DESCRIPTION AND CONTROL OF FLOWERING IN CALIFORNIA POPPY (ESCHSCHOLZIA CALIFORNICA)

by

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(ABSTRACT)

The California poppy (*Eschscholzia californica* Cham.) has floral marketplace potential provided it can be produced as a well-proportioned potted plant. Its attractive floral display and tolerance of extreme heat and drought make it a good candidate for research aimed at introducing it as a new ornamental crop.

The major objectives of this study were to document the apical meristem changes of California poppy during the transition to flowering, to determine the minimum number of inductive long-day (LD) cycles required for induction and initiation of flowering, and to examine the effects of exogenously applied gibberellin (GA_{4+7}) and auxin (NAA) on reproductive and vegetative development.

Histological examination of apical meristems exposed to varying numbers of LD cycles revealed many changes commonly associated with the onset of flowering. There was an

increase in RNA activity in the apical cells, an enhanced doming of the shoot apex, an increased elongation of primordia internodes, a disruption of the tunica-corpus organization, and the appearance of well-developed branch primordia.

Eight to ten LD cycles was identified as the critical range required for successful flowering in California poppy plants when exposure to the inductive photoperiod was begun at the 8 to 12 true, expanded leaf stage.

Exogeneous NAA was shown to have no significant effect on final reproductive status or vegetative development of California poppy. GA_{4+7} application resulted in an enhanced shift toward reproductive development and an increase in stem elongation, but it had little effect on peduncle elongation. These results indicate that stem and peduncle elongation may be controlled by different mechanisms and warrant further research.

The final chapter of the thesis concerning the design and evaluation of educational programs for the Virginia Tech Horticultural Gardens represents a departure from the major topic of study. This chapter is the result of the author's interest in, and the Garden's need for, an educational program suitable for the general public. This study can be considered the first step in the development of such an educational program.

ACKNOWLEDGEMENTS

The author wishes to express her appreciation to Dr. Robert Lyons for his guidance and encouragement during the course of this study. Dr. Richard Johnson and are acknowledged for their support and input as committee members. is sincerely thanked for her assistance in the greenhouse and laboratory. Finally, the author is extremely grateful for the unfailing love and support of her parents,

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CHAPTER 1

Changes in the Apical Meristem of California Poppy (*Eschscholzia californica* Cham.) During Induction and Initiation of Flowering

ABSTRACT

Histological examination of California poppy (*Eschscholzia californica* Cham.) plants exposed to varying numbers of inductive long-day (LD) cycles revealed changes in the apical meristem consistent with those associated with the onset of flowering. There was an increase in RNA activity after the first three LD cycles, enhanced doming of the apex after 6 LD cycles, increased elongation of primordia internodes after 7 LD cycles, disruption of the tunica-corpus organization after 8 LD cycles, and the appearance well-developed branch primordia after 9 LD cycles. Plants exposed to 5, 6, 7, 8, 9 and 10 LD cycles before transfer back to SD conditions required at least 8 LD cycles for complete development to anthesis when exposure to LD was begun at the 10 true, expanded leaf stage. Plants which were successfully induced, flowered with minimal stem elongation as a result of the limited number of LD cycles received.

INTRODUCTION

The California poppy (Eschscholzia californica Cham.) is a member of the Papaveraceae and a common native species of California and the Pacific Northwest (2). Its naturalization in many other diverse habitats is indicative of its ability to tolerate extremes in temperature and moisture availability (4). These tolerances, as well as its attractive floral display, make it an promising candidate for new ornamental crop research.

E. californica is known to be a qualitative long-day plant (LDP) which bolts from a rosette growth habit under inductive conditions (3, 8). The early experiments of Lewis and Went first revealed the photoperiodic nature of this plant (3). Specific short-day (SD) conditions failed to induce flowering regardless of night temperature treatments (7, 13, 19 and 26.5° C). Under LD conditions, however, flowering was induced, and anthesis was reached 42 days more quickly when the light period was extended from 18 to 24 hr and the temperature held at a constant 19° C. The fact that photoperiod rather than temperature played the key role was supported by the observation that several day/night temperature combinations failed to change the basic flowering response to photoperiod. Later research confirmed that 19° C was the optimal night temperature for flowering of *E. californica* under inductive conditions (10).

Sharma and Nanda investigated the effect of photoperiod on the reproductive development of *E. californica* (8). They worked with three different photoperiods: SD, consisting of 8 hr light alternating with 16 hr dark; normal days (ND) with natural day-length (11-13 hr light alternating with 13-11 hr dark); and LD, with continuous illumination. Floral buds emerged on the main shoots of LD plants after 50 days, approximately one-half the time observed for floral bud emergence in ND plants. In contrast, plants under SD failed to flower even after 135 days, at which time the experiment was terminated.

Certain photoperiodic effects were observed also on the growth and branching behavior of *E. californica* (8). Stem elongation began and reached its maximum first under LD, then under ND, and last under SD conditions. Branches emerged in a basipetal order after the flowering of the main shoot under LD conditions. Under SD, however, branches emerged acropetally. ND conditions resulted in branches which emerged acropetally, but flowered basipetally. Since quite different results were obtained earlier with the two SD species *Panicum miliaceum* and *Crotolaria juncea* (acropetal branch emergence under LD and basipetal branch emergence under SD), Sharma and Nanda concluded that daylength did not directly determine these responses. Instead, it was the physiochemical changes caused by the inductive daylength which resulted in the transformation of the shoot apical meristem from a vegetative to a reproductive state that was responsible for the pattern of lateral bud emergence.

Lyons and Neale attempted to determine when E. californica became most receptive to the inductive LD photoperiod (6). Seeds were germinated under SD conditions, and the resulting seedlings were moved to LD upon germination and at the 2, 4, 6 and 8 true, expanded leaf stages. A significant negative linear correlation was found between leaf stage and days to flower indicating that as the plant matured it became more responsive to the inductive photoperiod. Subsequent research has determined that the critical vegetative stage required to perceive the LD stimulus is 10 true leaves (5).

The bolting response in E. californica is superficially no different than that of many LD rosette plants; the overall bolting height is comprised of two separate tissues, stem and peduncle. To date, the predominant literature addresses only the phenomenon of stem tissue elongation in describing the bolting response (1, 11). While it is recognized that stem elongation and flower formation are two distinct processes in bolting species, specific mention is rarely made of peduncle tissue elongation. Preliminary data gathered with _E. californica_, however, suggest that stem and peduncle tissue elongation may be controlled by different mechanisms due to their differential responses to growth regulator application (6). These data point to an area of research which has received little previous attention.

Past studies with _E. californica_ have used macroscopic criteria to evaluate the response to certain photoperiodic treatments. Yet, many morphological changes occur at the apical, cellular level well in advance of this macroscopic evidence. By relying solely on the latter, the basic floral transition events have already been completed, and thus, have gone unexamined. Only through the documentation of these microscopic changes can a more complete understanding of the transition to the reproductive state be made for this plant. The more complete the understanding, the easier it is to manipulate the growth and flowering behavior to the grower's advantage.

Several early morphological events are commonly associated with floral induction and initiation, regardless of the species. These events include increased elongation of the primordia internodes, rapid elongation of axillary buds, enlargement and doming of the apical meristem, a marked change in the cytohistological zonation at the apex, and an increase in RNA activity in the apical cells (1). The objective of this study was to examine these changes during floral induction and initiation in California poppy and document when they occur in relation to the number of inductive cycles perceived.

MATERIALS AND METHODS

California poppy seeds were sown in a mixture of 3 parts peat moss: 1 part vermiculite: 1 part perlite (by volume) directly into 10 cm (4 in) pots and placed on greenhouse benches. The seeds were germinated and the resulting seedlings grown under SD conditions, achieved by covering plants from 1700-0800 hr with 100% cotton black sateen cloth, thus creating 9 hr days. When used, LD conditions were created by night interruption from 2200-0200 hr with 60 W incandescent bulbs strung overhead the plants to provide 3-4 $\mu mol \cdot m^{-2} \cdot sec^{-1}$ of photosynthetic photon flux. The ambient night temperature for germination and subsequent growth was maintained at a constant 19° C. Day temperatures varied with the prevailing external climatic conditions. After the seedlings reached the 2 to 4 true leaf stage, they were fertilized weekly with a 20-8.8-16.6 soluble fertilizer at the rate of 400 ppm N.

At the 10 true leaf stage, 100 plants remained in SD as paired controls with another set of 100 plants which were transferred to LD. Ten plants were simultaneously removed from SD and LD and fixed in formalin-acetic acid-alcohol (FAA) (7) after 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 LD cycles. In order to investigate the phenomenon of partial induction and determine the minimum number of LD cycles required for successful flowering, 60 additional plants were placed in LD for transfer back to SD after 5, 6, 7, 8, 9 and 10 LD cycles. These plants were allowed to flower, if so induced, and gross morphological data including peduncle length (cm), stem length (cm), and number of flower abortions were recorded at anthesis. The number of plants showing evidence of reproductive growth after each of the LD treatments was noted as well. Reproductive growth was defined as the appearance of a macroscopic floral bud. A chi-square analysis and an analysis of variance were used to examine these data. The experimental design was completely random.

The material fixed in FAA was prepared for histological examination with an automatic tissue processor. The procedure included dehydration of the tissue by immersion in ethanol solutions of increasing ethanol concentrations (70% to 80% to 95% to 100%), followed by xylene, then infiltration with paraffin (7). Infiltrated tissue was embedded in paraffin, sequentially and longitudinally sectioned at 8 μm until the approximate center of the apex was reached, and mounted on microscope slides to be examined via light microscopy.

Tissue sections which were used to characterize the morphological changes occurring in the apical meristem during floral induction were stained with Mayer's Hemalum and counter-stained with Erythrosin (7). The combined length of the three uppermost internodes and the combined length of the three uppermost axillary buds, if present, were measured with a digital micrometer.

Tissue sections which were used to determine changes in RNA activity were stained according to a Pyronin-Y/RNase procedure (9). This procedure involved staining one-half of the sections with Pyronin-Y, a selective RNA stain, and immersing the remaining sections in an RNase solution before staining with Pyronin-Y to provide cleared standards. Changes in RNA activity were determined by visually comparing the Pyronin-Y staining intensities of these two groups of sections over all SD and LD treatments.

RESULTS AND DISCUSSION

Analysis of the data collected on the additional 60 plants exposed to LD before transfer back to SD revealed that 5 or 6 LD cycles resulted in significantly fewer incidences of reproductive growth than 7, 8, 9 or 10 LD cycles (Table 1). While 7 LD cycles showed a tendency to induce flowering, many buds aborted prior to anthesis. It was not until 8 LD cycles that the induction to flower resulted in anthesis of most plants (data not shown). The phenomenon of partial induction was observed, therefore, for 7 LD cycles or less, leading to the conclusion that 8 LD cycles are critical to induce flowering to anthesis in _E. californica_ at the 10 true leaf stage.

This conclusion is supported partially by earlier work indicating that at the 8 to 10 leaf stage, _E. californica_ required 5 LD cycles for induction, but 10 LD cycles for complete development to anthesis (8). Since there is some discrepancy over the exact number of LD cycles required for successful flowering, a more accurate characterization of the required LD stimulus for anthesis to occur would be expressed best as a critical range rather than a specific number. In the case of _E. californica_, this range appears to be 8 to 10 LD cycles.

One should not extrapolate that this range would hold true for plants possessing fewer or greater than 10 true leaves at LD commencement. As mentioned previously, as California poppy matures it becomes more receptive to the

LD stimulus, flowering in a shorter period of time (6). The critical number of LD cycles required for complete floral development to anthesis in this plant appears to be a function of vegetative development.

The varying LD treatments before transfer back to SD had no significant effect on peduncle lengths (Table 1) which were within the range commonly observed with this species (4). However, stem elongation was greatly reduced, and in combination with the normal peduncle lengths, resulted in plants which were shorter and better proportioned than those which remained in LD until anthesis (Fig. 1). Therefore, by exposing the plant to only a specific range of LD cycles to ensure anthesis, then imposing SD conditions thereafter, excessive stem elongation can be avoided. This relatively simple and inexpensive manipulative technique could be used commercially to control overall plant height without the use of chemical retardants. Subsequent research has provided support for this proposed technique, pointing to a need for approximately twice the number of LD cycles for maximum stem elongation as for maximum peduncle elongation (unpublished data).

Histological examination of the apices of plants grown under SD and LD revealed those changes in the apical meristems exposed to inductive LD conditions. The apices of plants exposed to 1-5 SD cycles and 1-5 LD cycles did not appear visibly different in their dome sizes or internode lengths (Fig. 2). Enhanced apical meristem doming was first visible after 6 LD cycles, and there also appeared to be an increase in internode lengths (Fig. 3). Rapid elongation of the primordia internodes was evident after 7 LD cycles; control apices following 7 SD cycles appeared virtually unchanged from those receiving fewer SD cycles (Fig. 4). The tunica-corpus cell layers became disorganized by LD 8, while the apices following 8 SD cycles had a distinctive linear arrangement of cells in the outermost cell layers comprising the tunica covering the corpus portion of the meristem (Fig. 5). Apices were well advanced in the bolting response and possessed clearly defined branch primordia after 9 LD cycles (Fig. 6). Again, there was no apparent change following 9 SD cycles. Previous research has shown that a well-developed terminal floral bud is visible following 12 LD cycles (unpublished data) (Fig. 7).

There was no significant correlation between the number of SD cycles and the combined lengths of the three uppermost internodes, or the number of SD cycles and the three combined uppermost axillary bud lengths, if present. There was, however, a significant positive correlation between the number of LD cycles and internode lengths and the number of LD cycles and axillary bud lengths (Table 2). Therefore, as the LD exposure increased, the internode lengths and axillary bud lengths increased linearly.

Visual examination of the apices stained according to the Pyronin-Y/RNase procedure revealed no apparent differences in the Pyronin-Y staining intensities of the SD controls. Apparently, there were no differences in RNA activity with exposure to successive SD cycles (Fig. 8). A comparatively slight increase in Pyronin-Y staining was observed after just one LD cycle (Fig. 9), while a greater increase in Pyronin-Y staining was noted after 2 and 3 LD cycles (Fig. 10). RNA activity appeared to drop after 4 and 5 LD cycles since the density of Pyronin-Y staining returned to earlier, lighter levels (Fig. 11). It can be speculated that just prior to LD cycle 4, the increased RNA activity resulted in the synthesis of proteins necessary for a shift from vegetative to reproductive development. Perhaps once these proteins were formed, there was no longer a need for accelerated RNA activity, explaining the subsequent decrease in the RNA content of the apical cells.

In summary, when _E. californica_ is exposed to inductive LD conditions, the apex undergoes many changes often associated with the transition to flowering: an increase in RNA activity occurs in apical cells during the first 3 LD cycles; an enhanced doming of the apical meristem occurs after 6 LD cycles; primordia internodes elongate rapidly after 7 LD cycles; the tunica-corpus organization is disrupted after 8 LD cycles; and rapidly elongating lateral buds appear after 9 LD cycles. By documenting these changes, the floral response can be timed, controlled and manipulated more precisely.

Eight to ten LD cycles is the critical stimulus for floral induction to proceed to anthesis in _E. californica_ when begun at the 10 true, expanded leaf stage. By removing plants from LD shortly thereafter, the possibility of overall plant height reduction is enhanced.

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Table 1. The effect of a limited number of inductive long-days on California poppy prior to returning to short-days

No. long-days received	No. plants reproductive	Peduncle length (cm)	Stem length (cm)
5	4a[z]	11.5[y]	0.03
6	6a	10.4	0.00
7	8b	13.4	0.02
8	10b	12.5	0.25
9	9b	12.5	0.18
10	8b	11.9	0.06

[z]Results labeled with same letter within column not significantly different from each other according to chi-square analysis, 5% level. Maximum n=10.
[y]Results not significantly different within column according to SNK mean separation test, 5% level.

Fig. 1. Plants exposed to LD (left), continuous SD (middle) and 9 LD cycles before transfer back to SD (right).

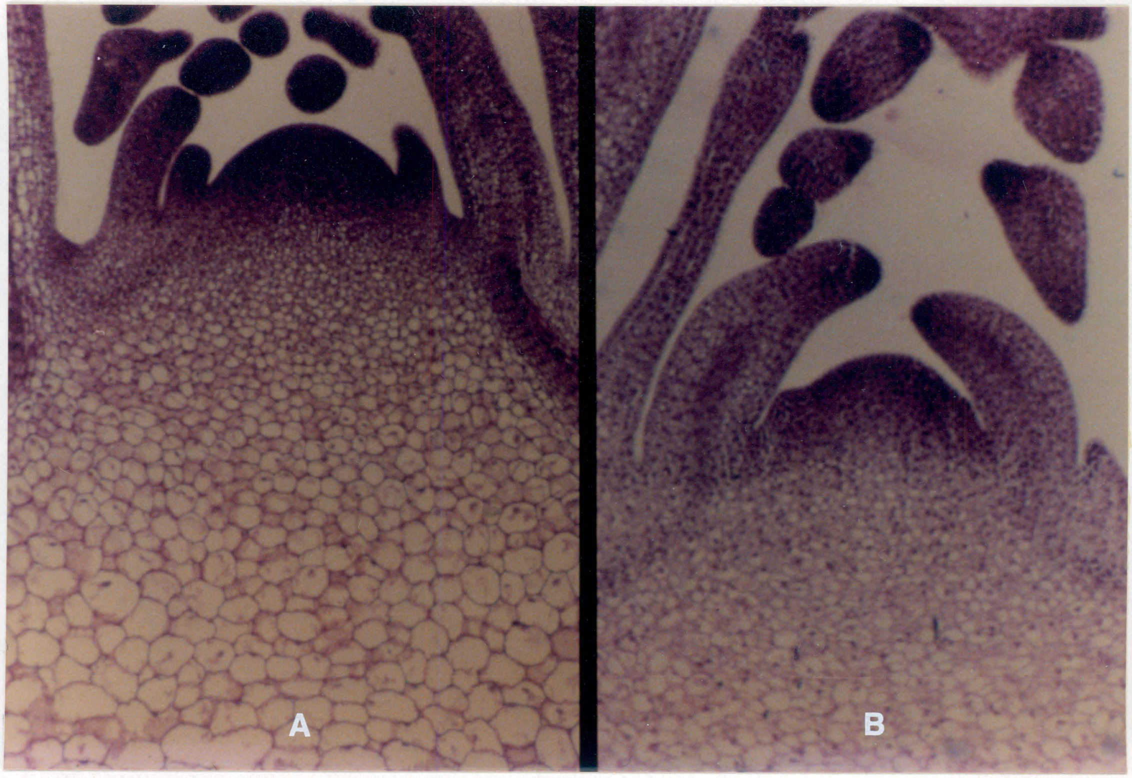

Fig. 2. Apical meristems of plants exposed to 1 SD cycle (A) and 3 LD cycles (B); x 26.8.

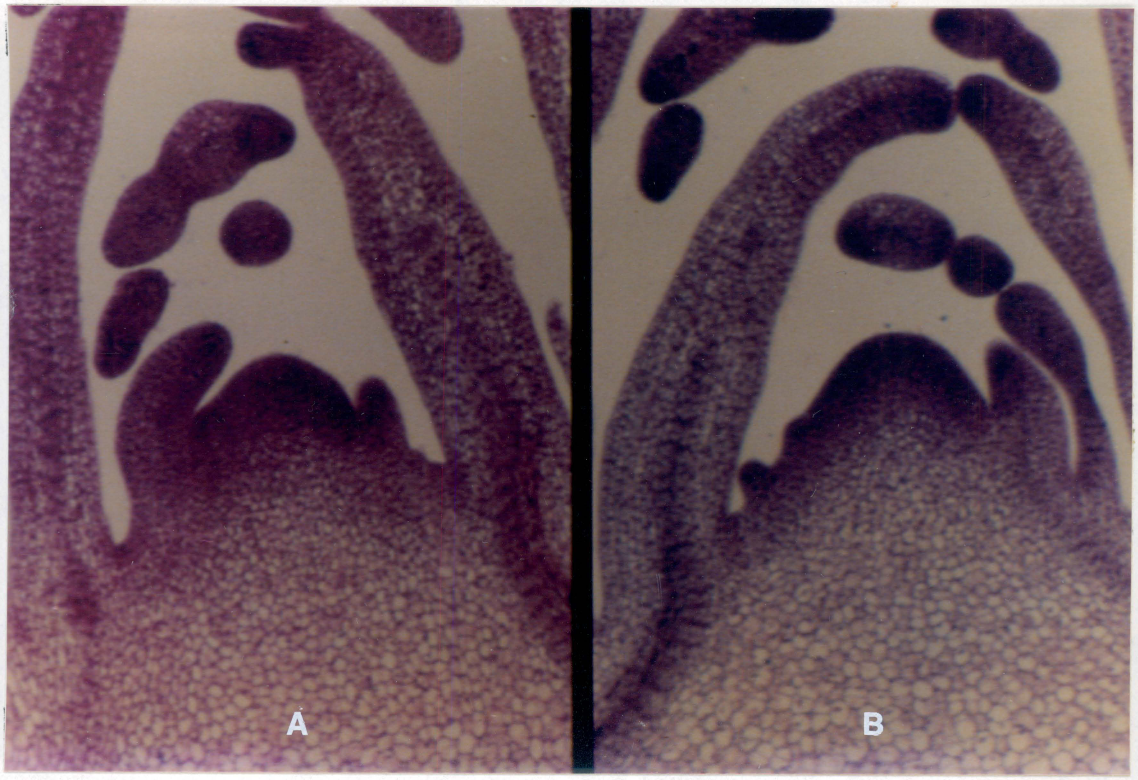

Fig. 3. Apical meristems of plants exposed to 6 SD cycles (A), and 6 LD cycles (B); x 26.8.

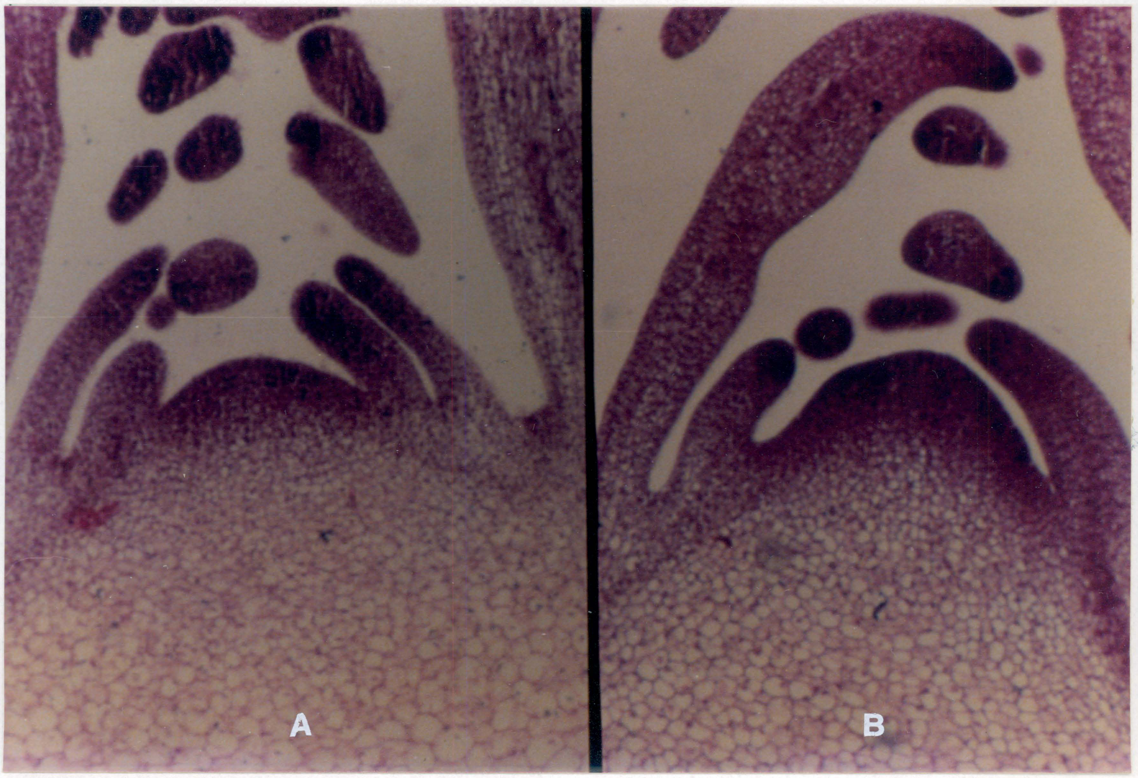

Fig. 4. Apical meristems of plants exposed to 7 SD cycles (A) and 7 LD cycles (B); x 26.8.

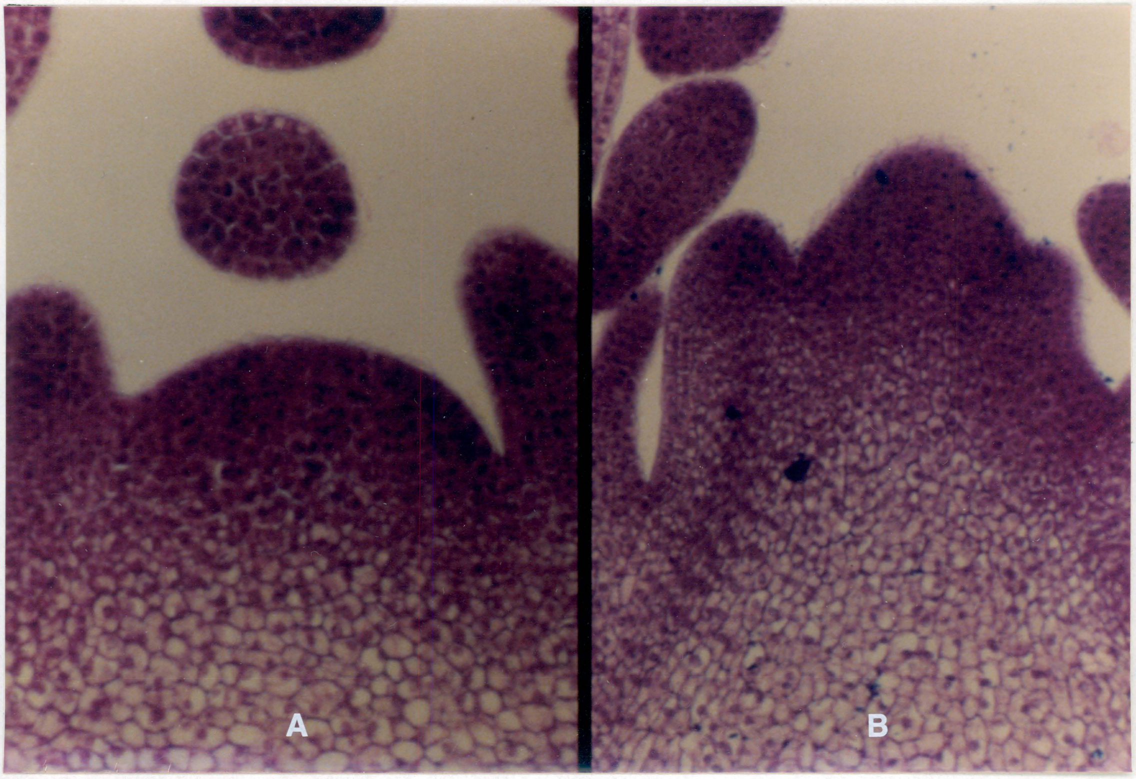

Fig. 5. Apical meristems of plants exposed to 8 SD cycles (A) and 8 LD cycles (B); x 67.

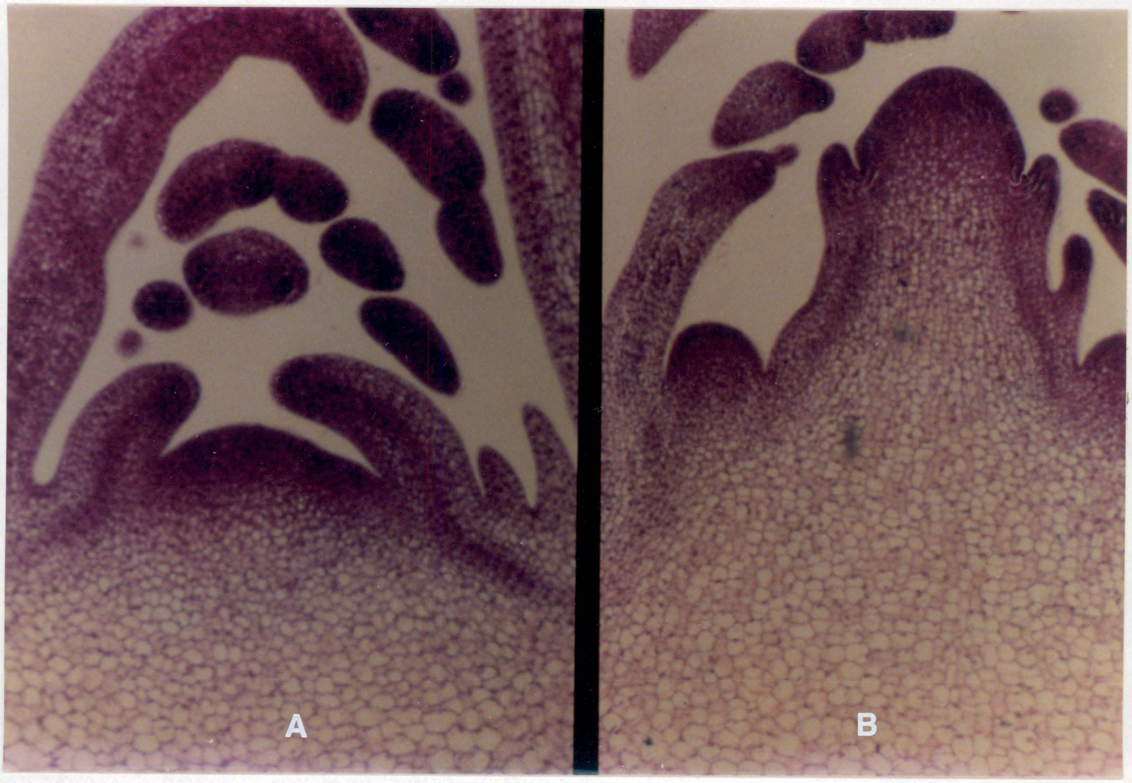

Fig. 6. Apical meristems of plants exposed to 9 SD cycles (A) and 9 LD cycles (B); x 26.8.

Fig. 7. Well-developed floral bud at apex of California poppy plant exposed to 12 LD cycles; x 13.2.

Table 2. Actual and predicted values of the combined lengths (μ) of the 3 uppermost internodes and the combined lengths (μ) of the 3 uppermost axillary buds, if present, of the apical meristems of California poppy plants as affected by the number of LD cycles according to regression analyses.

No. long-days received	Actual internode length	Predicted[z] internode length	Actual axil bud length	Predicted[y] axil bud length
1	175	155.8	0	0.9
2	180	171.5	0	19.2
3	140	187.3	80	37.5
4	213	203.0	260	55.9
5	200	218.7	155	74.2
6	250	234.5	0	92.6
7	255	250.2	150	110.9
8	230	266.0	130	129.3
9	350	281.7	310	147.6
10	265	297.4	80	166.0

[z]Regression equation: $y = 140.0 + 15.7x$; $R^2 = 0.36^{**}$.
[y]Regression equation: $y = -17.5 + 18.3x$; $R^2 = 0.23^{*}$.
**, *Significant at 1% and 5% levels, respectively.

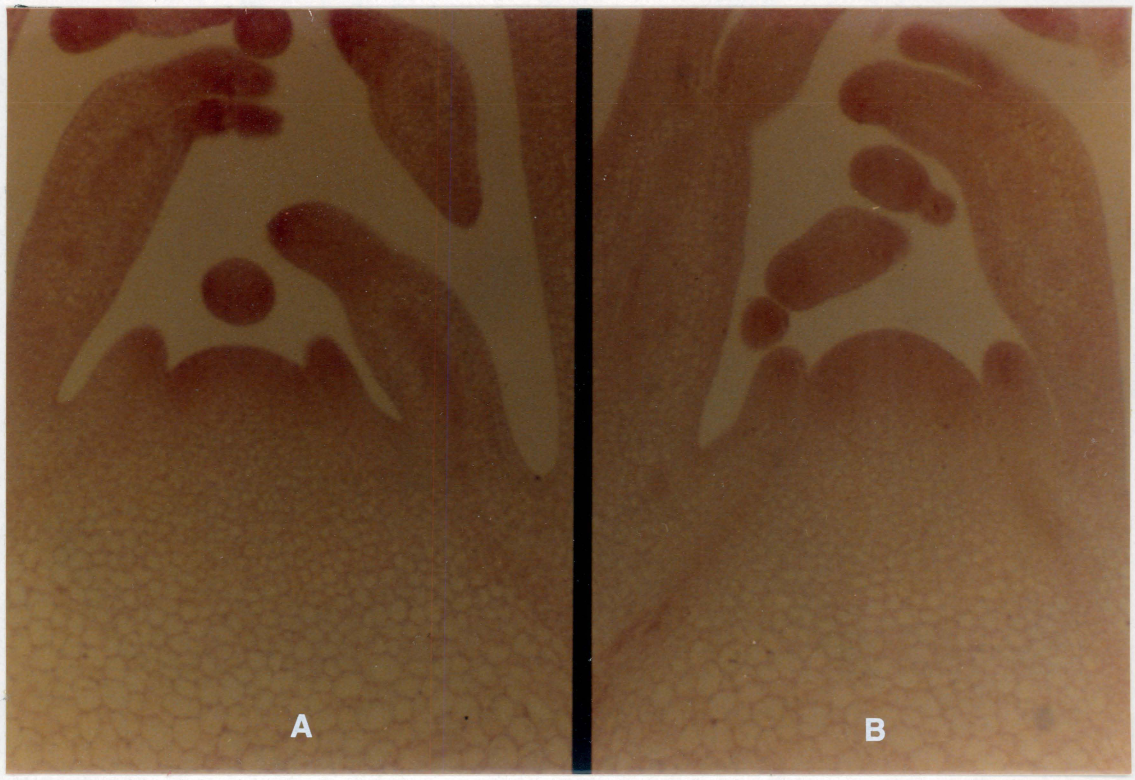

Fig. 8. Apical dome of plant exposed to 1 SD cycle stained with Pyronin-Y (A); apical dome of plant exposed to 3 SD cycles treated with RNase before staining with Pyronin-Y (B); x 26.8.

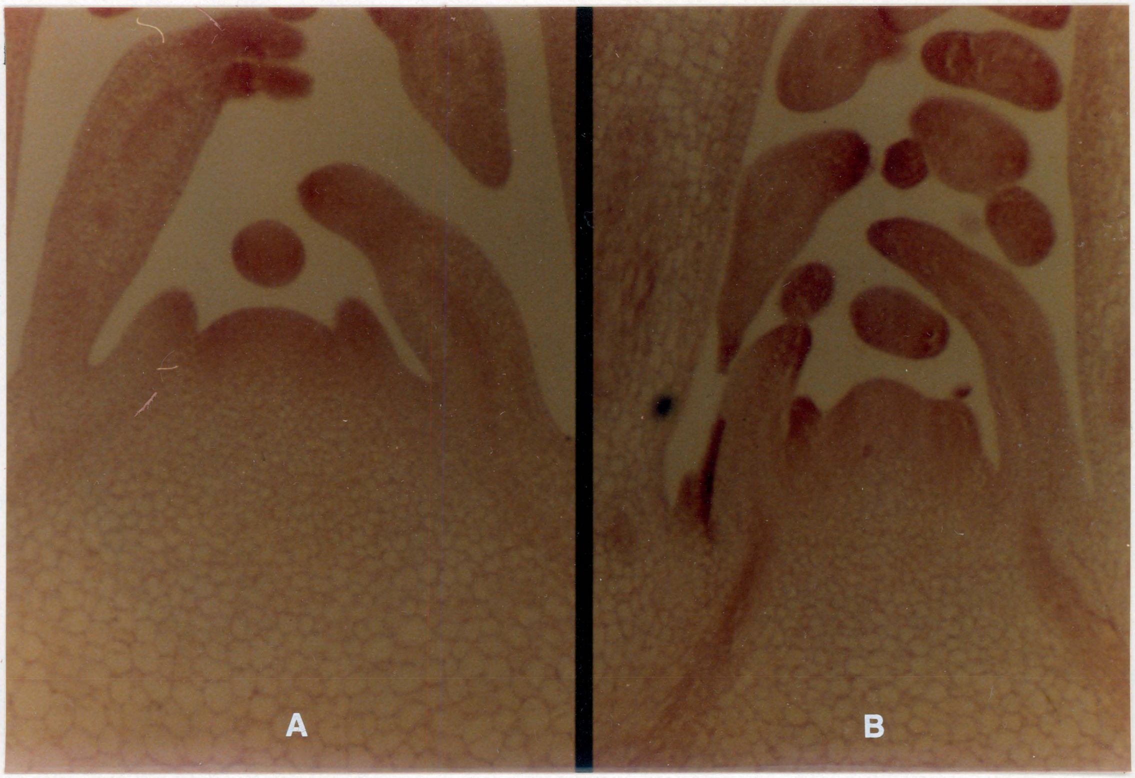

Fig. 9. Apical meristems of plants exposed to 1 SD cycle (A) and 1 LD cycle (B), both stained with Pyronin-Y; x 26.8.

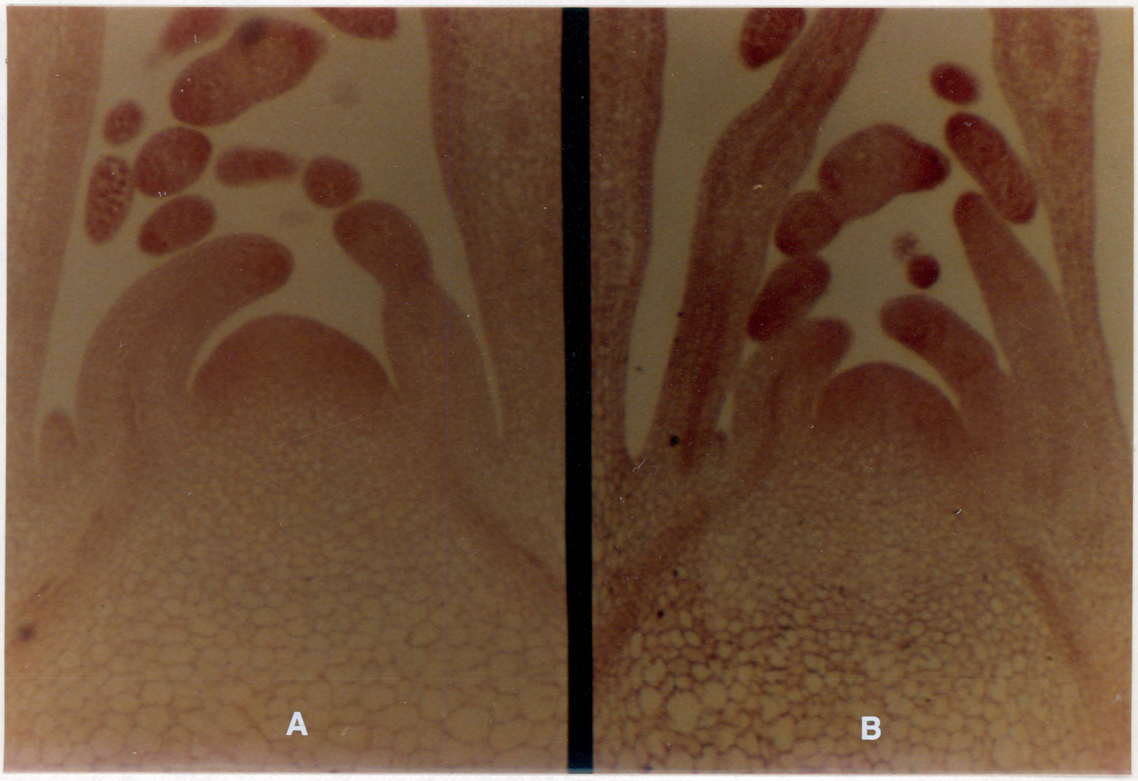

Fig. 10. Apical meristems of plants exposed to 3 SD cycles (A) and 2 LD cycles (B), both stained with Pyronin-Y; x 26.8.

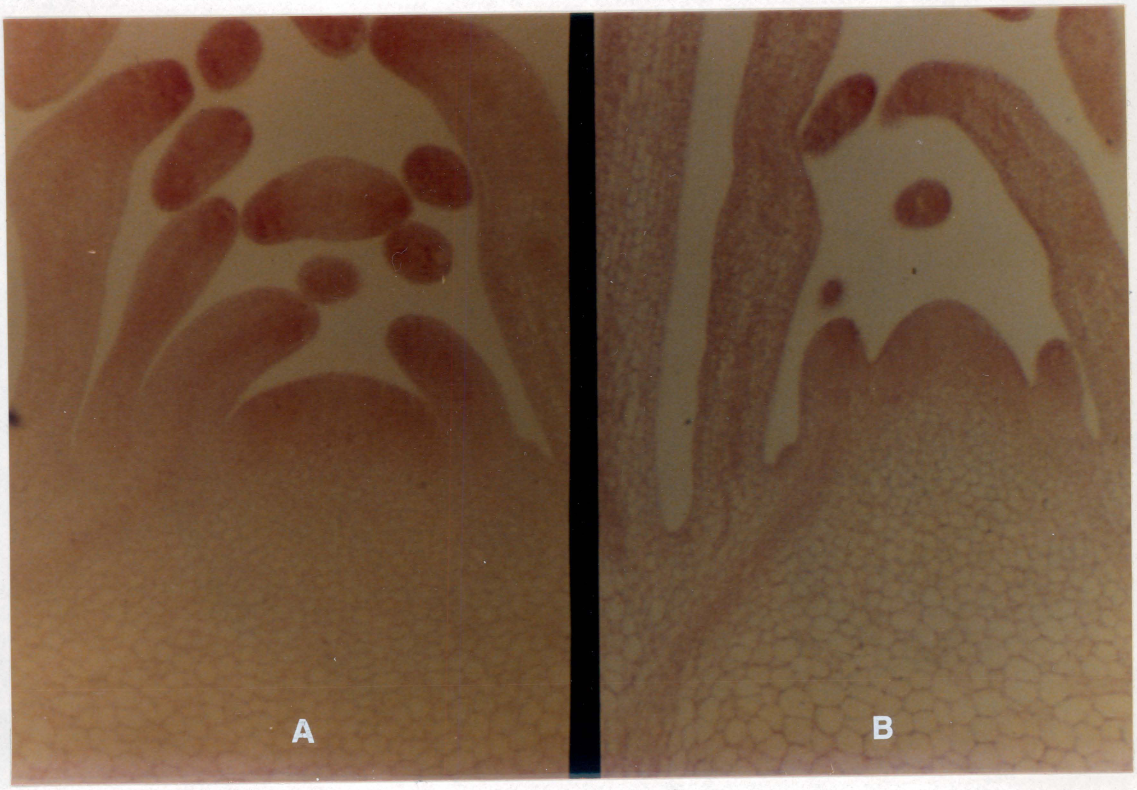

Fig. 11. Apical meristems of plants exposed to 5 SD cycles (A) and 5 LD cycles (B), both stained with Pyronin-Y; x 26.8.

CHAPTER 2

The Effects of Exogenously Applied GA and NAA on Flowering and Vegetative Development of California Poppy (*Eschscholzia californica* Cham.)

ABSTRACT

California poppy (*Eschscholzia californica* Cham.) plants were exposed to treatments consisting of four factors in complete factorial combination. These factors included gibberellin (GA_{4+7}), the auxin NAA, vegetative growth stage (number of true, expanded leaves at the time of treatment), and number of long-day (LD) cycles. Two categories of plant response to these treatment combinations were examined: final reproductive status and gross morphological measurements. There were no significant interactions among the four factors acting on either response category. Vegetative growth stage and single NAA applications at 1 and 10 ppm had no significant effects on final reproductive status. A single 100 ppm GA_{4+7} application resulted in an enhanced shift toward reproductive development, and 10 LD cycles was identified as the number critical to induce flowering to anthesis. The single NAA

applications at 1 and 10 ppm were completely ineffective in altering gross morphology. Vegetative growth stage resulted in significant differences, with more mature plants at treatment commencement producing longer stems and peduncles, and greater numbers of leaves and branches at experiment termination. The greatest number of LD cycles given, 12, resulted in significantly increased stem and peduncle lengths from lower cycles numbers, but no significant differences occurred in leaf or branch numbers with varying numbers of LD cycles. Single applications of GA_{4+7} at 1, 10 and 100 ppm produced significantly longer stems, but peduncle lengths remained relatively constant. Stem tissue, therefore, was more sensitive to GA_{4+7} at these concentrations than was peduncle tissue. While leaf numbers were not affected by the GA_{4+7} applications, branch numbers significantly increased after the 100 ppm treatment.

INTRODUCTION

The California poppy (*Eschscholzia californica* Cham.) is a member of the Papaveraceae and native to the landscapes of California and the Pacific Northwest (5). Its tolerance of extremes in environmental conditions (11) as well as its attractive floral display make it a strong candidate as a new crop in the floral marketplace. Its growth habit and flowering response, however, require research to reliably produce a well-proportioned potted plant on schedule.

E. californica is a qualitative long-day plant (LDP) which bolts from a rosette growth habit under inductive conditions (8, 17). As it matures, it becomes more receptive to the LD stimulus, flowering in a shorter period of time (12), with its most receptive stage occurring when it possesses 10 expanded, true leaves (10).

Growth regulators, particularly gibberellins (GA), have figured prominently in the research of LD rosette plants, including E. californica. It has been well-documented that certain gibberellins can induce bolting and flowering in some of these species under strictly noninductive daylengths (1, 4, 6, 7). For example, Kreasky and Bailey found that three weekly applications of GA_7 applied to the shoot apex of the LDP Papaver somniferum significantly increased flowering under short-day (SD) conditions (6).

A simple substitution of GA for the inductive photoperiod has not been demonstrated for E. californica, however. The effects of exogenously applied GA to this species appear to depend upon the number of applications and the prevailing photoperiod. One study reported that a single treatment of GA_{4+7} applied during SD significantly increased stem elongation and the rate of lateral branch emergence, but it did not induce floral bud formation (12). The same treatment applied during LD significantly increased stem elongation, but the rate of lateral branch emergence was decreased. Under LD, this treatment failed to accelerate flowering compared to the untreated controls, and peduncle length at anthesis was not affected. In other research, repeated applications of GA_3 resulted in floral bud formation under SD conditions, but the majority of these buds aborted prior to anthesis (15). Under LD, repeated applications successfully accelerated flowering.

The general effects of exogenously applied auxins on the flowering response are not as clearly defined as for gibberellins. Pertinent studies have produced greatly diverse results, mainly due to inherent differences in application timing, the presence or absence of young leaves, and the prevailing environmental conditions (1). These studies as a whole indicate that auxins can have either a promotive or an inhibitory effect on flowering. The promotive effects generally have occurred when the photoinductive conditions have been at the threshold required for flowering. Liverman and Lang demonstrated such a case when IAA was exogenously applied to the two LDP, <u>Hyoscyamus</u> <u>niger</u>

and *Silene armeria* (9).

Auxin (NAA) has been combined with GA to accelerate flowering in the day-neutral plant *Cyclamen persicum* (13, 14). Although this species is unrelated to *E. californica* and displays a different photoperiodic response, it shares the rosette habit with flowers arising from leaf axils on extended peduncles. As a solitary treatment, NAA had no significant effect on the number of days to flowering in *C. periscum*. When applied in combination with GA_3, specifically when the amount of GA_3 exceeded NAA, flowering was accelerated (13).

The bolting response which accompanies flowering in *E. californica* actually involves the elongation of two separate tissues, stem and peduncle. While the predominant literature (1) addresses only the phenomenon of stem tissue elongation in describing this response, preliminary data (3, 12) suggest that stem elongation and peduncle elongation may operate independently in *E. californica*.

The objective of this study was to examine the effects of two exogenously applied growth regulators, GA_{4+7} and NAA, on floral and vegetative development of *E. californica*. In addition, *E. californica* was used as a model system to examine the elongation responses of two directly connected yet different tissues, the stem and peduncle.

MATERIALS AND METHODS

California poppy seeds were sown in a mixture of 3 parts peat moss: 1 part vermiculite: 1 part perlite (by volume) directly into 10 cm (4 in) pots which were immediately placed on greenhouse benches. The seeds were germinated and the resulting seedlings grown under SD until the time of treatment. SD conditions were achieved by covering plants with 100% cotton black sateen cloth from 1700-0800 hr, thus creating 9 hr days. When used, LD were created by night interruption from 2200-0200 hr with 60 W incandescent bulbs strung overhead the plants to provide 3-4 $\mu mol \cdot m^{-2} \cdot sec^{-1}$ of photosynthetic photon flux. The ambient night temperature for germination and subsequent growth was maintained at 19° C. Day temperatures varied with the prevailing external climatic conditions. After the seedlings reached the 2 to 4 true leaf stage, they were fertilized on a weekly basis with a 20-8.8-17.6 soluble fertilizer at the rate of 400 ppm N.

The experimental design was completely random, and consisted of a four factor, 4 x 3 x 3 x 4 complete factorial with the following factors and levels:

1. $\underline{GA}_{4+7}$: 0 ppm, 1 ppm (2.9 µM), 10 ppm (28.9 µM), and 100 ppm (289 µM) applied once as 5 ml aqueous solutions to the terminal apex of the rosette.

2. <u>NAA</u>: 0 ppm, 1 ppm (5.4 μM), and 10 ppm (53.7 μM) applied once as 5 ml aqueous solutions to the terminal apex of the rosette.

3. <u>Vegetative Growth Stage</u>: the receptive leaf stage (10 true leaves), the receptive leaf stage plus 2 leaves (12 true leaves), and the receptive leaf stage minus 2 leaves (8 true leaves).

4. <u>Number of LD cycles</u>: none (continuous SD), the minimum number required for induction (8 cycles), the minimum number plus 2 cycles (10 cycles), and the minimum number minus 2 cycles (6 cycles).

There were 5 replications for each of the treatment combinations. The levels for vegetative growth stage and number of LD cycles were based on the results of previous research (3, 10).

The reproductive status of each plant was recorded using three categories: vegetative growth only (no macroscopic evidence of flowers), reproductive but aborted, and reproductive to anthesis. These data were analyzed using log-linear models for multi-way contingency tables. This type of analysis uses likelihood ratio tests in a step-wise model fitting procedure to choose the simplest model to explain the data (2).

Gross morphological data was recorded for each plant that flowered including stem length, peduncle length, number of leaves, and number of branches. These data were analyzed using a multiple analysis of variance.

RESULTS AND DISCUSSION

Examination of the reproductive status data during preliminary analysis revealed that the effects of the vegetative growth stage at the time of treatment were not significant. Therefore, the data were combined over all vegetative growth stages in the final model fitting procedure. Of the three remaining factors, only 2 main effects were significant: the number of LD cycles and the levels of GA applied. There were no significant interactions.

The effects of variable LD cycles on final reproductive status were very clear (Table 1). As the number of LD cycles increased from 0 to 10, the tendency for plants to remain vegetative decreased from approximately 76% to 6%. There was an approximate 10% increase in the number of abortions between 0 and 6 LD cycles, apparently due to the great increase in the proportion of plants which became reproductive at 6 LD cycles. The proportion of plants which flowered increased greatly from 0% at 0 LD, to over 50% at 6 LD. A continued gradual increase in flowering, accompanied by a gradual decrease in abortions, was noted as the number of LD cycles increased from 6 to 8 and 10. These results point to the need for approximately 10 LD cycles for *E. californica* to complete its floral development to anthesis.

The effects of exogenously applied GA_{4+7} at the 0, 1 and 10 ppm levels on final reproductive status were relatively the same (Table 2). At each of these levels, approximately 30% of the plants remained vegetative, 14-19% became reproductive but aborted, and about 50% became reproductive to anthesis. However, at the 100 ppm level, less than 4% of the plants remained vegetative, almost 60% became reproductive but aborted, and approximately 36% flowered. These results indicate that a single, high application of GA can induce and initiate flowering, even under non-inductive conditions, but does so inadequately since floral abortions increase.

Analysis of the gross morphological data for flowering plants indicated 3 significant main effects: vegetative growth stages, number of LD cycles and GA_{4+7} applications. There were no significant interactions.

Stem and peduncle lengths were greatest at the 10 and 12 true leaf stages (Table 3). Although not easily explained for the latter, longer stems could be the result of the elongation of the greater number of internodes possessed by these more mature plants at the time of treatment. Likewise, a greater number of leaves at the time of treatment would also be expected to result in a greater number of leaves and axillary branches at experiment termination (Table 3).

The number of LD cycles affected ultimate stem and peduncle elongation in much the same way with only slight differences occurring in response magnitudes (Table 4). Ten LD cycles resulted in the greatest stem and peduncle lengths, while LD cycles 6 and 8 produced shorter lengths which were not significantly different. There were no significant differences in leaf numbers or branch numbers.

In response to GA_{4+7}, stem and peduncle tissues displayed different degrees of elongation upon exposure to varying concentrations (Table 5). Maximum stem elongation occurred at 100 ppm GA while maximum peduncle elongation occurred at 10 ppm. There was also a consistent increase of approximately 4 cm in stem lengths as applied GA increased from 1 to 100 ppm. Peduncle lengths remained relatively constant despite rising GA concentrations; the only significant increase occurred at 10 ppm. By comparison, the magnitude of the increase in peduncle elongation was smaller than that observed for stem elongation. These results indicate that the stem tissue of _E_. _californica_ is more responsive to exogenous GA application than the peduncle tissue. Although plant leaf number was not significantly affected by the GA treatments, there was a slight yet significant increase of 2 branches at the 100 ppm level.

Based on the results of this experiment, several conclusions can be drawn. First, the vegetative growth stage (8, 10 or 12 true leaves) at the time of treatment has little effect on the final reproductive status of E. californica. This conclusion supports previous work which found that even California poppy plants placed in LD at the cotyledon stage eventually flowered, they simply required a greater number of days for development to anthesis than did plants induced at later vegetative stages (10).

Next, single applications of 1 and 10 ppm NAA have no affect on the final reproductive status of California poppy or on stem and peduncle length or leaf and branch number. This finding is not unusual in view of the diverse results obtained with exogenously applied auxin and its inconsistent role in flowering to date (1). Lang has stated that while auxin can modify the flowering response of many species, it is doubtful that it has an important or direct role in photoinduction (7).

Ten LD cycles is the critical number for successful flowering to anthesis when begun at the 8 to 12 true leaf stages. This conclusion supports previous findings that 5 LD cycles were required for induction, but 10 LD cycles were necessary for complete floral development to anthesis (17). Other results pointed to a need for 8 LD cycles at the 10 leaf stage to induce flowering to anthesis (3). In light of this slight discrepancy, a more accurate description of the stimulus needed would be expressed best as a critical range rather than a specific number. For California poppy, the critical range appears to be 8-10 LD cycles for plants first photoinduced at the 8 to 12 true leaf stage. Extrapolations from this conclusion for plants younger or older should not be made, however. It is already known that as E. californica matures, it becomes more receptive to the LD stimulus and flowers in a shorter period of time (12). Therefore, the critical range of LD cycles for floral induction, initiation and complete development appears to be a function of its vegetative growth stage when first exposed to LD.

As GA_{4+7} concentrations increase from 10 to 100 ppm in single application treatments, the reproductive development of E. californica is enhanced. While it is widely accepted that GA can stimulate flowering in several LD rosette plants under strictly noninductive conditions (1, 4, 6, 7), the conclusion drawn from the California poppy response must be qualified. Statistically, GA_{4+7} was a significant main effect. In looking at individual plant responses, however, it was clear that the GA did not substitute completely for the inductive photoperiod. Under continuous SD there was no flowering to anthesis regardless of the GA concentration applied. The highest concentration did result in some plants showing evidence of flower formation under SD, but they aborted prior to anthesis. It is possible that repeated applications of GA_{4+7} could have produced different results.

A 100 ppm GA_{4+7} application increases branching of _E. californica_, a response which has been observed previously with this species as well as many others (1, 12).

Finally, stem and peduncle elongation are affected differently by single applications of GA_{4+7} at concentrations of 1, 10 and 100 ppm. This conclusion supports the concept that stem and peduncle elongation may be controlled by different mechanisms. Because GA has been shown to stimulate bolting and flowering in many LD rosette species, it was at first thought that GA had some endogenous, causal role to play in flowering (7). More recently, it has been reported that in some of the LD rosette species, stem elongation can occur without flowering and vice versa (3, 4, 16). It is now accepted by these authors that GA is involved in stem elongation, but it has little direct influence on flowering.

While this work has shed light on some aspects of the flowering response of _E. californica_, there are still questions which remain unanswered. This particular question of stem vs. peduncle tissue elongation offers great promise for future research. Recent experiments with this species have shown a need for twice as many inductive LD cycles for maximum stem elongation as for maximum peduncle elongation (unpublished data). When one considers that a single application of GA_{4+7} fails to substitute completely for the inductive photoperiod, and that it stimulates stem elongation which is generally not aesthetically pleasing in a potted plant, these recent results point to the possibility that photoperiodic control may be the most reliable technique for the manipulation of overall plant height in this species.

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Table 1. Effect of the number of long-day cycles (LDC) on the percentage of E. californica plants remaining vegetative, forming but aborting flower buds, and forming buds which reached anthesis.

	Number of LDC			
Status	0	6	8	10
Vegetative	76.1%[z,y]	12.9	3.9	6.3
Floral abortion	23.9	33.5	31.8	20.6
Flowering	0.0	53.6	64.3	73.1

[z]Column percent
[y]Values significantly different (P=0.05) within columns, chi-square test for homogeneity of proportions.

Table 2. Effect of GA_{4+7} applications on the percentage of *E. californica* plants remaining vegetative, forming but aborting flower buds, and forming buds which reached anthesis.

Status	GA_{4+7} applications (ppm) 0	1	10	100
Vegetative	35.2%[z,y]	32.8	27.2	4.0
Floral abortion	18.4	18.9	13.9	59.8
Flowering	46.4	48.3	58.9	36.2

[z]Column percent
[y]Values significantly different (P=0.05) within columns, chi-square test for homogeneity of proportions.

Table 3. Effect of initial vegetative growth stage on stem and peduncle lengths (cm), and number of leaves and branches at first flowering of *E. californica*.

Initial no. leaves/plant	Stem length	Peduncle length	No. leaves	No. branches
8	4.6b[z]	5.0b	21.3c	11.6c
10	6.1a	6.5a	24.8b	13.5b
12	7.3a	7.2a	26.9a	15.5a

[z]SNK mean separation test within columns, 5% level.

Table 4. Effect of number of long-day cycles (LDC) on stem and peduncle lengths (cm), and number of leaves and branches at first flowering of *E. californica*.

Number LDC	Stem length	Peduncle length	No. leaves	No. branches
0	---	---	---	---
6	5.9b[z]	7.2b	25.2a	13.7a
8	7.3b	8.3b	24.6a	14.0a
12	10.9a	9.6a	24.2a	13.6a

[z]SNK mean separation test within columns, 5% level.

Table 5. Effect of GA_{4+7} application on stem and peduncle lengths (cm), and number of leaves and branches at first flowering of *E. californica*.

GA_{4+7} application	Stem length	Peduncle length	No. leaves	No. branches
0	2.5c[z]	5.5b	25.2a	13.7b
1	3.4c	5.7b	24.7a	13.8b
10	7.2b	7.6a	24.1a	12.9b
100	11.1a	6.1b	24.8a	15.1a

[z]SNK mean separation test within columns, 5% level.

CHAPTER 3

The Design and Evaluation of Educational Programs for the Virginia Tech Horticultural Gardens

ABSTRACT

As the first step in the development of an educational program for the Virginia Tech Horticultural Gardens, a survey was conducted to examine the existing educational programs of a selected group of public gardens and/or arboreta. Various aspects of these existing programs were evaluted for their usefulness and potential application to the Virginia Tech Horticultural Gardens' future educational program. Aspects deemed suitable were included as recommendations for either short- or long-term implementation. In addition, subject matter to be addressed in future educational publications distributed by the Gardens and suggestions concerning the initial steps to be taken in the implementation of the educational program were discussed.

INTRODUCTION

The Virginia Tech Horticultural Gardens, located on the Virginia Polytechnic Institute and State University campus in Blacksburg, Virginia, first became a tangible concept in 1983. Those involved in the development of these Gardens saw them as becoming an invaluable tool for meeting the instruction, research, and extension objectives of the University in general, and the Department of Horticulture in particular. Upon its completion, the Virginia Tech Horticultural Gardens will include annual and perennial displays, xerophytic and hydrophytic gardens, an ecocline area which will illustrate transitions in growing conditions, a trident maple allée, a vine and groundcovers area, and an arboretum.

The development of an educational program for the general public is a high priority item in the continuing evolution of the Gardens. It is essential that visitors, regardless of age, understand the concepts presented in the Gardens so that the extension component of its function is fulfilled. This study can be viewed as the first step in the development of such an educational program.

The stated objectives of this study were:

1. Obtain statements of the educational philosophy and goals of selected public gardens and arboreta.

2. Offer input into an appropriate statement of the educational philosophy and goals of the Virginia Tech Horticultural Gardens.

3. Obtain a broad sampling of educational materials used by selected public gardens and arboreta.

4. Identify the educational program needs for the Virginia Tech Horticultural Gardens, both short-term and long-term.

5. Target specific information for an educational publication which the Virginia Tech Horticultural Gardens can use in future educational materials.

6. Offer suggestions for implementing an educational program at the Virginia Tech Horticultural Gardens.

MATERIALS AND METHODS

A letter requesting samples of the materials used in educational programs was sent to the educational coordinators and/or directors of approximately 60 public gardens and/or arboreta (Appendix A). Each was selected based on how well their clientele matched that which would most likely utilize the Virginia Tech Gardens. Selection was based also on the kind and extent of the educational programs as described in North American Horticulture: A Reference Guide (1). A list of the gardens contacted along with their current mailing addresses has been included in Appendix B. All responses were evaluated for their relevancy and adaptability to the Virginia Tech Horticultural Gardens' future educational program, and appropriate materials served to generate ideas for educational publications and activities. In addition, a selected few of the respondents were contacted by telephone for more in-depth information concerning the costs involved in publishing their brochures and booklets, how decisions were made concerning course offerings to the public, their labeling practices, and other standard procedures.

RESULTS AND DISCUSSION

Of the 58 gardens contacted, 27 (47%) replied by sending a large amount of materials dealing with many program aspects. This response rate followed just the single letter request. Another aspect of the request received a more ambivalent response, however. The organizations contacted were asked to send a copy of their written statements of educational philosophy and goals. Only a few respondents complied with this request, and of those who did, most sent only simple listings of activities and programs. This situation was unfortunate, but despite the lack of input from other organizations, a suggested statement of purpose for the Virginia Tech Horticultural Gardens was formulated:

> In keeping with the stated purpose of Virginia Polytechnic Institute and State University, the Virginia Tech Horticultural Gardens will strive to fulfill the three missions of a comprehensive land-grant institution: <u>instruction</u>, <u>research</u>, and <u>extension</u>.
>
> For <u>instruction</u>, the Gardens will provide a teaching laboratory for construction and maintenance operations, as well as a site for plant identification and use.
>
> For <u>research</u>, the Gardens will be used to evaluate the performance of new plants with ornamental value within the Southwest Virginia environment.
>
> For <u>extension</u>, the Gardens will be used to increase public awareness of herbaceous and woody ornamentals for landscape settings. They will also provide gardening and design information to the general public applicable to the home residence.

All of the materials received were sorted and placed into one of these twelve categories: Visitor's Guides, Self-Guided Tours, Events Calendars, Course Offerings, Children's Programs, Newsletters, Gardening/Practical Horticultural Information, Plant Lists/Plant Sources, Labeling, "Friends of the Gardens" Programs, Foreign Tours, and the miscellaneous category of Postcards, Booklets, and Posters. The best representatives of each category were chosen for presentation. They represent desirable examples holding attributes worthy of incorporation into the educational program of the Virginia Tech Horticultural Gardens.

Visitor's Guides. Practically every organization that responded to the survey had some type of pamphlet or brochure for their visitors. The Chicago Botanic Garden's visitor's guide was one of the most attractive and professionally produced brochures received. It has the most promise of adaptability to the Virginia Tech program. It is a four-color glossy publication that is colorful and eye-pleasing despite its lack of photographs. The Chicago Botanic Garden paid approximately $7600.00 to have 100,000 of these guides printed, a unit cost of less than $0.08 each. This can be considered a moderate price based on cost information obtained from other gardens.

Old Westbury Gardens located in Long Island, New York has an interesting way of handling visitor's guides. They use two separate brochures: one color glossy for publicity purposes which is handed out at trade shows or included in mailings; and single tone black and white brochure with a matte finish which is given to visitors upon entering the Gardens. Each brochure contains slightly different information relevant to the targeted population.

The most attractive visitor's guides received were from Brookside Gardens located in Wheaton, Maryland, and the U.S. National Arboretum located in Washington, D. C. Both brochures are full-color glossies with photographs, and both are expensive. Brookside paid approximately $12,000.00 for 100,000 of their brochures in 1982, and the National Arboretum paid $8000.00 to have half that number printed. The Brookside visitor's guide has the unique feature of unfolding to a large 11" x 14" format, an ingenious way of increasing the amount of information which can be presented without adding to the overall bulk of the brochure.

Self-guided Tours. Many organizations include maps and diagrams of their gardens in the general brochure or visitor's guide, which can then be used as a means to move throughout the area. Some gardens, however, use a separate brochure with more detailed information concerning aspects of major interest in their gardens.

Callaway Gardens in Georgia has an attractive color glossy brochure for their visitors to take on self-guided tours. The Holden Arboretum in Ohio has a woodland trail interpretative guide for their visitors. This guide is an excellent example of how color and texture can be used to create an image in keeping with the subject being described. It is printed on heavy, roughly textured paper, and with the brown and tan tones used, the overall effect is reminiscent of a woodland setting.

Events Calendars. The public gardens and arboreta that sponsor a number of activities and courses throughout the year often keep their public informed through events calendars. The Tyler Arboretum in Pennsylvania publicizes their events by seasons. A calendar received from Old Westbury Gardens contains events listings for the entire year, while Callaway Gardens' "Callaway Calendar" has listings for one week only during peak seasons. Other weeks during the year are most likely not as event-filled at Callaway Gardens, and are not handled separately.

Course Offerings. Noncredit course offerings to the public make up a large proportion of the total educational programs of many of the public gardens and arboreta contacted. Longwood Gardens in Pennsylvania has one of the most extensive range of offerings of any of the respondents. In fact, their educational program assumes many of the responsibilities normally associated with a university program, and is a reflection of the tremendous resources available to this organization.

The Chicago Botanic Garden also offers an impressive course listing, although not as diverse as Longwood. Their course offerings brochure is as nicely done as their visitor's guide, colorful, distinctive and easy to follow.

All classes offered by the U. S. Botanic Garden are free to the public because the Garden is funded solely by Congress. They are not allowed to solicit any additional funds and, as a result, their course offerings are very basic in nature, such as "Growing Begonias" and "Orchids as Indoor Plants". Their example is an appropriate one for the Virginia Tech Horticultural Gardens to follow, at least in its formative years.

The Holden Arboretum course offerings brochure is an example of the type of format which should be avoided. Several other large "you-unfold-it" packets were sent by various organizations similar to the one sent by Holden, and they are all awkward to handle and confusing to follow.

Children's Programs. Most of the materials received focused on children's programs. This area is one in which many organizations invest a great deal of thought, time, and labor. For example, the "Phil and Rhoda Dendron" logo used by Brookside Gardens on all their educational materials for children is a creative way to cultivate interest in and identification with the program.

Simple worksheets for young children, ages 3 to 8, are used by the Missouri Botanical Garden and are an inexpensive way to reinforce the learning experience provided by a visit to the Garden.

"Nature Naturally" is a children's "newsletter" published three times each year by Callaway Gardens. It is free for students in grades 4 to 6 who attend schools in the Southeastern United States.

Several different kinds of booklets for children and their teachers were received from a number of the institutions contacted. "Bringing the Garden Back Home" and "Living With Plants" are booklets used by the Brooklyn Botanic Garden. Both contain games and activities related to the themes suggested by their titles. "A Teacher's Guide to Trees" is published by Brookside Gardens. It contains an explanation of photosynthesis, and has master copies of worksheets and suggested activities.

Another item sent by the Missouri Botanical Garden was one of the most intriguing of all the materials received. They give their young visitors a "collector's bag", a paper bag with handles, to carry during their tour of the Garden. An obviously well designed instructional tool, it is accompanied by a set of rules and suggestions to prevent mass destruction of the Garden while still allowing students the freedom to collect interesting objects.

Newsletters. One of the best ways of keeping the general public informed of various events and activities sponsored by a public garden is through the use of periodic newsletters. The Holden Arboretum uses a single-page, front and back mimeographed newsletter titled "Environmental Thinking and Learning" as a means of communicating with their membership. This is a very simple format and would be quite easy to adapt for the Virginia Tech Horticultural Gardens.

The New England Wild Flower Society's newsletter is attractive and similar to "The Virginia Gardener" newsletter in appearance, but of the two, "The Virginia Gardener" has the superior printing quality. It would be an excellent use of resources if the Virginia Tech Horticultural Gardens cooperated with "The Virginia Gardener", at least during the formative years of the Gardens, in distributing gardening news to the public. For example, the Gardens could contribute a regular column to "The Virginia Gardener" rather than printing an entire newsletter.

Gardening/Practical Horticultural Information. One way public gardens and arboreta meet their extension obligations is by providing gardening and practical horticultural information. Callaway Gardens uses several different formats including brochures, booklets, and fact sheets for this purpose.

Interested persons can obtain Callaway's booklet titled "Vegetable Gardening", which is actually a reprint from Southern Living magazine. The article contained in the booklet was the result of a joint venture between the garden department at Southern Living and the educational and horticulture departments at Callaway Gardens.

The "Logistics of Building..." series from Old Westbury Gardens is another example of how magazine reprints are being used, in this instance House and Garden.

An inexpensive and practical format for exchanging gardening information is illustrated by the "Garden Notes From Brookside". Simply laid out, the "notes" are eye-pleasing and present a favorable image of Brookside Gardens.

Plant Lists/Plant Sources. The general public frequently asks where specific plants can be obtained and what varieties do best in their particular area. For this reason, providing lists of plant sources and varieties suitable for Southwest Virginia would be one of the best and easiest ways for the Virginia Tech Horticultural Gardens to establish educational contact with the general public. Two examples of efforts worthy of emulation originate from Callaway Gardens and the Missouri Botanical Garden, the latter being the best starting point for the Virginia Tech Gardens as it has the simpler format and would be less expensive to produce.

Labeling. Suzanne Friis, Horticulturist at Brookside Gardens, mentioned that labeling plants is one of the most important forms of what she calls "passive education". Long-lasting, easy to read labels are a valuable educational tool for any public garden. Els Benjamin, Director of Brookside Gardens, suggested two types of labels: engraved plastic and metal photo. The engraved plastic labels are used at Brookside with seasonal, temporary displays. These labels last approximately two to three years, and they are made in-house by one of the Brookside gardeners during slower periods of the year. Metal photo labels are used with permanent plantings outside, and at one time they were made in-house as well. Brookside has since discovered that it is more economical to have them made commercially due to the high cost of labor. They are presently using a firm by the name of Timsco, Inc. located in Washington D. C. One 3"x 5" metal photo label costs approximately $7.00 which is quite an investment considering the vast species list of any public garden. These labels remain in good condition for many years, however, and seldom need replacement. Brookside mounts their labels on aluminum stakes, but the U. S. Botanic Garden has recently switched to transparent stakes which detract less from the plant material.

<u>"Friends of the Gardens" Programs</u>. An excellent idea for fund-raising and promotional purposes is a "Friends of the Gardens" membership drive. Both the U. S. National Arboretum and the Michigan State University Horticultural Gardens have such a program, as do many other public gardens across the country. The National Arboretum uses a simple, single page presentation with a tear-off sheet at the bottom to attract new members. This format would be suitable for the Virginia Tech program. Michigan State

University sends out formal, double-enveloped invitations to prospective members, but this format would be less suited to the Virginia Tech program because it does not represent the best use of available resources. The preferred option for the Virginia Tech program would be to mention membership opportunities in the general brochure or visitor's guide, as done by other organizations.

Foreign Tours. An idea to consider in the long term, but one which would require substantial resources, would be the sponsoring of foreign tours. For example, the Holden Arboretum organizes garden tours to Scotland, Ontario and Japan. The Virginia Tech program might consider tours closer to home, however, such as those organized by Robert McDuffie for the Department's landscape design students in the spring of each year.

Postcards, Booklets and Posters. This last category is somewhat miscellaneous and reserved for the more unusual and/or decorative items received. Two sets of postcards were sent in response to the survey, one from Biltmore House and Gardens and the other from Hidden Lake Gardens at Michigan State University. Biltmore House and Gardens also sent a booklet containing full-page, full-color photographs printed on heavy glossy paper. The U. S. National Arboretum sent a large poster with full-color photographs on the display side, and a detailed description of the Arboretum on the reverse. Erik Neumann of the National Arboretum indicated that they had originally planned to present this information in a booklet form, with accompanying photographs. They found, however, that the full-color poster cost approximately the same to publish as a black and white booklet. With that in mind, it seems they made the better investment by chosing the poster format.

RECOMMENDATIONS

Certain items have been identified which should be given serious consideration for inclusion in the total educational program of the Virginia Tech Horticultural Gardens. The first is the development of a general brochure. Next, the use of attractive, long-lasting labels would be one of the most valuable educational techniques available to the Gardens. Garden notes, newsletters, and plant sources and varieties listings all would be relatively inexpensive starting points from which to establish educational contact with the public. Finally, a "Friends of the Gardens" program would serve both fund-raising and promotional purposes.

Several additional items have been identified which warrant some consideration at the present time, but their implementation will most likely not be realized for some time to come. A children's program, youth program and/or senior citizens' program would all serve to involve many age groups within the public-at-large. Noncredit courses, a "plant hotline", quarterly field days, a plant exchange and distribution program, educational field trips, a calendar of scheduled events, a reference library and a lecture series would all be valuable components of a future educational program. Which of these become realities, however, must be dictated and put in priority by directors with resource allocation authority.

Some considerations and topics for future educational publications, which can be applied to other aspects of the educational program, have been targeted. An identifying logo should appear on all materials distributed by the Gardens. It would be an excellent way to establish public recognition and identification. A description of the ecocline and its application to the home situation, materials concerning xerophytic and hydrophytic gardens, and information about the culture of annuals and perennials all would aid the public in interpreting concepts presented in the Gardens. Providing basic gardening information could well be the main thrust of the Garden's educational program for meeting the extension objective outlined earlier. The materials used to provide this information could be somewhat generic in nature, the sort of publications most any public garden or arboretum might be obligated to provide.

As a final consideration for the future, concepts in botany, plant physiology, and other plant sciences should be presented to those interested in more advanced topics. This consideration results from some of the telephone conversations conducted in the second part of the survey. While all administrators agreed that the basic, hands-on horticultural materials or courses are by far the most popular, individuals who enjoy "learning for the sake of learning" should not be ignored. These are the people who benefit from course offerings and materials of a more academic nature.

After all the suggestions and considerations have been addressed, the question of implementation must be approached. It is obvious that a considerable amount of time will be needed to accomplish even a few of the items which have been identified as necessary or important. There are a few good places from which to start, however. First, existing networks such as "The Virginia Gardener" and the Virginia Cooperative Extension Service should be utilized where possible. The YMCA Free University might be a useful vehicle for offering noncredit courses to the public during the Gardens' formative years.

Second, promotional materials and activities should be developed. Again, a "Friends of the Gardens" program would serve this purpose well, as would a slide/tape promotional package which could be loaned to garden clubs and other interested organizations. The Virginia Tech Campaign for Excellence has been used in the past to promote the Gardens, as has the news media, which remains one of the best ways to establish good public relations. Both of these resources should continue to be used in the future.

Third, volunteer resources must be cultivated. Master Gardener programs are excellent places to look for volunteers to work with the Gardens in many capacities. Even though Montgomery County does not have a Master Gardener program at the present time, it remains a possibility for the future. In the meantime, cooperative efforts with Master Gardener programs located in nearby counties could be established. Local gardening clubs and senior citizens' groups are often good places to enlist volunteers, as is the horticulture student body which is already being utilized heavily. Local schools are filled with teachers who are experts in relating to the age groups they teach. Some of these teachers may be willing to help develop materials suitable for a children's or youth program. Finally, members of the community who are experts in a certain aspect of gardening and general horticulture should be sought out.

These persons might be persuaded to teach courses, give lectures, help develop publications, and so on.

These ideas for implementation are suggestions only. Some may turn out to be nonviable, and many other possibilities may exist which have not been mentioned. However, these suggestions, as well as the other points which have been discussed, do represent a step forward in the development of an educational program for the Virginia Tech Horticultural Gardens.

LITERATURE CITED

1. Ellis, Barbara (ed.). 1982. North American Horticulture: A Reference Guide. Charles Scribner's Sons, N.Y.

APPENDIX A

Sample Letter Sent to Gardens Contacted

A LAND-GRANT UNIVERSITY

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Blacksburg, Virginia 24061

Department of Horticulture

April 24, 1985

The Dawes Arboretum
7770 Jacksontown Road, SE
Newark, OH 43055

Dear Mr. White:

The Department of Horticulture at Virginia Tech is presently developing the Virginia Tech Horticultural Gardens to present landscape plants to the public and to the university community. This project will eventually form the nucleus of the new Campus Arboretum, replacing the existing arboretum which is neither open to the public nor conveniently located for educational use.

Diverse educational programs spanning all ages are currently being planned, but your experience can be a valuable aid to us. As a first step, I am conducting a survey of public gardens and arboreta known to sponsor various educational programs to generate as many ideas as possible. I would greatly appreciate your assistance in this endeavor. At this point in the survey, I am requesting any printed material used in your educational offerings, such as a statement of philosophy and goals, brochures, children's worksheets, course/workshop descriptions, etc. This material will prove invaluable in completing both the later stages of the survey and in the eventual design process itself. Thank you in advance for any effort you can make on my behalf, and should you wish to discuss this project further, please call 703/961-6274.

Sincerely,

Karen F. Carter
Graduate Student

KFC/mfe

APPENDIX B

Gardens Contacted for Educational Programs Survey

Arizona

Arizona-Sonora Desert Musuem
Route 9, Box 900
Tucson, Arizona 85702
(Mark Dimmitt)

California

Fullerton Arboretum
California State University
Fullerton, California 92632

* Huntington Botanical Garden
1151 Oxford Road
San Marino, California 91108
(James P. Folsom, Assistant Curator)

Living Desert Reserve
P. O. Box 1775
Palm Desert, California 92260
(Ruth Hendricks)

Colorado

Denver Botanic Gardens, Inc.
909 York Street
Denver, Colorado 80206
(Merle M. Moore, Director)

Connecticut

The Connecticut Arboretum
Connecticut College
New London, Connecticut 06320
(James T. Robinson, Assistant Director)

*Denotes organizations which responded to the survey

* Audubon Fairchild Garden of the National Audubon Society
North Porchuck Road
Greenwich, Connecticut 06830

The Bartlett Arboretum Association
151 Brookdale Road
Stamford, Connecticut 06903
(Ted Lockwood, Director)

Delaware

Winterthur Museum and Gardens
Winterthur, Delaware 19735
(Philip G. Correll, Coordinator of Gardens Educational Programs)

Georgia

* The State Botanical Garden of Georgia
2450 S. Milledge Avenue
Athens, Georgia 30605
(Anne M. Shenk, Educational Coordinator)

The Atlanta Botanical Garden
Piedmont Park at South Prado
Box 77246
Atlanta, Georgia 30357
(Ann L. Crammond, Executive Director)

Fernbank Science Center
156 Heaton Park Drive, N. E.
Atlanta, Georgia 30307
(Lewis Shelton, Director)

* Callaway Gardens
Pine Mountain, Georgia 31822-9800
(Patricia L. Collins, Director of Education)

Illinois

* Chicago Botanic Garden
P. O. Box 400
Glencoe, Illinois 60022
(Sue Brogdon)

The Morton Arboretum
Lisle, Illinois 60532
(Dr. Ross Clark)

Indiana

Christy Woods of Ball State University
Muncie, Indiana 47306
(Allen Winters, Manager)

* The Hayes Regional Arboretum
801 Elks Road
Richmond, Indiana 47374
(Donald R. Hendricks, Director)

Iowa

* Bickelhaupt Arboretum
340 South 14th Street
Clinton, Iowa 52732
(F. K. Bickelhaupt or R. E. Bickelhaupt)

Maryland

* Brookside Gardens
1500 Glenallan Avenue
Wheaton, Maryland 20902
(Suzanne Friis, Educational Horticulturist)

Massachusetts

* Garden in the Woods
Hemenway Road
Framingham, Massachusetts 01701
(Thomas Buchter, Executive Director)

The Arnold Arboretum of Harvard University
The Arbor Way
Jamaica Plain, Massachusetts 02130
(Cornelia McMurtrie)

Botanic Garden of Smith College
Northampton, Massachusetts 01063
(Gregory D. Armstrong, Director)

Berkshire Garden Center, Inc.
Stockbridge, Massachusetts 01262
(Marsha Tuchscherer)

Michigan

Cranbrook Gardens
P. O. Box 801
Bloomfield Hills, Michigan 48013
(JoAnn Dorn)

Matthaei Botanical Garden
1800 Dixboro Road
Ann Arbor, Michigan 48105
(William W. Collins)

* Michigan State University
Department of Horticulture
East Lansing, Michigan 48824-1112
(Dr. J. F. Kelly)

Dow Gardens
1018 West Main Street
Midland, Michigan 48640
(Douglas J. Chapman)

Fernwood, Inc.
1720 Range Line Road
Niles, Michigan 49120
(Stan Beikmann, Director)

* Hidden Lake Gardens
Tipton, Michigan 49287
(Dr. Fred W. Freeman)

Minnesota

* University of Minnesota
Landscape Arboretum
P. O. Box 39
3675 Arboretum Drive
Chanhassen, Minnesota 55317
(Shirley Mah Kooyman, Educational Department)

Missouri

Shaw Arboretum of the Missouri Botanical Garden
Box 38
Gray Summit, Missouri 63039
(George Wise)

* Missouri Botanical Garden
Box 299
St. Louis, Missouri 63166
(Linda Sanford, Instructional Coordinator, Youth Programs; Glenn E. Knopp, Instructional Coordinator, Adult Programs)

New Jersey

The George Griswold Frelinghuysen Arboretum
Box 1295R
53 East Hanover Avenue
Morristown, New Jersey 07960
(Quentin C. Schlieder, Jr., Director of Horticulture)

New York

Clark Garden of the Brooklyn Botanic Garden
193 I. U. Willets Road
Albertson, New York 11507
(Ellen Basile)

* The New York Botanical Garden
The Mary Flagler Cary Arboretum
Box AB
Millbrook, New York 12545

* Brooklyn Botanic Garden
1000 Washington Avenue
Brooklyn, New York 11225
(Lucy E. Jones, Director of Education)

Queens Botanical Garden
43-50 Main Street
Flushing, New York 11355
(Roland Wade, Executive Director)

The Cornell Plantations of Cornell University
100 Judd Falls Road
Ithaca, New York 14850
(Richard M. Lewis, Director)

Bayard Cutting Arboretum
Box 466
Oakdale, New York 11769
(Daniel D. Tompkins, Director)

* Old Westbury Gardens
Box 430
Old Westbury, New York 11568
(Nancy Kline Gorkin)

North Carolina

* Biltmore House and Gardens
Box 5375
Asheville, North Carolina 28803

University Botanical Gardens at Asheville, Inc.
6 Northwood Road
Asheville, North Carolina 28804
(John A. Broadbooks, President)

Ohio

* Garden Center of Greater Cleveland
11030 East Boulevard
Cleveland, Ohio 44106
(Susan A. McClure)

* The Holden Arboretum
9500 Sperry Road
Mentor, Ohio 44060
(C. W. Eliot Paine, Executive Director)

George P. Crosby Gardens
5403 Elmer Drive
Toledo, Ohio 43615
(Susan le Cron, Executive Director)

Pennsylvania

* John Bartram Association
54th Street and Lindbergh Boulevard
Philadelphia, Pennsylvania 19143
(D. Roger Mower, Jr., Administrator)

* The Barnes Foundation
Box 128
Merion Station, Pennsylvania 19066

Hershey Gardens
621 Park Avenue
Hershey, Pennsylvania 17033

* Pennsylvania Horticultural Society
325 Walnut Street
Philadelphia, Pennsylvania 19106
(Cheryl Lee Monroe)

* The Gardens at the Ambler Campus of Temple University
Department of Horticulture and Landscape Design
Temple University
Ambler, Pennsylvania 19002
(George Manaker, Chairman)

* Longwood Gardens, Inc.
Kennett Square, Pennsylvania 19348
(Bob Hyland, Visitor Education)

* The John J. Tyler Arboretum
P. O. Box 216
515 Painter Road
Lima, Pennsylvania 19037
(Jean H. Schumacher)

Morris Arboretum of the University of Pennsylvania
9414 Meadowbrook Avenue
Philadelphia, Pennsylvania 19118
(Jeffrey R. Clark)

Texas

Dallas Civic Garden Center
P. O. Box 26194
Dallas, Texas 75226
(Mike Kasper)

Virginia

Maymount Foundation
1700 Hampton Street
Richmond, Virginia 23220
(Alfred D. Bjelland, Director)

Washington D. C.

* The U. S. National Arboretum
3501 New York Ave., N. E.
Washington, D. C. 20002
(Erik Neumann)

Kenilworth Aquatic Gardens
National Capital Parks, East
National Park Service
Anacostia Avenue and Douglas Street, N. E.
Washington, D. C. 20019
(James M. Poole, Horticulturist)

* U. S. Botanic Garden
First and Canal Streets, S. W.
Washington, D. C. 20024
(Ramah Overton)

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