HEIGHT CONTROL OF *ESCHSCHOLTZIA CALIFORNICA* USING ANCYMIDOL, CYCOCEL, AND LIMITED INDUCTIVE PHOTOPERIOD

by

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(ABSTRACT)

Limited inductive photoperiod (LIP) significantly reduced stem length but had no effect on the peduncle length, leaf number, plant diameter, days from seed to first flower or days from start of long days (LD) to first flower in *Eschscholtzia californica*. However with fewer LD cycles, negative effects associated with LIP included an increasing number of bud abortions and plants remaining vegetative, while the number of axillary buds decreased.

Ancymidol [alpha-cyclopropyl-alpha-(4-methoxyphenyl)-5-pyrimidinemethanol] at 35, 45 and 50 ppm reduced stem length, but had no effect on peduncle length. Although plant diameter was significantly reduced, ancymidol had no effect on number of leaves or days to flower. There were no bud abortions, all plants flowered successfully, and there was no negative effect on axillary bud number with the use of ancymidol.

Cycocel [(2-chloroethyl) trimethylammonium chloride] had

no effect on stem length or the overall plant height in the Eschscholtzia californica. In addition, cycocel proved to be ineffective on associated vegetative growth and reproductive development.

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INTRODUCTION

Eschscholtzia californica, California poppy, along with approximately 12 additional species within the genus, is a member of the Papaveraceae (1,2,17). It is named for Dr. J.F. Eschscholtz, 1793-1831, who was a surgeon and naturalist with the Russian Kotzebue's scientific expeditions to the Pacific coast in 1816 and 1824 (1,9,17). The plant's origin includes California and other areas of Western North America (1,8,15,17). However, due to the species' tolerance to extreme temperature and moisture availability, E. californica has been found naturalized in other diverse habitats of Australia, India and much of the North American continent (9,15).

Jepson and Munz (9,17) have described four basic ecotypes of E. californica. One, a "typical" form, is found growing from dunes and bluffs along the coast. This form is characterized as being a heavy-rooted perennial with yellow flowers. Its leaves tend to be broadly compact, smooth and glaucous. An "inland-perennial" form has also been identified as a second ecotypical classification. This form has less compact leaves which are smooth and glaucous. Also indicative of this form is a seasonal variation in flower size and color. Two varieties common to this ecotype

are identified as var. douglasii (Benth.) Gray, and a later flowering var. crocea (Benth.) Jepson. Another inland type, or "inland-annual", is the third of four ecotypes described by Jepson and Munz (9,17). The var. peninsularis (Greene) Munz is a member of this ecotype and is found in the San Joaquin Valley and in southern California. A fourth ecotype, var. maritima (Greene) Jepson, is a perennial with prostrate stems and pubescent gray leaves. This variety is found on sand dunes on San Miguel Island and Monterey (9,15,17).

E. californica is known to be a qualitative long-day plant comprised of a stem and peduncle floral stalk which bolts from a rosette tuft of basal leaves to bear a terminal flower. Later, in several of the leaf axils, axillary flowers are produced (1,2,7,9,15,17). Flowers consist of 4 yellow-orange petals, possessing a satin texture, which are attached on the inside of a hollow receptacle. The sepals tend to be fused or joined, a unique characteristic of the genus Eschscholtzia, as is the hollow receptacle. As the petals expand, a "mitre-shaped" calyx is forced off allowing the petals to completely unfold (1,2,9). E. californica usually grows to 25-60 cm tall with a narrow taproot. Its stem is characterized as being very weak with a tendancy to fall over with maturity. The leaves are blue-green in color, glaucous, alternate and highly dissected into fine segments (1,2,7,8,15,17).

Comparatively, there has been very little research involving E. californica to date. In 1945, experiments of Lewis and Went (12) first described the photoperiodic tendency of E. californica. Lewis and Went (12), using various combinations of photoperiod (8, 10, 12, 14, 18 and 24 hrs.) and night temperatures (7, 13, 19 and 26.5 °C), discovered that regardless of night temperature, E. californica did not flower under described short day (SD) conditions. However, it was revealed that flowering was induced under long day (LD) conditions and anthesis reached much faster when the light period was increased to 24 hrs and the temperature held at a constant 19 °C. Twelve years later (1957), Went (22) described the optimal night temperature for flower induction in E. californica to be 19 °C.

Almost 20 years later (1976), Sharma and Nanda (20) began to describe the effect of photoperiod on the growth and development of E. californica. Their study involved three different photoperiods defined as: LD - continuous illumination, ND - natural day length (11-13 hrs.), and SD - 8 hr. light period. Under LD conditions, the main shoot began to elongate after 35 days and reached its maximum after 70 days. However, under ND and SD the plants remained in a rosette form until 77 and 98 days; and maximum height in both cases was obtained after 119 days. Floral buds on the main shoots of poppies in LD emerged after 50 days, while it took

97 days for these buds to emerge on poppies in ND. Furthermore, plants in SD did not flower at all, thus supporting preliminary findings of Lewis and Went (12,20).

Another important discovery was that under LD conditions, the branches emerged in basipetal order after flowering of the main shoot; while under contrasting SD conditions, E. californica remained in a vegetative state and the branches emerged in acropetal order. In addition, plants in ND flowered basipetally, but vegetative branching occured in acropetal order. The exact opposite lateral bud emergent patterns were known to occur in certain SD plants such as Crotolaria juncea and Panicum miliaceum. Based on this, they concluded that the pattern of lateral bud emergence was related to the physiochemical changes involved with the transfer from a vegetative to a reproductive state rather than being a direct result of photoperiod (20).

In more recent years, there was an effort to determine when E. californica actually became receptive to an inductive photoperiod. Lyons and Neale (16) started seeds under SD conditions, and the resulting seedlings were then transferred to LD at the time of germination and at the 2, 4, 6 and 8 true leaf stages. They identified an important negative linear relationship between leaf stage and the rapidity of flowering, suggesting that as the plant aged, it became more responsive to the induced photoperiod. It was later confirmed

by Lyons and Booze-Daniels (14) that E. californica is increasingly sensitive to LD as the plant matures; and the presence of at least 10 true, expanded leaves is necessary for these plants to flower rapidly if so induced. Furthermore, the quantity of photosynthetic leaf area remaining during LD was not crucial for flowering, therefore suggesting that the important factor in this flowering response is the specific leaf number and not the need for a source of continually produced photosynthates.

Little work has described the flowering response of E. californica, particularly as it is affected by a limited number of inductive LD cycles. It was completely unknown how low temperatures (4 °C) affected its vegetative and reproductive behavior. Unpublished work (6) suggests that 1 to 10 cold days do not stimulate reproductive processes in E. californica. After dissection, there were no signs of reproductive structures in the cold-treated plants. It is not known at this point what effect more than 10 days of low temperatures might have on flower initiation and development.

This unpublished work also generated the first preliminary data for subsequent limited inductive photoperiod (LIP) experimentations. Plants that were germinated in SD and moved to LD at the 10 leaf stage were moved back to SD after 1 to 20 LD cycles. Results concluded that 8 LD or less were not sufficient to induce flowering in 100% of the plants.

However, 100% flowering success was observed in those poppies exposed to at least 9 or 10 LD cycles. A significant reduction in stem length was also seen in the 10 to 16 LD cycles. This is a positive aspect of such LIP with E. californica since its overall height is aesthetically limiting. Furthermore, although stem length was affected by LIP, peduncle length remained virtually unchanged, suggesting that stem and peduncle elongation are functions of different physiological mechanisms. These findings, although unpublished, open doors for new areas of research with Eschscholtzia californica.

More recently, Carter (3) investigated changes in the apical meristem of E. californica during induction and initiation of flowering. Histological studies revealed that the apices of plants exposed to 1 to 5 SD cycles and 1 to 5 LD cycles were visibly similar in their dome sizes and internode lengths. Apical meristem doming was enhanced and internode lengths increased after 6 LD cycles. Evidence of rapid primordia internode elongation was observed at 7 LD; and apices were advanced in the bolting response and branch primordia clearly defined at 9 LD. It appeared that although 7 LD cycles showed the first signs of flower initiation, many buds aborted prior to anthesis after transfer back to SD. After 8 LD, most of the plants reached anthesis and it was concluded that a critical range of 8 to 10 LD were required

for anthesis to occur if the LD stimulus was terminated.

Carter (3) also examined the effects of exogenously applied gibberellin$_{4+7}$ (GA) and napthalene acetic acid (NAA) on flowering and vegetative development of E. californica. This was the first time these two growth substances have been applied to this plant. A single application of GA did not substitute for an inductive photoperiod. Stem elongation was also increased, thus decreasing the aesthetics of the poppy as a potted plant. Furthermore, a single application of NAA had no affect on leaf number or stem and peduncle length of E. californica.

Currently a relatively insignificant commercial plant, E. californica has the potential to become an important marketable potted ornamental. It has many marketable qualities including a beautiful display of flowers, elegantly dissected foliage and the ability to tolerate many diverse conditions and environments. The primary limitation for potted ornamental culture of poppy is its tall, weak stems and unbalanced growth habit. In order to obtain a more compact, well-proportioned plant, research must be done in the area of overall height reduction and compactness.

It is well reported that ancymidol has the broadest spectrum of growth retardant activity known to date, thus effectively reducing the stem length in the following plants: Chrysanthemum spp., Lilium spp., Euphorbia

pulcherrima, Tulipa spp., Dahlia spp., Pelargonium spp., Vinca rosea, Hibiscus spp., Ageratum spp., Celosia spp., Callistephus chinensis, Salvia splendons, Tagetes spp., Zinnia spp., Coleus spp., Impatiens spp., Rudbeckia hirta, and many foliage plants (4,10,13,18,19,21,23). A second growth retardant, cycocel, is known to significantly inhibit stem elongation in Euphorbia pulcherrima, Pelargonium spp., Celosia plumosa, Dianthus caryophyllus, Lilium spp., and Salvia splendens (4,10,13,21).

The primary objective of this study was to control the height of Eschscholtzia californica using ancymidol, cycocel and limited inductive photoperiod treatments. A secondary objective was to examine any significant effects these treatments might have on associated vegetative growth and reproductive development.

MATERIALS AND METHODS

Experiment 1:

Seeds of Eschscholtzia californica were sown directly into 10 cm (4 inch) square pots in a soil-less mixture containing 3 parts peat moss: 1 part vermiculite: 1 part perlite, by volume. The resulting young plants were thinned to one per pot and grown on greenhouse benches under SD conditions established by covering the poppies with 100% black cotton sateen cloth from 1700-0800 hr., creating a 9 hour daylength. LD conditions were created by using 60 watt incandescent bulbs hung above the benches providing an average of 4 uE/m^2/sec of photosynthetic photon flux night interruption from 2200-0200 hr. All plants were fertilized with 400 ppm N from a 20-8.8-16.6 source weekly upon germination, and 6 weeks later received an additional top dressing sprinkle application of a 14-6-11.6 slow release fertilizer.

Seeds were sown on February 13, 1987 and the poppy seedlings reached the critical 10 true-leaf stage on March 22 (true leaf being when a leaf lamina was fully expanded). Fifteen plants remained under SD for the duration of the experiment, while 180 plants were transferred to LD conditions. Fifteen of the 180 plants remained untreated

under LD for the duration of the experiment. Groups of 15 plants each were moved back to SD following treatment of 10, 12, 14, 16, 18, 20 and 22 LD. Four groups of 15 plants each were treated with a 25 ml soil drench of either ancymidol [alpha-cyclopropyl-alpha-(4-methoxyphenyl)-5-pyrimidinemethanol] at 25 ppm (0.625 mg active ingredient) or 50 ppm (1.25 mg active ingredient), or with cycocel [(2-chloroethyl) trimethyl-ammonium chloride] at 1500 ppm (37.5 mg active ingredient) or 2500 ppm (62.5 mg active ingredient). Treatments were applied after 10 LD, and those plants remained under LD.

Experiment 2:

Eschscholtzia californica seeds were sown on November 19, 1987 into 10 cm (4 inch) square pots in a soil-less media containing 3 parts peat moss: 1 part vermiculite: 1 part perlite (by volume). The seedlings were thinned to one per pot and grown on greenhouse benches under a 9 hour daylength (SD) created as described previously. An ambient night temperature for seed germination, as well as the growth of subsequent plants was a constant 19 °C as continuously recorded by a thermograph. All poppies were fertilized once weekly with 400 ppm N from a 20-8.8-16.6 source. After 10 weeks this fertilizer application was increased to twice weekly.

When the critical 10 leaf stage was reached, 260 of 280 plants were moved to LD conditions, the other 20 remaining in SD. Twenty of the 260 remained in LD. Long days were created with 60 watt incandescent bulbs strung above the benches providing approximately 4 uE/m^2/sec of photosynthetic photon flux night interruption from 2200-0200 hr. In addition, daytime light intensity averaged 625 uE/m^2/sec photosynthetic photon flux; and daily temperatures tended to fluctuate with the varying external climate.

Four groups of 20 plants received a 25 ml soil drench of either 25, 35 (0.825 mg active ingredient), 45 (1.125 mg active ingredient) or 50 ppm ancymidol following 10 LD and remained under LD. Following 10, 12, 14, 16, 18, 20, 22 and 24 LD, 20 plants were moved back to SD conditions.

Both experiments followed a completely random design. At first flowering, when the calyx was forced off by emerging petals on the terminal stalk, the following data were recorded: number of days from seed to first flower, number of days from start of LD to first flower, stem length (from soil line to the receptacle base), peduncle length (from last vegetative branch to the receptacle base), plant diameter (from leaf tip to leaf tip with the stem as the central axis), and the number of leaves along the main stem. The number of axillary buds flowering simultaneously with the terminal bud was recorded for ancymidol-treated and LD

control plants (experiment 2 only). At the termination of each experiment, the number of axillary floral buds was recorded.

A Chi-square procedure was used to determine a relationship between an observed bud abortion phenomenon and LIP. To reinforce this statistical method, a Probit (5) or "dose response" procedure was used in an effort to transform or linearize this bud abortion/LIP relationship. Probit analyses are also used to predict probable outcomes given certain prerequisite data. Bud abortion data were omitted from the following analysis so as not to bias the overall conclusions. ANOVA and regression analysis evaluated the relationship of dependent variables (stem length, peduncle length, etc.) to a single independent variable (number of LD). Mean separation tests (Student-Newman-Keuls) were used with the photoperiod data and with the combined photoperiod and growth retardant data. Because a research objective was to observe how both photoperiod and growth retardants ultimately compare, the mean separation results for the combined data set will be the basis for the majority of the results and discussion.

RESULTS

Experiment 1:

Eschscholtzia californica which received only SD did not flower. All plants which received LD with ancymidol or cycocel reached anthesis, while those receiving LIP flowered with varying degrees of success due mainly to terminal floral bud abortion. A Chi-square procedure indicated that the number of these abortions was directly related to the duration of the LD period (Table 1). As the number of LD increased, the number of bud abortions decreased. The subsequent Probit test determined the number of LD required to achieve 50% flowering success to be 14 (Table 2).

The number of days from seed to first flower was statistically similar among all treatments, averaging 63 days (data not shown). The number of days from the start of LD to first flower also proved to be similar among all treatments, with the number being approximately half the number from seed to first flower (data not shown).

Linear and quadratic regressions of plant diameter and leaf number were statistically insignificant, with averages of 25 cm and 29 leaves. Few treatments affected peduncle length. The 12 and 16 LD reduced this structure by 4.5 to 5.5 cm (Table 3).

There was a significant positive linear regression between axillary bud number and LIP (Figure 1). All plants treated with ancymidol or cycocel averaged 12.3 axillary buds, with LIP-treated plants having the fewest (Table 4).

The mean separation test indicated that stem length was significantly reduced by LIP and ancymidol (Table 5). Cycocel had no effect on stem length.

Experiment 2:

Those plants which were exposed only to SD did not become reproductive (Table 6), and all plants which received ancymidol reached anthesis under LD. However, plants exposed to LIP flowered sporadically. Like experiment one, these results show a similar bud abortion phenomenon. Although a chi-square value of 575 indicates a direct treatment relationship, there is no particular pattern in abortion frequency. The floral bud abortions occur in random amounts ranging from 25 to 60% in the LIP-treated plants. In addition to the plants which aborted buds, there were many that remained vegetative. A chi-square test revealed that as the number of LD increased, the percentage of plants remaining vegetative decreased.

The number of days from seed to first flower averaged 72, and the number of days from the start of LD to first flower averaged 35 and did not differ among treatments (data

not shown). Plant diameter was influenced only by the single application of ancymidol (Table 7), with a 10 to 12 cm reduction in diameter noted at all levels.

The leaf number response was also consistent with experiment one (data not shown). Approximately 31 main stem leaves were present for each treatment. Peduncle length proved to be relatively unaffected by the treatments, (Figure 2).

The number of axillary buds flowering simultaneously with the terminal flower decreased with the ancymidol application (Table 8). The LD control plants averaged 3.25 axillary flowers opened at the same time as the terminal bud, while ancymidol-treated plants averaged only 1.8, a significant reduction.

Axillary bud number at the end of experiment 2 followed a linear relationship with LIP data (Figure 3). The 10 to 24 LD cycles were the same among each other, but differed statistically from plants exposed to continuous LD (Table 4). These 10 to 24 LD cycles reduced axillary bud number from 10.3 (continuous LD) to 0 to 2.2 buds. All concentrations of ancymidol tested were similar among each other and the LD control.

Regressions on ancymidol data indicated a significant negative linear relationship in stem length (Figure 4). All levels of ancymidol reduced stem length by 8 to 11 cm compared

to the control (Figure 2). This stem length reduction was enhanced with increasing concentrations, with 50 ppm ancymidol having 2 cm stems and 25 ppm ancymidol yielding 5 cm stems. Stem length also decreased with decreasing number of LD, with significant reductions at the 10 to 20 LD cycles (Table 9).

Plant height increased from 7 to 30 cm (continuous LD) with increasing number of LD (Table 10, Figure 5). Although 25 ppm ancymidol reduced overall plant height to 18.3 cm, the higher concentrations of ancymidol tested were much more effective in reducing height (Table 10, Figure 6).

DISCUSSION

The theory of transferring a LD plant from SD to LD and back again to SD to reduce overall plant height is not altogether new. Many experiments show that the transfer of LD plants from SD to a LD causes an increase in the rate of both gibberellin (GA) biosynthesis and metabolism (24). Theoretically, transferring the LD plants back to SD would decrease GA biosynthesis and metabolism and possibly limit stem elongation as a result of interrupting the photoperiodic nature and associated physiological processes of the plant.

It has been found that many other factors need to be considered, however, making this theory more complex. For instance, plant age or juvenility (as determined by leaf number) plays a vital role in determining when a LD plant can actually perceive the LD stimulus (14,16). The number of LD required to permit flower development to anthesis, and yet interrupt the GA pathway early enough to significantly reduce stem elongation is also an important factor in this theory (3,6,14,16). Knowing and understanding this concept opens new avenues for research in the area of photoperiod manipulation.

For many years researchers and commercial growers have

used various growth regulators to manipulate plant growth habits and flowering capabilities. Ancymidol and cycocel, both growth retardants, have been tremendously effective inhibitors of stem elongation. In our studies, ancymidol and cycocel were chosen in an effort to reduce stem length and plant height. Because the terminology is often confusing, it is important to have a clear understanding of growth retardants. Luckwill (13) describes a growth retardant as a substance which inhibits cell division and cell expansion in the subapical region of the stem. Many growth retardants function by inhibiting GA biosynthesis, but can be reversed with a subsequent GA treatment.

The results from this study are consistent with prior findings that E. californica will not become reproductive under SD (3,6,12,14,15,16,20). E. californica has been found to remain vegetative under SD, and induced to flower with exposure to at least 10 LD (3,6). Although results indicate that following 10 LD a plant may flower, it does so with varying degrees of success. This can be explained by the plant's apparent inability to initiate floral buds under SD; and as the plants are introduced to increasing number of LD before being transferred back to SD, they become more successful in the initiation and continued development of flowers. When exposed to a minimum of 10 LD, many plants receive just enough stimulus to induce reproductive activity,

but not enough to allow for complete developmental processes to occur in the majority of those plants. As a result, E. californica either successfully completes flowering to anthesis, remains vegetative, or induces a floral bud and aborts it shortly thereafter. Previous studies revealed similar results. Carter (3) observed not only a partial induction of floral buds resulting in abortion, but also plants which were never reproductively induced, instead remaining in a vegetative state. As Probit results indicated in this study, 14 LD are required for 50% flowering success (FS50). This suggests that increasing the number of LD increase the percent-flowering success. However, this does not mean that the increase will always be an acceptable one. In experiment 1, at 22 LD, 93% (FS93) of the plants reach anthesis; and only 70% do so in experiment 2 following 22 LD.

Results from experiment 1 confirm earlier reports (3,6,14) that the number of days from start of LD to first flower is approximately 30; while the number of days from seed to first flower averages twice that. This includes those plants treated with ancymidol and cycocel, therefore indicating that neither has an effect on reaching maturity (10-leaf stage), or flower initiation and development. However, experiment 2 and experiment 1 bear some disimilarities in that the number of days are somewhat higher

in experiment 2, even though the number of days from start of LD to flower is still approximately half that of days from seed to first flower. This could be explained by the different times of year these experiments were conducted (expt.1 in the spring, and expt. 2 in the winter).

Another important characteristic described is that the stem length varies among both the photoperiod and growth retardant treatments. Stem length increases as the number of LD increase. The GA pathway of stem elongation seems to be inhibited by LIP, thus effectively reducing stem length. This response whereby E. californica stem elongation is encouraged under LD but stops upon transfer to SD, creating the same direct relationship between number of LD cycles and stem length, was recently demonstrated in Rudbeckia hirta (18). R. hirta and E. californica share a similar rosette flower bolting behavior but are in very different families.

In experiment 1, 25 ppm ancymidol was virtually ineffective in reducing the height; however, all levels of ancymidol had an impact on stem reduction in experiment 2. Quite different results were obtained from the cycocel data. There was very little stem reduction observed in E. californica plants treated with cycocel, contrary to evidence supporting it as an effective inhibitor in other plants (4,10,13,21). This obvious lack of response to cycocel can be explained in several ways: roots of different species

have different abilities to absorb and translocate cycocel; inactivation mechanisms within some species but not others (compartmentation, metabolism); and possibly differences in the mode of action in relation to the endogenous mechanisms controlling internode extension (21).

Although stem length is clearly affected by limited inductive photoperiod, ancymidol and only slightly so by cycocel, these treatments have limited reducing effects in the peduncle region. As suggested by Carter (3), Lyons and Booze-Daniels (15), and demonstrated once again here, stem and peduncle activities are possibly controlled by two different mechanisms. It is not known at this time if there may be some anatomical barrier or hormonal difference between the E. californica stem and peduncle tissue which can explain these different effects satisfactorily. However, it does raise many unanswered questions and thus new possibilities for research.

Plant diameter was similar for all treatments in experiment one, but was significantly reduced by all concentrations of ancymidol in experiment 2. In addition, leaf number remained the same as the LD control, even in those plants treated with ancymidol and cycocel. This is not surprising since it is well documented that growth retardants (in particular, ancymidol and cycocel) usually have no deleterious growth malformations or a major

inhibitory influence on the terminal meristem (4,13,21). In general, leaf number remains the same resulting in a more compact plant, although in some cases leaf expansion may be affected (21), thus partially explaining the plant diameter results of experiment 2. It is also reported that leaf size and apical dominance usually remain unchanged (13). Regarding this, ancymidol and cycocel axillary bud number results are statistically similar to the LD control, each with high numbers of floral buds per plant. It is the limited inductive photoperiod that has a subsequent detrimental effect on axillary bud number. Furthermore, there was no evidence of a preservative effect of ancymidol or cycocel on flower life, as was suggested by Clifford (4) and Luckwill (13).

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Table 1. Effect of limited inductive photoperiod on number of terminal flower bud abortions in Eschscholtzia californica, expt. 1.

No. of long days[z]	No. of plants[y] with aborted terminal buds
continuous (control)	0
22	1
20	3
18	5
16	8
14	7
12	9
10	11

[z] number of long days received prior to transfer to short days.

[y] number of plants out of 15, $X^2 = 532^{**}$).

Table 2. Relationship between long days (LD) and flowering success of Eschscholtzia californica, expt. 1.

Probable % flowering[z]	Prerequisite LD exposure[y]
10	8
20	9
30	11
40	12
50	14
60	16
70	18
80	20
90	25
100	40

[z] Results of a Probit analysis, p = 0.05.

[y] predicted number of LD required before transfer back to short day to achieve corresponding flowering success probabilities.

Table 3. Effects of limited inductive photoperiod, ancymidol, and cycocel on the peduncle length of Eschscholtzia. californica, expt. 1.

Treatment	Peduncle length (cm)
No. of long days[z]	
10	10.1 ab[y]
12	8.8 b
14	10.4 ab
16	9.3 b
18	10.6 ab
20	10.3 ab
22	10.3 ab
continuous	13.8 a
Ancymidol (ppm)	
25	11.2 ab
50	10.6 ab
Cycocel (ppm)	
1500	13.9 a
2500	11.9 ab

[z] number of long days received before transfer to short days.

[y] mean separation within entire column, Student-Newman-Keuls test, p = 0.05.

Table 4. Effects of limited inductive photoperiod, ancymidol and cycocel on axillary bud number in Eschscholtzia californica, expt. 1 & 2.

Treatment	Axillary Bud Number	
	Expt. 1	Expt. 2
No. of LD[z]		
10	0.0 c[y]	0.0 c[x]
12	1.3 c	1.0 c
14	0.1 c	0.0 c
16	0.4 c	0.0 c
18	1.7 c	0.7 c
20	2.3 c	1.6 c
22	4.3 c	2.1 c
24	---	2.2 c
Continuous (control)	11.8 b	10.3 a
Ancymidol (ppm)		
25	16.1 a	6.3 ab
35	---	4.2 ab
45	---	4.8 ab
50	12.0 b	4.2 ab
Cycocel (ppm)		
1500	9.6 b	---
2500	12.0 b	---

[z] number of long days prior to transfer to short days.

[y] mean separation within the entire column, Student-Newman-Keuls test, p = 0.05.

[x] mean separation within the entire column, Student-Newman-Keuls test, p = 0.05.

Table 5. Comparison effects of limited inductive photoperiod, ancymidol, and cycocel on stem length of Eschscholtzia. californica, expt. 1.

Treatment	Stem length (cm)
No. of long days[z]	
10	7.8 c[y]
12	8.3 c
14	8.9 c
16	12.8 bc
18	16.9 ab
20	16.4 ab
22	20.0 ab
continuous	21.1 a
Ancymidol (ppm)	
25	17.4 ab
50	8.3 c
Cycocel (ppm)	
1500	18.4 ab
2500	20.2 ab

[z] number of long days prior to transfer to short days.

[y] mean separation within the entire column, Student-Newman-Keuls test, p = 0.05.

Table 6. Effects of limited inductive photoperiod on flowering status of Eschscholtzia californica, expt. 2.

Treatments	Percentage of Plants[y]		
	Reaching Anthesis	Aborting Buds	Remaining Vegetative
No. of LD[z]			
0 (SD control)	0	0	100
continuous	100	0	0
10	5	40	55
12	10	35	55
14	20	45	35
16	10	60	30
18	40	45	15
20	35	35	30
22	70	25	5
24	60	40	0
X^2 value		575**	675**

[z] number of long days received prior to transfer back to short days.

[y] percentages based on 20 plants, analysis conducted on actual data and presented here as percentages.

Table 7. Plant diameter of Eschscholtzia californica as affected by limited inductive photoperiod and ancymidol, expt. 2.

Treatment	Plant diameter (cm)
No. of long days[z]	
10	35.0 a[y]
12	29.5 abc
14	33.8 a
16	32.7 ab
18	33.9 a
20	34.8 a
22	35.6 a
24	35.6 a
continuous	37.0 a
Ancymidol (ppm)	
25	26.8 bc
35	25.3 c
45	26.1 bc
50	26.7 bc

[z] number of long days prior to transfer back to short days.

[y] mean separation within the entire column, Student-Newman-Keuls test, p = 0.05.

Table 8. The effect of ancymidol on the number of axillary buds flowering simultaneously with the terminal bud of Eschscholtzia californica, expt. 2.

Ancymidol (ppm)	Flower number
0 (continuous LD)	3.25 a[z]
25	2.15 ab
35	1.70 b
45	1.60 b
50	1.75 b

[z] Student-Newman-Keuls test, p = 0.05.

Table 9. Effects of limited inductive photoperiod on stem length in Eschscholtzia californica, expt. 2.

No. of long days	Stem length (cm)
10	1.0 c[z]
12	1.0 c
14	2.0 c
16	2.6 bc
18	5.5 bc
20	6.3 bc
22	8.9 abc
24	10.8 ab
continuous	13.6 a

[z] mean separation within the entire column, Student-Newman-Keuls test, p = 0.05.

Table 10. Comparison of plant height in limited inductive photoperiod and ancymidol treated Eschscholtzia californica plants, expt. 2.

Treatment	Plant height (cm)[Y]
No. of long days[Z]	
10	11.5
12	7.0
14	12.8
16	15.6
18	16.4
20	18.2
22	20.5
24	23.9
continuous	30.4
Ancymidol (ppm)	
25	18.3
35	11.5
45	11.8
50	12.0

[Z] number of long days prior to transfer back to short days.

[Y] plant height reflects the combined means of stem and peduncle lengths (cm) for each treatment.

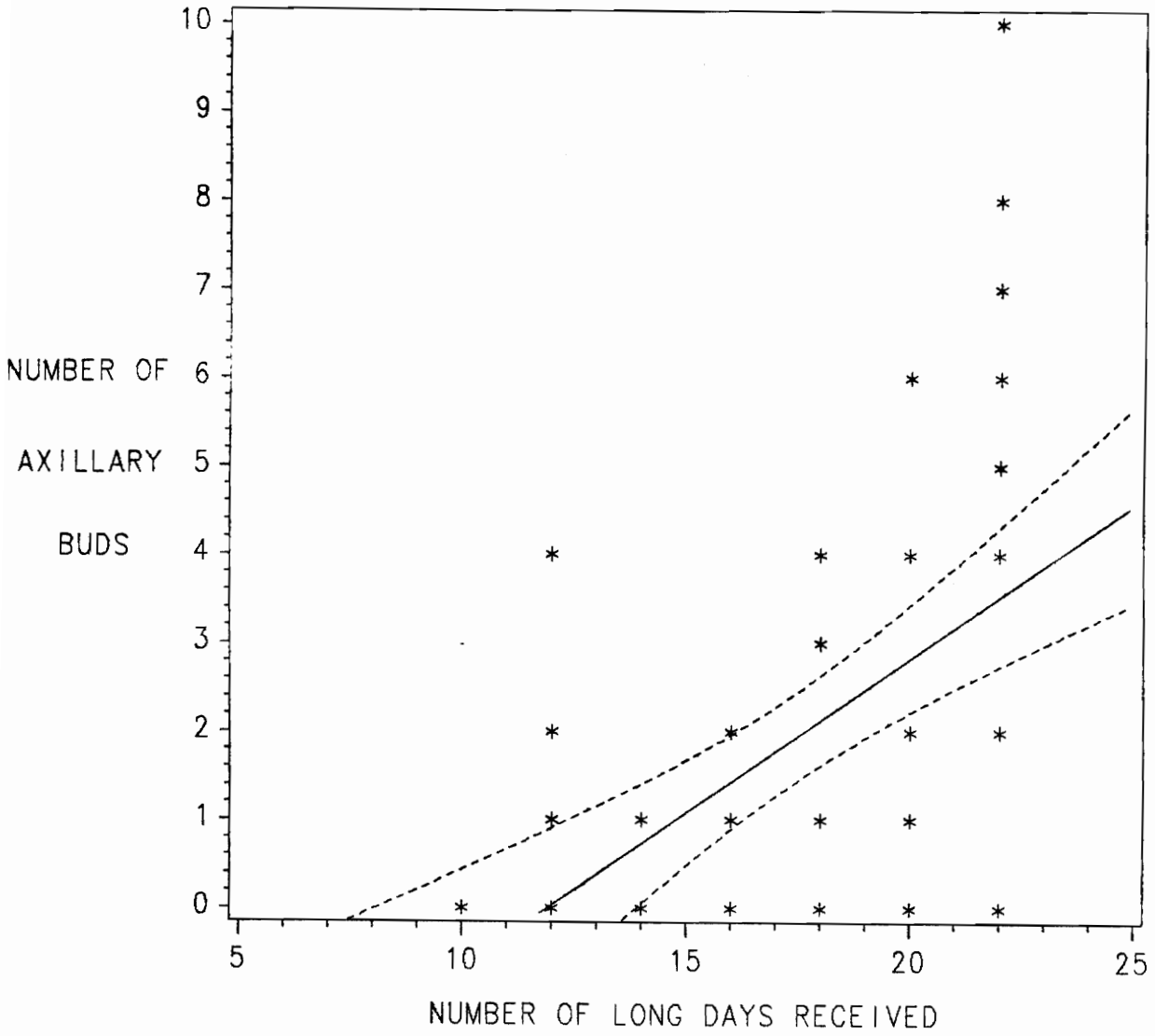

Figure 1. The effect of limiting the number of inductive long day cycles received by Eshcscholtzia californica on the number of axillary buds present at first flower, expt. 1; y = 0.35x - 4.16, R^2 = .33**, (---) = 95% confidence, data points often indicate multiple values.

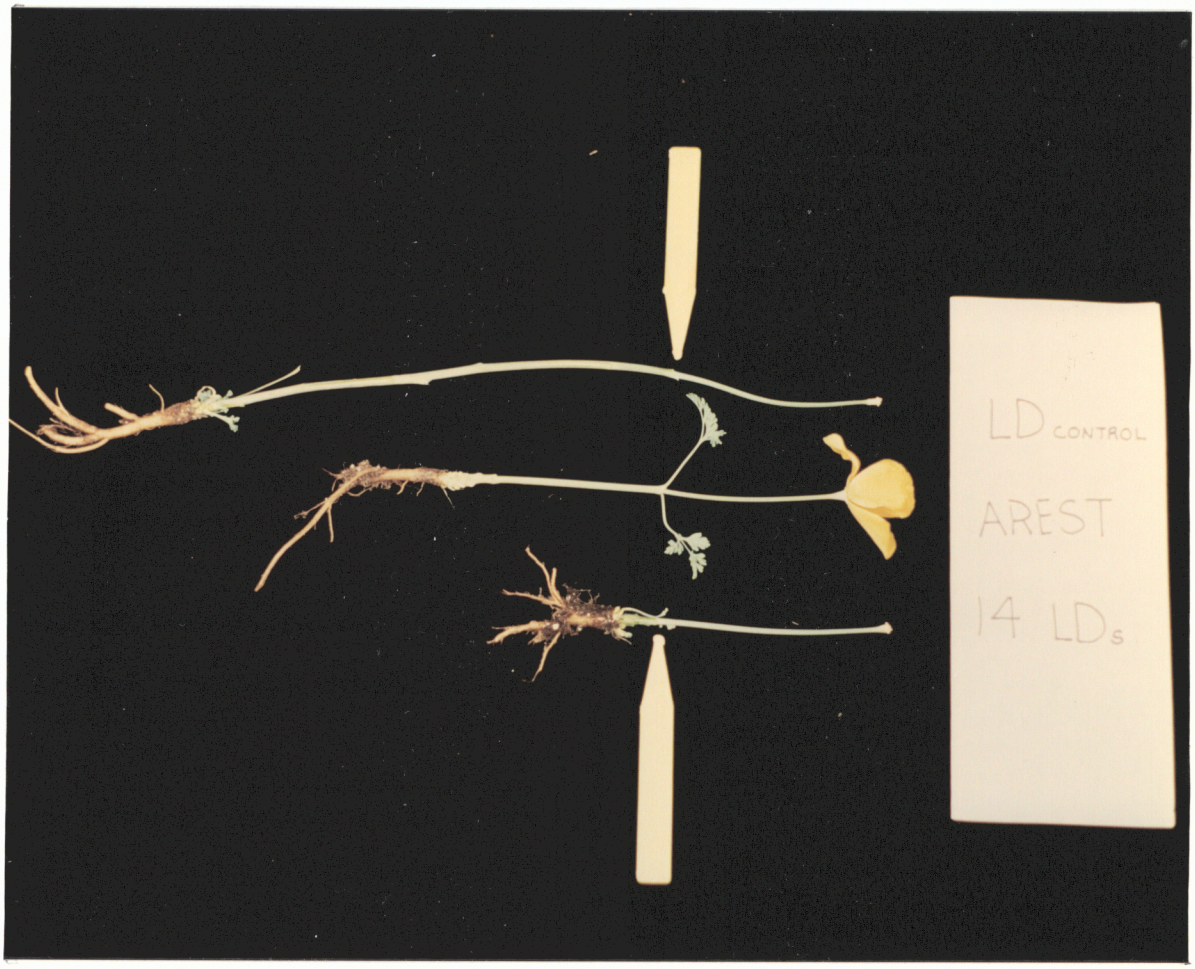

Figure 2. A comparison of stem (left) and peduncle (right) lengths on long day control (top), ancymidol (middle), and limited inductive photoperiod (bottom) treated Eschscholtzia californica, expt.2. (Marker indicates the stem and peduncle junction).

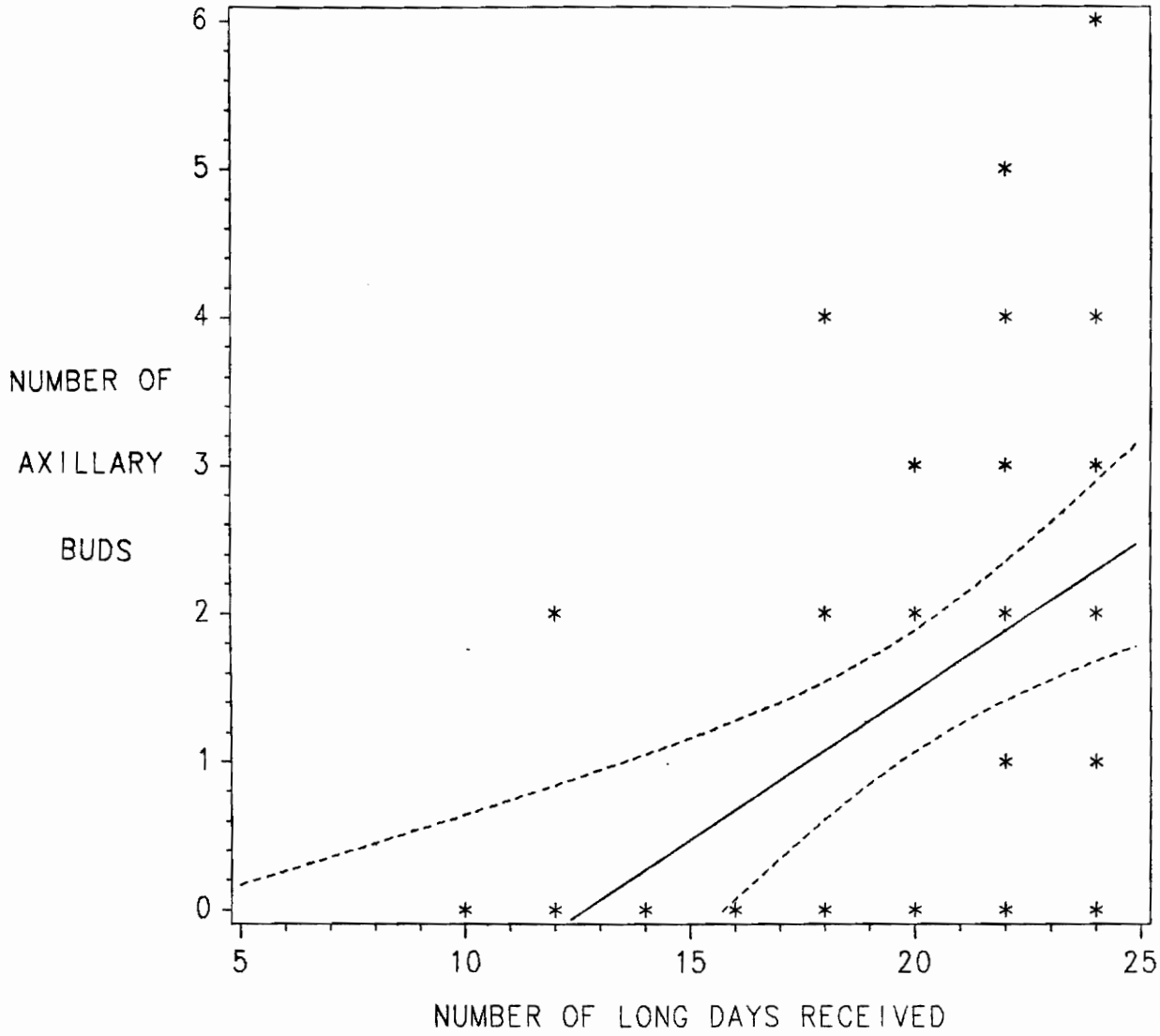

Figure 3. The effect of limiting the number of inductive long day cycles received by Eschscholtzia californica on the number of axillary buds present at first flower, expt. 2; $y = 0.20x - 2.55$, $R^2 = .21^{**}$, (---) = 95% confidence, data points often indicate multiple values.

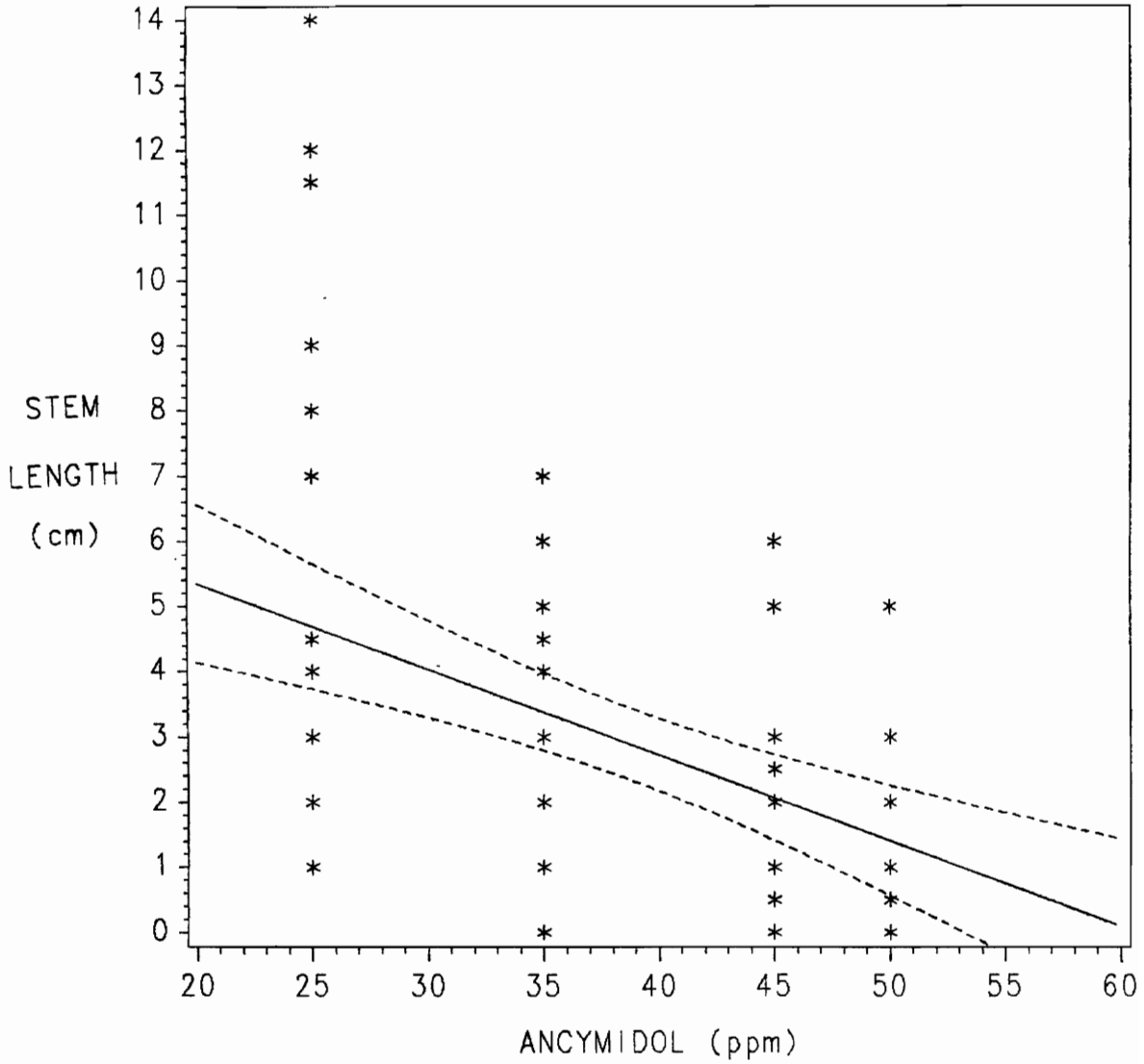

Figure 4. The effect of 25, 35, 45 and 50 ppm ancymidol received by Eschscholtzia californica on stem length (cm) at first flower, expt. 2; $y = -0.13x + 7.98$, $R^2 = .21^{**}$, (---) = 95% confidence, data points often indicate multiple values.

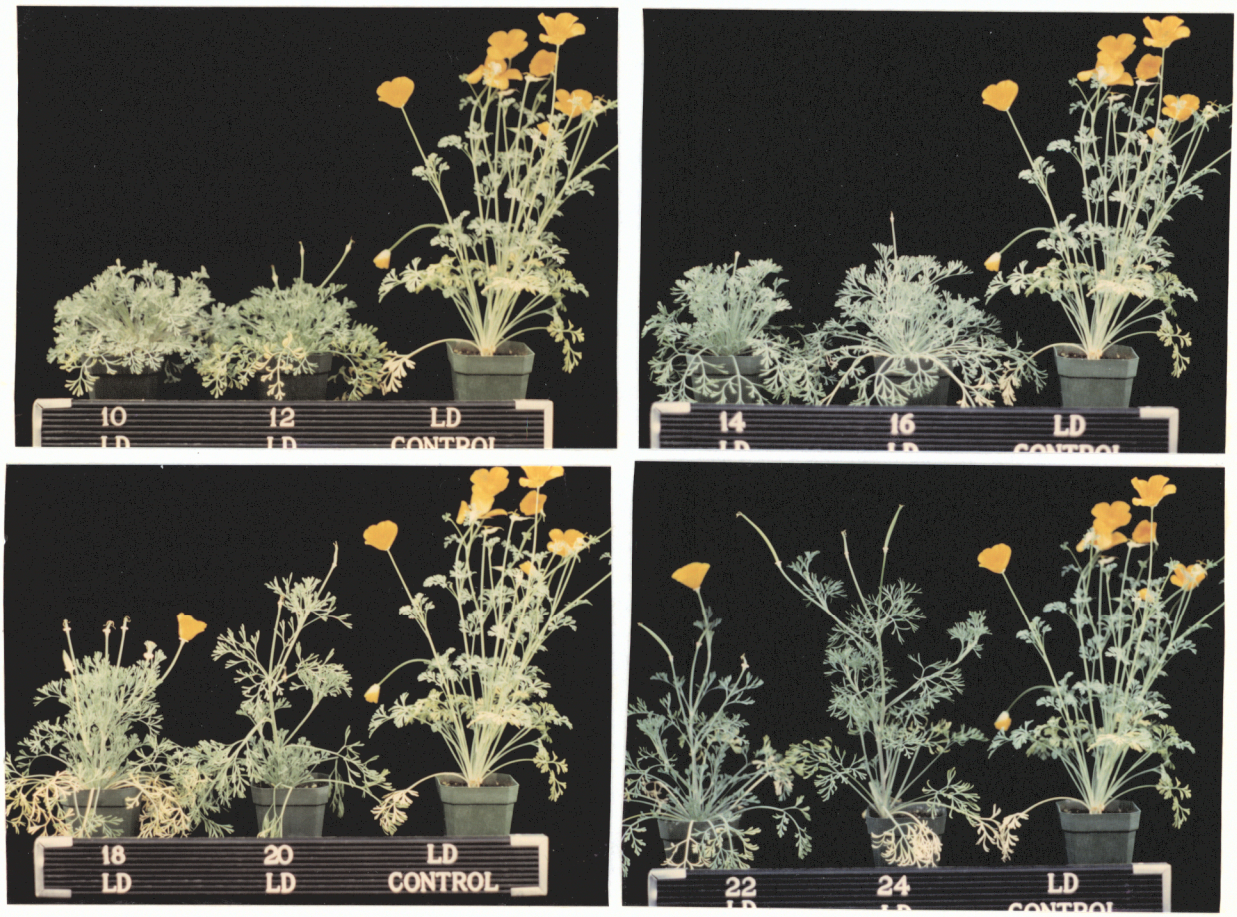

Figure 5. Response of Eschscholtzia californica plant height to increasing number of long days (LD), expt. 2:
10LD, 12LD, LDcontrol (top left),
14LD, 16LD, LDcontrol (top right),
18LD, 20LD, LDcontrol (bottom left),
22LD, 24LD, LDcontrol (bottom right).

Figure 6. Effects of ancymidol on overall plant height in Eschscholtzia californica, expt. 2.

VITA

The author was born in Prince Edward County, Virginia on May 24, 1962. She was raised on the family dairy farm where her first interest in agriculture began.

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