THESIS

CULTURAL STUDIES OF GREENHOUSE GROWN *EUSTOMA grandiflorum*

Submitted by

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In partial fulfillment of the requirements

for the Degree of Master of Science

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY MOHAMED F. AZRAK

ENTITLED CULTURAL STUDIES OF GREENHOUSE GROWN EUSTOMA GRANDIFLORUM

BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

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ABSTRACT OF THESIS

CULTURAL STUDIES OF GREENHOUSE GROWN

EUSTOMA grandiflorum

Change in photoperiod had no affect on flower initiation of Sakata F-1 hybrid E. grandiflorum; however, plant flower buds developed faster, had increased stem length, greater number of bud nodes, and more plant fresh and dry weight when exposed to day growing temperature and relative humidities of 22° C and 70%, compared to 17° C and 30-50% respectively.

Sakata plants grown in volcanic scoria, gravel, and idealite had better growth and production than those in soil medium. The removal of terminal shoots at the fourth, fifth or sixth leaf pairs above the base, had no effect on growth, however, the removal of the growing tip only, reduced the flowering time by 10 days.

The Weddle hybrid of E. grandiflorum was more productive and had larger stems than the Sakata hybrids. Both hybrids had two definite flowering cycles per year, one from May through June, and a second from August to mid-October. The vase life of both hybrids ranged from 8 to 18 days, but was not increased by preservative addition of 8-hydroxy-quinoline citrate, (8-HQC), plus sugar.

E. grandiflorum was attacked by red spider mite (Tetranychus urticae) and white fly (Trialeurades vaporariorum) and was highly susceptible to Rhizoctonia solani and Fusarium spp.

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Dedicated to my mother,
my sister, and my brothers
especially Ghallab, whom I
love very dearly.

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I. INTRODUCTION

E. grandiflorum, a native wild flower of the United States, is found in nature from Texas to New Mexico and northward to Nebraska and Colorado, it blooms only in mid to late-summer (9). It has gained much attention in the past two years by floriculture researchers as a potential flowering pot plant and cut flower.

The plant belongs to the Gentiancea family and was known botanically as *Eustoma russelianum*, *Lisianthus russelianum* and more recently as *Eustoma grandiflorum* (3, 9). The common names for *E. grandiflorum* includes prairie gentian, prairie tulip and Texas bluebell (14).

Botanically, the plant has been described as having smooth leaves with a bloom, the leaves have no petioles and may partly surround the stem with their basal lobes. They are one or two inches long with usually three veins (9). The flowers are deep blue or purple, with usually five petals. From the ovary a threadlike style rises, bearing a plate, two-lobed stigma at its tip. There are five or six stamens. The flowers are usually borne singly and have corolla-lobes one inch or longer (9).

The Sakata seed company of Yokohama, Japan, reports they have listed Lisianthus in their catalog since 1934 (11) and in 1982 offered a new F-1 hybrid in three separate

colors of soft salmon pink, pure white, and deep blue. Sakata further described their flowers as "looking like roses in bud, expand to resemble tulip, and open to look like poppies".

Wilkins and Brueber (16) classified the lastest Sakata F-1 hybrid of E. grandiflorum as annuals or biennial plants. Tija and Sheehan observed the Sakata F-1 hybrid when grown as bedding plants outdoors. They also observed E. grandiflorum between 1980-1982 in the Walt Disney World trial garden in Gainsville, Florida. The plants usually develop lateral branches from the vbase, show a tolerance to high and low temperature, had a 14 day flowering life, and hardy growth habits (14).

Charles Weddle of Weddle Native Plants, Palisade, Colorado, a collector of native American plant materials, made one F-1 line available to Colorado State University in 1980.

The F-1 species of E. grandiflorum (Fig. 1) developed by Sakata and Weddle range from 60 to 100 cm tall with five to eight branches, each having four to six flowers.

The lack of information on the culture of E. grandiflorum as a cutflower crop lead to the development of the objectives for this study.

1. Evaluate the growth habits of Sakata and Weddle F-1 plant material for possible cut flower production.

2. To investigate the plant response of Sakata F-1 plants to photoperiod in two different growing temperatures.
3. Evaluate the effects of media and pinching level on the growth and flowering responses.

Figure 1. Flowering stems of E. grandiflorum, Sakata and Weddle hybrids.


SAKATA
WEDDLE

Chapter II

Photoperiod Studies

Literature Review

Photoperiod is the duration, timing, and quality of the light or dark conditions to which plants often respond (6). The flowering of many plant species can be controlled by photoperiod, during their growth cycle.

Heins and Wilkins (5) reported that winter flower pro- duction of *Dianthus caryophyllus* cv. white Sim, was reduces because the flowering shoots were initiated in long days of summer when lateral shoot growth was inhibited. Con- versely, summer production was increased because the shoots were initiated in short days of winter, when lateral shoot growth was stimulated.

Chrysanthemum species require long dark periods to induce flowering under natural long days, and short dark periods in winter to prevent flowering (4). Research conducted at 42^{o} north latitude showed that a long daylength of 14.5 hr. was necessary for flower initiation of chrysanthemum species, but a shorter daylength of 13.4 hr. was required for flower bud development (7). Some cultivars of the same species respond differently to photoperiod treatment. Post and Kamemoto (8) found that an early cultivar

of chrysanthemum, Gold Coast, initated flower buds after 4 days of short photoperiod and late cultivar, Vibrant, required 5 days.

E. grandiflorum Versus Photoperiod

There is some indication that E. grandiflorum F-1 hybrid respond to photoperiod treatment. The plants need at least 13 hr. of daylight for best flowering (1). Wilkins and Grueber (16) assumed that E. grandiflorum was a long day plant because under the short days of winter, plants rosette, and develop branches. The plants also grew rapidly and flowered sooner during spring and summer months. Roh and Lawson (10) reported that E. grandiflorum F-1 hybrid blue, does not respond to long-day photoperiod treatments prior to stem elongation or when treated for 30 days or less. However, when plants were given a long day treatment for more than 150 days and this treatment was discontinued when 10 to 12 pairs of leaves were formed, accelerated flowering occurred. Based on their report, using Sakata plant material, Roh and Lawson (10) recommended a 16 hr. photoperiods with long day extension treatments for the production of tall cut flowers, and a 12 hr. long day photoperiod treatment with night interruption method, for short pot plants.

Interaction Between Temperature and Photoperiod

Temperature often modifies the effects of daylength on flower initiation.

Cathey (2) found the critical daylength for floral initiation and development of three chrysanthemum cultivars, White Wonder, Encore and Show, were altered with change in the minimum night temperature. He concluded the photoperiod required for initiation of inflorescence was shortened by lowering the temperature from 27 to 10° C. Conversely, the required photoperiod for developmnt of inflorescence was shortened by raising the temperature from 10 to 27° C. Samman and Langhans (14) found that low minimum temperature (13° - 2° C) at the beginning of photoperiod delays Chrysanthemum morifolum flower bud initiation from 1 to 49 days, depending on cultivar and duration of low temperature. According to Salisbury (12) poinsettia is a short day plant at high temperatures but a long-day plant at low temperatures.

E. grandiflorum Versus Temperature and Photoperiod

Wilkins and Gruber (16) reported that best seed germination occurred at 20 - 25° C in light and both seedlings and transplant stages of growth required 15.6 - 18.3° C. Wilkerson (15) indicated that E. grandiflorum thrives in hot weather, but cool temperatures delay growth. Temperatures below 12.8° C delayed blooming, while temperatures above 25° C stretched plants under winter light (1). Roh and Lawson (10) reported the best flower bud initiation temperature for E. grandiflorum F-1 hybrids was 15.6° C or higher during long day treatment. Temperatures of 15.6° C and 20° C during the long day treatment accelerated flowering over

a short day treatment by 64 and 60 days respectively. Night temperatures higher than 21.1 to 27.7° C resulted in faster growth and flowering, but the quality of the plants were greatly reduced. However, growth was stopped at temperatures below 8° C. The optimal night temperature during the growing period was 15.6 to 18.3° C (10).

This study was undertaken to determine the plant respone of Sakata F-1 hybrid plants to the photoperiod treatments in two different growing temperatures.

METHODS AND MATERIALS

Two experiments were conducted to determine the effect of photoperiod and two day and night temperatures regimes on the growth and development of E. grandiflorum. They were conducted at W. D. Holley Plant Research Center, Colorado State University, Fort Collins, Colorado (105° 4'W, 40° 35'N, elevation 1550 m).

Seeds of Sakata F-1 hybrid blue and pink cultivars of E. grandiflorum were germinated on September 24, 1983 in a mixture of vermiculite and Canadian sphaghum peat moss (V/V) with intermittent mist and bottom heat of 20° C. The seedlings transplanted in the three leaf stage on December 2, 1983 into cell packs using a pasturized CSU soil mixture 1:2:1 of Fort Collins clay loam, Canadian sphaghum peat moss and No. 6 perlite (V/V/V). Carbon dioxide was injected at concentration 1000 $ul l^{-1}$ into the greenhouse during daylight hours and periods of no ventilation.

Nutrients were applied in each irrigation at a rate of 4.4 meq/lK^+, 10.1 meq/l No_3^-, 3.7 meq/l Ca^{2+}, 1.3 meq/l Mg^{2+}, 1.3 meq/l SO^{2-}, 1 meq/l H_2PO_4, 0.18 ppm Zn, and 1 ppm Fe per 3800 liters of water.

Experiment 1

Plants were grown in a fiberflass reinforced plastic covered peak-style greenhouse, oriented in an east-west direction. The cover transmitted approximately 78% of the photosynthetically active radiation at plant level.

The greenhouse was heated to 17° C day and night, with a stem radiation system. A pan-pad cooling system started cooling the facility automatically at 20° C. Relative humidity ranged from 30 to 50%. On January 22, 1984, cell packs of Sakata blue cultivars were placed in the middle of the three treatment benches which are oriented from north to south (Table 1). When the seedlings reached the four leaf stage, February 25, 1984, they were shifted to 9 cm_diam. pots using the CSU soil medium.

The natural daylength treatment was adjacent to the short day treatment which was achieved with a manually operated black cloth system used daily from 5:00 PM to 8:00 AM. The long day treatment was achieved by lighting from
10:00 PM to 2:00 AM with one 40 watt incandescent bulb per 1.5 m^2 of bench area and 1.5 m above the plant.

Seven plant groups (Table 1) were in each treatment from 20 to 120 days. At 20 day intervals half of each group (six plants) were transferred to the other two photoperiod treatments where they remained until the end of the experiment (Table 1). Control plants for each group remained in the same position throughout the experiment.

Table 1. List of photoperiod treatments[a] evaluated a E. grandiflorum, Sakata F-1 hybrid blue, in Experiment 1 between January 22, and June 19, 1984.

1st Period		2nd Period	1st Period		2nd Period	1st Period		2nd Period
20 (ND)	+	120 (SD)	20 (SD)	+	120 (ND)	20 (LD)	+	120 (SD)
20 (ND)	+	120 (LD)	20 (SD)	+	120 (LD)	20 (LD)	+	120 (ND)
40 (ND)	+	100 (SD)	40 (SD)	+	100 (ND)	40 (LD)	+	100 (SD)
40 (ND)	+	100 (LD)	40 (SD)	+	100 (LD)	40 (LD)	+	100 (ND)
60 (ND)	+	80 (SD)	60 (SD)	+	80 (ND)	60 (LD)	+	80 (SD)
60 (ND)	+	80 (LD)	60 (SD)	+	80 (LD)	60 (LD)	+	80 (ND)
80 (ND)	+	60 (SD)	80 (SD)	+	60 (ND)	80 (LD)	+	60 (SD)
80 (ND)	+	60 (LD)	80 (SD)	+	60 (LD)	80 (LD)	+	60 (ND)
100 (ND)	+	40 (SD)	100 (SD)	+	40 (ND)	100 (LD)	+	40 (SD)
100 (ND)	+	40 (LD)	100 (SD)	+	40 (LD)	100 (LD)	+	40 (ND)
120 (ND)	+	20 (SD)	120 (SD)	+	20 (ND)	120 (LD)	+	20 (SD)
120 (ND)	+	20 (LD)	120 (SD)	+	20 (LD)	120 (LD)	+	20 (SD)
140 (ND)	control		140 (SD)	control		140 (LD)	control	

[a]Treatment in days ND = Natural Day SD = Short Day LD = Long Day

Fresh and dry weight, stem length, flower development, and number of nodes were measured.

Experiment 2

The experiment was conducted on the east-west oriented bench in a fiberglass reinforced covered peak-style greenhouse used for cut rose research.

The house was heated to 17° C nights and 22° C days. Cooling occurred automatically at 30° C. Relative humidity was maintained at 70% and CO_2 at 1,000 ull-l during daylight hours and periods of no ventilation.

Seedlings of E. grandiflorum Sakata F-l hybrid pink, were transplanted into cell packs and grown in the greenhouse through the seedling stage. Seedlings in the five leaf stage were transplanted into 10. cm_diam. pots using CSU soil on March 3, 1984 and the photoperiod treatment started. Plants were transplanted to 15. cm_diam. pots on April 6, 1984. A bench was divided into three treatment plots, each with five groups of four plants (Table 2). The long day treatment was accomplished with one 100 watt incandescent bulb per 1.5 m^{-2} bench area, suspended 1.5 m above pots and turned on from 10:00 PM to 2:00 AM for night interruption purpose. The short day trteatment was imposed from 5:00 PM to 8:00 AM, and the third treatment involved natural photoperiod.

The plants were divided into five groups of four plants (Table 2) and rotated through the treatments as described in Experiment 1 at intervals of 20 days (Table 2).

Table 2. List of photoperiod treatments[a] evaluated a E. grandiflorum, Sakata F-1 hybrid pink, in Experiment 2 between March 3, and June 8, 1984.

1st Period		2nd Period	1st Period		2nd Period	1st Period		2nd Period
20 (ND)	+	80 (SD)	20 (SD)	+	80 (ND)	20 (LD)	+	80 (SD)
20 (ND)	+	80 (LD)	20 (SD)	+	80 (LD)	20 (LD)	+	80 (ND)
40 (ND)	+	60 (SD)	40 (SD)	+	60 (ND)	40 (LD)	+	60 (SD)
40 (ND)	+	60 (LD)	40 (SD)	+	60 (LD)	40 (LD)	+	60 (ND)
60 (ND)	+	40 (SD)	60 (SD)	+	40 (ND)	60 (LD)	+	40 (SD)
60 (ND)	+	40 (LD)	60 (SD)	+	40 (LD)	60 (LD)	+	40 (ND)
80 (ND)	+	20 (SD)	80 (SD)	+	20 (ND)	80 (LD)	+	20 (SD)
80 (ND)	+	20 (LD)	80 (SD)	+	20 (LD)	80 (LD)	+	20 (ND)
100 (ND) control			100 (SD) control			100 (LD) control		

[a]Treatments in days
ND = Natural Day
SD = Short Day
LD = Long Day

Data included fresh and dry weight, stem length, flower development and number of nodes.

The two experiments were analyzed as two-way ANOVA and Tukey's HSD Test for mean separation at (P = 0.05). However, for statistical analyses used involved the square root of the number of flowers, breaks, and nodes was used since the data were skewed.

RESULTS AND DISCUSSION

Experiment 1

There were no significant differences in flower stem length, number of flowers and nodes, or fresh and dry weights of the control plants grown exclusively in the three photoperiod treatments (Table 3). The longest flower stems were produced by plants grown for 100 days in the natural day treatment and then placed in the long day treatment for additional 40 days (Fig. 2a). The stems of these plants were significantly longer than those of the control plants in the long day treatment. The shortest flower stems in the experiment were produced by plants grown in the short day photoperiod treatment for 100 days and then placed in the long day treatment for additional 40 days. However, the stem length did not differ significantly from the stems produced by the control plants in the initial treatment (Fig. 2a).

The greatest number of flowers were obtained from plants given 100 natural days, then placed in the under long days for 40 days (Fig. 3a).

There were no differences in flower production between control plants in the photoperiod treatments or within their combinations (Fig. 3a, b, and c).

Table 3. Response of control plants of E. grandiflorum, Sakata F-1 hybrid blue, in Experiment 1 at day and night temperature 17° C and relative humidity ranged from 30 to 50%.

Photo Period Treatment	Stem length (cm)	$\sqrt{x}$ flowers per plant	$\sqrt{x}$ node per main stem	Fresh weight (g) per plant	Dry weight (g) per plant
Short Day	44.7	1.6	3.4	34.6	7.0
Long Day	41.9	1.8	3.3	34.2	6.1
Natural Day	43.6	2.2	3.2	30.0	6.2
$HSD_{0.05}$ =	NS	NS	NS	NS	NS

Figure 2. Influence of natural day (ND), short day (SD), and long day (LD) photoperiod combination to totaling 140 days, on the flowering stem length of E. grandiflorum, Sakata F-1 hybrid blue, grown in 17° C day and night temperature (Experiment 1).

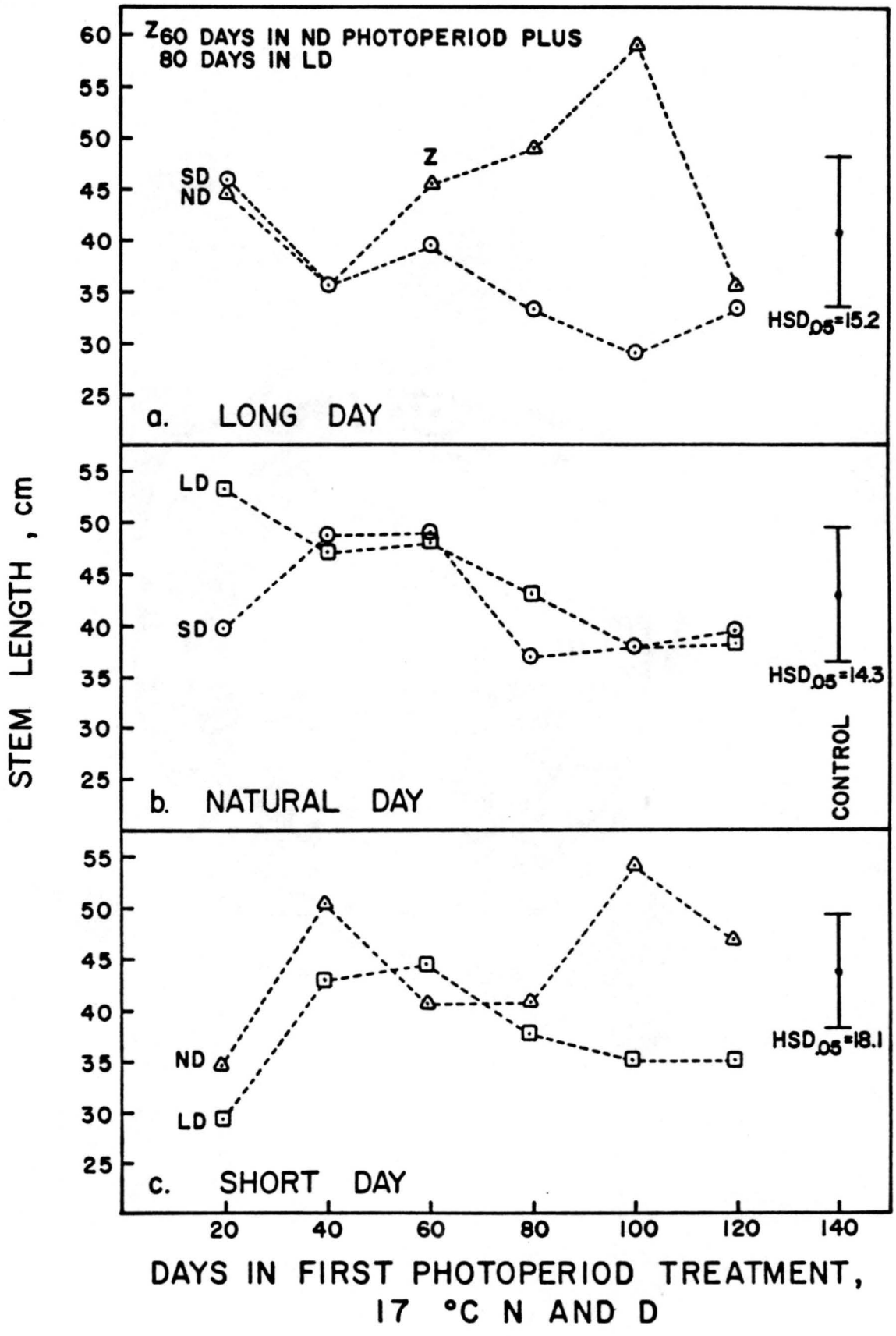
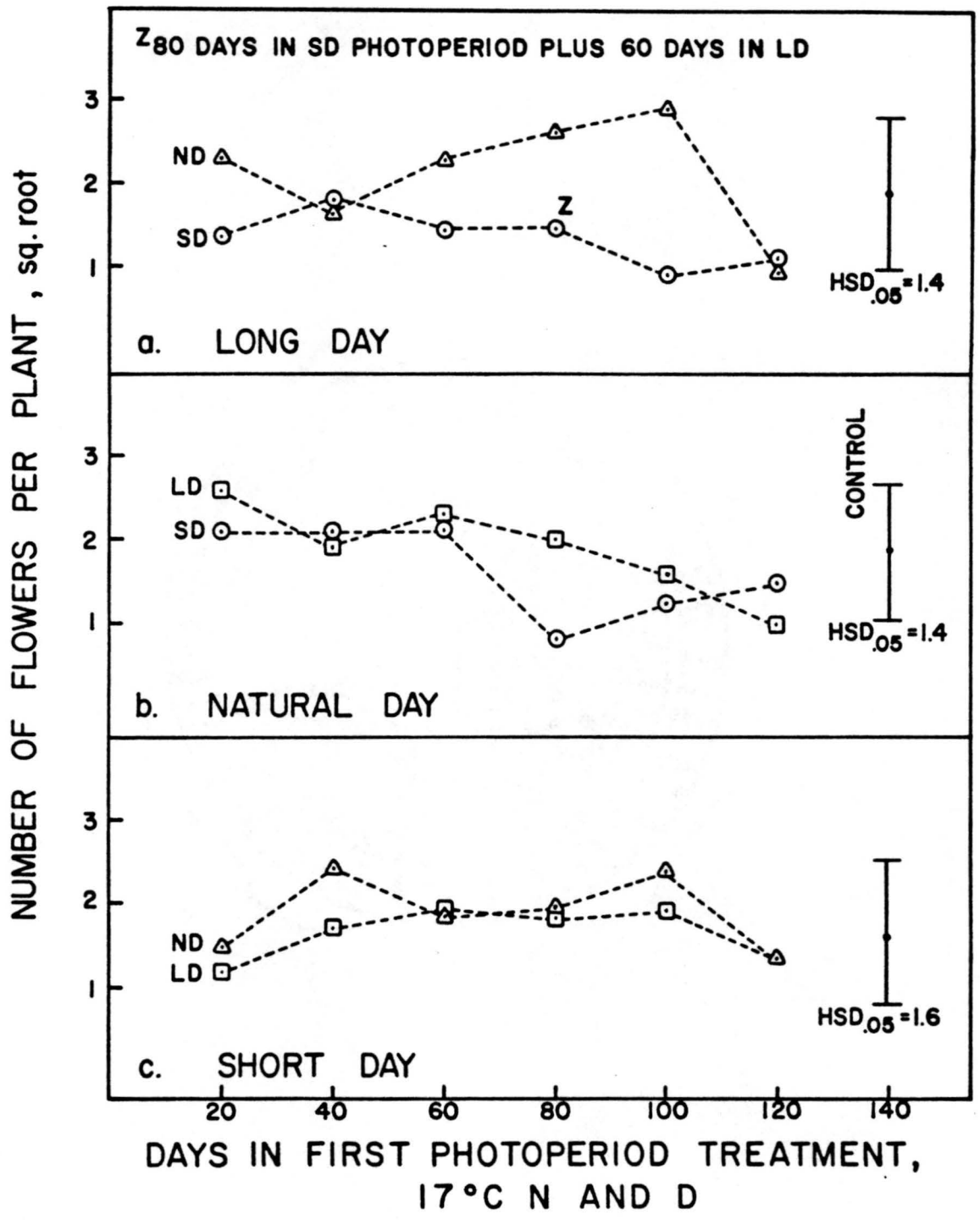

Z 60 DAYS IN ND PHOTOPERIOD PLUS 80 DAYS IN LD
SD
ND
Z
HSD.05=15.2
a. LONG DAY
LD
SD
HSD.05=14.3
b. NATURAL DAY
CONTROL
ND
LD
HSD.05=18.1
c. SHORT DAY
STEM LENGTH , cm
60
55
50
45
40
35
30
25
20
40
60
80
100
120
140
DAYS IN FIRST PHOTOPERIOD TREATMENT, 17 °C N AND D

Figure 3. Influence of natural day (ND), short day (SD), and long day (LD) photoperiod combinations to totaling 140 days, on the flower production of E. grandiflorum, Sakata F-1 hybrid blue, grown in 17° C day and night temperatures (Experiment 1).


Z 80 DAYS IN SD PHOTOPERIOD PLUS 60 DAYS IN LD
ND
SD
Z
HSD.05=1.4
a. LONG DAY
LD
SD
CONTROL
HSD.05=1.4
b. NATURAL DAY
ND
LD
HSD.05=1.6
c. SHORT DAY
NUMBER OF FLOWERS PER PLANT, sq. root
1
2
3
20
40
60
80
100
120
140
DAYS IN FIRST PHOTOPERIOD TREATMENT, 17°C N AND D

There were no significant differences in the number of nodes or fresh weights of plants within or between photoperiod treatments (Table A-12 and A-13).

Plants with the greatest dry weights were grown under the long day photoperiod for 20 days then placed in the natural day treatment for 120 days (Fig. 4b).

Data obtained in this experiment indicates that E. grandiflorum Sakata F-1 hybrid blue, was not photoperiod responsive.

The flower buds were visually initiated in all plants by week of April 15 and flowers were in prime condition on May 5.

Experiment 2

There were no significant differences in flower stem lengths and number of nodes of control plants grown in the three photoperiod treatments. However, there were significant differences in the number of flowers and fresh and dry weights (Table 4).

The longest stems were produced on plants grown 80 days in the long day photoperiod and then grown 20 days in the short day treatment (Fig. 5c).

The plants grown under the various long day photoperiods, conditions and then moved to the natural day, had longer stems than the ND control and approached the stem lengths of the LD control (Fig. 5a and b).

Figure 4. Influence of natural days (ND), short day (SD), and long day (LD) photoperiod combination total 140 days, on the dry weight of E. grandiflorum, Sakata F-1 hybrid blue, grown in 17° C day and night temperature (Experiment 1).

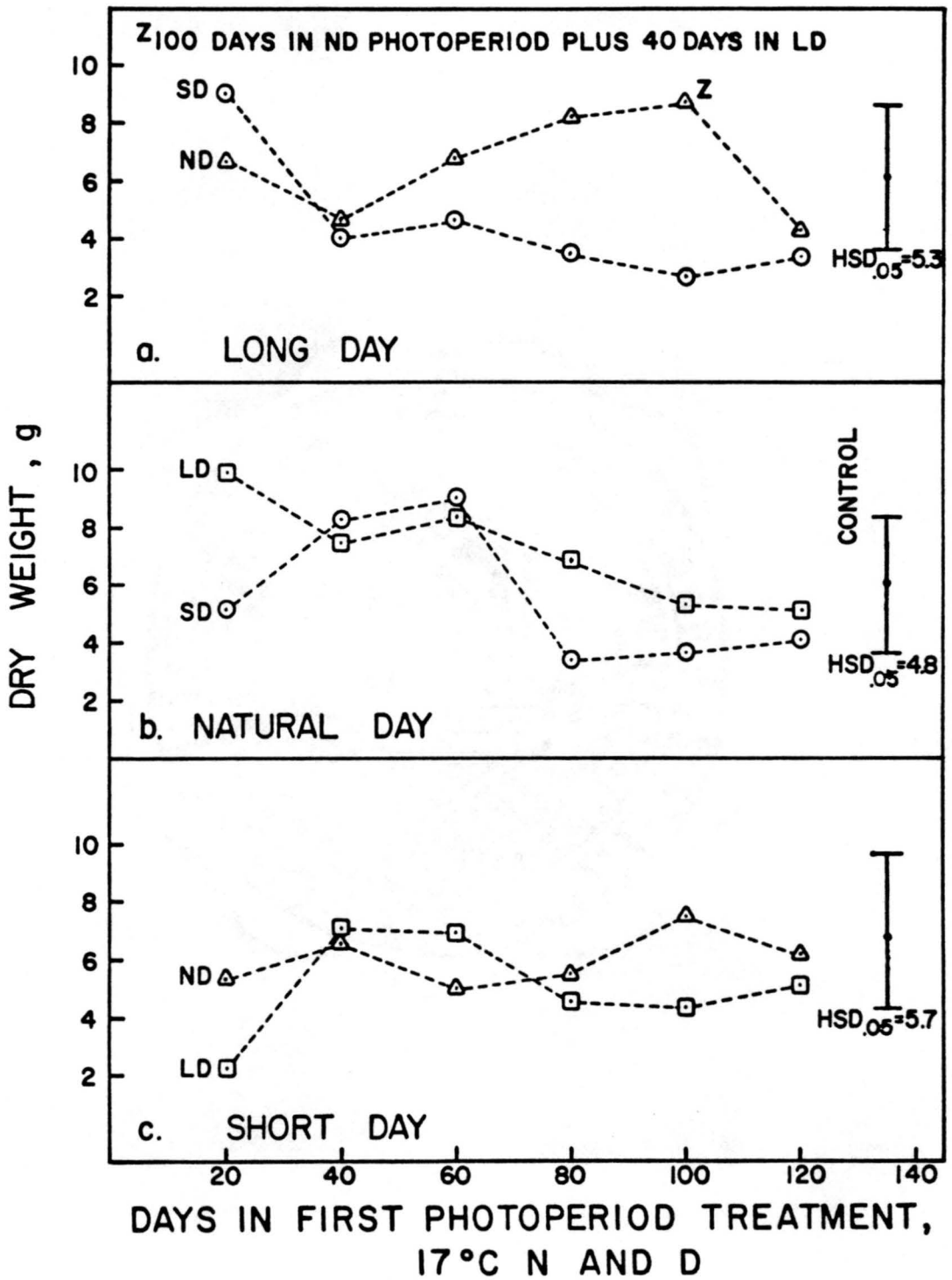

Z 100 DAYS IN ND PHOTOPERIOD PLUS 40 DAYS IN LD
SD
ND
Z
HSD.05=5.3
a. LONG DAY
LD
SD
CONTROL
HSD.05=4.8
b. NATURAL DAY
ND
LD
HSD.05=5.7
c. SHORT DAY
DRY WEIGHT, g
10
8
6
4
2
20
40
60
80
100
120
140
DAYS IN FIRST PHOTOPERIOD TREATMENT, 17°C N AND D

Figure 5. Influence of natural day (ND), short day (SD), and long day (LD) photoperiod combinations to totaling 100 days, on the flowering stem length of *E. grandiflorum*, Sakata F-1 hybrid pink, grown in 17° C night and 22° C day temperatures (Experiment 2).

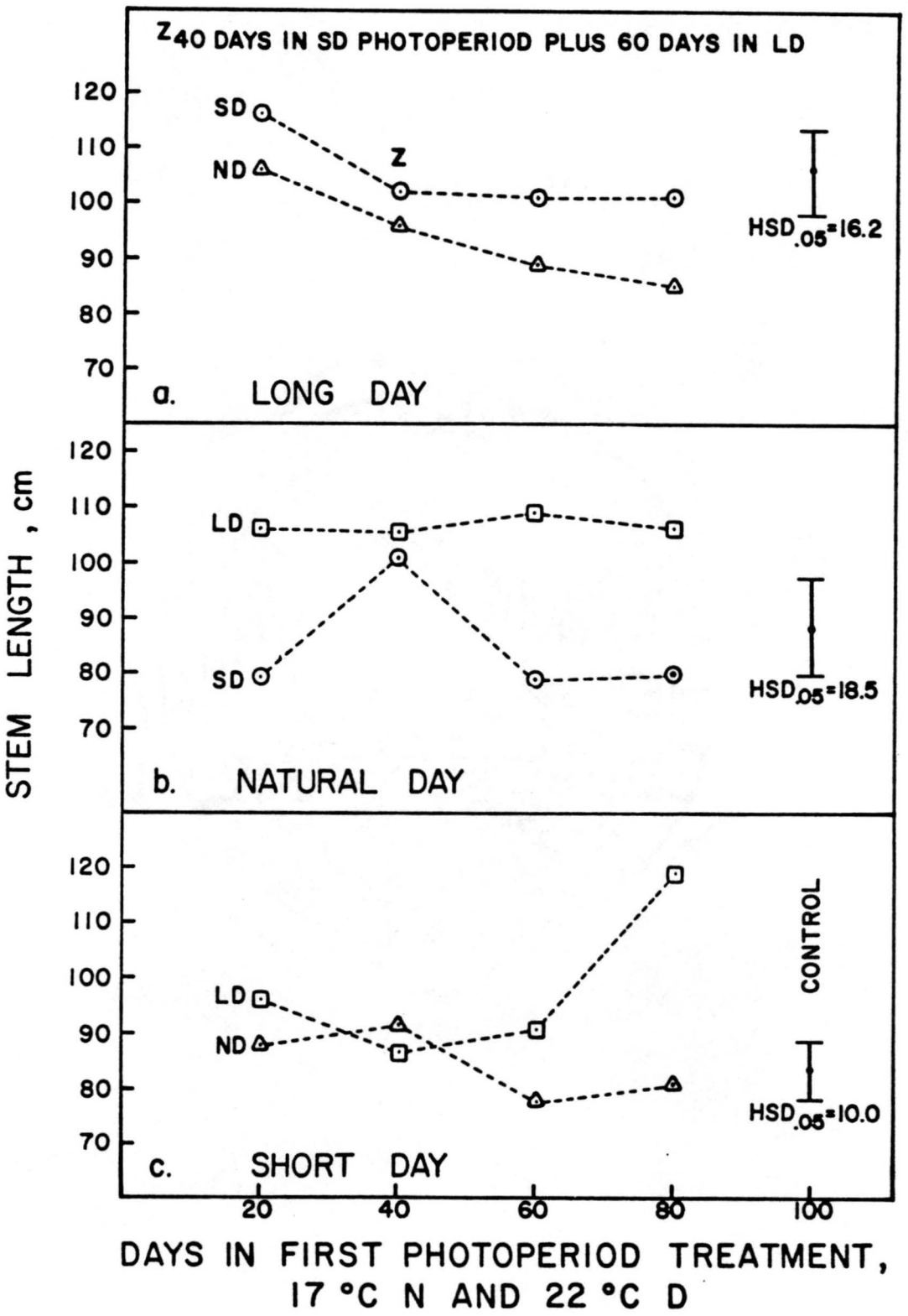

Z 40 DAYS IN SD PHOTOPERIOD PLUS 60 DAYS IN LD
SD
Z
ND
HSD.05=16.2
a. LONG DAY
LD
SD
HSD.05=18.5
b. NATURAL DAY
LD
ND
CONTROL
HSD.05=10.0
c. SHORT DAY
120
110
100
90
80
70
20
40
60
80
100
STEM LENGTH , cm
DAYS IN FIRST PHOTOPERIOD TREATMENT,
17 °C N AND 22 °C D

Table 4. Response of control plants of *E. grandiflorum*, Sakata F-1 hybrid pink, in Experiment 2 in 17° C night and 22° C day temperatures and relative humidity 70%.

Photo Period Treatment	Stem length (cm)	$\sqrt{x}$ flowers per plant	$\sqrt{x}$ node per main stem	Fresh weight (g) per plant	Dry weight (g) per plant
Short Day	84.3	4.6^{a}	3.9	86.9^{a}	19.5^{a}
Long Day	106.5	3.7^{a}	3.9	77.4^{ab}	15.7^{ab}
Natural Day	88.3	2.0^{b}	4.9	52.0^{b}	12.0^{a}
$HSD_{0.05}$ =	NS	1.53	NS	28.1	6.0

The least number of flowers were produced on plants grown continuously in natural days (Table 4). Plants receiving the SD treatment in any combination tended to have the lowest flower count (Fig. 6 and b).

No significant differences occurred in the number of nodes or fresh weights of plants within or between photoperiod treatments (Talbe A-17 and A-18).

The greatest dry weights were obtained from plants given 20 long days and then placed in natural days treatment for 80 days (Fig. 7b). Control plants in the short day photoperiod treatment had the largest dry weight (Table 4).

However, there were significant differences in the dry weight of the natural day control plants and the plants given 20 long days and then placed in the natural day treatment for 80 days (Fig. 7b).

In the three photoperiod treatments, the flower buds were visually initiated in April 15, and flowers in prime condition in April 28.

The results of these experiments indicated that E. grandiflorum Sakata F-1 hybrid blue and pink, were natural day plant and flower after reaching a certain age or size. The results were not in agreement with previous reports (1, 10, 16).

The E. grandiflorum was definitely sensitive to temperature and the greatest positive growth responses occur in relatively warm temperature regimes. As day temperature increased

from 17° C (Experiment 1) to 22° C (Experiment 2), the average stem length, number of flowers, nodes, and fresh and dry weights increased two-fold regardless of the photoperiod treatment. However, the number of days to flower did not differ in the two temperature treatments.

Figure 6. Influence of natural day (ND), short day (SD), and long day (LD) photoperiod combinations to totaling 100 days, on the flower production of *E. grandiflorum*, Sakata F-1 hybrid pink, grown in 17° C night and 22° C day temperatures (Experiment 2).

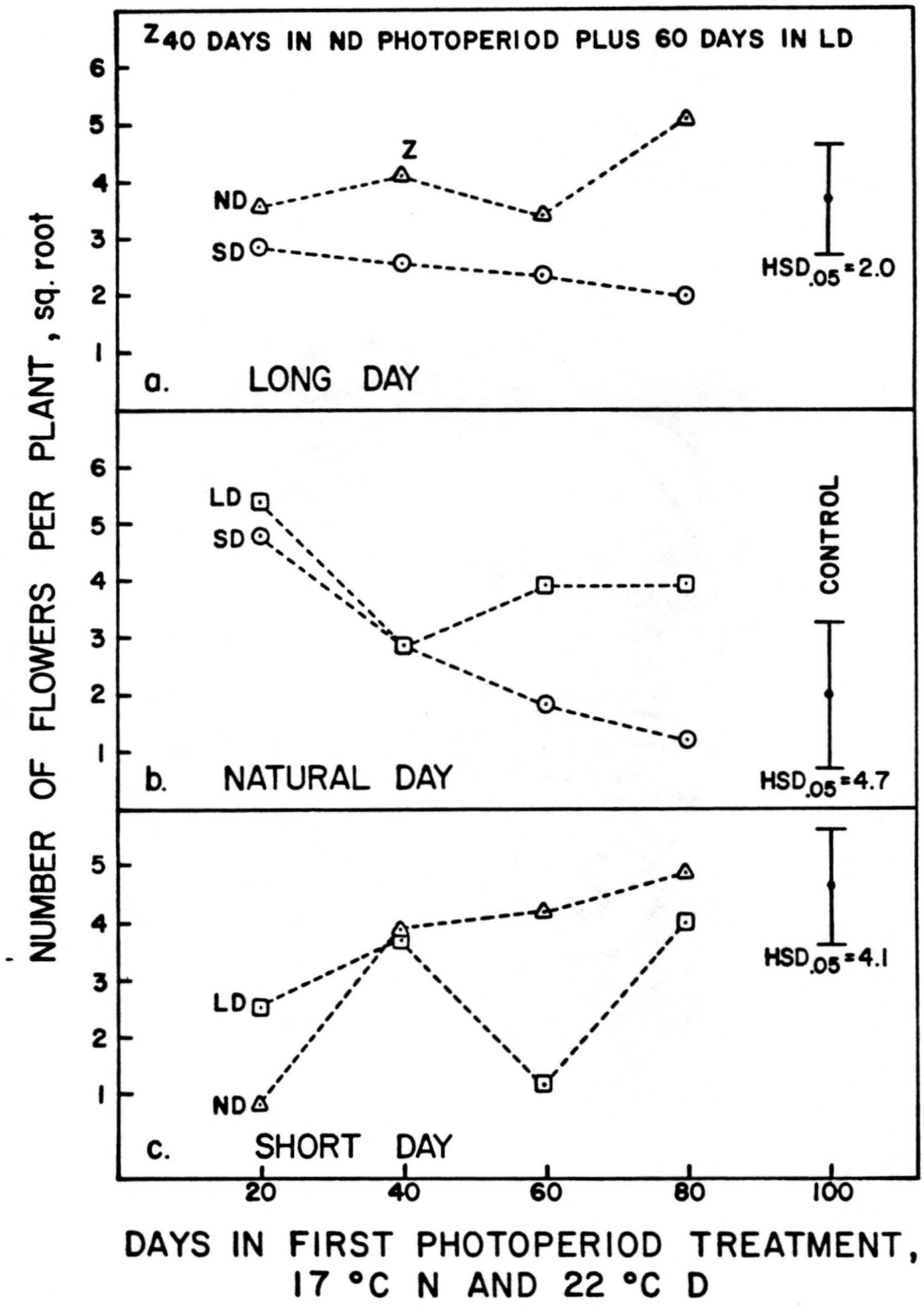
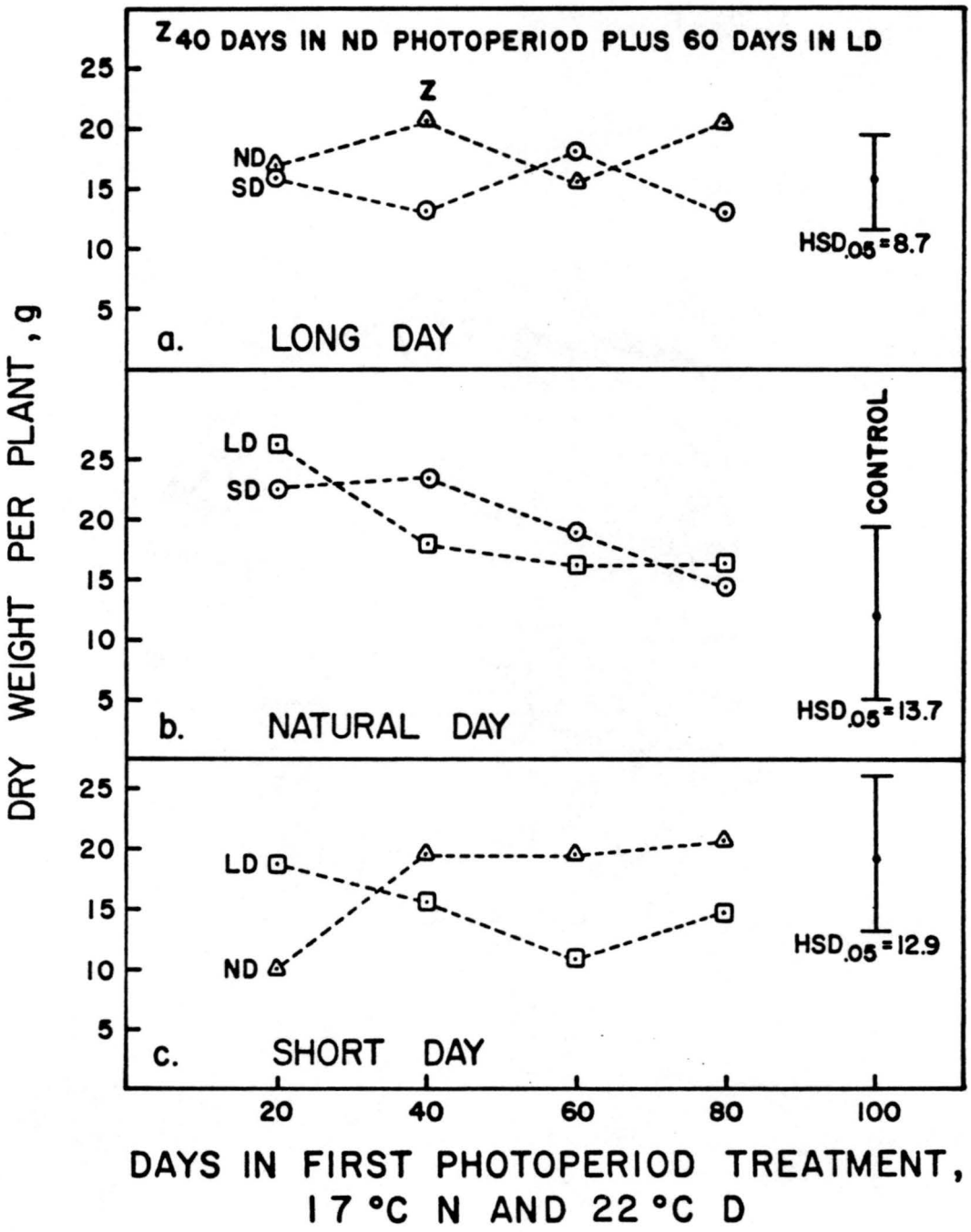

Z 40 DAYS IN ND PHOTOPERIOD PLUS 60 DAYS IN LD
Z
ND
SD
HSD.05=2.0
a. LONG DAY
LD
SD
CONTROL
HSD.05=4.7
b. NATURAL DAY
LD
ND
HSD.05=4.1
c. SHORT DAY
NUMBER OF FLOWERS PER PLANT, sq. root
1
2
3
4
5
6
20
40
60
80
100
DAYS IN FIRST PHOTOPERIOD TREATMENT,
17 °C N AND 22 °C D

Figure 7. Influence of natural day (ND), short day (SD), and long day (LD) photoperiod combinations to totaling 100 days, on the dry weight of *E. grandiflorum* hybrid pink, in 17° C night and 22° C day temperature (Experiment 2).


Z 40 DAYS IN ND PHOTOPERIOD PLUS 60 DAYS IN LD
Z
ND
SD
HSD.05=8.7
a. LONG DAY
LD
SD
CONTROL
HSD.05=13.7
b. NATURAL DAY
LD
ND
HSD.05=12.9
c. SHORT DAY
DRY WEIGHT PER PLANT, g
25
20
15
10
5
20
40
60
80
100
DAYS IN FIRST PHOTOPERIOD TREATMENT,
17 °C N AND 22 °C D

LITERATURE CITED

1. Anonymous. 1983. Producing Lisianthun profitably. Greenhouse Grower 11:12.

2. Cathey, H. M. 1957. Chrysanthemum temperature study. The effect of temperature upon the critical photoperiod necessary for initiation and development of Chrysanthemum morifolium. Proc. Am. Soc. Hort. Sci. 69:485-491.

3. Correl, D. S. and M. C. Johnston. 1970. Manual of the vascular plants of Texas. Texas Research Foundation, Renner Texas.

4. Hanan, J. J., D. Holley and K. L. Goldsberry. 1978. Greenhouse Management. Springer-Verlag, Heidelsberg.

5. Heins, R. D. and H. F. Wilkins. 1979. The influence of photoperiod on lateral shoot development of carnation. Colo. Flower Growers' Assn. Bull. 347.

6. Hillman, W. S. 1962. The physiology of flowering. Holt, Rinehart, and Winston. New York.

7. Post, K. 1949. Florist Corp. production and marketing. Orange-Judd, New York.

8. Post, K. and H. Kamemoto. 1950. A study on the number of short photoperiod required for flower initiation and the effect of interruption on flower spray formation in two commercial varieties of chrysanthemums. Proc. Am. Soc. Hort. Sci. 55:488-482.

9. Rickett, H. W. 1966. Wild flowers of the United States. Volume 3. Texas. McGraw-Hill Book Company. New York.

10. Roh, M. S. and R. H. Lawson. 1984. The lure of Lisian thus. Flower of the Far East captures interest in West. Greenhouse Manager 3:67-121.

11. Sakata, T. Company. 1984. Personal communication with Dr. K. L. Goldsberry.

12. Salisbury, F. B. 1963. The flowering process. Elmsford, New York. Pergamon.

13. Samman, Y. and R. W. Langhans. 1962. Interaction of temperature and photoperiodism in Chrysanthemum morifolium. Proc. 15th Int. Hort. Cong., Nice, France, 1958, 2, 400-411.

14. Tija, B. and T. J. Sheehan. 1984. Lisianthus (Eustoma) as a bedding plant. Florida Ornamental Grower's Assn. Newsletter 6(4):1.

15. Wilkerson, D. C. 1983. Result from Texas Bluebell trials. Texas Greenhouse Bull. 66.

16. Wilkins, H. F. and K. L. Grueber. 1983. Eustoma grandiflorum. Minnesota Bull. December.

CHAPTER III

MEDIA EVALUATION

Literature Review

A soil medium is complex physically and chemically, and is often considered as a living organism (2). The ideal growing medium for plants provides support, facilitates the water requirement, insures available nutrients, and contains an excess of air even immediately following irrigation (2). Hanan and Jasper (3) indicated that yield and flower grade of carnation plants were directly related to the amount of water availability to them and maximum production occur red when soil moisture stress was minimized, provided other factors were favorable.

Holley (4) reported that many cultural problems are associated with improper soil media. A poorly aerated soil contributes to root loss and increases the susceptibility of soil borne pathogens. Plant water stress is frequently due to lack of water holding capacity and increased watering frequencies lead to over watering in a soil medium. Holley (4) recommended a soilless, inert media for producing greenhouse plants.

An inert medium was defined as a material which does not break down, and has no organic matter for sustaining

microbial activity. Specific media described were pea gravel, volcanic scoria and idealite, a heat treated pierre shale.

The yield of carnation plants grown in pea gravel medium was 15% greater than the production from plants in soil substrate during (3 yr.) period (5). Holley (4) reported the use of volcanic scoria as a medium at Colorado State University in 1957. It was used for growing nucleus carnation stock plants in pots and for bench culture of cut flowers. He indicated a bench of Forever Yours roses had been grown for (8 yr.) in scoria and was one of the most productive benches in the house. Idealite also provided similar rose production.

The correct irrigation frequency and adequate nutrients are very important factors for optimum plant growth when inert growing media are used.

Roh and Lawson (6) reported that E. grandiflorum can be grown in any light, porous and well-drained medium high in organic matter. Wilkerson (7) used a peat perlite medium in his study.

The lack of information in the literature on a plant grown medium for E. grandiflorum lead to a study to evaluate various media on the growth and flowering of the plant.

METHODS AND MATERIALS

The experiment was conducted in a north-south oriented, quonset-style greenhouse, heated with gas fired unit heater, cooled with a fan-pad cooling system and covered with PVF-nexglaze panel. The cover transmitted approximately 68% of photosynthetically active radiation (1). Temperature controls were set to heat to 16° C night and 21° C day and cool to 27° C during the day.

On March 20, 1984, seven to eight leaf stage seedlings of Sakata F-1 hybrid Pink E. grandiflorum were planted into 15 cm. diam. pots using ten different kinds of media (Table 5). After the plants were well established, the terminal stem was removed leaving six pairs of leaves on the plant. Inert media (volcanic scoria, gravel, and idealite) were automatically watered three times per day with a nutrient treated water (Chapter 2). The rest of the treatments were watered when the media became dry to the touch. The plants were observed until their flowers were developed.

After 85 days, data were taken on whole plant fresh and dry weight, stem length, number of flowers, breaks and nodes, and visual observation of plant stems and roots.

The experiment was analyzed as one-way ANOVA and Tukey's HSD test for mean separation at ($P = 0.05$).

Table 5. Media treatments used to evaluate the growth of *E. grandiflorum*, Sakata F-1 hybrid pink.

Code	Designation	Volume Ratio	Description
a.	Volcanic scoria	1	Commercially available with no particles larger than 5.6-8 mm and few larger than 1-2 mm.
b.	Idealite	1	A manufactured light-weight aggregate with no particles larger than 5.6-8 mm and few less than 1-2 mm.
c.	CSU soil	1:2:1	Fort Collins clay loam - Canadian sphaghum peat moss, No. 6 perlite.
d.	Gravel	1	With particles larger than 8-10 mm.
e.	Volcanic Scoria + peat	2:1	Scoria (a) plus Canadian sphaghum, moss, peat.
f.	Volcanic scoria + peat	3:1	Scoria (a) plus Canadian sphaghum peat moss.
g.	Idealite + peat	2:1	Idealite (b) plus Canadian sphaghum moss, peat
h.	Idealite + peat	3:1	Idealite(b) plus Canadian sphaghum peat moss.
i.	Gravel + peat	2:1	Gravel (d) plus Canadian sphaghum peat moss.
j.	Gravel + peat	3:1	Gravel (d) plus Canadian sphaghum peat moss.

RESULTS AND DISCUSSION

The longest flower stems were produced by plants grown in the 100% volcanic scoria medium, and the shortest length from plants grown in the idealite plus peatmoss medium (2:1 V/V, Fig. 8).

There were no significant differences in the average number of the flowers per plant produced in the different media (Table 6). Plants in the gravel-peatmoss 3:1 V/V medium had the most vegetative breaks but only differred significantly from the volcanic scoria peatmost (3:1 V/V). No significant differences occurred in the number of breaks produced by plants grown in the 3 100% inert growing media (Fig. 9).

There were no significant differences in the number of nodes produced by plants due to the growing media. However, the plants in idealite-peatmoss 2:1 V/V medium had the least nodes and those growing in 100% idealite, the most (Table 6).

Dry weight of the plants grown in 100% idealite medium was largest but only differred significantly from plants grown in the CSU soil or idealite-peat 2:1 V/V substrates (Fig. 10).

Plants which were grown in gravel, volcanic scoria and idealite media had the most root development when compared with roots of the plants grown in CSU soil (Fig. 11).

Figure 8. The influence of 10 growing media on the plant stem length produced by E. grandiflorum, Sakata F-1 hybrid pink.

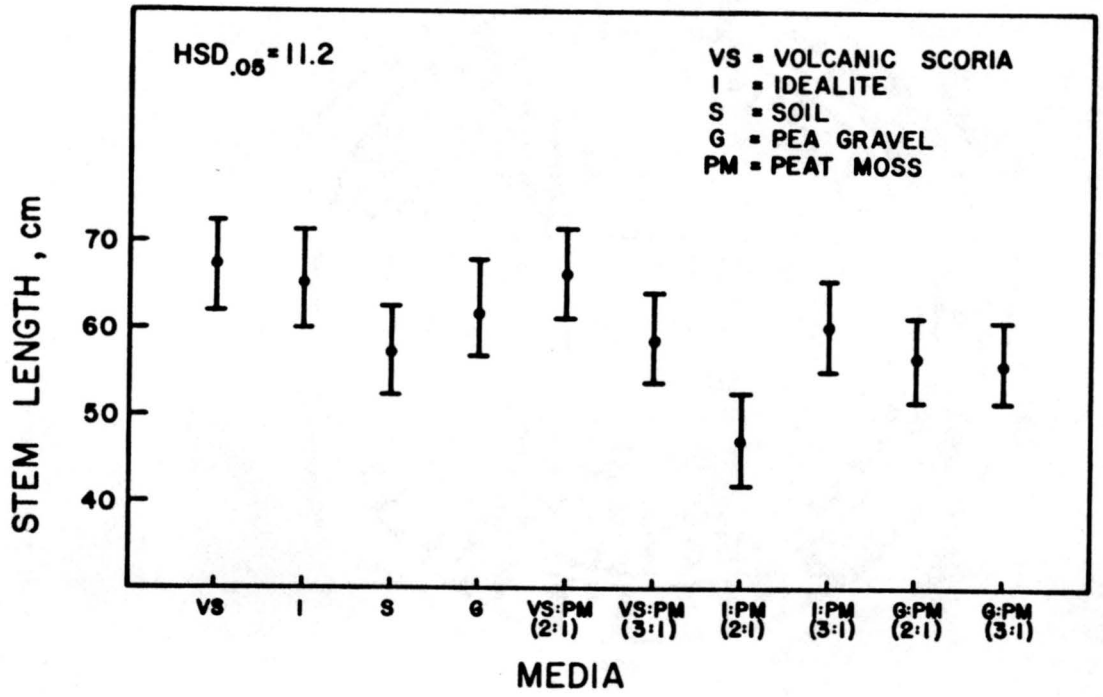

HSD.05 = 11.2
VS = VOLCANIC SCORIA
I = IDEALITE
S = SOIL
G = PEA GRAVEL
PM = PEAT MOSS
STEM LENGTH, cm
70
60
50
40
VS
I
S
G
VS:PM (2:1)
VS:PM (3:1)
I:PM (2:1)
I:PM (3:1)
G:PM (2:1)
G:PM (3:1)
MEDIA

Figure 9. Number of breaks (square root) produced by *E. grandiflorum*, Sakata F-1 hybrid pink in 10 different substrates.

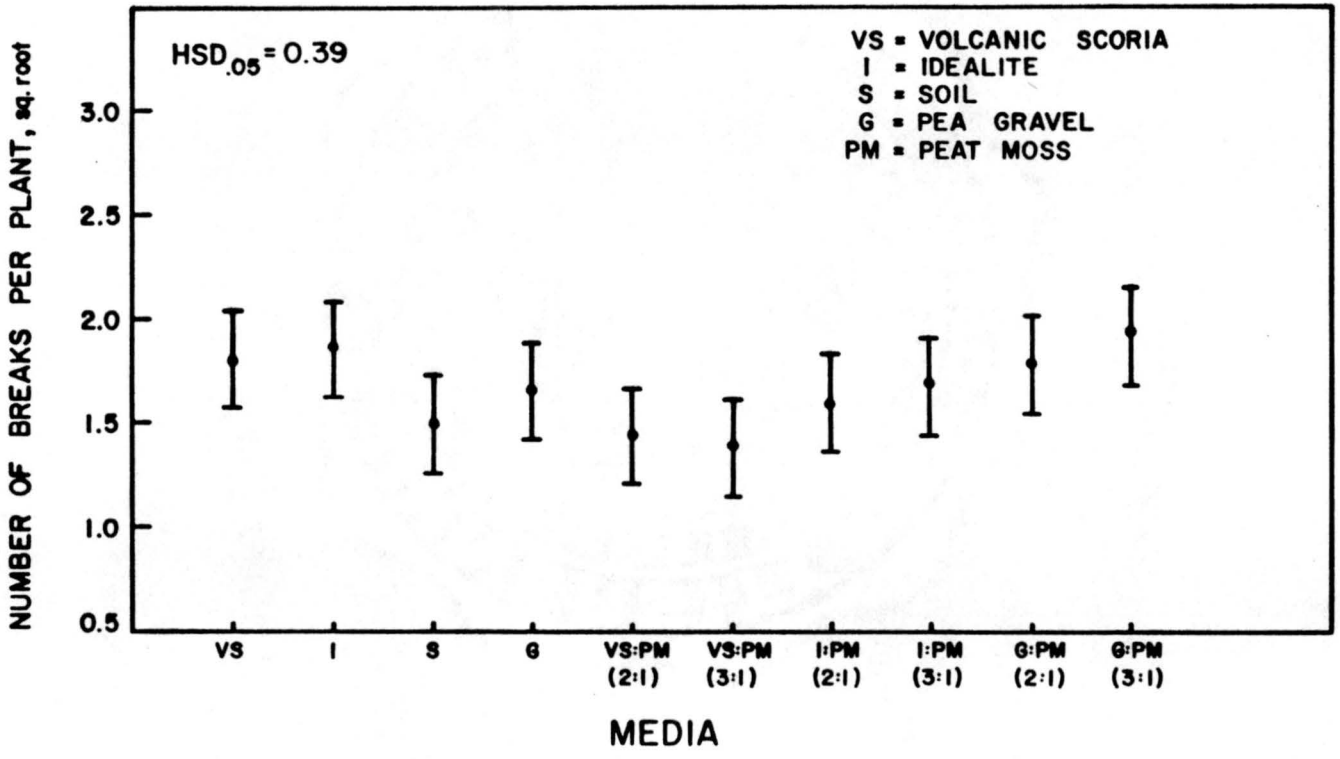

HSD.05 = 0.39
VS = VOLCANIC SCORIA
I = IDEALITE
S = SOIL
G = PEA GRAVEL
PM = PEAT MOSS
NUMBER OF BREAKS PER PLANT, sq. root
3.0
2.5
2.0
1.5
1.0
0.5
VS
I
S
G
VS:PM (2:1)
VS:PM (3:1)
I:PM (2:1)
I:PM (3:1)
G:PM (2:1)
G:PM (3:1)
MEDIA

Figure 10. The influence of 10 growing media on the plant dry weight produced by E. grandiflorum, Sakata F-1 hybrid pink.

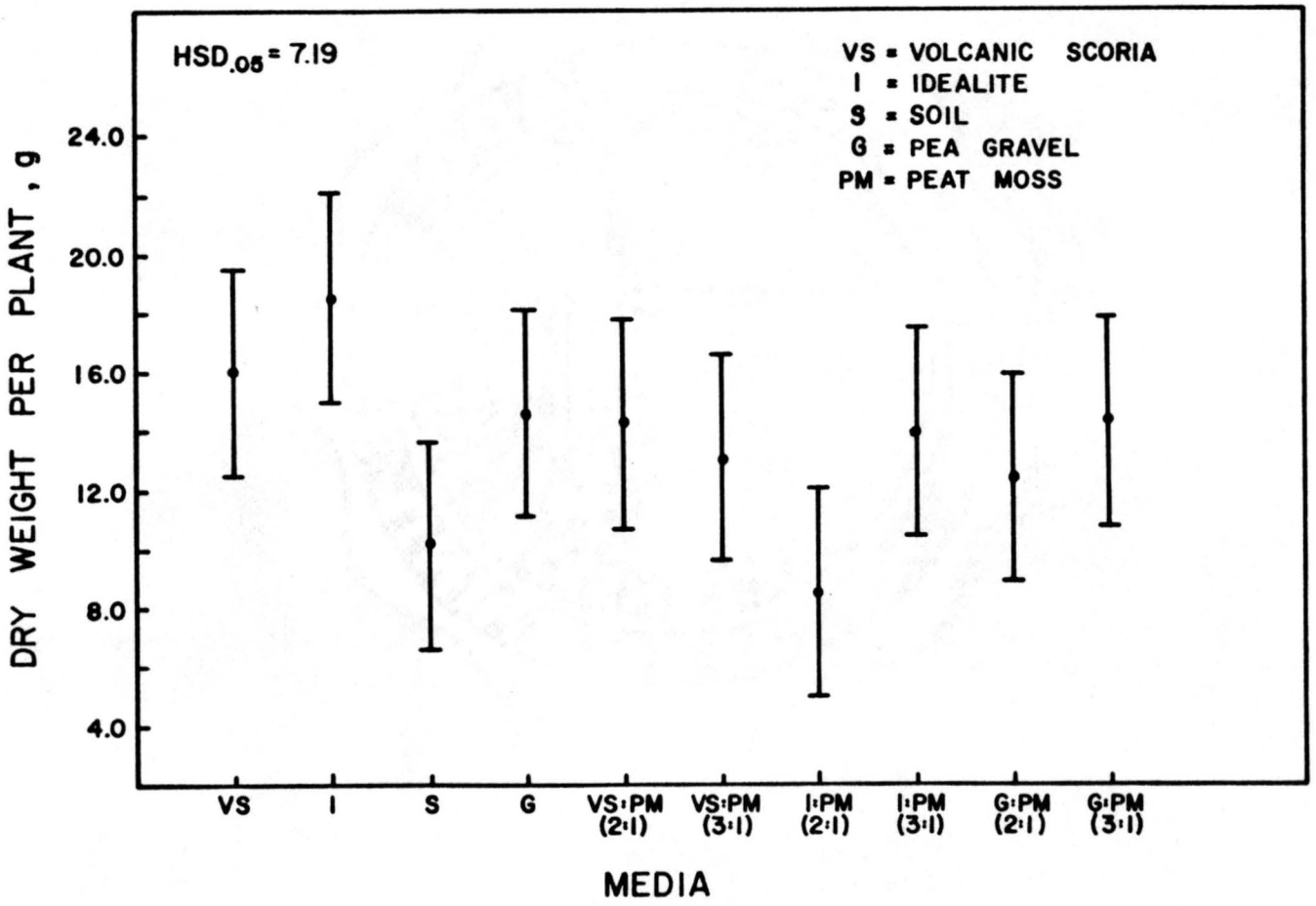
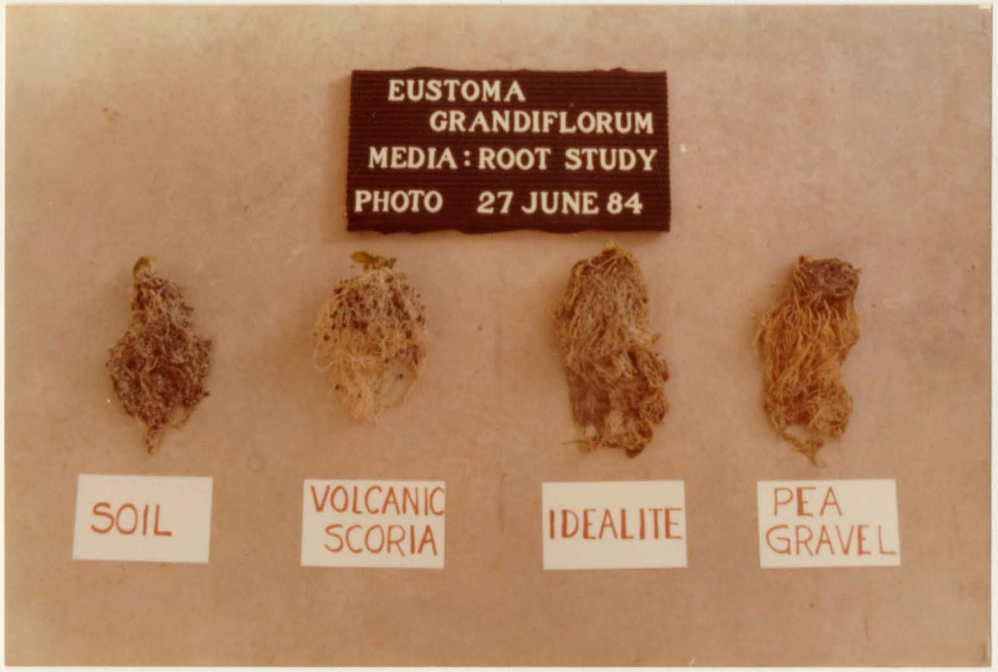

HSD.05 = 7.19
VS = VOLCANIC SCORIA
I = IDEALITE
S = SOIL
G = PEA GRAVEL
PM = PEAT MOSS
DRY WEIGHT PER PLANT, g
24.0
20.0
16.0
12.0
8.0
4.0
VS
I
S
G
VS:PM (2:1)
VS:PM (3:1)
I:PM (2:1)
I:PM (3:1)
G:PM (2:1)
G:PM (3:1)
MEDIA

Table 6. Growth response of E. grandiflorum, Sakata F-1 hybrid pink, grown in ten media from March 20, 1984 to June 15, 1984.

Media	Stem Length (cm)	$\sqrt{x}$ flowers per plant	$\sqrt{x}$ breaks per plant	$\sqrt{x}$ nodes per main stem	Fresh Weight (g)	Dry Weight (g)
Idealite plus peatmoss (2:1 V/V)	47.4^{a}	2.66^{a}	1.63^{abcd}	3.103^{a}	48.96^{a}	8.51^{a}
Gravel plus peatmoss (3:1 V/V)	55.0^{ab}	3.13^{a}	1.94^{d}	3.211^{ab}	71.32^{abc}	14.37^{abc}
Gravel plus peatmoss (2:1 V/V)	56.3^{abc}	3.81^{a}	1.79^{abcd}	3.335^{ab}	66.05^{abc}	12.40^{abc}
CSU soil, peatmoss, clayloam, perlite (2:1:1 V/V)	57.4^{abcd}	2.89^{a}	1.54^{abc}	3.326^{ab}	52.90^{a}	10.52^{ab}
Volcanic scoria plus peatmoss (3:1 V/V)	58.2^{abcd}	3.46^{a}	1.41^{a}	3.262^{ab}	60.10^{ab}	14.05^{abc}
Idealite plus peatmoss (3:1 V/V)	61.4^{bcd}	2.96^{a}	1.75^{abcd}	3.251^{ab}	73.59^{abc}	13.00^{abc}
100% gravel	62.1^{bcd}	3.79^{a}	1.66^{abcd}	3.325^{ab}	72.81^{abc}	18.32^{c}
100% Idealite	65.8^{bcd}	3.46^{a}	1.87^{cd}	3.421^{b}	95.40^{bc}	18.52^{c}
Volcanic scoria plus peatmoss (2:1 V/V)	66.7^{cd}	4.01^{a}	1.44^{ab}	3.346^{b}	70.58^{abc}	14.32^{abc}
100% Volcanic scoria	67.7^{d}	3.35^{a}	1.87^{cd}	3.208^{ab}	90.40^{bc}	16.04^{bc}
$HSD_{0.05}$	11.2	1.76	0.39	0.237	34.95	7.19

Figure 11. The influence of four growing media on the root development of E. grandiflorum, Sakata F-1 hybrid pink.


EUSTOMA
GRANDIFLORUM
MEDIA : ROOT STUDY
PHOTO 27 JUNE 84
SOIL
VOLCANIC SCORIA
IDEALITE
PEA GRAVEL

The pH of the ten media ranged from 6.29 to 7.28. Substrate aeration and moisture availability appeared to be the most important factors in the growth of the plants. The inert media were automatically watered four times per day, but drainage was rapid permitting good aeration.

The production and yield of E. grandiflorum in the inert media were similar to results reported by Holley (4) and Holley and Novovesky (5), regarding the growth of roses and carnations in the same media.

LITERATURE CITED

1. Ferare, J. and K. L. Goldsberry. 1984. Environmental conditions created by plastic film glazings. Colo. Greenhouse Grower's Assn. Research Bull. 404.

2. Hanan, J. J., D. Holley and K. L. Goldsberry. 1978. Greenhouse Management. Springer-Verlag, Heidelberg.

3. Hanan, J. J. and F. D. Jasper. 1969. Consumptive water use and response of carnation to three irrigation regimes. J. Am. Soc. Hort. Sci. 94:70-73.

4. Holley, W. D. 1967. Inert media to replace soil. Colo. Flower Grower's Assn. Bull. 239.

5. Holley, W. D. and M. P. Novovesky. 1971. Carnation production in an inert substrate compare to soil. Colo. Flower Grower's Assn. Bull. 256.

6. Roh, M. S. M. and R. H. Lawson. 1984. The lure of Lisianthus. Flower of the Far East capture interest in West. Greenhouse Manager 3:103-121.

7. Wilkins, H. F. and K. L. Grueber. 1983. Eustoma grandiflorum. Minnesota Bull. December.

CHAPTER IV

Evaluation of Pinching Level

Literature Review

Husain and Linck (3) studied the relationship of apical dominance to nutrient accumulation pattern in Pisum sativum var. and found that stem apex and flowers were a primary sink for nutrients. They postulated that removal of the stem apex (pinching) freed nutrients which were utilized by leaves, lateral bud growth, and roots.

Quinlan and Weaver (4) grew Vitis vinifera L. using ^{14}C for pinching studies and determined the removal of the stem apex or flower increased the availability of assimilates to an adjacent sink. During flowering, ^{14}C accumulated in leaves near the base of the shoot and then moved mainly upward to the flower. Removal of the terminal shoot or flowers reversed the flow.

Harris and Jeffcoat (2) observed that vegetative lateral buds on stem of Dianthus caryophyllus cv., white Sim, remained dormant until the outer petals of flower petals reflexed. After the petals reflexed, the lateral buds developed rapidly since the flower was no longer major metabolic sink.

Roh and Lawson (5) reported that Sakata E. grandiflorum F-1 hybrids developed one to four lateral shoots depending on the variety, when three pairs of leaves were left on

the plant after pinching. When four pair of leaves were left, two lateral shoots developed in all cultivars of blue, white and pink. When plants terminals were removed at higher node positions, the resulting laterals were shorter than when pinched at a lower leve. Large lateral branches were obtained when the terminal stems were removed above the third or fourth node (1,6).

The objective of this study were to determine if the removal of minimum amounts of stem from plants of E. grandiflorum will provide increased development of lateral branches.

METHODS AND MATERIALS

This study was conducted in the same environment described for the media study (Chapter 3). Plants of *E. grandiflorum*, Sakata F-1 hybrid pink, were potted at the seven to eight leaves stage into 15 cm_diam. pots using CSU soil. Plants were divided into four pinch treatments which were randomly chosen for the various types of pinches. The pinch treatments included:

1. Terminal stem removed leaving four leaf pairs.
2. Five leaf pairs retained on the plants.
3. Six leaf pairs retained on the plants.
4. Removal of growing point of stem ("roll out").

Data taken after 87 days of plant growth included stem length, number of flowers, breaks, and nodes, and whole plant fresh and dry weight.

The experiment was analyzed as one-way ANOVA and Tukey's HSD test for mean separation at ($P = 0.05$).

RESULTS AND DISCUSSION

The various types of pinches had no significant effect on the stem length, number of fresh weight or day weight (Table 7). However, significant differences did exist in the number of flowers (Fig. A-16) breaks (Fig. 12) created by the roll out pinch and the pinches at fifth and fourth leaf pairs. The removal of the growing point, roll out pinch, provided the best plant development (Table 7) and resulted in 10 days faster flowering.

Data obtained in this study indicates that pinches above the third or at sixth node provided similar results on the production and yield of E. grandiflorum. The results were in agreement with the data reported in previous studies (1, 6). Stem terminals removed at higher or lower node positions had no effect on the lateral's length and the number of bottom breaks. However, Roh and Lawson (5) reported opposite results.

Figure 12. The influence of the terminal shoot removal position on the number of breaks (square root) produced by E. grandiflorum, Sakata F-1 hybrid pink.

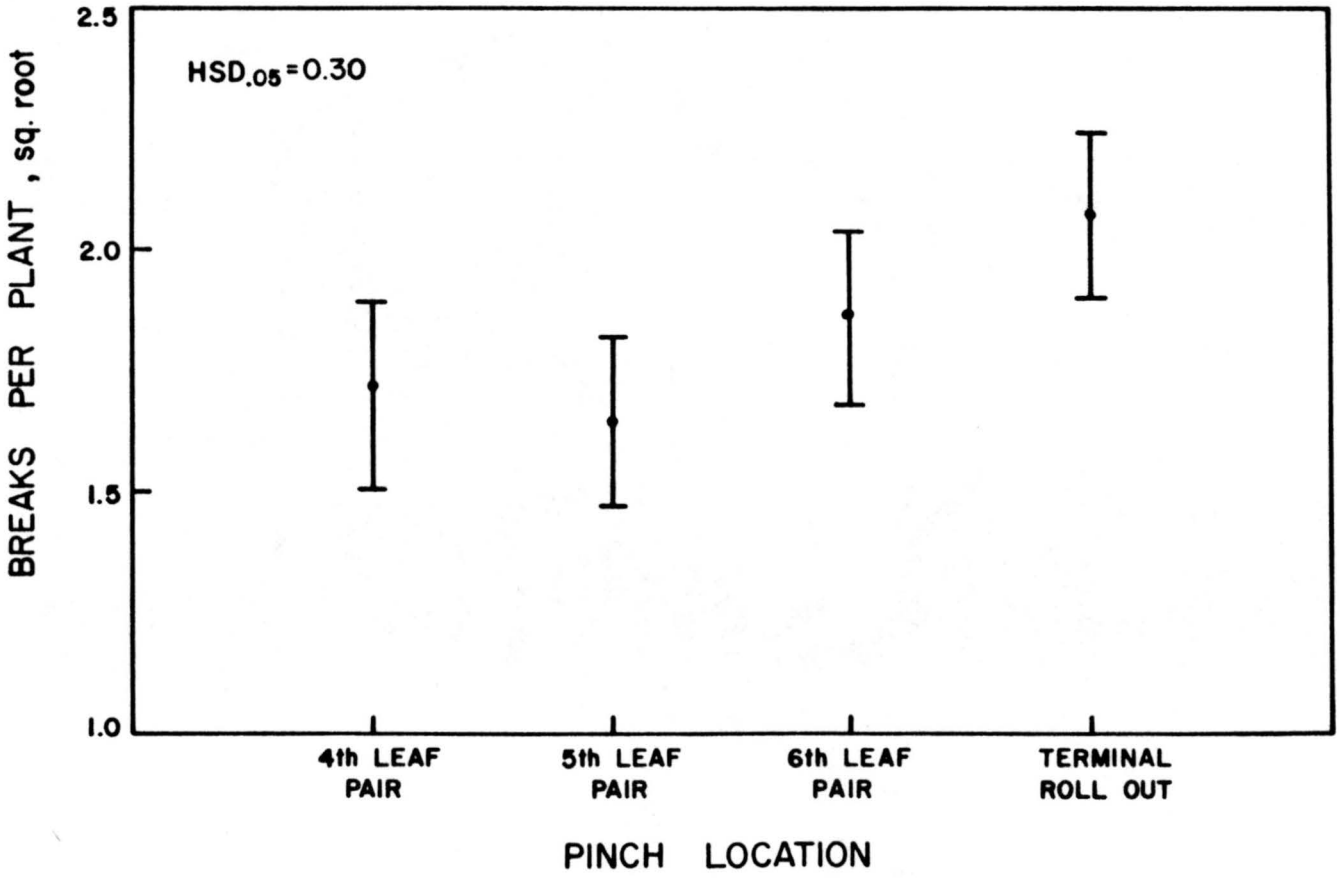

2.5
2.0
1.5
1.0
HSD.05=0.30
BREAKS PER PLANT, sq. root
4th LEAF PAIR
5th LEAF PAIR
6th LEAF PAIR
TERMINAL ROLL OUT
PINCH LOCATION

Table 7. Response to four "pinch levels on plants of E. grandiflorum, Sakata F-1 hybrid pink, grown in CSU soil from March 20, 1984 to June 16, 1984.

Type of pinch from plant base	Stem length	$\sqrt{x}$ Flowers per plant	$\sqrt{x}$ breaks per plant	$\sqrt{x}$ nodes per main stem	Fresh weight	Dry weight
Growing point removed	67.63[a]	4.64[a]	2.07[b]	3.495[a]	102.65[a]	20.0[a]
Sixth leaf pair	70.43[a]	3.66[a]	1.86[ab]	3.354[a]	94.84[a]	18.8[a]
Fifth leaf pair	73.98[a]	2.99[a]	1.65[a]	3.422[a]	80.74[a]	15.8[a]
Fourth leaf pair	69.22[a]	2.25[b]	1.72[a]	3.351[a]	79.95[a]	14.6[a]
$HSD_{0.05}$	11.64	2.1	.30	0.299	31.15	6.6

LITERATURE CITED

1. Anonymous. 1983. Producing Lisianthus profitably. Greenhouse Grower 11:12.

2. Harris, G. P. and B. Jeffcoat. 1972. Distribution of ^{14}C labelled assimulates in flowering carnation plants. J. Hort. Sci. 47:25-35.

3. Husain, S. M. and A. J. Linck. 1966. Relationship of apical dominance to the nutrient accumulation pattern in Pisum sativum var. Alaska. Physiol. Plant 19:992-1010.

4. Quinalan, J. D. and J. R. Weaver. 1970. Modification of patterns of the photosynthate movement within and between shoots of Vitis virriferal. Plant Physiol. 46: 527-530.

5. Roh, M. S. M. and R. H. Lawson. 1984. The lure of Lisianthus. Flower of the Far East captures interest in West. Greenhouse Manager 3:103-121.

6. Tija, B. and T. J. Sheehan. 1983. Lisianthus (Eustoma) as a bedding plant. Florida Ornamental Grower's Assn. Newsletter 6(4):1.

Chapter V

GENERAL OBSERVATIONS

Vegetative propagation and growth response of Weddle F-1 hybrid

Approximately 15 plants of E. grandiflorum obtained from Weddle in 1980 were planted in 5-gal plastic containers using a CSU soil medium. A portion of the plants were grown for flower production evaluation and the remaining ones for vegetative propagation information. They were grown on a raised bench in a FRP covered, peak-style, east-west oriented greenhouse. It was heated to 17° C day and night with a steam radiation-forced air system. The fan-pad cooling system cooled the facility automatically, at 20° C. Relative humidity ranged from 30 to 50%. Carbon dioxide was injected into the greenhouse during daylight hours and periods of no ventilation to maintain a concentration to 1000 $ul\,l^{-1}$. The plants were watered by hand with balanced nutrient solution (Chapter 2).

The plants used for preliminary vegetative propagation studies were sprayed and drenched with the fungicide, Banrot, (2.4g $3L^{-1}$) and sprayed with the insecticide, Pentac, (2.3g $3L^{-1}$) on a biweekly basis prior to propagation. Stem and tip cuttings were taken from uninitiated flowering stems. Cuttings 8 to 12 cm length, with lower leaves removed,

were dipped in Hormex no. 8 rooting hormone, and placed in a 20° C propagating medium (two parts no. 8 perlite, one part canadian sphaghum peatmoss and 1,000 g $CaCo_3$ m^{-2}) under intermittent mist. Root formation occurred within 18 days in July, but required approximately 32 days in November. The growth habit and cut flower yield were evaluated from early May 1983 to October 1983. Individual plants, even though they were F-1 hybrids, had completely different growth habits (Table 8).

The Weddle F-1 hybrid flowers had a vase life ranging from 14 to 18 days in untreated water at room temperature. The addition of a preservative, 60g. 8-HQC + 1,500 $3L^{-1}$ of water, did not increase the vase life. Preliminary evaluations on refrigerating the cut flowers of the Weddle hybrid indicated they can be placed in water and stored in 3° C for approximately 10 days. A vase life approximately 12 days was achieved at room temperatures. Cut flowers can not be dry stored.

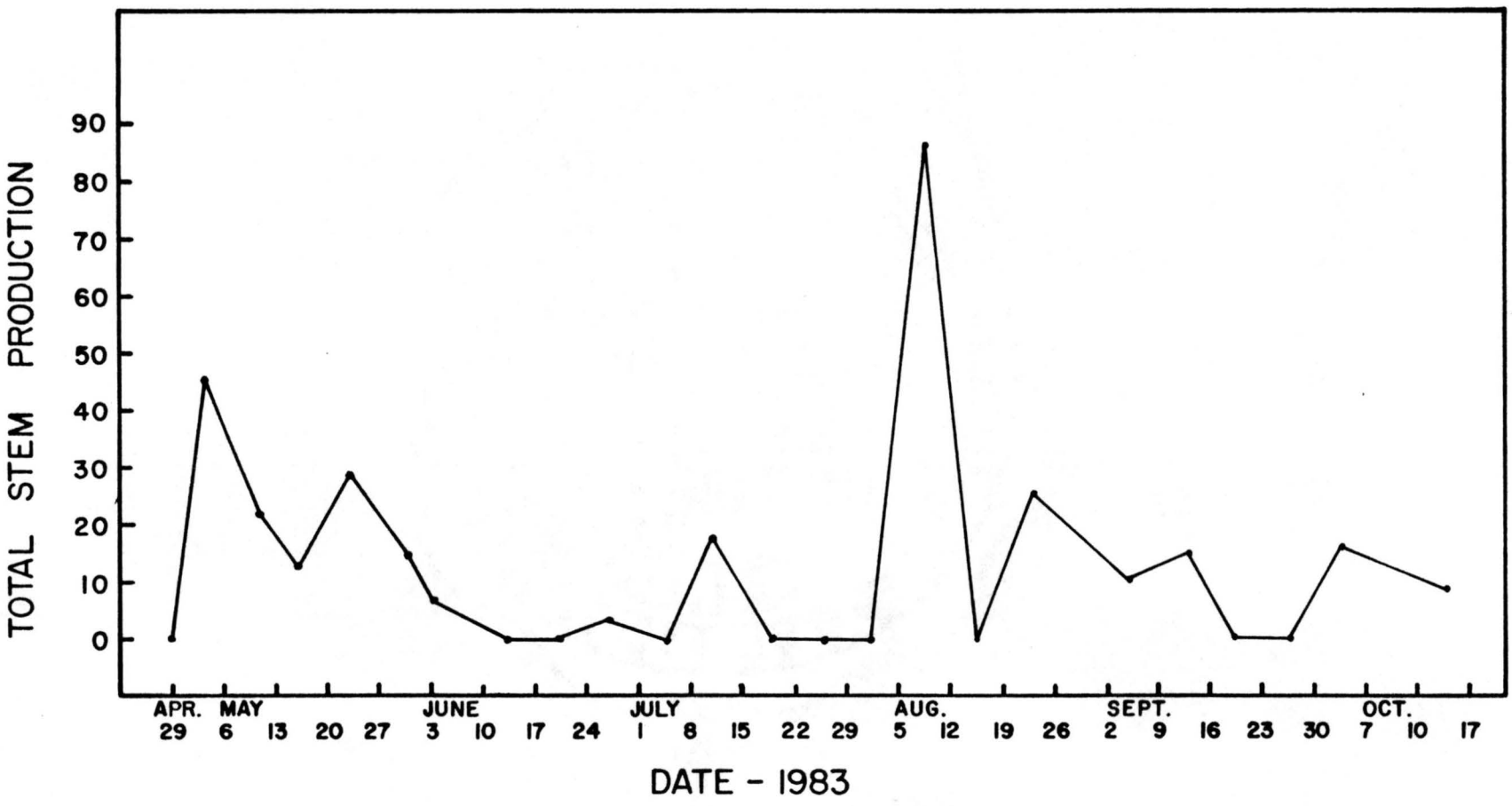
The container grown plants had two definite flowering cycles. One in early May to late June and a second in August through early October (Table 8). Each year the plant spreads and produced more stems but the production remained similar (Fig. 13). It is possible E. grandiflorum could be grown continuously in the greenhouse, but more research is needed on timing, croping and disease control.

Table 8. Growth habit evaluation, May 1, 1983 to October 8, 1983, of eight Weddle F-1 hybrid *E. grandiflorum* plants varying in age from one to three years.

Plant	Stem length (cm)	Number of stems	Number of flowers[a] per stem	Time of first cut	Time of second cut
1	58.9	41.0	5.4	May 5 to June 8	Aug. 11 to Sept. 9
2	58.4	32.0	8.0	Apr. 30 to June 30	Aug. 11 to Sept. 7
3	51.8	53.0	6.5	May 3 to June 30	Aug. 11 to Oct. 2
4	53.3	78.0	6.6	May 3 to June 1	Aug. 11 to Aug. 22
5	50.0	42.0	7.5	June 1 to July 7	Aug. 11 to Oct. 8
6	49.5	35.0	9.4	May 5 to July 7	Aug. 6 to Oct. 8
7	49.5	37.0	7.6	May 22 to July 7	Aug. 6 to Oct. 2
8	50.8	24.0	6.4	May 22 to June 30	Aug. 22 to Oct. 2
Mean	52.8	41.6	7.2		

[a]Open flowers plus buds with color.

Figure 13. The production cycles of eight container grown plants of E. grandiflorum, Weddle F-1 hybrid, varying in age from one to three years old.


TOTAL STEM PRODUCTION
90
80
70
60
50
40
30
20
10
0
APR. MAY JUNE JULY AUG. SEPT. OCT.
29 6 13 20 27 3 10 17 24 1 8 15 22 29 5 12 19 26 2 9 16 23 30 7 10 17
DATE - 1983

Comparison of Weddle and Sakata hybrids

The growth habits and flower production of E. grandiflorum from two sources were evaluated from the seed germination stage through 15 months of development and production.

Seeds of Sakata F-1 pink, blue, and white cultivars and Weddle blue were germinated on November 16, 1982 in a mixture of vermiculite and Canadian sphaghum peat (V/V), with intermittent mist and bottom heat of 20° C. Uniform germination occurred in 11 days. The first true leaf stage was reached in four weeks under continuous fluorescent light. The seedlings were transplanted into cell packs containing CSU soil; there were pinched to three leaf pairs after ten weeks of growth. On May 23, 1983 two blocks of the four seed grown hybrids and two groups of Weddle F-1 cuttings were planted in a raised bench containing a steam pasteurized limestone chip enriched pea gravel medium. Each block contained 12 plants per m^2. The bench was located in FRP covered, peak-style, east-west oriented greenhouse. It was heated to 17° C at night and 17° C during the day with a steam radiation-forced air system. A fan-pad cooling system automatically cooled the facility at 25° C. Relative humidity ranged from 30 to 50%. The carbon dioxide concentration was enriched to 1,000 $ul l^{-1}$ during daylight and periods no ventilation. The plants were automatically watered three to four times per day depending on the season with a nutrient treated water (Chapter 2). A drench of Banrot, 2.2 g/3L, was applied once per month.

The first flowers from Sakata and Weddle hybrids were harvested in early May when the plants were still in 10 cm_diameter pots and prior to planting in the gravel bench on May 23, 1983. The second flower crop from the benched hybrids were harvested in August and September. The stem lengths of both crop of Sakata flowers averaged 12 cm, too short to use as cut flowers. Weddle hybrid had somewhat longer stems, but still could not be used effectively as cut flowers.

All hybrids were completely out of production from mid October 1983 until early May 1984. Two major cropping periods occurred, one in early May to mid June and the other throughout August for the Sakata hybrid and to the end of early October for the Weddle hybrid.

Three plants of each hybrid were selected for observation and yield evaluation. The Sakata hybrids were highly variable in production and timing. The pink plants all flowered within 9 days during the first harvest period and 25 days in the second. The white hybrid flowered within a 30 day period during both the first and second harvests. The blue Sakata, the most prolific of the hybrids, and completed its production cycle within 30 days in both harvest periods.

The Weddle F-1 hybrids had two definite production cycles, one in May and the other in August; however the total harvest period lasted from early May to early October. The Weddle F-1 hybrid produced more and larger stems than any of the Sakata hybrid cultivars (Table 9).

Table 9. Growth habits evaluation of Sakata and Weddle F-1 cultivars of E. grandiflorum from May 5, 1984 to September 23, 1984.

Cultivars[a]	Stem length (cm)	Number of stems per plant	Number of[b] flowers per stem	Days of vase life in water at room temperature
Sakata F-1 hybrid blue	42.7	17.0	5.7	8-10
Sakata F-1 hybrid pink	51.0	14.0	5.7	9-11
Sakata F-1 hybrid white	51.2	14.0	8.7	10-11
Weddle F-1 hybrid blue	60.5	29.0	7.5	14-18

[a]Average of three plants.

[b]Open flowers plus buds with color.

Insect and Disease Problems

A high mortality rate was observed with Sakata hybrids and to a lesser degree for the Weddle plant material, following the planting of well developed plants into a gravel bench. Plants that survived the transplant had a relatively high death rate following the harvest of the third flower crop.

samples of diseased plants were diagnosed for pathogen infection four times during the 2 yr evaluation of E. grandiflorum. Fusarium wilt (Fusarum oxysporum), and stem rot (F. roseum, F. solani, and Rhizoctonia solani) were found on both Sakata and Weddle hybrid. Sakata F-1 hybrid pink was most susceptible to root rot pathogens, the blue more resistant and the white hybrid was intermediate in susceptibility when grown in the gravel medium. The Weddle F-1 hybrid plants were more susceptible to the diseases when grown in the gravel medium, than they were in CSU soil medium in 5 gal. plastic containers.

Whitefly (Trialeurades vaporariorum) and red spider (Retranychus urticae) were found to be the most damaging insects to the Weddle F-1 hybrid. However, the three Sakata F-1 hybrids appeared to be somewhat resistant. Most of the plants that died due to mentioned disease had holes in the stems at the media line. The causal agent was identified as the larvae of the shore fly (Scatella stagnalis), which has been implicated in the transmission of Fusarium wilt to greenhouse tomatoes (personal communication).

Chapter VI

SUMMARY AND CONCLUSIONS

The growth habits of E. grandiflorum, Sakata F-1 hybrid blue and pink cultivars were evaluated for potential cut flower production. Four factors were considered: Photoperiod, temperature, media, and the position of terminal stem removal. The growth habits of the Weddle F-1 hybrid were also compared to those of Sakata hybrids.

E. grandiflorum, Sakata F-1 hybrids are apparently a day neutral plant for flower induction, initiation or development. Plant and flower development were not influenced by the interaction of growing temperature and photoperiod. However, stem length, number of flowers, nodes, and the plant fresh and dry weights were increased more than two-fold when plants were grown in day temperatures of 22° C and 70% relative humidity compared to 17° C and relative humidity from 30 - 50%. Increased day temperature and relative humidity did not effect flower bud initiation, but accelerated flower bud development.

The production and yield of E. grandiflorum, Sakata F-1 hybrid, was comparable in all inert growing media, volcanic scoria, idealite and pea gravel. However, inert media were more desirable than the CSU soil medium.

Removal of the terminal stem tip (pinching) of the E. grandiflorum having four, five, and six leaf pairs pinch,

nodes and fresh and dry weight. However, the roll-out pinch provided the best plant development and resulted in 10 days earlier flowering.

Weddle F-1 hybrid flowers had a vase life five of 14-18 days. Sakata F-1 hybrid blue had a vase life of 8-10 days, pink 8-11 days and white 10-11 days. The addition of a preservative, 60 g, 8-HQC + 1,500 sugar per three liters water, had no effect on the vase life of Weddle or Sakata hybrids. The flowers of the Weddle hybrid were lighter in color than Sakata hybrids.

Based on the experiments, the following recommendations for E. grandiflorum cut flower production are presented.

1. Use clean rooted vegetative cuttings instead of seed propagation to eliminate the variability of plant growth habits.
2. Reduce contamination, spread of diseases and provide better irrigation control by growing plants in 5 gal. plastic containers filled with inert media.
3. Three to four layers of wire mesh are necessary for plant support. The first layer is about 15 cm above the medium, and the upper layers are spaced about 20 cm apart.
4. Systemic fungicide in the form of a spray and drench should be applied once every month. Preventative measures for control of spider mite and other insects are required.

5. When propagating by seed, it is important to drench the seedlings with an insecticide once a week to control the larvae of shore fly which are implicated in the loss of many plants.
6. The best time for rooting cuttings or germinating seeds is from July to August for the most rapid development. Following germination, seedlings should be grown to the transplanting stage under continuous fluorescent light.
7. When an inert growing media is used, plant water stress should be avoided by providing a good irrigation system with ample water. Care should be taken not to over water a soil medium.
8. Flowers should be harvested when three to four flowers are open and the remaining buds are showing color. The lower third of stem should be stripped of leaves at harvest and immediately placed in warm water.

Suggestions for Further Study

Based on the results and experiences associated with this study, the following investigations are recommended in order to evaluate the full potential of *E. grandiflorum* as commercial cut flowers:

1. Due to variability of plants grown from Sakata F-1 hybrid seed, a method of selecting seedlings for year-round flowering and for post-harvest qualities needs to be developed.

2. Determine if the flower production cycles can be expanded through the incorporation of single pinch, pinch-and-a-half, and double pinch, or a single pinch plus pull pinches on the lateral branches.
3. Determine if there is an optimum range of relative humidity and carbon dioxide required for maximum growth and production of plants.
4. Investigate the influence of flower cutting height on basal shoot formation and flower production.
5. Evaluate the methods of selecting durable cultivars of E. grandiflorum for the production of disease-free, high quality rooted cuttings.
6. Investigate the relationship between stem rot diseases and larvae of Scatella stagnalis (Shore fly).
7. Determine the optimum nutrient and water relation required for maximum flower production.
8. Determine if there is any effect of lighting by using HID lighting to promote light year-round flowering.

APPENDICES

Table A-10. The effect of short, natural, and long day lengths on the flower stem length (cm) of E. grandiflorum, Sakata F-1 hybrid blue, grown in 39 photoperiod combinations for a total of 140 days in Experiment 1[a].

Photoperiod Treatments	Days exposed to photoperiod treatment[b]						
	20	40	60	80	100	120	140
Short day photoperiod							
Long day[b]	29.6	43.2	44.9	37.7	36.0	36.0	
Natural day	34.7	50.8	40.6	41.1	54.6	47.2	
Control							44.7
$HSD_{0.05}$ = 18.1							
Natural day photoperiod							
Long day	53.8	47.4	47.8	42.8	37.7	39.8	
Short day	39.4	48.7	48.7	37.3	37.7	38.9	
Control							43.6
$HSD_{0.05}$ = 14.3							
Long day photoperiod							
Short day	46.6	36.0	39.4	32.6	29.2	33.0	
Natural day	44.5	36.0	46.6	49.5	58.0	36.8	
Control							41.9
$HSD_{0.05}$ = 15.2							

[a]Day and night temperature 17° C and relative humidity ranged 30 to 50%.

[b]Remaining days were under photoperiod conditions as indicated.

Table A-11. The effect of short, natural, and long day treatment on the square root of number of flowers of E. grandiflorum, Sakata F-1 hybrid blue, grown in 39 photoperiod combinations for a total of 140 days Experiment 1[a].

Photoperiod treatments	Days exposed to photoperiod treatment[b]						
	20	40	60	80	100	120	140
Short day photoperiod							
Long day[b]	1.2	1.7	1.9	1.8	1.9	1.3	
Natural day	1.5	2.4	1.8	2.0	2.4	1.3	
Control							1.6
$HSD_{0.05}$ = 1.6							
Natural day photoperiod							
Long day	2.6	1.9	2.3	2.1	1.6	1.1	
Short day	2.1	2.1	2.1	0.7	1.3	1.5	
Control							2.2
$HSD_{0.05}$ = 1.4							
Long day photoperiod							
Short day	2.2	1.6	2.2	2.5	2.7	0.9	
Natural day	1.3	1.7	1.4	1.4	0.7	1.1	
Control							1.8
$HSD_{0.05}$ = 1.4							

[a]Day and night temperature 17° C, and relative humidity ranged 30 - 50%

[b]Remaining days were under photoperiod conditions as indicated.

Table A-12. The effect of short, natural, and long day treatment on the square root of the number of nodes of E. grandiflorum, Sakata F-1 hybrid blue, grown in 36 photoperiod combinations for a total of 140 days in Experiment 1.

Photoperiod treatments	Days exposed to photoperiod treatment[b]						
	20	40	60	80	100	120	140
Short day photoperiod							
Long day[b]	4.2	3.2	3.2	3.0	3.0	3.2	
Natural day	3.2	3.1	3.1	2.8	3.1	3.4	
Control							3.4
$HSD_{0.05}$ = 1.2							
Natural day photoperiod							
Long day	3.2	3.1	3.4	3.2	3.1	3.3	
Short day	3.1	3.4	3.4	3.5	3.1	3.1	
Control							3.2
$HSD_{0.05}$ = 0.5							
Long day photoperiod							
Short day	3.3	3.2	3.3	3.2	3.3	3.3	
Natural day	3.2	4.3	3.4	3.2	3.2	3.3	
Control							3.3
$HSD_{0.05}$ = 1.0							

[a]Day and night temperature 17° C, and relative humidity ranged 30 - 50%.

[b]Remaining days were under photoperiod conditions as indicated.

Table A-13. The effect of short, natural, long day treatment on the fresh weight of E. grandiflorum, Sakata F-1 hybrid blue, grown 36 photoperiod combinations for a total of 140 days in Experiment 1[a].

Photoperiod treatments	Days exposed to photoperiod treatment[b]						
	20	40	60	80	100	120	180
Short day photoperiod							
Long day[b]	13.4	35.3	31.5	21.3	23.3	26.2	
Natural day	25.6	31.7	26.6	29.2	35.2	33.3	
Control							34.6
$HSD_{0.05}$ = 27.5							
Natural day photoperiod							
Long day	47.7	38.6	44.1	28.6	20.2	26.2	
Short day	26.0	44.0	49.6	20.2	21.0	25.9	
Control							30.0
$HSD_{0.05}$ = 25.7							
Long day photoperiod							
Short day	40.8	21.5	29.5	22.6	14.3	20.1	
Natural day	36.6	25.1	37.2	40.1	42.5	21.3	
Control							34.2
$HSD_{0.05}$ = 28.1							

[a]Day and night temperature 17° C, and relative humidity ranged 30 to 50%.

[b]Remaining days were under photoperiod conditions as indicated.

Table A-14. The effect of short, natural, and long day treatment on the dry weight *E. grandiflorum*, Sakata F-1 hybrid blue, grown 36 photoperiod combinations for a total of 140 days in Experiment 1[a].

Photoperiod treatments	Days exposed to photoperiod treatments[b]						
	20	40	60	80	100	120	140
Short day photoperiod							
Long day[b]	2.3	7.0	6.9	4.6	4.3	5.1	
Natural day	5.4	6.7	6.0	5.6	7.5	6.1	
Control							7.0
$HSD_{0.05}$ = 5.7							
Natural day photoperiod							
Long day	10.0	7.6	8.5	7.0	5.5	5.2	
Short day	5.2	8.4	9.1	3.5	3.7	4.3	
Control							6.2
$HSD_{0.05}$ = 4.8							
Long day photoperiod							
Short day	9.0	4.0	4.7	3.6	2.7	3.4	
Natural day	6.7	4.7	6.8	8.2	8.7	4.1	
Control							6.1
$HSD_{0.05}$ = 5.3							

[a]Day and night temperature was at 17° C, and relative humidity ranged 30 to 50%.

[b]Remaining days were under photoperiod conditions as indicated.

Table A-15. The effect of short, natural, and long day treatment on the flower stem length (cm) of E. grandiflorum, Sakata F-1 hybrid pink, grown in 27 photoperiod combinations for a total of 100 days in Experiment 1[a].

Photoperiod treatments	Days exposed to photoperiod treatments[b]				
	20	40	60	80	100
Short day photoperiod					
Long day[b]	96.5	86.4	90.2	119.4	
Natural day	87.6	92.7	77.4	81.3	
Control					84.3
$HSD_{0.05}$ = 10.0					
Natural day photoperiod					
Long day	106.7	105.4	109.2	106.7	
Short day	79.6	101.6	79.6	80.0	
Control					88.3
$HSD_{0.05}$ = 18.5					
Long day photoperiod					
Short day	116.8	102.9	100.3	101.6	
Natural day	105.4	96.5	88.9	85.1	
Control					106.5
$HSD_{0.05}$ = 16.2					

[a]Day temperature 22° C, night temperature 17° C, and relative humidity 70%.

[b]Remaining days were under photoperiod conditions as indicated.

Table A-16. The effect of short, natural, and long day treatment on the square root of the number of flowers of E. grandiflorum, Sakata F-1 hybrid pink, grown in 27 photoperiod combinations for a total of 100 days in Experiment 2[a].

Photoperiod treatments	Days exposed to photoperiod treatment[b]				
	20	40	60	80	100
Short day photoperiod					
Long day[b]	2.5	3.8	1.2	4.0	
Natural day	0.71	3.9	4.2	4.9	
Control					4.6
$HSD_{0.05}$ = 4.1					
Natural day photoperiod					
Long day	5.4	2.8	3.9	3.9	
Short day	4.7	2.8	1.8	1.2	
Control					2.0
$HSD_{0.05}$ = 4.7					
Long day photoperiod					
Short day	2.9	2.6	2.4	2.0	
Natural day	3.6	4.1	3.4	5.1	
Control					3.7
$HSD_{0.05}$ = 2.0					

[a]Day temperature 22° C, night temperature 17° C, and relative humidity ranged 70%.

[b]Remaining days were under photoperiod conditions as indicated.

Table A-17. The effect of short, natural, and long day treatment on the square number of nodes of E. grandiflorum, Sakata F-1 hybrid pink, grown in 27 photoperiod combinations for a total of 100 days in Experiment 2[a].

Photoperiod treatment	Days exposed to photoperiod treatment[b]				
	20	40	60	80	100
Short day photoperiod					
Long day[b]	4.0	3.7	4.1	3.9	
Natural day	4.2	4.0	4.0	3.8	
Control					3.9
$HSD_{0.05}$ = 0.9					
Natural day photoperiod					
Long day	3.8	4.1	3.7	3.7	
Short day	3.8	4.3	4.0	4.2	
Control					4.0
$HSD_{0.05}$ = 0.8					
Long day photoperiod					
Short day	4.0	4.0	4.3	4.1	
Natural day	3.8	4.0	3.9	3.8	
Control					3.9
$HSD_{0.05}$ = 0.7					

[a]Day temperature 22° C, night temperature 17° C, and relative humidity 70%.

[b]Remaining days were under photoperiod conditions as indicated.

Table A-18. The effect of short, natural, long day treatment in the fresh weight of E. grandiflorum, Sakata F-1 hybrid pink, grown in 27 photoperiod combinations for a total of 100 days in Experiment 2[a].

Photoperiod treatment	Days exposed to photoperiod treatment[b]				
	20	40	60	80	100
Short day photoperiod					
Long day[b]	82.1	71.9	62.7	80.4	
Natural day	53.6	85.6	93.5	92.2	
Control					86.9
$HSD_{0.05}$ = 47.2					
Natural day photoperiod					
Long day	103.6	80.1	76.6	75.6	
Short day	98.9	99.8	79.6	67.2	
Control					52.0
$HSD_{0.05}$ = 51.2					
Long day photoperiod					
Short day	77.3	63.5	82.3	65.9	
Natural day	82.8	104.0	70.5	96.9	
Control					77.4
$HSD_{0.05}$ = 41.8					

[a]Day temperature 22° C, night temperature 17° C, and relative humidity ranged 70%.

[b]Remaining days were under photoperiod conditions as indicated.

Table A-19. The effect of short, natural, and long day treatment on dry weight of E. grandiflorum, Sakata F-1 hybrid pink, grown in 27 photoperiod combinations for a total of 100 days in Experiment 2[a].

Photoperiod treatment	Days exposed to photoperiod treatment[b]				
	20	40	60	80	100
Short day photoperiod					
Long day[b]	18.8	15.3	11.8	17.1	
Natural day	10.0	19.5	19.5	20.8	
Control					19.5
$HSD_{0.05}$ = 12.9					
Natural day photoperiod					
Long day	26.6	17.9	16.5	14.1	
Short day	22.5	23.4	18.0	16.4	
Control					12.0
$HSD_{0.05}$ = 13.7					
Long day photoperiod					
Short day	15.7	13.6	18.2	13.8	
Natural day treatment	16.6	20.8	15.6	20.3	
Control					15.7
$HSD_{0.05}$ = 8.7					

[a]Day temperature 22° C, night temperature 17° C, and relative humidity ranged 70%.

[b]Remaining days were under photoperiod conditions as indicated.

Figure 14. Number of flowers (square root) produced by E. grandiflorum, Sakata F-1 hybrid pink in 10 different substrates.

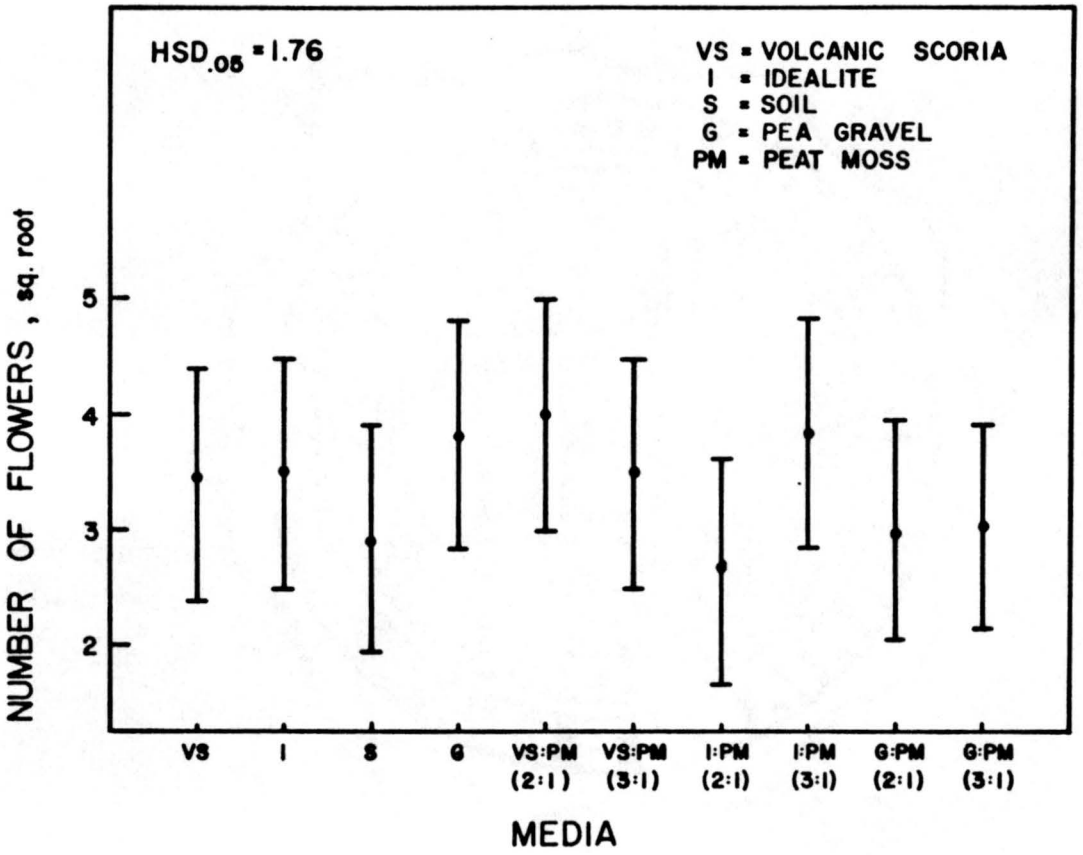

HSD.05 = 1.76
VS = VOLCANIC SCORIA
I = IDEALITE
S = SOIL
G = PEA GRAVEL
PM = PEAT MOSS
NUMBER OF FLOWERS , sq. root
5
4
3
2
VS
I
S
G
VS:PM (2:1)
VS:PM (3:1)
I:PM (2:1)
I:PM (3:1)
G:PM (2:1)
G:PM (3:1)
MEDIA

Figure 15. The influence of the terminal shoot removal position on the stem length of *E. grandiflorum*, Sakata F-1 hybrid pink.

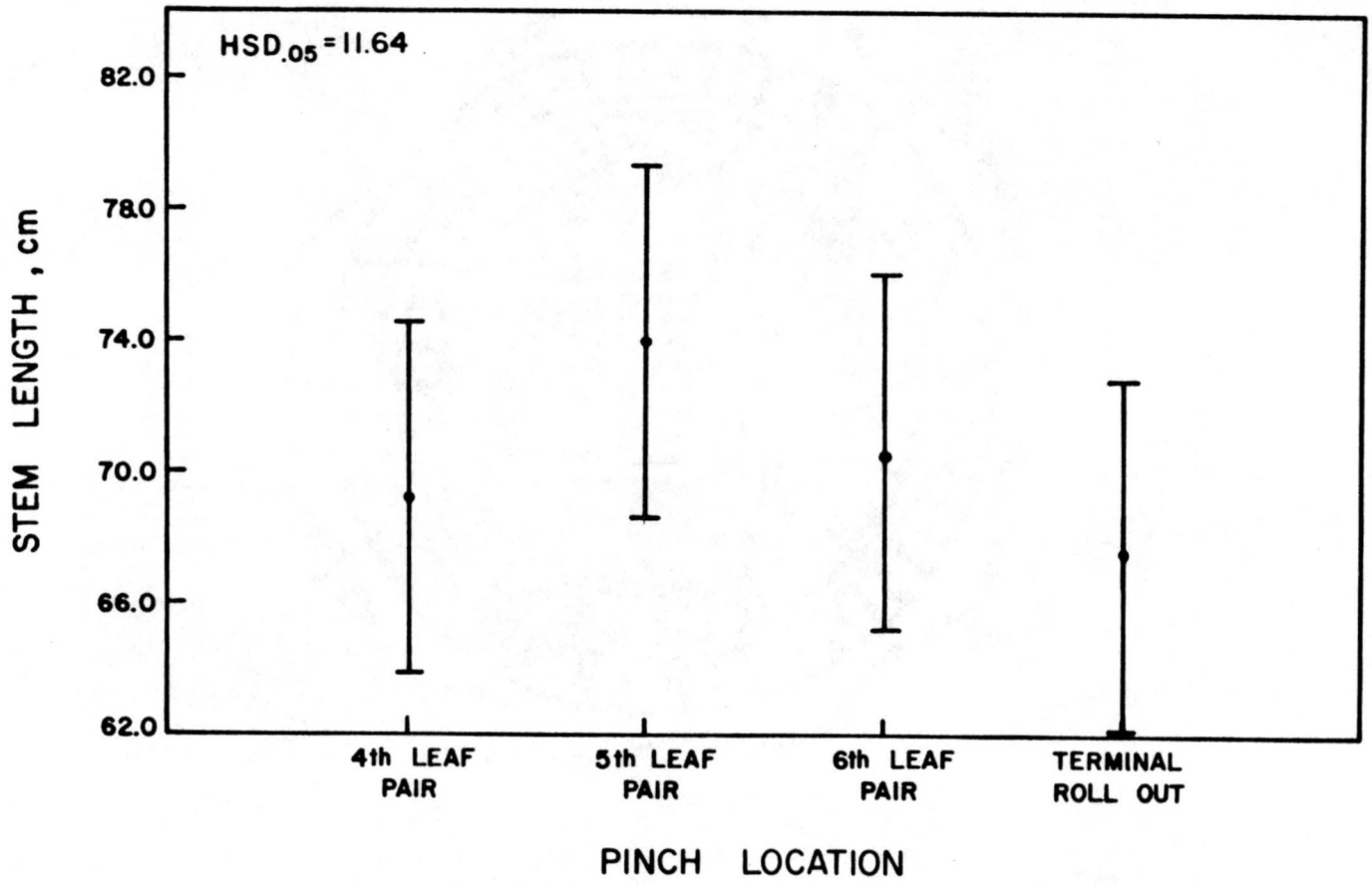

HSD.05 = 11.64
82.0
78.0
74.0
70.0
66.0
62.0
STEM LENGTH , cm
4th LEAF PAIR
5th LEAF PAIR
6th LEAF PAIR
TERMINAL ROLL OUT
PINCH LOCATION

Figure 16. The influence of the terminal shoot removal position on the number of flowers (square root) produced by E. grandiflorum, Sakata F-1 hybrid pink.

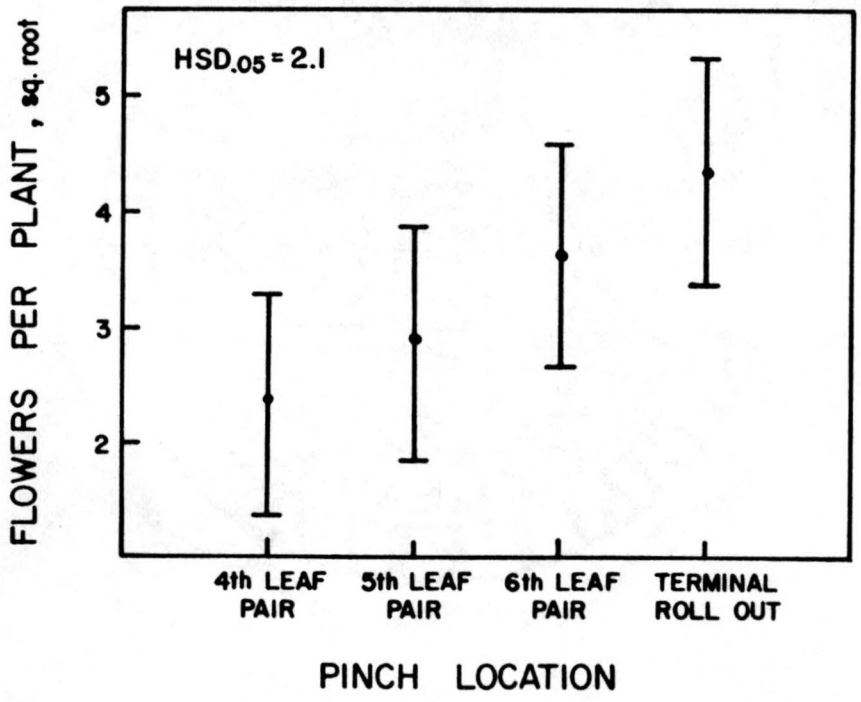
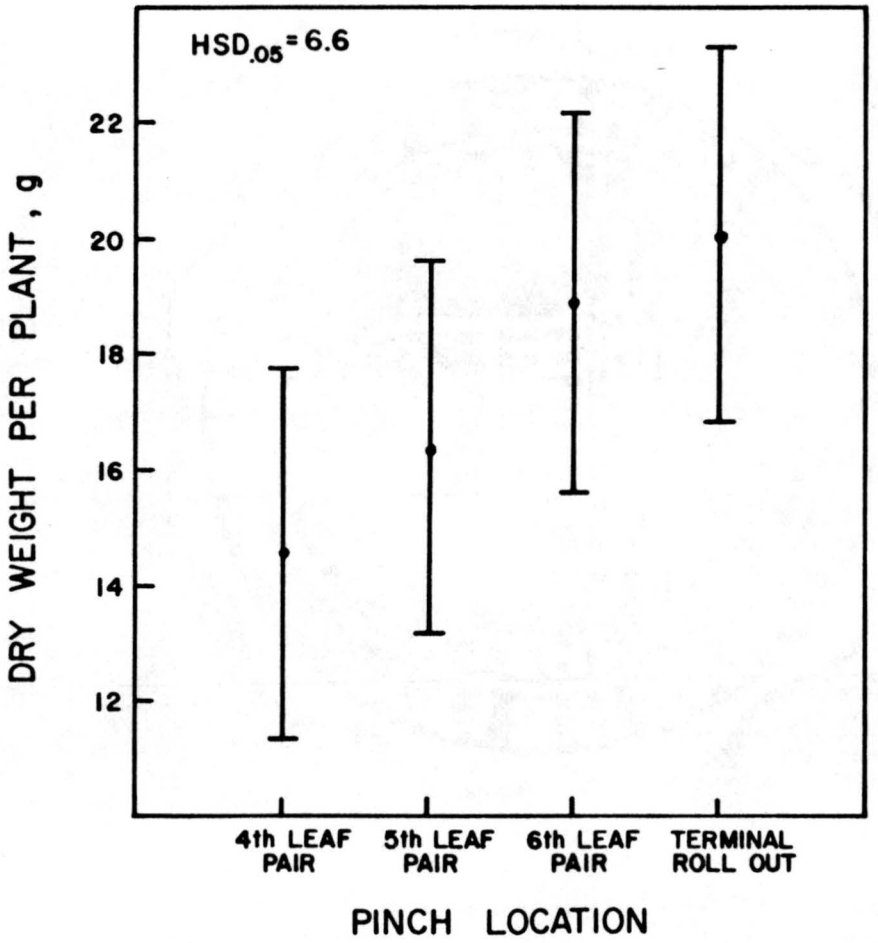

HSD.05 = 2.1
FLOWERS PER PLANT, sq. root
5
4
3
2
4th LEAF PAIR
5th LEAF PAIR
6th LEAF PAIR
TERMINAL ROLL OUT
PINCH LOCATION

Figure 17. The influence of the terminal shoot removal position on the plant dry weight of E. grandiflorum, Sakata F-1 hybrid pink.


HSD.05 = 6.6
DRY WEIGHT PER PLANT, g
22
20
18
16
14
12
4th LEAF PAIR
5th LEAF PAIR
6th LEAF PAIR
TERMINAL ROLL OUT
PINCH LOCATION