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Flowering in florists ċineraria, Senecio cruentus, as influenced by gibberellin, light, and temperature

Marianne Brod Leese

To the Graduate Council:

I am submitting herewith a thesis written by Marianne Brod Leese entitled "Flowering in florists ċineraria, Senecio cruentus, as influenced by gibberellin, light, and temperature." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Landscape Architecture.

Gary I. McDaniel, Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a thesis written by Marianne Brod Leese entitled "Flowering in Florists' Cineraria, Senecio cruentus, as Influenced by Gibberellin, Light, and Temperature." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Ornamental Horticulture and Landscape Design.

Gary L. McDaniel

Gary L. McDaniel, Major Professor

We have read this thesis
and recommend its acceptance:

D B Williams

Elfin T. Graham

Joe S. Alexander

Accepted for the Council:

Hilton A. Smith

Vice Chancellor
Graduate Studies and Research

FLOWERING IN FLORISTS' CINERARIA, *SENECIO CRUENTUS*, AS INFLUENCED BY GIBBERELLIN, LIGHT, AND TEMPERATURE

A Thesis

Presented for the

Master of Science

Degree

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Marianne Brod Leese

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ABSTRACT

Various treatments were used to manipulate the flowering of the florists' cineraria, Senecio cruentus DC. 'Hansa' and 'Stellata' for the ultimate purpose of raising the cineraria as a cut flower. Various light intensities and temperatures were used to understand better the flowering process in the cineraria. Gibberellin was applied in an attempt to initiate flowering without the required cold induction, to hasten flowering, and to elongate the floral stems.

Neither GA_3 nor GA_7 significantly hastened flowering of the cultivars Hansa and Stellata grown under various cultural conditions, with one exception. When applied twice weekly as a 10-ppm spray after a six-week cold induction (4.5-7.0° C), the gibberellins did hasten flowering of Stellata plants. Both gibberellins significantly increased stem length.

Floral buds appeared at the same time whether Hansa plants were vernalized (10-13° C) for four weeks or for six weeks. A two-week cold induction, low light intensity (25-80 foot-candles), or warm temperatures (minimum 15° C) delayed floral development.

Floral initiation was observed histologically as early as two weeks after the start of cold induction (15.7° C days, 9° C nights in Hansa plants. Most of these showed

floral primordia four to six weeks after inductive treatments were begun.

The later Hansa plants were vernalized, the earlier after cold induction (15.7° C days, 9° C nights) floral buds appeared. However, total flowering time from sowing tended to increase as vernalization was delayed. Earliest floral development occurred in plants that were vernalized beginning six weeks after sowing.

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I. INTRODUCTION

The florists' cineraria, Senecio cruentus DC., is grown as a flowering pot plant for spring sales. It has long been popular in Europe, but interest has lagged in the United States for the past 40 years until recently. Now northern greenhouse operators are again growing them; and customers are pleased with the large truss of colorful, bright flowers that the cineraria produces above dense, dark-green foliage.

There seem to be two main reasons for the recent popularity of cinerarias in the United States. First, they are a cool-season crop, requiring minimum night temperatures of 7-10° C (45-50° F) to initiate floral buds. Concerned about high fuel costs, floriculturalists welcome cold-requiring plants. Presently growers are lowering greenhouse temperatures on such crops as chrysanthemums and bedding plants without impairing quality. Too, the cineraria lasts longer in the home since many homeowners have lowered their thermostate settings to reduce fuel costs.

The second reason for their current popularity is the development of new hybrids in Europe. The new strains are shorter with smaller leaves. The large leaves of the older, taller strains easily wilted when temperatures were above 21° C (70° F), and the plants needed frequent watering. Although the dwarf strains still do not perform well at high temperatures, they do not wilt as readily on hot days as did

the taller strains. Being short, the dwarf strains also travel and pack well.

The ultimate goal of this research project is to develop the cineraria as a cut flower. Cinerarias have not been used commercially as a cut flower, yet their daisylike flowers offer strikingly bright colors of deep blues, deep purples, and magentas presently missing in the florist trade. Besides floral heads of a solid color, many have a ring of white around the base of the ray floret (an "eye") that makes them particularly attractive.

Several problems exist in trying to raise cinerarias as a cut flower. The seed bought by the grower from the seed company is a mixture of many different floral colors. Some of these may not be desirable for floral arrangements. Seed packets containing seed of only one select color would be preferable for the grower.

Too, tallness would need to be bred back into the cineraria. The tallest cultivars on the American market are Giant Exhibition (W. Atlee Burpee Company and Geo. W. Park Seed Company, Inc.) and Bernary's Mammoth (J. L. Hudson, Seedsman, Redwood City, California). Both reach a height of about 40 cm.

In the 1920's and 1930's the cultivar Stellata was claimed to be an excellent, long-lasting cut flower (1, 9). It was taller (about 76 cm) than current strains. This hybrid is no longer found on the American market, but seed

is available from Hurst Gunson Cooper Taber Ltd. and from Thompson and Morgan (Ipswich) Ltd., both in England. It reportedly grows to about 60 cm (personal communication with both companies).

Cinerarias cannot be flowered the year round in most areas of the country since they are cold requiring. The current flowering season is limited to a period between Christmas and Mother's Day. For year-round flowering of the cineraria, development of heat-tolerant plants that would uniformly initiate flowers at minimum night temperatures of about 18.5° C (65° F) is needed. Chemical regulation of growth to overcome the cold requirement would also seem practical for extending the season of the cineraria.

The purpose of this thesis is to understand further the flowering process in the cineraria through use of chemicals that effect flowering and elongate floral stems and through manipulation of light and temperature.

II. LITERATURE REVIEW

The exact origin and development of the florists' cineraria, Senecio cruentus DC., is unknown. Cinerarias grow wild on the Canary Islands but look little like the cultivated plant. Apparently the cultivated form is a hybrid resulting from crosses involving several Canary Island species of Senecios--S. cruentus DC.; S. heritieri DC., which unlike the other species has "white-eyed" floral heads; perhaps S. populifolius DC.; and possibly others (2, 5, 9).

In trying to determine its origin, Barkley (6) conducted compatibility studies among and within several cultivars of cineraria. He found that high temperatures adversely affected fertility. Although mostly self sterile and cross fertile, the cineraria is not totally an obligate outbreeder as some self fertility and infertile crosses did occur. Breeding barriers were also found to exist between and within cultivars. One plant could be crossed with a second but not with a third. However, the second plant could be crossed with the third.

The literature does not indicate whether cinerarias have a juvenile growth phase, a period when they are insensitive to vernalization. Potter (23) writes that bud set occurs three months after germination. Experiments done on flowering by various workers have been with plants seven and eight weeks old (e.g., 10, 11, 26); however, at no point is it clear when floral initiation first occurs.

To initiate flowering in cinerarias, minimum night temperatures of 7-10° C for six weeks is recommended. Following induction, the temperature can be raised to hasten floral-bud development (13, 22, 23). Reiss Greenhouses, Inc., Minneapolis, claim that raising the post-inductive temperature to 15.5° C hastens flowering while not impairing quality (4).

Potter (23) suggests that keeping the temperature at 7-10° C produces a better quality plant. This is verified by Hildrum (13). He kept cineraria plants at a constant 9° C or 12° C for 3, 6, or 9 weeks and then at a constant 9, 12, 15, or 18° C for the rest of the experiment. He judged quality on plant form: a compact, well-formed plant received the highest marks. Those plants kept at a constant 12° C for 3, 6, or 9 weeks followed by a constant 9° C were judged the best in quality. Plants kept at a constant 9° C throughout the experiment also received high marks. Flowering was hastened by raising the temperature from the initial 9 or 12° C, but quality decreased. The poorest quality plants were those kept at a constant 15 or 18° C.

In the same experiment, Hildrum found that three weeks was sufficient to vernalize the cineraria. Plants kept at a constant 9° C for three weeks or for six weeks and then at a constant 15° C flowered at about the same time, an average 129 and 127 days, respectively, after the start of the

experiment. Those plants kept nine weeks at a constant 9° C and then at 15° C flowered in an average 132 days.

Continuously growing cinerarias at high temperatures (15-20° C) delays flowering and may prevent it. In Hildrum's experiments, out of six plants kept at a constant 15° C, two bloomed. None of those kept at a constant 18° C bloomed. Plants initially kept at 9° C flowered sooner than those initially kept at 12° C. Post (21) every 10 days moved five plants from a 15.5-21° C greenhouse to one kept at 10-15.5° C. The plants bloomed successively later. Of the plants remaining at the warmer temperatures, 50% bloomed with flowering occurring mainly two months later than the last group introduced to the cooler temperatures. Post concluded that the hybrid cineraria is so variable that in his experiment temperatures were not sufficiently high to prevent flowering.

Earlier flowering occurs when cinerarias are root bound in small pots (23). This is evident by the sowing dates recommended by Ball (3). For midwinter and Easter sales in 12.5- or 15-cm pots, it is suggested that seed be sown in August and September. For 10- to 12.5-cm pot plants, sowing can be done about October 1; but in 7.5-cm pots, sowing can wait until December.

Post (22) found that lengthening the day by applying artificial lights when the floral buds are visible hastens flowering somewhat and also causes considerable stem

elongation. This elongation seems to occur with incandescent lights and not significantly with fluorescent lights (13). In Hall's experiments (10, 11), cinerarias given a two-hour night break in the early stages of floral-bud development flowered three weeks earlier than the controls. At more advanced stages, flowering was hastened by less than a week. Hildrum (13) reported that cinerarias given 24 hours of lighting at visible-bud stage flowered 10-14 days earlier than the controls.

There is no indication in the literature whether gibberellin can partially or totally overcome the cold requirement in the cineraria. Lang (16) reported that GA_3 induced flowering in the biennial Hyoscyamus niger L., European henbane, when not cold treated. Other nonthermo-induced plants were also found to flower after GA_3 treatment (8, 17, 27).

Not all cold-requiring plants respond to GA_3 (18, 19). Gibberellic acid is most effective in those plants having a rosette habit of growth, as has the cineraria; but not all such plants respond positively. This may be due to the wrong gibberellin being used (19). Among nine gibberellins used by Michniewicz and Lang (20), only GA_7 and GA_3 caused flowering in Myosotis alpestris Schmidt, alpine forget-me-not, with the latter gibberellin being less effective. In Centaurium minus Moench, centaury, GA_3 was most effective in causing flowering, followed by GA_1, GA_4, and GA_7.

A rosette plant similar to the cineraria in its flowering requirements is Lunaria annua L. (L. biennis Moench), honesty or money plant. About the first six weeks from sowing, Lunaria is insensitive to chilling and remains in a juvenile state. Thereafter, an 8- to 10-week cold period at about 3-4° C is necessary for floral initiation. After induction floral development will occur at higher temperatures either under short or long days. Brian, Hemming, and Lowe (7) tried eight different gibberellins on Lunaria. GA_7 induced stem elongation but not floral formation. The other gibberellins elicited no response. Zeevaart (28) reported stem elongation with both GA_3 and GA_7, the latter being more effective. However, again no flowering occurred in the treated, nonvernalized plants.

Lang (18) has noted that with most rosette plants low temperatures simultaneously trigger floral initiation and stem elongation. But when gibberellin is applied, stem elongation occurs before floral initiation. Thus, Lang suggests that gibberellin primary acts in stimulating stem elongation and not flowering.

III. MATERIALS AND METHODS

In general, all cineraria seed for the following experiments were sown uncovered on Pro-Mix B, moistened with a Dexon drench (p-dimethylaminobenzenediazo sodium sulfonate) to control Pythium sp., damping-off organisms. The seed tray was enclosed in a polyethylene bag and placed under Sylvania Gro-Lux lights (about 60 foot-candles) at 25.5° C. The seed germinated in about three days and the bags were removed in about a week. Two weeks later the seedlings were taken to the greenhouse. When about a month old, the seedlings were transplanted into 7-cm plastic pots. Peat pots were not used because the roots would not penetrate the pots very well. In the experiments small plants (usually eight weeks from sowing) were often used due to limited space in the growth chamber. A Percival growth chamber was used in which day length and temperature, both day and night, could be controlled.

Gibberellic Acid Treatment

Seed of the cultivar Hansa was sown July 23, 1974. The seedlings were transplanted into 7-cm pots on August 23 and grown under prevailing greenhouse conditions. Temperatures ranged from an average high of 28° C and an average low of 18° C until the start of the experiment.

Controlled Induction--Growth Chamber Experiments

On September 20, 1974, 66 plants were placed both on the top and on the bottom shelf of the growth chamber kept at a constant 10-12° C. The plants on both shelves were treated similarly except that the light intensity was considerably lower on the bottom shelf--20 foot-candles (ft-c) as opposed to 300 ft-c on the top shelf. Fluorescent lighting was used.

A randomized complete block design was used with six treatments per block and 11 replications. Beginning September 20, half of each group of 66 plants were sprayed with 10 ppm GA_3 weekly for six weeks while the other half were sprayed with distilled water. Both solutions contained per 500 ml two drops of Tween-20, polyoxyethylene(20) sorbitan monolaurate, a surfactant. At the end of 2, 3, and 6 weeks, 22 plants from each shelf were removed from the chamber, transplanted into 10-cm plastic pots, and grown under prevailing greenhouse conditions.

As the plants were removed from the chamber, the light intensity on the bottom shelf rose to 25-40 ft-c after the first removal and to 30-80 ft-c after the second removal. Lowest readings were taken at the sides of the growth chamber.

Uncontrolled Induction--Greenhouse Experiment

Sixty plants were transplanted into 10-cm plastic pots and set up in a randomized complete block design with

two treatments and six plants per block, replicated 10 times. Beginning September 20, the plants were sprayed weekly for six weeks either with 10 ppm GA_3 or with distilled water. As above, Tween-20 was added to the solutions.

Temperatures during the six weeks ranged from 5.5° C to 33.5° C. Average high was 27° C; average low, 13.5° C. The low temperatures occurred the two weeks before the heat was turned on October 7. The night temperature was then set for a minimum 15° C.

In the above experiments, the plants were observed for signs of floral buds. The date was recorded when the terminal bud was 3 mm in diameter. Data were taken until January 24, 1975.

From the end of the six-week period until the end of the experiments, greenhouse temperatures ranged from a high 25.5° C to a low 9° C. On seven occasions the temperatures were a low 9-10° C due to the heat being turned off or the vents being opened too early in the day. Average high was 20° C; average low, 15° C.

An analysis of variance was made on the data taken from the above three experiments. Level of significance was set at 5%. The two growth chamber experiments were analyzed both separately and together. Where applicable, Duncan's New Multiple Range Test was used.

GA_7 Treatment

Hansa seed was sown October 23, 1974. Thirty seedlings were transplanted into 7-cm plastic pots November 5 and into 10-cm styrafoam pots January 28. Stellata seed was sown September 13 and October 15. The former planting was transplanted October 14, November 20, and January 8; and the latter, November 2, December 24, and January 22 into successively larger styrafoam pots. Final pot size was 15 cm. During this time greenhouse temperatures averaged an 18.5° C. Although the thermostat was set at 15° C, temperatures occasionally dropped to 10° C, as explained before.

Fifteen Stellata plants of the first sowing were vernalized for five weeks December 30 to February 4 at a constant 4.5-7.0° C. Fifteen other plants were vernalized for six weeks January 8 to February 19. Fifteen plants from each sowing plus the Hansa plants were continuously grown in the greenhouse.

Beginning January 28, 10 Hansa plants and 5 Stellata plants in each of the four groups were sprayed with 10 ppm GA_3 or 10 ppm GA_7. Again Tween-20 was added to the solutions. The plants were treated twice weekly for three weeks and once weekly for two more weeks. The controls were not treated. A randomized complete block design was used with six Hansa plants per block, replicated five times, and three Stellata plants per block, also replicated five times.

Plant height and flowering date were recorded until the end of the experiment April 24. Height was measured from the soil to the terminal floral head.

Microscopic Investigation of Floral Primordia

Seed of the cultivar Hansa was sown September 13, 1974. Transplanted into 7-cm plastic pots October 14, the seedlings were placed in the growth chamber November 8. Temperatures were 9° C for 12 hours at night and 15.7° C for 12 hours during the day. During the 12-hour day, the plants were illuminated with both fluorescent and incandescent lights (about 300 ft-c). After six weeks, plants that remained in the growth chamber were taken to the greenhouse and transplanted into 10-cm plastic pots.

At the start of the study, apical meristems were removed from five plants that were not put into the growth chamber. Thereafter, five plants were randomly chosen twice a week for eight weeks, and the apical meristems were removed. The tissues were fixed in 2% paraformaldehyde and 3% glutaraldehyde in 0.02 M cacodylate buffer at pH 7.2 (15).

The dehydration process was first begun in ethanol (10, 15, 20, 30, and 40%). This was followed by a tertiary butyl alcohol (TBA) series (40, 70, 80, 90, 95, 100%, and pure TBA) (14). The dehydrated material was infiltrated with and then embedded in Paraplast, sectioned at a thickness of eight microns, and mounted on glass slides.

Staining was through the paraffin with toluidine blue O in benzoate buffer at pH 4.4 for 10 minutes (Sakai, 1973; Sidman, Mottla, and Feder, 1961). The paraffin was removed with xylene and cover slips were placed on the slides.

The slides were examined to determine the earliest point at which floral primordia could be seen in the cineraria. Polaroid Land pack film, Type 105 Positive/ Negative, was used to take pictures of the apical meristems.

Juvenility Study

Seed of the cultivar Hansa was sown October 22 and November 26. Seedlings of the first sowing were transplanted November 18 and December 20; those of the later sowing, December 17 and February 28. Beginning December 20, six plants from each sowing were randomly placed in the growth chamber each week for five weeks. This made it possible to vernalize plants 3 through 12 weeks from sowing. Temperatures and lighting were as for the previous study.

After a six-week induction, the plants were taken to the greenhouse where temperatures averaged a high 22° C and a low 16° C. The date was recorded when the terminal floral bud was 2 mm in diameter.

IV. RESULTS AND DISCUSSION

Gibberellic Acid Treatment

By the end of the experiments on January 24, three of the 66 Hansa plants that were on the bottom shelf of the growth chamber had not shown floral buds. All three had been given a two-week cold induction. One had been treated with GA_3 while the other two had not been treated. Also, eight of the 66 Hansa plants continuously grown in the greenhouse had not shown floral buds. Five had been treated with GA_3; the other three were controls. To do a statistical analysis, a sufficiently high bud date, 200 days from sowing, was assigned to each of these plants. The data shown on the following pages include the assigned bud dates.

There was no difference in the rate of floral-bud development between the GA_3-treated and the nontreated plants on either the top or the bottom shelf of the growth chamber (Table 1). However, there was a significant difference among the three cold-inductive treatments. Visible buds appeared about the same time among those plants vernalized for four or six weeks on the top shelf, but the two-week cold induction significantly delayed bud development by 17-19 days. On the bottom shelf the plants vernalized for four weeks had buds the earliest, those vernalized for six weeks were significantly later, and those vernalized for only two weeks were the slowest to show buds.

Table 1. Average number of days from sowing to floral-bud date of the florists' cineraria, cultivar Hansa: the effect of individual treatments.

Top Shelf		Bottom Shelf	
GA_3	137	GA_3	149
No GA_3	137	No GA_3	149
2 weeks	149b*	2 weeks	157a
4 weeks	130a	4 weeks	140c
6 weeks	132a	6 weeks	150b

*Means within columns followed by the same letter were judged not significantly different at the 0.05 probability level using Duncan's New Multiple Range.

The low light intensity on the bottom shelf of the growth chamber definitely delayed flowering and influenced floral-bud development within the three inductive treatments. Four weeks was sufficient to initiate flowering in all of the plants, but the low light intensity delayed bud development by an average 8-10 days. Adding two more weeks of cold induction further delayed the development by an average 10 more days. The two-week induction at low light intensity was inadequate to initiate flowering in all of the plants.

On neither shelf was there a significant interaction between gibberellic acid and the length of the cold induction (Table 2 and Figure 1). Although on the bottom shelf there was a significant difference in bud dates between GA_3-treated and nontreated plants when chilled two or six weeks, GA_3 hastened flowering in the former but delayed it in the latter. The results tend to cancel each other out. Besides, the question is not whether gibberellin can hasten flowering under low light intensity but whether light is critical in the early stages of floral development.

In the greenhouse experiment the average bud date was the same as for the plants on the bottom shelf of the growth chamber--149 days. But bud development in the GA_3-treated plants was significantly later than that of the controls. Plants treated with GA_3 developed buds in an average 151 days; the controls, in an average 147 days.

Table 2. Average number of days from sowing to floral-bud date of the florists' cineraria, cultivar Hansa: the effect of combined treatments.

Treatment	Length of Induction (10-13° C) 2 weeks	4 weeks	6 weeks
Top Shelf			
GA_3	151a*	130b	129b
No GA_3	146a	130b	134b
Bottom Shelf			
GA_3	153b	139c	154b
No GA_3	161a	140c	145c

*Means followed by the same letter were judged not significantly different at the 0.05 probability level using Duncan's New Multiple Range.

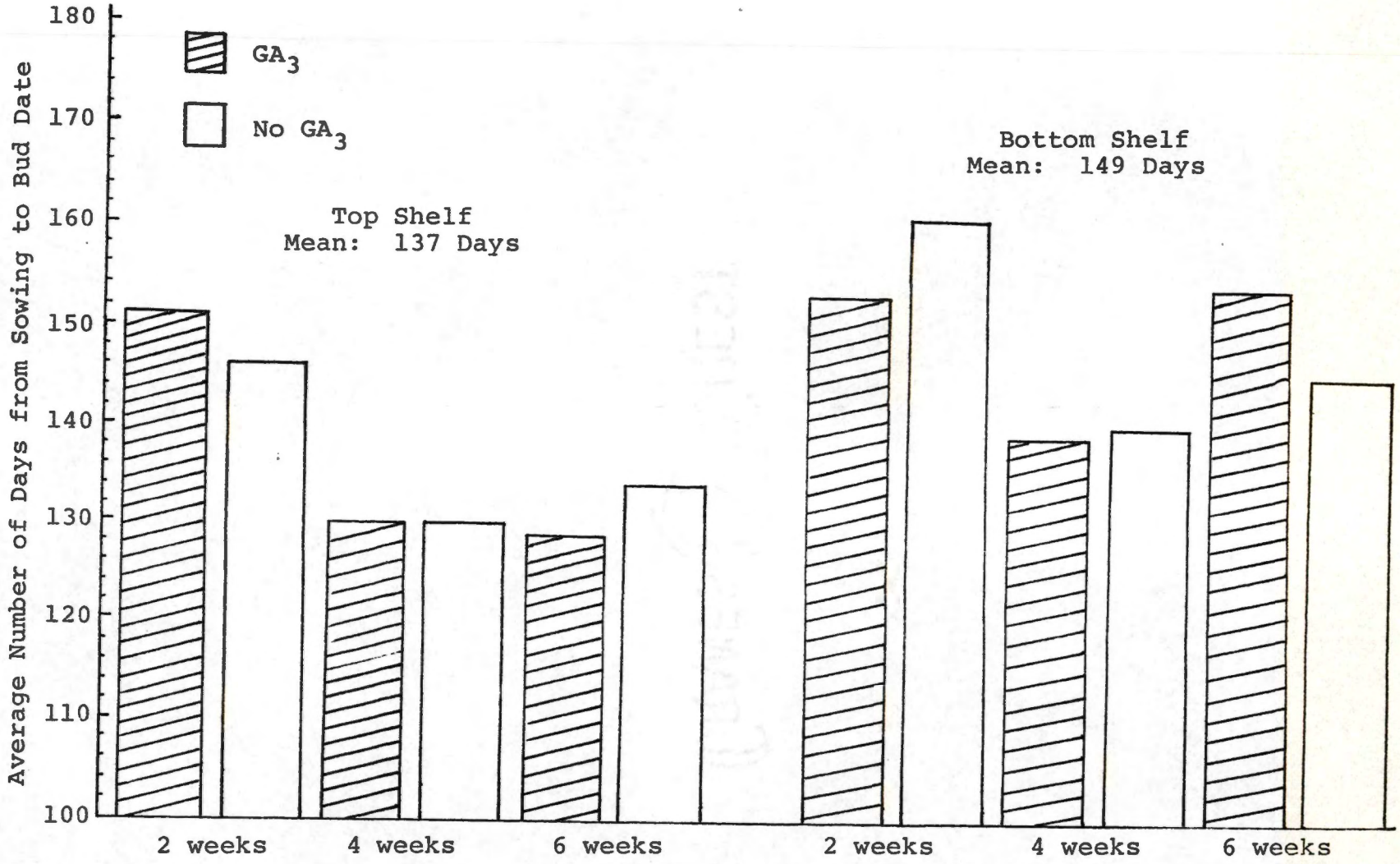

Figure 1. Effect of gibberellic acid, light, and length of cold induction on the flowering of the florists' cineraria, cultivar Hansa.

The results show that GA_3 is not effective in hastening flowering when applied to Hansa plants during vernalization, but neither does it delay flowering. However, light is a critical factor in the early stages of floral development. Light intensity of 25-80 ft-c significantly delayed bud development by 12 days.

It is evident that under 300 ft-c of light and at a constant 10-13° C, four weeks of cold induction is just as effective as six weeks for the Hansa. Keeping the plants under a very low light intensity for four weeks caused less delay in bud development than for the full six weeks.

From the greenhouse experiment, it is apparent that the Hansa is a facultatively cold-requiring plant. Flowering will occur at a minimum 18° C but is delayed. In this experiment floral-bud development was delayed an average 18 days compared with the plants induced two and four weeks on the top shelf of the growth chamber. Gibberellic acid did not hasten this development but instead slightly delayed it.

GA_7 Treatment

Cold-treated Stellata

The gibberellins had more effect on flowering time in the group vernalized beginning December 30 (Group I) than in the group vernalized beginning January 8 (Group II). As shown in Table 3, plants treated with gibberellin in Group I flowered an average 16-17 days before the nontreated plants.

Table 3. Effect of GA_3 and GA_7 on the flowering and height of Senecio cruentus 'Stellata' given a cold treatment (4.5-7.0° C).

Treatment	Group I		Group II	
	Average Number of Days from Sowing to Flowering	Average Height (cm)	Average Number of Days from Sowing to Flowering	Average Height (cm)
GA_3	181[x]	67	195	53
GA_7	180	55	194	52
Control	197	36	195	38

[x]One plant did not flower but buds were visible.

The average flowering dates among the plants in Group II were about the same.

Group I was vernalized before Group II, but gibberellin treatments began at the same time. As a result, in Group I two out of the eight treatments were given during cold induction; in Group II seven out of the eight treatments were given during induction. Apparently neither GA_3 nor GA_7 effects flowering time when applied during induction but may hasten flowering when applied after induction. This can be clearly seen in Figure 2. That GA_3 acts significantly differently from GA_7 is not evident.

Plant height was significantly increased by the gibberellins by an average 20 cm over the nontreated plants. However, none of the latter reached the 60 cm reported by the English growers. With gibberellin treatment, only five plants in Group I and one plant in Group II reached 60 cm or more.

In Group I the differences in the average heights between the GA_3-treated plants and those treated with GA_7 seems due mostly to one plant that measured 85 cm. In general these plants were taller than those in Group II because of the rather shady and warm area in which they were placed after induction.

One plant treated with GA_7 in Group I did not flower by the end of the experiment but did show a tiny cluster of floral buds. Presumably the five-week inductive period was

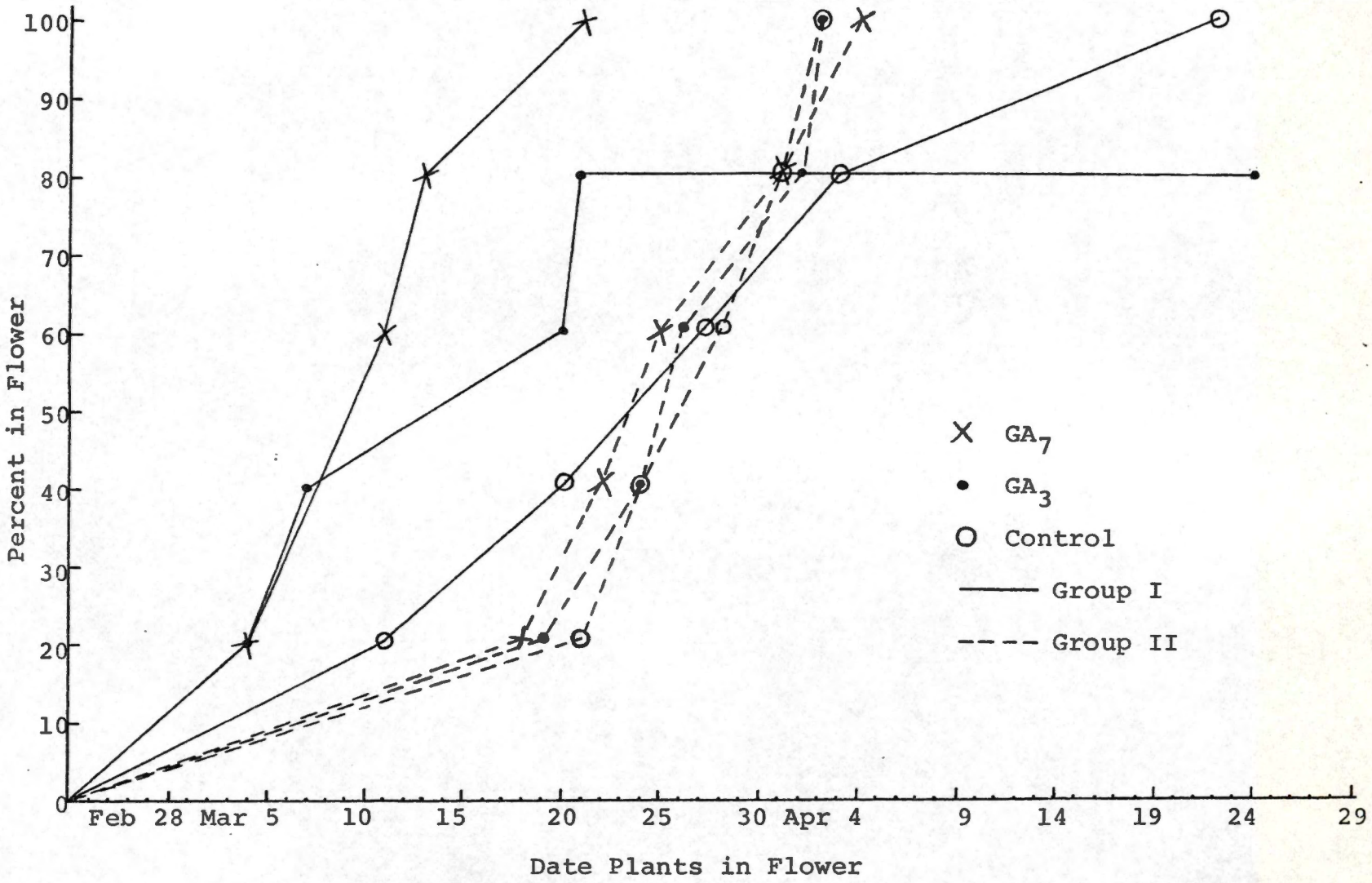

Figure 2. Percent flowering of Stellata when cold treated (4.5-7.0° C).

not long enough to adequately vernalize the plant.

Noncold-treated Stellata

In both the September 13 sowing (Group III) and the October 15 sowing (Group IV), there was at least one plant in each treatment that had failed to flower by the end of the experiment. Of those that did flower, the GA_7-treated plants were the earliest (Table 4). This was especially true in Group III in which 80% of the plants treated with GA_7 had flowered by March 25 while 80% flowering did not occur with the GA_3-treated plants until April 15 (Figure 3). The one control did not flower until April 10.

In Group IV there was not a wide difference in flowering time among the treatments. Eighty percent flowering occurred among the GA_7-treated plants by April 18. As Figure 3 shows, the controls tended to flower earlier than the GA_3-treated plants.

Although Group III was sown before Group IV, the latter flowered earlier than the former. Group III flowered in an average 201 days; Group IV, in 157 days. No clear explanation can be given for this without complete data on humidity, light, temperature, watering, and soil pH. It is assumed that during early growth the earlier sowing was exposed to higher temperatures than the later sowing so as to delay flowering and that light intensity may not have been optimum since light intensity varied in different parts of the greenhouse.

Table 4. Effect of GA_3 and GA_7 on the flowering and height of Senecio cruentus 'Stellata' not given a cold treatment.

Treatment	Group III		Group IV	
	Average Number of Days from Sowing to Flowering	Average Height (cm)	Average Number of Days from Sowing to Flowering	Average Height (cm)
GA_3	205[x]	59	162[x]	50
GA_7	190[y]	51	153[y]	52
Control	209[z]	36	156[y]	33

[x]One plant did not flower but buds were visible.

[y]One plant did not flower; no visible buds.

[z]Four plants did not flower; no visible buds.

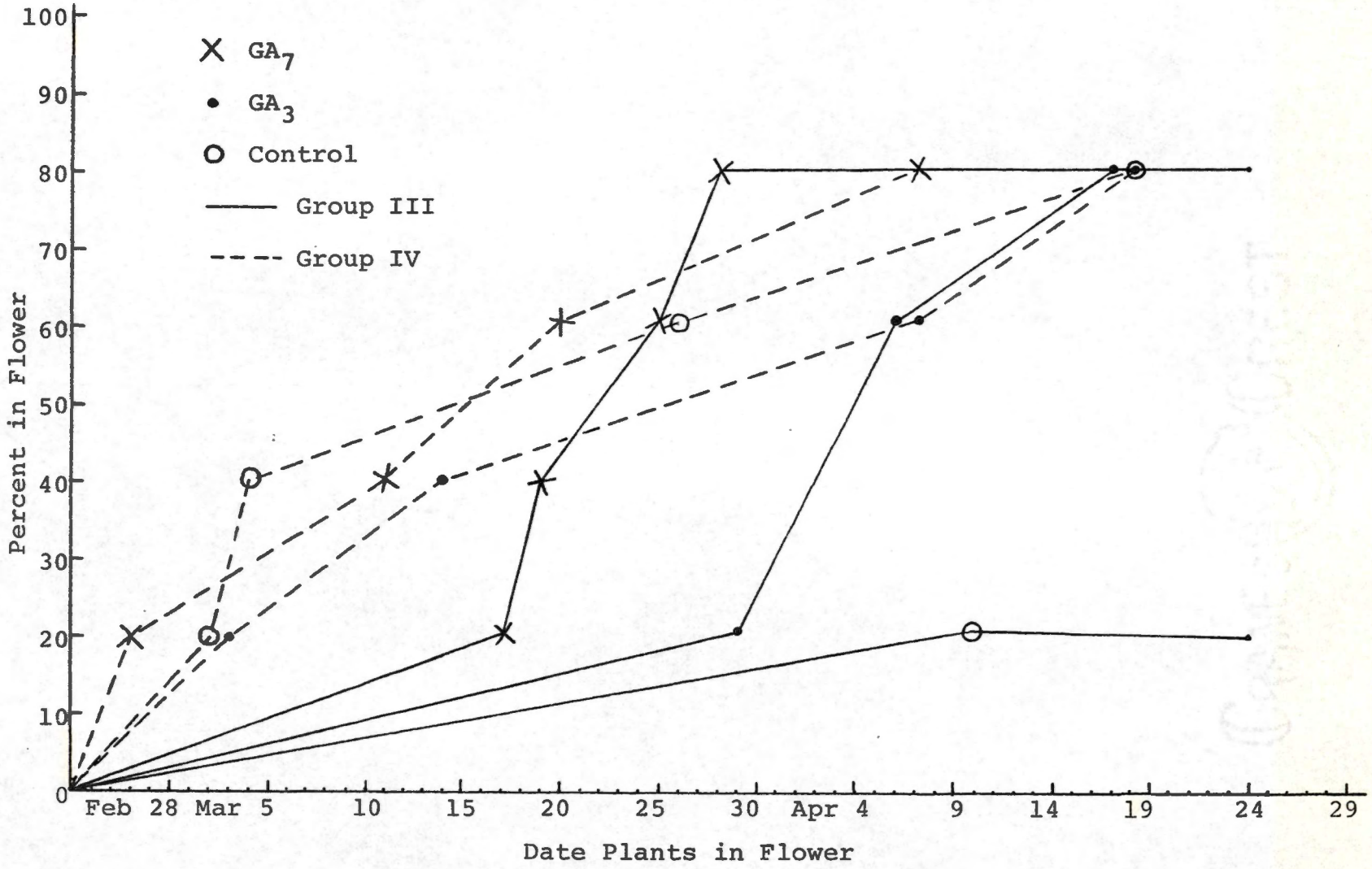

Figure 3. Percent flowering of Stellata when not cold treated.

As with the cultivar Hansa, the cultivar Stellata was capable of flowering without a formal six-week induction at minimum 7-10° C; however, flowering was not uniform and some plants did not flower at all.

As in Group I and Group II, the gibberellins significantly elongated the stems of the Stellata with the plants being an average 20 cm higher than the controls. Only in Group III did any of the treated plants (three) reach 60 cm or more in height. This is probably because this group was in the vegetative state longer than Group IV and had more time for stem growth before flowering occurred.

Since the results from the two groups disagree, no definite conclusions can be drawn about the effects of GA_3 or GA_7 on the flowering of noncold-treated Stellata without a more controlled experiment with a larger sampling. However, of the two gibberellins, GA_7 seems to be more effective in hastening flowering; but neither gibberellin seems to fully overcome the cold requirement.

Noncold-treated Hansa

Flowering time was nearly the same among the variously treated plants. As in the experiment using GA_3 alone, the gibberellins showed a tendency to delay flowering in the Hansa when not cold treated. On the average, the GA_3-treated plants flowered in 150 days, the GA_7-treated plants in 151 days, and the controls in 147 days. All plants had flowered by the end of the experiment.

Gibberellin treatment increased the height of the Hansa. The GA_3-treated plants averaged 17 cm in height; the GA_7-treated plants, 15 cm; and the controls, 11 cm.

There seems to be no difference between GA_3 and GA_7 in their effect on flowering and height of the cultivar Hansa when it has not been given six weeks of minimum 7-10° C temperatures. Both gibberellins elongated the stems and slightly delayed flowering.

Microscopic Investigation of Floral Primordia

Microscopic inspection revealed that the cineraria in the vegetative state has a flat apical meristem (Figure 4). A slight rounding of the meristem could be seen in two of the samples taken after two weeks of induction (Figure 5). This seemed to be the first visible evidence of floral primordia. At the end of three weeks, three more samples had slightly rounded meristems.

Floral primordia could definitely be seen in a sample taken the end of 3 1/2 weeks in which the meristem had become quite rounded. Further development was seen at the end of four weeks. Two of the samples taken had meristems that had become a hump (Figure 6). The other three samples had rounded meristems.

Elongation of the floral stem, development of the floral head, and the beginnings of the individual florets could first be seen in a sample (Figure 7) taken at the end

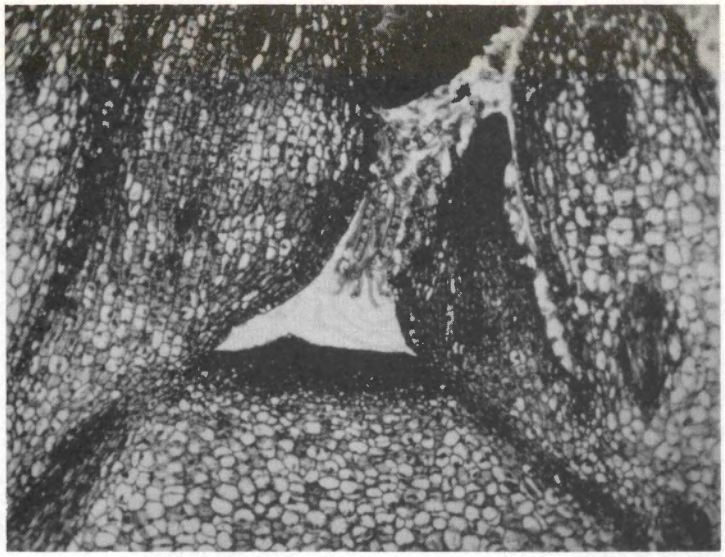

Figure 4. Vegetative apical meristem of Senecio cruentus 'Hansa' (X 100).

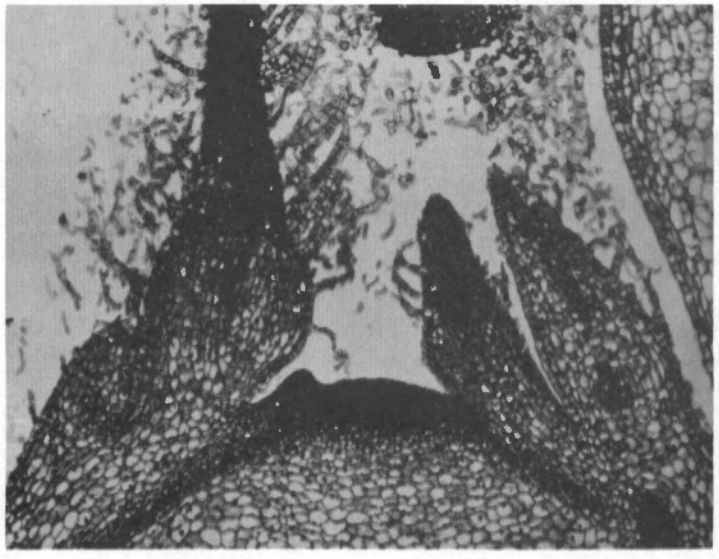

Figure 5. Floral primordium in Senecio cruentus 'Hansa' after two weeks of vernalization (X 100).

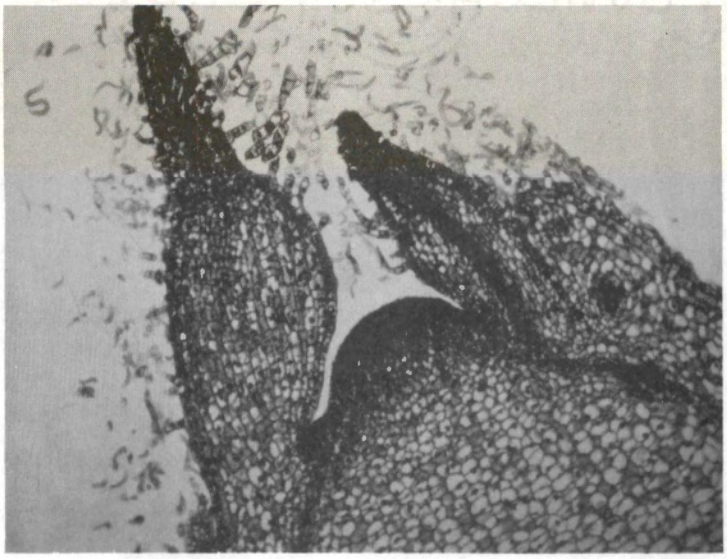

Figure 6. Floral primordium in Senecio cruentus 'Hansa' after four weeks of vernalization (X 100).

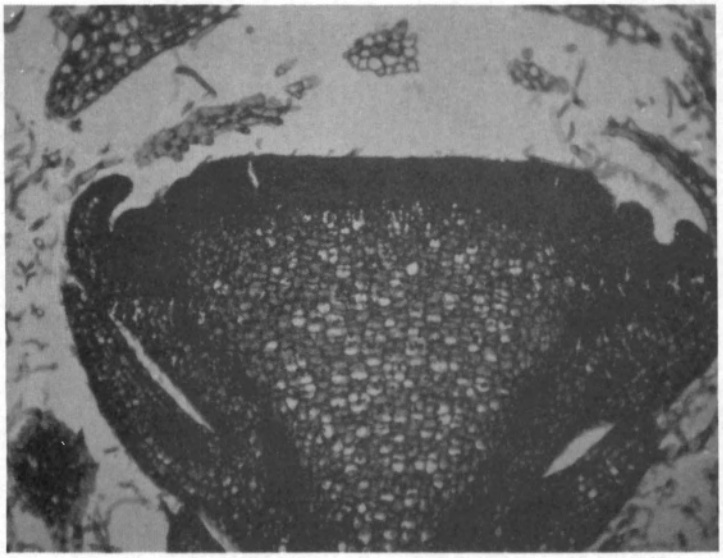

Figure 7. Immature floral head of the Senecio cruentus 'Hansa' after six weeks of vernalization (X 100).

of six weeks. Among the other four samples, two showed floral development just starting while the other two showed floral primordia that were slightly more advanced. In the period from the end of the fourth week to the end of the sixth week of vernalization, the samples that were taken either showed no signs of floral primordia or were in various stages of floral development.

Material taken the last two weeks of the study all showed floral primordia. Most of the material was about the size of that shown in Figure 5 and Figure 6.

Floral initiation in the cultivar Hansa definitely occurs before the end of the six-week cold induction. Floral primordia did begin as early as the second week in a few of the plants. Unquestionably floral primordia were present by the end of the fourth week in many of the plants. This tends to varify that cinerarias need less than six weeks of chilling; but due to variability among plants, six weeks insures that all of the plants have been successfully vernalized.

Juvenility

All plants produced floral buds by the end of the experiment except for one that was vernalized seven weeks from sowing. Delaying vernalization decreased the number of days from the end of induction until floral buds 2 mm in diameter appeared (Table 5). Plants introduced to chilling three weeks from sowing showed buds in an average 50.8 days;

Table 5. Juvenility in Senecio cruentus 'Hansa.'

Weeks from Sowing Vernalization Begun	Floral Buds 2 mm in Diameter: Average Number of Days from End of Vernalization	Floral Buds 2 mm in Diameter: Average Number of Days from Sowing
3	50.8	116.8
4	42.1	115.1
5	40.3	120.3
6	25.8	112.8
7[x]	25.0	119.0
8	21.5	122.5
9	21.0	129.0
10	14.0	129.0
11	13.5	135.5
12	11.7	140.7

[x]No floral bud visible in one plant.

those chilled 12 weeks from sowing showed buds in an average 11.7 days.

In contrast, the average number of days from sowing to bud date was less among the younger five groups of plants than among the five older groups. Among the older plants, the later the cold inductive treatment began, the later buds appeared after sowing. The plants vernalized six weeks after sowing showed 2-mm buds the earliest, an average 112.8 days from sowing.

It appears that in the cultivar Hansa, plants can be vernalized as young as three weeks from sowing. Since the plants treated 3, 4, and 5 weeks after sowing showed floral buds on the average later than those treated six weeks after sowing, juvenility may be delaying sensitivity to flowering in the early part of the cold induction. As the plant ages, sensitivity to chilling seems to increase. Initiation may occur early during vernalization but the floral bud is slow to develop due to the cool temperatures. Once given warmer temperatures, the bud quickly develops.

Although the Hansa is capable of flowering when it is yet a tiny plant, other cultivars may not have this capability, particularly the Giant Exhibition and Stellata. Their tallness may indicate that they have a longer vegetative period than the dwarf strains. Further experiments would be needed to prove this to be correct.

It was hoped that the early vernalization would not induce flowering right away but would activate certain pre-requisites to flowering that would trigger the actual flowering mechanism when the plant was older. This way, the seedlings or even the seeds could be vernalized in a small space, as in a growth chamber, and then grown with other greenhouse crops at about 18.5° C.

Further Discussion

Other gibberellins (GA_1, GA_4, GA_5, GA_9) are known to cause flowering in cold-requiring, rosette plants (20); but they are difficult to obtain since their numerous optical isomers make it impossible to synthesize them in the laboratory. Were any of them found to effect positively the flowering of the cineraria, the study would likely be of no value to the commercial grower since he could not obtain the chemical for his own use. Why the cineraria is not sensitive to gibberellin is uncertain. One reason may be that its cold requirement is not absolute as in the biennial Digitalis purpurea, foxglove, or Brassica oleracea var. capitata, cabbage (8, 27).

Noticeable stem elongation always occurred after gibberellin treatment of the cinerarias. This elongation did not usually enhance the quality of the cineraria as a flowering pot plant. When gibberellin was applied before floral initiation, the petioles and stems elongated and the

leaves became etiolated. Eventually these leaves died, leaving a bare stem at the base of the plant. After treatment stopped, the rosette habit returned.

However, the gibberellins applied after floral initiation may be effective in producing an adequate cut flower. The Stellata is not tall enough (about 36 cm) to be grown as a cut flower, but 10 ppm gibberellin applied weekly for about three weeks after vernalization will elongate the central stem to about 50 cm. At this stage of growth, the petioles will not be greatly affected and etiolation does not occur. Instead, the gibberellin will have its greatest effect on the peduncle and produce an effective spray of flowers above the foliage. Since flowers are produced along the entire length of the stem in the leaf axils, disbudding all but the top two or three laterals would be necessary.

V. SUMMARY

Both GA_3 and GA_7 used as 10-ppm sprays applied weekly or biweekly were found to be ineffective in overcoming the cold requirement in the florists' cineraria, Senecio cruentus 'Hansa.' Rather, they delayed flowering somewhat. Neither did a weekly application of the gibberellins hasten flowering when used during vernalization.

The gibberellins were also ineffective in the cultivar Stellata when applied twice weekly at 10 ppm during vernalization. However, application made mostly after the cold induction advanced flowering by six to seven days. This seems to indicate that GA_3 and GA_7 may be most effective in shortening the time elasping between the end of vernalization and anthesis.

Neither were the gibberellins effective in overcoming the cold requirement in the Stellata. There was 80% flowering in the treated plants as well as in the controls. Although a larger number of replications would be necessary before definite conclusions can be made, GA_7 seems to have some effect in hastening flowering of the nonvernalized Stellata.

Low light intensity (25-80 ft-c) during vernalization significantly delayed floral-bud development. Delay was greatest in the plants chilled for only two weeks, intermediate in those chilled for six weeks, and the least in those chilled for four weeks.

Hildrum's experiments (13) point out that cinerarias will flower under various temperature regimes. This was found to be true in both the Hansa and the Stellata. The most uniform flowering occurred when the plants were given a cold inductive period, but flowering also occurred when minimum temperatures were, for the majority of the time, 15° C or higher. The tolerance range for the cineraria is obviously high and necessitates carefully controlled temperatures when conducting experiments.

In the cultivar Hansa, four weeks of 10-13° C temperatures was just as effective as six weeks in initiating flowering. When the apical meristems were examined under the microscope, it was found that floral primordia were present as early as the second week of vernalization in a very few of the plants but in many of the plants by the end of the fourth week. Since variability exists as to when initiation occurs in each plant, the full six-week induction insures 100% initiation.

In a juvenility study on the cultivar Hansa, plants given six weeks of cold induction (9° C, 12 hours a night; 15.7° C, 12 hours a day) as young as three weeks from sowing were able to initiate flowering. Plants vernalized three to five weeks from sowing flowered about the same time. This seemed to indicate that the plants may have been insensitive to chilling until later in the inductive period. Plants vernalized six weeks from sowing flowered the earliest.

Thereafter, delaying vernalization delayed flowering although less time elapsed between the end of cold induction and visible-bud date. Although the Hansa can be vernalized at an early age, this may not be true for the Giant Exhibition and Stellata. Their tallness may indicate that they have a longer vegetative period than the dwarf strains.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Bahr, F. 1948. Fritz Bahr's Commercial Floriculture: A Practical Manual for the Retail Grower. 4th Ed. A. T. De La Mare Company, Inc., New York. p. 381-383.

2. Bailey, L. H. 1928. The Standard Cyclopedia of Horticulture. Vol. I. The Macmillan Company, New York. p. 771-772.

3. Ball, V., ed. 1972. The Ball Red Book. 12th Ed. Geo. J. Ball, Inc., West Chicago. p. 302-303.

4. _____. 1974. Cinerarias/calceolarias--Bill Reiss. Grower Talks 37(10):10-11.

5. Barkley, T. M. 1966. A review of the origin and development of the florists' cineraria, Senecio cruentus. Econ. Bot. 20:386-395.

6. _____. 1968. Observations on the compatibility system in the florists' cineraria, Senecio cruentus DC. (Compositae). Phyton Rev. Int. Bot. Exp. 25:135-140.

7. Brian, P. W., H. G. Hemming, and D. Lowe. 1964. Comparative potency of nine gibberellins. Ann. Bot. 28:369-389.

8. Bukovac, M. J., and S. H. Wittwer. 1957. Gibberellins and higher plants: II. Induction of flowering in biennials. Mich. State Univ. Agr. Expt. Sta. Quart. Bull. 39:650-660.

9. Chittenden, F. J., ed. 1956. The Royal Horticultre Society Dictionary of Gardening. Vol. I. 2nd Ed. The Clarendon Press, Oxford. p. 485-486.

10. Hall, O. G. 1968. The response of pot plants to night-break light: calceolarias, regal pelargoniums and cinerarias. Shinfield Progress No. 13, 26-29.

11. _____. 1969. The response of pot plants to night-break light: cinerarias. Shinfield Progress No. 15, 32-34.

12. Hentig, W.-U. von. 1959. Erste versuchsergebnisse mit gibberellin. Gartenwelt 59:233-234.

13. Hildrum, H. 1967. Virkning av temperatur og daglengde på vekst og blomstring hos sineraria (Senecio cruentus L'Her.). Gartneryrket 57:849-851.

14. Johansen, D. A. 1940. Plant Microtechnique. McGraw-Hill Book Company, Inc., New York. p. 130-132.

15. Karnovsky, M. J. 1965. A formaldehyde-glutaraldehyde fixative of high osmolarity for use in electron microscopy. J. Cell Biol. 27:137A-138A.

16. Lang, A. 1956. Induction of flower formation in biennial Hyoscyamus by treatment with gibberellin. Naturwissenschaften 43:284-285.

17. _____. 1957. The effect of gibberellin upon flower formation. Proc. Nat. Acad. Sci. U. S. 43:709-717.

18. _____. 1965. Physiology of flower initiation. In W. Ruhland, ed. Encyclopedia of Plant Physiology. Vol. 15, Part 1. Springer-Verlag, Berlin. p. 1380-1536.

19. _____, and E. Reinhard. 1961. Gibberellins and flower formation. Advan. Chem. Series 28:71-79.

20. Michniewicz, M., and A. Lang. 1962. Effect of nine gibberellins on stem elongation and flower formation in cold-requiring and photoperiodic plants grown under non-inductive conditions. Planta 58:549-563.

21. Post, K. 1936. Further responses of miscellaneous plants to temperature. Proc. Amer. Soc. Hort. Sci. 34:627-629.

22. _____. 1949. Florist Crop Production and Marketing. Orange Judd Publishing Company, Inc., New York. p. 811-814.

23. Potter, C. H. 1962. Flowering Pot Plants. Florists' Publishing Company, Chicago. (Reprinted from a series of articles in The Florists' Review, 1961 and 1962.) p. 66-69.

24. Sakai, W. S. 1973. Simple method for differential staining of paraffin embedded plant material using toluidine blue O. Stain Technol. 48:247-249.

25. Sidman, R. L., P. A. Mottla, and N. Feder. 1961. Improved polyester wax embedding for histology. Stain Technol. 36:279-284.

26. Singh, B. P. 1966. Influence of gibberellic acid on vegetative growth and flowering of winter annuals. Science and Culture 32:551-552.

27. Wittwer, S. H., and M. J. Bukovac. 1957. Gibberellin effects on temperature and photoperiodic requirements for flowering of some plants. Science 126:30-31.

28. Zeevaart, J. A. D. 1968. Vernalization and gibberellins in Lunaria annua L. In F. Wightman and G. Setterfield, ed. Biochemistry and Physiology of Plant Growth Substances. The Runge Press Ltd., Ottawa. p. 1357-1370.

VITA

Marianne Brod Leese was born to Clayton T. and Marion K. Brod on November 29, 1945, and raised on a farm in Erie County, Ohio. She attended Berlin Local School, Berlin Heights, Ohio, and graduated in 1963. In 1967, she received her Bachelor of Arts degree from The Defiance College, Defiance, Ohio, with a comprehensive major in social studies. For two years she worked as a claims representative for the Social Security Administration in Sandusky, Ohio, and in Bloomington, Indiana. In the fall of 1972, she entered the University of Tennessee, Knoxville, in the Department of Ornamental Horticulture and Landscape Design and graduated in June 1975 with a Master of Science degree in Agriculture.

She is married to Richard A. Leese of Dayton, Ohio, who is pursuing a Doctor of Philosophy degree in chemistry at the University of Tennessee, Knoxville.