Table 6. Effect of an asphalt barrier on water-depletion rates in cabbage plots, 1969.

Treatment	Water-depletion rate, inches/day[a]					
	1[b]	2	3	4	5	6
	10/24-31	10/31-11/6	11/6-14	11/14-21	11/21-12/8	12/8-16
Control	0.06	0.07	0.09	0.04	0.03	0.43
Barrier	0.07	0.08	0.09	0.04	0.06	0.23

[a]Data show average over the irrigation treatments since there was only one irrigation (October 17). Estimated evapotranspiration rates are 0.09, 0.06, and 0.04 inches per day for the months of October, November and December, respectively; see footnote, Table 5.
[b]Time period for reference in the text.

Table 7. Effect of an asphalt barrier and irrigation on water-use efficiencies of cabbage and tomatoes.

Treatment	Water-use efficiency, cwt/A-inch						
	Cabbage				Tomatoes		
	1967	1968	1969	Mean	1968	1969	Mean
Control	33.3	29.9	8.5	23.9	5.5	6.1	5.8
Control with irrigation	28.7	22.6	9.2	20.3	7.6	9.5	8.6
Mean	31.0	26.3	8.9	22.1	6.5	7.8	7.2
Barrier	43.3	39.7	16.1	33.0	14.3	20.9	17.6
Barrier with irrigation	35.9	31.3	19.5	28.9	10.4	15.0	12.7
Mean	39.6	35.5	17.8	31.0	12.4	18.0	15.2

and semi-humid regions. It has produced significant increases in yields of vegetable crops as a consequence of the enhanced storage of water in the root zone. Moreover, it was found that irrigation could be used less frequently and in lower total amounts. The latter advantage of the asphalt barrier was not exploited to the maximum in the present experiment.

Table 8. Rainfall and irrigation amounts for all cabbage and tomato seasons.

Source of water and treatment	Amount of water, inches				
	1967	1968		1969	
	Cabbage	Cabbage	Tomato	Cabbage	Tomato
Rainfall	9.63	8.62	17.88	10.41	13.62
Irrigation:					
Control	3.00	2.50	3.50	0.78	6.92
Barrier	3.00	2.50	2.50	0.78	5.34

Literature Cited

1. Brunstrum, L. C., L. E. Ott, and T. L. Speer. 1967. Increasing crop yields with underground asphalt moisture barriers. *World Petroleum Congress.* I. P. No. 62.
2. Erickson, A. E., C. M. Hansen, and J. M. Smucker. 1968. The influence of sub-surface asphalt barriers on the water properties and productivity of sand soils. *Trans. 9th Int. Congr. Soil Sci.* 1:331-337.
3. Hammond, L. C., H. W. Lundy, and G. K. Saxena. 1967. Influence of underground asphalt barriers on water retention and movement in Lakeland fine sand. *Soil and Crop Sci. Soc. Fla. Proc.* 27:11-19.
4. Hansen, C. M., and A. E. Erickson. 1969. Use of asphalt to increase water-holding capacity of droughty sand soils. *I & EC Product Research and Development.* 8:256-259.
5. Rawitz, E., and D. I. Hillel. 1969. Comparison of indexes relating plant response to soil moisture status. *Agron. J.* 61:231-235.
6. Saxena, G. K., L. C. Hammond, and H. W. Lundy. 1967. Response of several vegetable crops to underground asphalt moisture barrier in Lakeland fine sand. *Proc. Fla. State Hort. Soc.* 80:211-217.
7. ______, ______, and ______. 1968. Effect of asphalt moisture barrier on soil salinity and yields of vegetables under variable irrigation and fertilization. *Soil and Crop Sci. Soc. Fla. Proc.* 28:310-318.
8. ______, ______, and ______. 1969. Yields and water-use efficiency of vegetables as influenced by a soil moisture barrier. *Proc. Fla. State Hort. Soc.* 82:168-172.
9. Taylor, S. A. 1952. Use of mean soil moisture tension to evaluate the effect of soil moisture on crop yields. *Soil Sci.* 74:217-226.

Effects of Exogenous Gibberellin on the Development of *Lilium longiflorum* Thunb. 'Ace'[1,2]

Sandra Kays, William Carlson, N. Blakely, and A. A. De Hertogh
Michigan State University, East Lansing

Abstract. Potted 'Ace' lily bulbs were treated with gibberellic acid (GA_3) as a soil drench using varying concentrations, numbers of applications and at different stages of development. There was no consistent effect on the forcing days to flower, plant height or the number of leaves, however, specific treatments with 1000 ppm significantly reduced the number of floral buds initiated. It appears that the most sensitive stage of application is that period just prior to flower initiation and that the GA_3 must be applied at this time in order to reduce the number of floral buds initiated. A preliminary experiment indicated that GA_{4+7} was more effective than GA_3. GA_{4+7} influenced plant height and leaf length as well as the number of floral buds but had no effect on the forcing days to flower.

Easter lilies require a specific low temperature treatment to accelerate flowering (4, 17). This treatment also reduces the number of flowers and leaves. In many plant species gibberellins are associated with low temperature treatments (13). In some cases, applied gibberellins can either completely or partially substitute for a low temperature treatment. Applications of GA are known to influence flowering (13, 16), seed and bud dormancy (2, 7) and vegetative growth (15). Little information is available on the relationship of either endogenous or exogenous gibberellins to the low temperature treatments used with the lily. Kelley and Schlamp (12) applied gibberellic acid (GA_3) to lilies when the floral buds were 1-1 1/4 to 6 1/4 - 6 1/2 inches long. They observed no effect on the date of flowering or flower size but found that the keeping quality of the potted plants was enhanced.

[1]Received for publication September 14, 1970.
[2]The authors wish to express appreciation to the United Bulb Company, Mt. Clemens, Michigan for supplying the experimental bulbs and to Abbott Laboratories, North Chicago, Illinois for the 2% 'Pro-Gibb'.

In this study GA3 was applied prior to the time of floral initiation and in combination with various low temperature treatments to determine the effect on the subsequent development of the lily during forcing.

Materials and Methods

Lily bulbs, *Lilium longiflorum* Thunb, cv. Ace, size 7 to 8 inch were grown in Smith River, California and transported to East Lansing without cold storage. They were planted immediately on arrival and forced using the controlled temperature forcing (CTF) procedure (6). Commercially accepted fertilizer, insecticidal and fungicidal practices were followed.

Experiment I, 1967-68. Treatments are described in Table 1. The bulbs were planted on October 26, 1967, grown for 3 weeks at 63°F and cooled at 35°F for either 3 or 5 weeks. The GA3 was applied as a 200 ml soil drench. A randomized block design with 4 replications and 6 observations per replication was utilized. Bulbs receiving 3 and 5 weeks of cold were removed from cold storage on December 7, 1967 and December 21, 1967, respectively. They were forced in a greenhouse with a temperature of 62°F.

Table 1. Description of GA3 treatments for Experiment 1, 1967-68.

Treatment No.	Weeks at 40° F	Date of 1st application	Date of 2nd application	GA3 (ppm)
1	5	Nov. 16	Jan. 7	0
2	5	Nov. 16	Jan. 7	10
3	5	Nov. 16	Jan. 7	100
4	5	Nov. 16	Jan. 7	1000
5	5	Dec. 21	Jan. 7	10
6	5	Dec. 21	Jan. 7	100
7	5	Dec. 21	Jan. 7	1000
8	3	Nov. 16	Jan. 7	0
9	3	Nov. 16	Jan. 7	10
10	3	Nov. 16	Jan. 7	1000
11	3	Dec. 21	Jan. 7	10
12	3	Dec. 21	Jan. 7	1000

Experiment II, 1968-69. Treatments are described in Table 2. The bulbs were planted on October 23, 1968, grown for 3 weeks at 63°F and cooled at 40°F for 5 weeks. The GA3 was applied as a 200 ml soil drench. A 3 x 5 factorial design was utilized with 4 replications of 6 observations per replicate. All bulbs were placed in a greenhouse at 62°F on December 17, 1968.

In addition to the GA3 treatments, 6 plants were treated with GA_{4+7} at 100 and 1000 ppm on December 17, 1968 and January 7, 1969.

Data Recorded. The number of forcing days to flowering was recorded as the number of days from the date the bulbs were removed from the cooler until the date of the first flower. Plant height was measured from soil level to the base of the pedicel.

Table 2. Description of GA3 treatments for Experiment 2, 1968-69.

Treatment no.	Date of 1st application	Date of 2nd application	GA3 Conc. (ppm)
1	None	None	0
2	Nov. 12	None	100
3	Nov. 12	None	1000
4	None	None	0
5	Dec. 17	None	100
6	Dec. 17	None	1000
7	None	None	0
8	Nov. 12	Jan. 7	100
9	Nov. 12	Jan. 7	1000
10	None	None	0
11	Dec. 17	Jan. 7	100
12	Dec. 17	Jan. 7	1000
13	None	None	0
14	None	Jan. 7	100
15	None	Jan. 7	1000

The number of leaves was recorded from soil level to the pedicel. The number of buds on each plant was counted on the day the first flower opened. All data were analyzed by means of orthogonal comparisons.

Results

A 1000 ppm GA3 treatment resulted in fewer floral buds per plant in both experiments (Table 3, Figs. 1, 2 and 3). The time of application was an important factor in influencing the number of buds initiated. A single application at 1000 ppm on January 7, reduced the bud count while 100 ppm may have increased it. Single applications either immediately before or after the cold treatment either had no effect or slightly increased the number of buds. When these treatments were combined with a January 7 application the number of buds was decreased. A decrease was also observed when the length of the cold treatment was increased from 3 to 5 weeks (Table 3, Fig. 1).

The number of forcing days to flowering does not appear to be influenced by GA3 (Table 3). In Experiment 1, GA3 at 10 ppm applied after a cold treatment of 3 weeks decreased the number of days to flowering while 1000 ppm increased the number of days to flowering. Although statistically significant, all these responses were small in terms of the days required to flower. These trends were not observed in the following year's experiments. In Experiment 1, the increased length of the cold treatment from 3 to 5 weeks resulted in a significant reduction in the number of forcing days. This was true even if the additional 2 weeks of time in the greenhouse are taken into consideration.

In Experiment 1, the application of GA3 resulted in a general increase in height of the plants. In Experiment 2, no effect on height was observed except in treatments 10, 11, and 12, which duplicated treatments 1, 6 and 7 of Experiment 1 (Table 3). Again, these differences are small. The increased length of the cold storage period did not appear to have any consistent effect on height of the plants (Table 3).

Table 3. The effect of exogenous GA3 on the forcing days to flower, number of floral buds, height to pedicel and number of leaves of 'Ace' lilies.

Exp. no.	Trt. no.	Forcing days to flower	No. of floral buds	Height to pedicel (cm)	No. of leaves
1	1	102	7.8	38.5	99
	2	100	7.3	39.0	99
	3	101	7.0	39.7	97
	4	103	6.2	40.4	101
	5	100	7.5	38.9	99
	6	102	7.1	39.7	100
	7	106	5.1	45.3	105
	8	121	9.4	40.4	120
	9	122	9.1	40.7	116
	10	121	7.5	44.7	121
	11	119	9.2	41.9	118
	12	124	7.0	43.2	120
Standard Error		0.81	0.34	1.14	2.33
2	1	101	7.1	35.9	102
	2	101	7.5	37.3	106
	3	101	7.1	37.4	100
	4	100	6.5	33.0	102
	5	103	7.2	31.8	102
	6	101	7.4	35.8	105
	7	101	7.2	33.2	103
	8	102	6.8	31.3	99
	9	101	5.5	30.9	99
	10	104	7.1	30.0	99
	11	104	6.9	28.7	99
	12	103	5.8	37.3	103
	13	104	6.7	38.0	101
	14	103	7.7	32.5	101
	15	105	5.8	33.1	101
Standard Error		1.53	0.38	2.04	N.S.

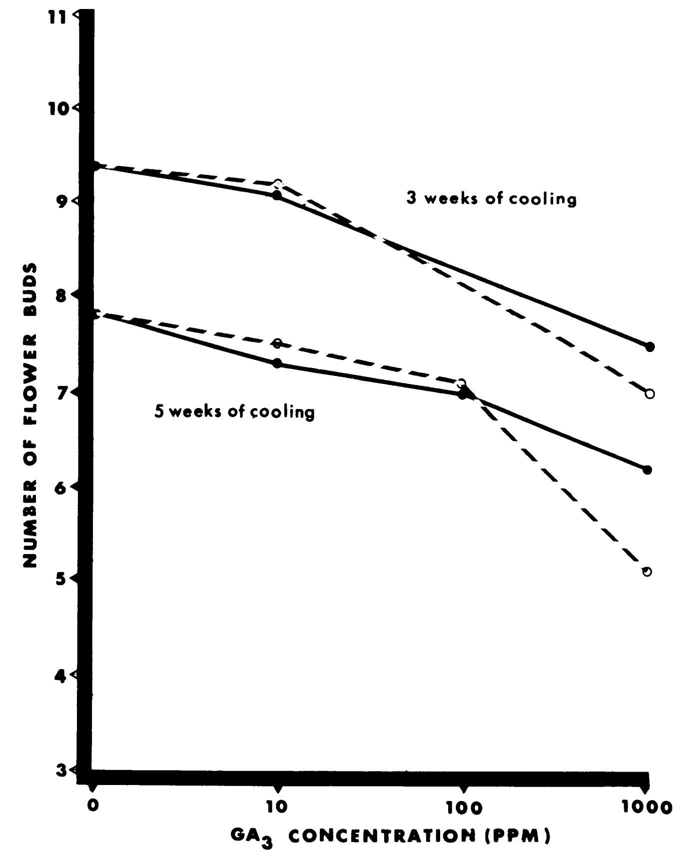

Fig. 1. Experiment 1. Effect of exogenous GA3 and the length of cooling on the number of floral buds of 'Ace' lilies. Solid line - GA3 applied prior to cooling plus 2nd application. Broken line - GA3 application after cooling plus 2nd application.

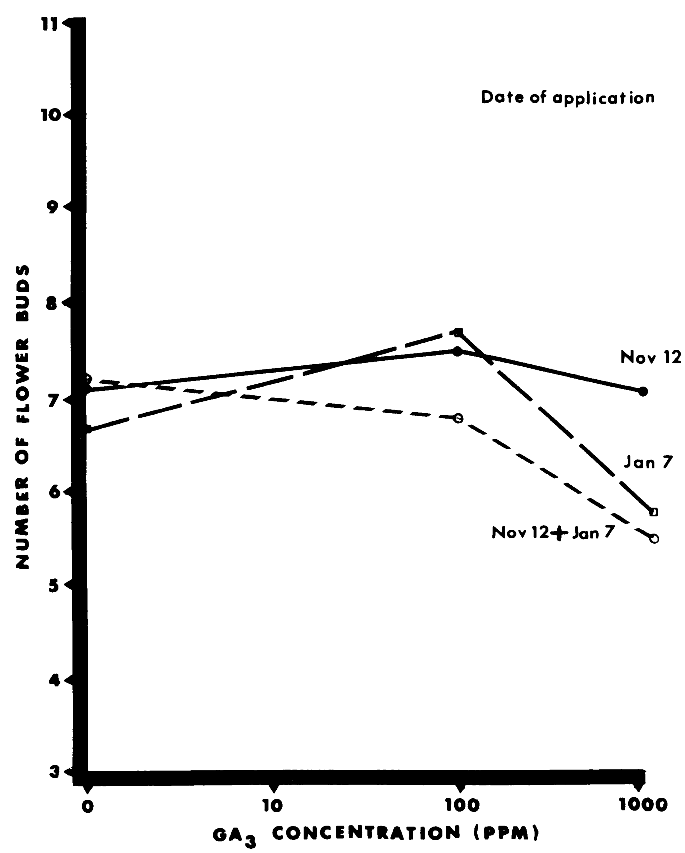

Fig. 2. Experiment 2. Effect of exogenous GA3 application applied prior to cooling either alone or in combination with an application on January 7.

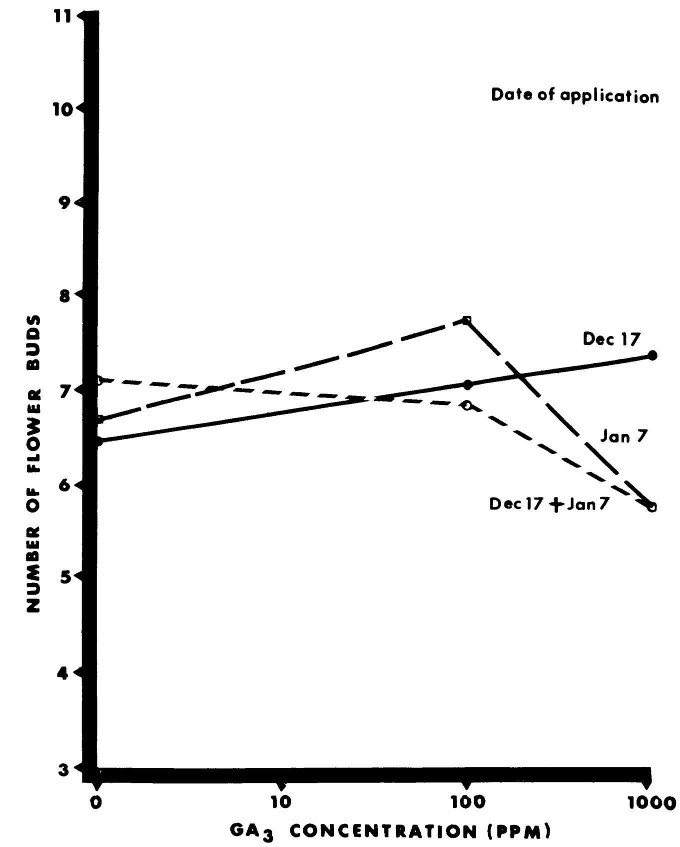

Fig. 3. Experiment 2. Effect of exogenous GA3 application applied after cooling either alone or in combination with an application on January 7.

The GA3 applications did not affect the number of leaves but the increased cold treatment resulted in a reduction in leaf number (Table 3).

Figure 4 illustrates the effects of the GA4+7 treatment on the development of the lily. It was observed that the number of buds was decreased by approximately 50%, the height was significantly increased and the leaf length was reduced. The forcing days to flower was not influenced. This combination of gibberellins appears to be more effective in affecting the development of the lily than GA3.

Discussion

The effects of increasing lengths of cold storage on flowering of Easter lilies have been investigated by many workers and reviewed by Stuart (18) and Langhans and Weiler (14). The data (Table 3) from this investigation are in agreement that prolonged low temperature treatments decrease the forcing days to flowering, the number of flower buds per plant and the number of leaves produced.

Exogenous applications of GA3 had no effect on the number of days to flowering or the number of leaves produced (Table 3). There was no consistent effect on the height of the plants (Table 3). There was a greater difference between years than between treatments. This indicates that the nature of the bulbs or the forcing conditions are significantly different from year to year. An effect on bud count was observed (Table 3, Figs. 1, 2 and 3). GA4+7 (Fig. 4) markedly decreased the bud count and increased plant height with no influence on the days to flower. This implies that the effects of applied GA's with the lily are dependent on the nature of the gibberellins. This has been demonstrated to be true for other plant species (16). Aung et al. (1) have demonstrated the presence of endogenous gibberellins in *Lilium longiflorum*. At present, no identification of the specific gibberellins has been made; this information would be

Fig. 4. Effect of Dec. 17 and Jan. 7 applications of 1000 ppm of GA_3 and GA_{4+7} on the development of the 'Ace' lily compared with water control.

of much value.

The GA_3 effect on bud count appears to mimic at least one effect of low temperature on lily development. Increasing the length of cold storage from 3 to 5 weeks decreased the number of buds from 9.4 to 7.8 (Table 3). Two applications of GA_3 at 1000 ppm reduced the number of buds from 9.4 to 7.0, and from 7.8 to 5.1 in bulbs stored for 3 weeks and 5 weeks, respectively (Exp. 1). A reduction in flower number by exogenously applied GA_3 has been noted in many plant species, e.g., *Lycopersicon* (5), *Prunus* (3), *Malus* (8), and *Euphorbia* (9). In many of these experiments the stage of development of plant was important in producing the flowering response.

In Experiment 1, the strongest effect of GA_3 was observed when 1000 ppm was applied after 5 weeks of cold, and a second application 3 weeks later. This effect of GA_3 could have been due either to the time of the first application or the length of time between the first and second application of GA_3. The data of Experiment 2 indicates that a single application, either before or after the cold period, had no effect in reducing the bud count. The January 7 application did have a significant effect. Hence, a specifically timed application of GA_3 was required to produce this response. Halevy and Shoub (10) have found a similar relationship with Wedgwood iris. They found that the exogenous GA_3 was most effective after floral initiation but before the completion of organogenesis. Since floral initiation in the CTF lily occurs shortly after January 7 (unpublished data) the applied GA may be influencing this process.

The relationship of the GA treatments used in this study to the low temperature treatments must be considered in the light of certain facts. To implicate the role of a hormone it should be administered at a physiological concentration near 10^{-6}M. If concentrations greater than this are used the response may be pharmacological in nature, i.e., caused by an overdose. It was found that only the 1000 ppm (3.5×10^{-2}M) produced a significant effect on the number of floral buds initiated. The possibility that this was a pharmacological response cannot be overlooked. It should be pointed out, however, that the GA_3 was applied as a soil drench and that colloidal binding, leaching or degradation may have taken place. The amount absorbed by the plant and transported to the apical meristem is unknown.

Thus, the relationship between gibberellins and cold treatments in the lily is not clear since the reduction in bud count is only one of the several parameters normally affected by cold treatments. Other gibberellins may be involved and the lack of response of other parameters (e.g., number of days to flowering) might be explained on the grounds of specificity of the different gibberellins. In a preliminary trial where a mixture of GA_{4+7} was applied to the bulbs, it was observed that the plant height and leaf length were also influenced. This observation would tend to support the idea of the specificity of different gibberellins.

Literature Cited

1. Aung, L. H., A. A. De Hertogh, and G. L. Staby. 1969. Gibberellin-like substances in bulb species. *Can. J. Bot.* 47:1817-1819.
2. Ballantyne, D. J. 1966. The influence of low temperature and gibberellin on development and respiration of flower buds of the Red Wing azalea (*Rhododendron* cv.). *Proc. Amer. Soc. Hort. Sci.* 88:595-599.
3. Bradley, M. V., and J. C. Crane. 1960. Gibberellin-like inhibition of bud development in some species of *Prunus. Science* 131:825-826.
4. Brierly, P. 1941. Effect of cool storage of Easter lily bulbs on subsequent forcing performance. *J. Agr. Res.* 62:317-335.
5. Bukovac, M. J., S. W. Wittwer, and F. G. Tuebner. 1957. Gibberellin and higher plants: VII. Flower formation in the tomato. *Mich. Agr. Expt. Sta. Quart. Bul.* 40:207-214.
6. De Hertogh, A. A., W. H. Carlson, and S. Kays. 1969. Controlled temperature forcing of planted lily bulbs. *J. Amer. Soc. Hort. Sci.* 94:433-436.
7. Frankland, B. 1961. Effect of gibberellic acid, kinetin and other substances on seed dormancy. *Nature* 192:678-679.
8. Guttridge, C. G. 1962. Inhibition of fruit bud formation in apple with gibberellic acid. *Nature* 196:1008.
9. ———. 1963. Inhibition of flowering in Poinsettia by gibberellic acid. *Nature* 197:920-921.
10. Halevy, A. H., and J. Shoub. 1964. The effect of cold storage and treatment with gibberellic acid on flowering and bulb yields of Dutch iris. *J. Hort. Sci.* 39:120-129.
11. Itakura, T., Y. Shiraki, and S. Shiraki. 1958. Effects of gibberellin on the growth and flowering of several flower crops (The Second Report). *J. Hort. Assoc.* (Japan) 27:186-192.
12. Kelley, J. D., and A. L. Schlamp. 1964. Keeping quality, flower size and flowering response of three varieties of Easter lilies to gibberellic acid. *Proc. Amer. Soc. Hort. Sci.* 85:631-634.
13. Lang, A. 1965. The physiology of flower initiation. *Encycl. Plant Physiol.* 15:1380-1536.
14. Langhans, R. W., and T. Weiler. 1967. Factors affecting flowering. Easter lilies: the culture, diseases, insects and economics of Easter lilies. Ed. D. C. Kiplinger and R. W. Langhans. Cornell University, p. 37-46.
15. Marth, P. C., W. V. Audia, and J. W. Mitchell. 1956. Effects of gibberellic acids on growth and development of plants of various genera and species. *Bot. Gaz.* 118:106-111.
16. Michniewicz, M., and A. Lang. 1962. Effect of nine different gibberellins on stem elongation and flower formation in cold requiring and photoperiodic plants grown under non-inductive conditions. *Planta* 58:549-563.
17. Stuart, N. W. 1946. Temperature and length of storage effects on lilies. *Florist Rev.* 98:35-37.
18. ———. 1967. Present methods of handling bulbs. In: Easter lilies: the culture, diseases, insects and economics of Easter lilies, Ed. D. C. Kiplinger and R. W. Langhans. Cornell University, p. 47-58.