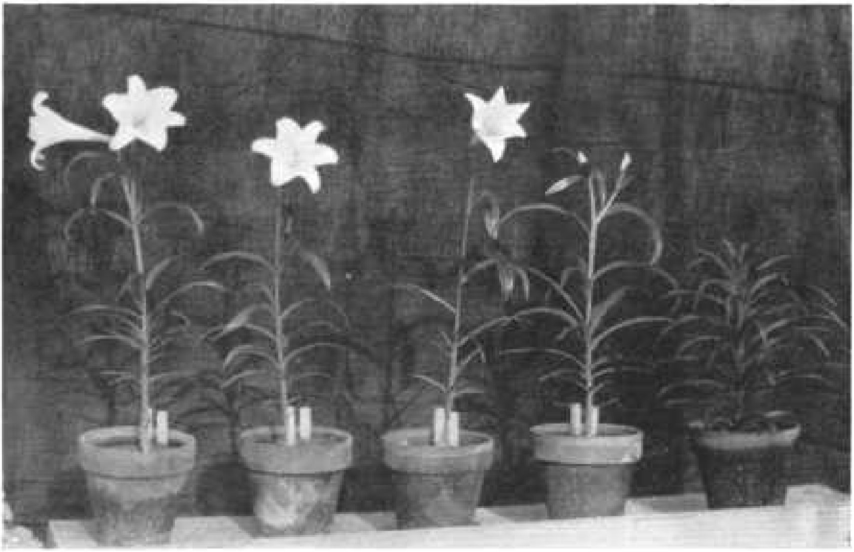

FIGURE 5.—Creole Easter lilies in bloom January 12, 1939, after 60 weeks' storage in dry soil at 32° F. and 94 days in the greenhouse. Note reduced number of leaves and flowers and imperfect leaf development. For comparison, one plant (at extreme right) is from a new crop commercial Creole bulb not subjected to cool storage, after 97 days in the greenhouse.

HARRISII VARIETY

The treatments and data for the 1937–38 Harrisii stock are shown in table 3. These data are of interest chiefly because of the differences shown between the Harrisii and Creole varieties when treated alike, and because of certain marked departures in behavior of the Harrisii stock under discussion from that of the Harrisii stock of 1936–37. If the data for Harrisii are compared with those for Creole (table 3), it is found that in untreated lots (lot 1) Harrisii was a month earlier, but after 5 weeks in dry storage at 40° F. Creole was the earlier; after 10 and 15 weeks Creole was again the earlier. Thus Harrisii proved earlier but less responsive to cool storage than Creole in these samples. None of the storage treatments applied to Harrisii (40° dry, for 5, 10, 15 weeks) advanced the actual date of flowering, while Creole exposed to the same treatment flowered in advance of the control after both 5 and 10 weeks' storage, and after 15 weeks it flowered at essentially the same time as the control lot. However, all three intervals at 40° shortened the number of days required to bloom after planting in both varieties. In Harrisii the number of flowers per plant declined steadily with progressively longer storage intervals, with all differences significant. After comparable storage intervals the number of Creole flowers dropped sharply after 5 weeks' storage, remained unchanged after 10 weeks, then dropped lower after 15 weeks. In Harrisii the size of flower increased steadily with increasing time in storage; in Creole no such change was evident. Incidentally, the significant increase in Harrisii is believed to be due not to storage, but to environmental factors that became successively more favorable for growth and development as these lots flowered. Such comparisons between these two varieties are probably sound, since the two presumably matured and were harvested at the same time and were without storage treatment before arrival. It is still conceivable that the environmental effects of the two production areas were responsible for the differences observed, but this evidence is the best the writer has obtained thus far to show that commercial stocks differ in capacity to respond to cool storage.

A comparison of the Harrisii stock of 1936–37 (table 2) with that of 1937–38 (table 3) shows some striking differences. The 1936–37 stock was purchased through a New York dealer and reached Beltsville one month later in the season than the 1937–38 stock, which was bought direct from a producer in Bermuda. The bulbs in the two lots were of the same size and grade, and received similar treatment by the writer except that more varied treatments were imposed on the earlier lot. The 1937–38 untreated lot emerged much more promptly, bloomed earlier, and produced twice as many flowers per plant as the corresponding lot of the preceding year. The response to storage was similar in the 2 years; in neither year did any stored lot bloom before the control lot. It seems probable that the 1936–37 stock of Harrisii received some unfavorable treatment before reaching Beltsville. Since the evidence presented above indicates that Harrisii is somewhat divergent from other Easter lilies in response to storage, it is possible that the variety suffers adverse effects from routine bulb-storage practices.

CORRELATION AMONG THE CHARACTERISTICS MEASURED

Cool storage is utilized chiefly to advance or retard the date of flowering in Easter lilies, but a number of other characteristics recorded in this study such as number of leaves and number of flowers, appeared to be strongly modified by the treatments. It is of considerable interest to learn how closely these characteristics are correlated, or how strong is their tendency to respond together to storage treatments. Simple correlation coefficients have been computed for all possible pairs of the seven characteristics measured in the Creole variety and of the six measured in the Harrisii variety in the 1937–38 trials.

Because of the large number of degrees of freedom, even very low correlation coefficients have statistical significance; however, comparatively few pairs of characteristics show close association. The square of the value of r is sometimes used as an index of percentage correlation. For example, in the Creole variety, 52 percent of the variation in height, 37 percent of that in number of flowers, 77 percent of that in number of leaves, and 30 percent of that in duration of bloom are found associated with days to blooming. Consequently treatments designed to accelerate bloom may be expected to reduce the number of leaves, and they are also likely to reduce height, number of flowers, and duration of bloom. Number of flowers shows a 57-percent correlation with number of leaves. Few of the other relationships are sufficiently close to assume practical importance. Size of the flower shows little or no correlation with other factors studied in the Creole variety.

The Harrisii variety included only 160 recorded individuals, and less varied treatments were imposed on these than on Creole. Few of the correlation values are high, although many are significant. Some differences in varietal tendency appear. Accelerated flowering is associated to the degree of 25 percent with taller plants in Harrisii, but to 52 percent with shorter plants in Creole. There is a 25-percent tendency for late-blooming plants of Harrisii to bear larger flowers, but no relation at all appears between days to bloom and size of flower in Creole. As explained above, there is some reason to believe that Harrisii displays different responses to storage from those of Creole, but the differences found here may result chiefly from sampling during part of the calendar year with Harrisii (March to May) and during the entire year (February to January) with Creole.

1938–39 EXPERIMENT

No formal storage trials were planned for the season of 1938–39 but the performance of one lot stored and forced for early vegetative growth for other purposes seems of sufficient interest to report. Seedling Easter lilies were dug at Charleston, S. C., on July 13, 22 months from seed. At this time some of the tops were well matured and some still green. A random selection of five seedlings from each of five progenies made up the experimental lot. The bulbs were shipped to Beltsville, Md., and stored in moistened peat at 50° F. from July 22 to September 2, or 6 weeks. On the latter date they were potted into 4- or 6-inch pots according to size, and were forced under the conditions of previous trials. A large number produced flowers at far earlier dates than any lot of new crop Easter lilies previously forced. The range of flowering dates was December 10 to January 17 for the 25 bulbs from which data were collected. The mean flowering date was January 2. The plants required 121.4 ± 2.25 days to bloom, and bore 2.6 ± 0.32 flowers per bulb, at a height of 18.3 ± 1.24 inches above the soil.

These data suggest that Easter lilies for December and January bloom should be produced from new crop bulbs rather than from stored bulbs of the previous season, provided the new crop bulbs can be prepared safely and consistently. The new crop lilies compared very favorably with stored Creoles of the previous season. At least four factors may be utilized in inducing maximum earliness of bloom in new crop Easter lilies: Genetic earliness, early digging, cool storing, and forcing at comparatively high temperatures. Considerably more detailed information on the hazards involved and on the most efficient combination of these factors is needed before new crop lilies will appear on the market at Christmas, but this objective should be attainable.

DISCUSSION

The control of flowering time in bulbous plants by suitable manipulation of storage temperatures has long been in commercial use. Workers at the Wageningen and Lisse laboratories in the Netherlands have made detailed studies of the seasonal changes in bulbs of hyacinth, tulip, and narcissus.[2] The Netherlands workers have determined the temperature requirements for organ formation and for elongation in these bulbs, and have then devised temperature sequences for early and for late forcing.

Pfeiffer [3] studied the successive stages of development of the floral axis in bulbs of Bermuda Harrisii lilies stored at 10° to 13° C. (50° to 55.4° F.) and in Japanese Giganteum stored at 3° C. (37.4° F.). Harrisii bulbs received in August were in the vegetative stage, which persisted to mid-October when the predifferentiation stage of the terminal bud was recognizable. In the variety Giganteum, bulbs received in December already showed evidence of the predifferentiation stage, but floral organs were not recognizable in storage until April 16. Development in storage was slow in both varieties, but the cumulative effect of this development brought more rapid completion of the flower primordia after planting and hence more prompt blooming.

No morphological study of the Creole variety, which was used chiefly in the present study, is available. It may be assumed tentatively, however, that the cool storage treatments were applied mainly prior to differentiation of the floral organs. The early stages of bud development and possibly also the later stage of organ formation may have an optimum temperature near 50° F. The observed advantage of 50° over 32° storage, and some of the differences in performance of the several varieties and of different stocks of the same variety may thus be explainable on the basis of the temperature requirements of successive developmental phases within the bulbs.

Previous studies of the effect of cool storage on the performance of Easter lilies replanted in the field have been made in Bermuda [4] and in Florida. [5] In the Bermuda experiment, bulbs of the Harrisii variety were subjected to 37° F. storage in sand for monthly periods ranging from 0 to 4 months, beginning September 18, about 8 or 10 weeks after harvest. The bulbs subjected to cool storage emerged and bloomed more promptly but produced fewer flowers than controls planted at the start of the storage trial; there was an actual advance over the controls in the flowering date of the lots stored 1 and 2 months. The authors of the Bermuda report stated that the decline in number of flowers per bulb resulted from ordinary storage as well as from cool storage. Shippy [5] found that the Florida strain of Easter lily (similar to Creole and perhaps identical with it) emerges and blooms earlier in Florida field culture after a period of cool storage. A temperature of 40° F. and a packing of dry sand were used. Shippy varied the

[2] PURVIS, O. M. RECENT DUTCH RESEARCH ON THE GROWTH AND FLOWERING OF BULBS. I. THE TEMPERATURE REQUIREMENTS OF HYACINTHS. Sci. Hort. [Wye, Kent] 5: 127–140, illus. 1937.
——— RECENT DUTCH WORK ON THE GROWTH AND FLOWERING OF BULBS. II. THE TEMPERATURE REQUIREMENTS OF TULIPS AND DAFFODILS. Sci. Hort. [Wye, Kent] 6: 160–177, illus. 1938.

[3] PFEIFFER, NORMA E. DEVELOPMENT OF THE FLORAL AXIS AND NEW BUD IN IMPORTED EASTER LILIES. Boyce Thompson Inst. Contrib. 7:311–321, illus. 1935.

[4] BERMUDA DEPARTMENT OF AGRICULTURE. AN EXPERIMENT ON COLD STORAGE OF LILY BULBS. Bermuda Dept. Agr., Agr. Bul. 14: 52–54. 1935.

[5] SHIPPY, WILLIAM B. FACTORS AFFECTING EASTER LILY FLOWER PRODUCTION IN FLORIDA. Fla. Agr. Expt. Sta. Bul. 312, 19 pp., illus. 1937.

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digging date and the date and duration of cooling, and included warm storage treatments and bulbs replanted immediately as controls. Bulbs were accelerated in emergence and flowering by cool storage for an interval of 30 days or more but not for a 21-day interval. A few flowers were produced in December, and more in January, from cool-stored bulbs replanted in the field. The most favorable effects in the production of early bloom followed cool storage of 30 days or more applied after the middle of August. Shippy found that fewer flowers were produced from cool-stored lots, but that the increase in number of bulbs was not similarly affected.

The present investigation indicates that 50° F. is more effective in inducing early bloom than lower temperatures, and that moistened peat is slightly superior to dry-sand pack for this purpose. It also appears that all possible factors subject to control and tending to early bloom have not yet been combined. A possible danger in digging before bulbs are sufficiently mature is suggested in one of the writer's tests not here detailed.

However, early bloom is only one goal of Easter lily forcing. It is necessary to provide Easter lilies in every month of the year in response to market demand. The present study shows that this can be done with a single variety and a single digging date, but suggests that better ways should be found for producing fall bloom. After Easter lily bulbs are held for long periods in the least deleterious storage condition known (32° F. dry), they are inferior in forcing performance. Commerical Creole bulbs of the 7- to 9-inch size can be brought to flower from late February to September by simple manipulation of the conditions of storage, and the plants and flowers will be of satisfactory grade. Bulbs of larger size, commonly used for long storing in the trade, will probably produce satisfactory bloom from October to December. Further research on the effects of digging date and forcing temperature should lead to safe provision for November to January bloom from new crop bulbs. The period from September to November probably must be covered by bulbs stored nearly a full year, the practice now followed with Japanese Giganteum. Bulbs of the larger sizes should be used, as is customary when long storage is planned. Present commercial practice now utilizes Erabu for early bloom and Giganteum for late bloom. Although much of the year can be covered with a single variety such as Creole, it is perhaps doubtful whether a single variety can be made to perform most satisfactorily over the whole period.

SUMMARY

Storing Easter lily bulbs for 5 or more weeks at 32° to 50° F. accelerates flowering. Storage at 50° is more effective than at 40° or 32° in producing this effect. Bulbs packed in moistened peat moss during the storage interval flowered slightly in advance of those packed in dry soil or sand.

Storage for 10 weeks or more at 50° F. is distinctly deleterious, reducing the number of flowers and the number of leaves per plant. Similar effects result from storage for longer intervals at 40°. Storage at 32° in dry sand kept Creole Easter lilies with less deleterious effects on forcing quality than at 40° or 50°. After 45 weeks at 32° the

quality was barely acceptable, and after 60 weeks the average performance of 7- to 9-inch bulbs was poor.

Effects of cool storage on time required for the plants to emerge from the soil and on the height of the plant are less consistently evident, but when differences appear they are in the direction of decline from the level shown by control plants not subjected to storage. The size of the flower is a relatively constant characteristic of the variety, and is little affected by storage of the bulbs.

It appears probable that new crop bulbs of early varieties can be forced for Christmas by suitable combination of early harvest and cool storage treatment.

Cool storage of Easter lily bulbs is a convenient primary control over time of flowering. The customary control factor, forcing temperature, can be used as a fine adjustment after this primary control has been applied.