THE EFFECT OF TEMPERATURE ON FLOWER BUD INITIATION OF CHRYSANTHEMUM MORIFOLIUM

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

Paul S. Andrews

1951

This is to certify that the

thesis entitled

THE INFLUENCE OF TEMPERATURE

ON THE FLOWER BUD INITIATION

OF CHRYSANTHEMUM MORIFOLIUM

presented by

PAUL S. ANDREWS

has been accepted towards fulfillment
of the requirements for

M.S. degree in HORTICULTURE

Donald P. Watson

Major professor

DONALD P. WATSON

Date 29 JUNE 1951

O-169

THE EFFECT OF TEMPERATURE ON FLOWER BUD INITIATION

OF

CHRYSANTHEMUM MORIFOLIUM

by

Paul S. Andrews

A THESIS

Submitted to the School of Graduate Studies of Michigan State College
of Agriculture and Applied Science in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE

Department of Horticulture

1951

THESIS

ACKNOWLEDGMENT

The author wishes to express his gratitude to the following persons: Dr. Donald P. Watson, for his capable assistance, helpful suggestions, and untiring patience; Martha Davidson, for technical assistance; and Marion Barrett, for aid in obtaining essential materials.

The author also wishes to express his appreciation to the Michigan State Florists Association for sponsorship of this investigation.

TABLE OF CONTENTS

PLATES

INTRODUCTION

The effect of temperature on flower bud initiation of *Chrysanthemum morifolium* has not been investigated as completely as the effect of daylength. As early as 1920, Garner and Allard showed the effect of daylength on flower formation of several plants. Since that time Tincker (1925), Poesch (1931), Post (1931), and others, have established the specific effect of daylength on *Chrysanthemum morifolium*. Flower buds will initiate if the dark period is at least $14\frac{1}{2}$ hours long provided the temperature is 55°F. or higher.

Growers are being advised that a minimum temperature of 60°F. must be maintained to insure bud formation and rapid growth of the chrysanthemum (Post 1949). Kiplinger and Hasek (1949), reported that the best growth and flowering resulted in the pompon varieties: Golden Herald, Little America, Masterpiece, and Bronze Masterpiece, when the night temperature was maintained at 60°F. except during the period of flower bud initiation, for which they recommended a night temperature of 65°F.

Post (1939), grew the variety Copper City both in a refrigerator at 50°F. and in a room where the temperature ranged from 75°F to 85°F. The plants in the refrigerator were lighted with incandescent lights hung 3 feet above the plants. The intensity of illumination at the tip of the plants averaged 300 foot candles. The plants in the 75°F. to 85°F. greenhouse received the normal daylight illumination found in Ithaca, New York during the early summer months. Post believed that data tabulated from this experiment showed that higher night temperatures hastened bud formation and increased the number of buds per plant. The low night temperatures were thought to cause fewer buds to form but larger flowers developed from those that did form. Post stated, "The low light intensity doubtless affected this budding."

Chrysanthemum growers in central Michigan have observed many "blind shoots" on crops initiating flower buds during the early fall months when accurate night temperature regulation in the greenhouses was not in effect. Since it was thought that the night temperature at this critical initiation period might have a definite effect on the resulting crop and the existing information on temperature influences was not too comprehensive, the present experiment was designed.

REVIEW OF LITERATURE

<u>Influences of daylength</u>: Post in 1942, observed that greenhouse varieties of chrysanthemum normally start forming flower buds from August 15th to 25th in the latitude of Ithaca, New York. The method for determining this date consisted of shortening the day length on several plots of chrysanthemum plants at ten day intervals, prior to the estimated date of flower bud initiation, and then comparing the flowering dates with similar plants, grown under normal daylength conditions. The plants which produced flowers at the same time as those grown under normal daylength conditions were assumed to have been shaded at the date of normal flower bud initiation.

Post observed vigorous vegetative growth on chrysanthemum plants from April 1st to August 20th. After flowering, they became dormant and grew only slightly during the winter. He postulated that this dormancy was the result of low light intensity, low temperature, short days, or an interrelation of all three.

Anatomical studies were made of chrysanthemum plants, variety Silver Sheen, by Link, 1936. These plants were grown from rooted cuttings potted May 30th. Beginning July 20th the photoperiod was reduced to 10 hours per day on one half of the plants. This short day treatment was continued for 22 days at which time the terminal buds averaged one-fourth inch in diameter. The terminal buds on the plants grown with normal daylength averaged one-fourth inch in diameter on September 21st. While Link did not explain his technique of bud examination, he concluded from his anatomical studies that the growing point changed from a vegetative to reproductive state within 8 to 10 days after short days were begun.

Influence of temperature: Comparatively little information on the specific effect of temperature on flower initiation has been reported. Experimental work with Xanthium by Hamner and Bonner in 1936 indicates that the temperature during the dark periods greatly influences the initiation of flower buds. One long dark period with temperatures of 21°C. to 32°C. resulted in flower bud formation. If the temperature was maintained at 4°C. or lower, seven long dark periods were required to achieve the same results. Hamner and Bonner further state that "In contrast to the striking effect of varying the temperature during the dark periods, varying the temperature during the photoperiods exerts little effect on the initiation of floral primordia. Although low temperatures during the photoperiod was without significant effect on the initiation of floral primordia, there was marked decrease in the subsequent rate of development of the primordia." These results led them to theorize that the reaction leading to the manufacture of floral initiating substance was adversely affected by low temperatures during the dark period.

A later report by Bonner in 1947 stated that a night temperature below 60°F. was unfavorable to flower bud formation in the Camellia variety Pink Perfection. Post (1942), found that at the latitude of 42°N., vegetative growth in chrysanthemums started before April 1st at 50°F. but no flower buds were initiated. He attributed this to low temperatures. Substantiation of this belief lies in the behavior of plants which initiated flower buds when grown with a night temperature above 60°F. during the same period.

Anatomy of flower bud initiation: The anatomy of stem apexes has been studied on many plants: Glycine ussuriensis, Borthwick and Parker (1938); Phlox drummondii, Miller and Wetmore (1946); Bellis perennis, Philipson (1946); Succisa pratensis and Dipsacus fullonum, Philipson (1947); Hieracum boreale and Dahlia gracilis, Philipson (1948; and Chrysanthemum morifolium, Chan (1949).

Because of the composite structure of Bellis perennis, Philipson's work with this plant is more applicable to the chrysanthemum than most work and warrants closest scrutiny. He described the transition of the stem apexes from the vegetative to the reproductive state. The vegetative apex during the period of maximal area was broad and flat. At the time of minimal area, after the appearance of a leaf primordia, the curvature was greatest and still very low. The leaf primordium grew more rapidly than the stem apex which was never "overtopped" as long as the stem remained vegetative. His photomicrographs illustrated stem apexes arranged in a pattern described as typically dicotyledonous. The tunica was two cell layers deep and regular; the apex was filled with a lens shaped mass of meristematic tissue in layers parallel with the tunica. Cell divisions in this area were radial to the arch of the apex. Philipson recognized the onset of flowering immediately by the more strongly arched apex which "overtopped" the primordium of the highest leaf. The morphological appearance of the flower primordium suggested that the primary change which led to the onset of flowering was an elongation of the cells immediately below the apical meristem. This cell elongation was suggested to be the result of: an increase in osmotic pressure, an increase in the plasticity of cell walls, or a decrease in the permeability of membranes. Since the increase in size was along one axis, Philipson concluded that the factor involved was plasticity of the cell wall and cited a report by Went that auxin had an effect on the plasticity of cell walls.

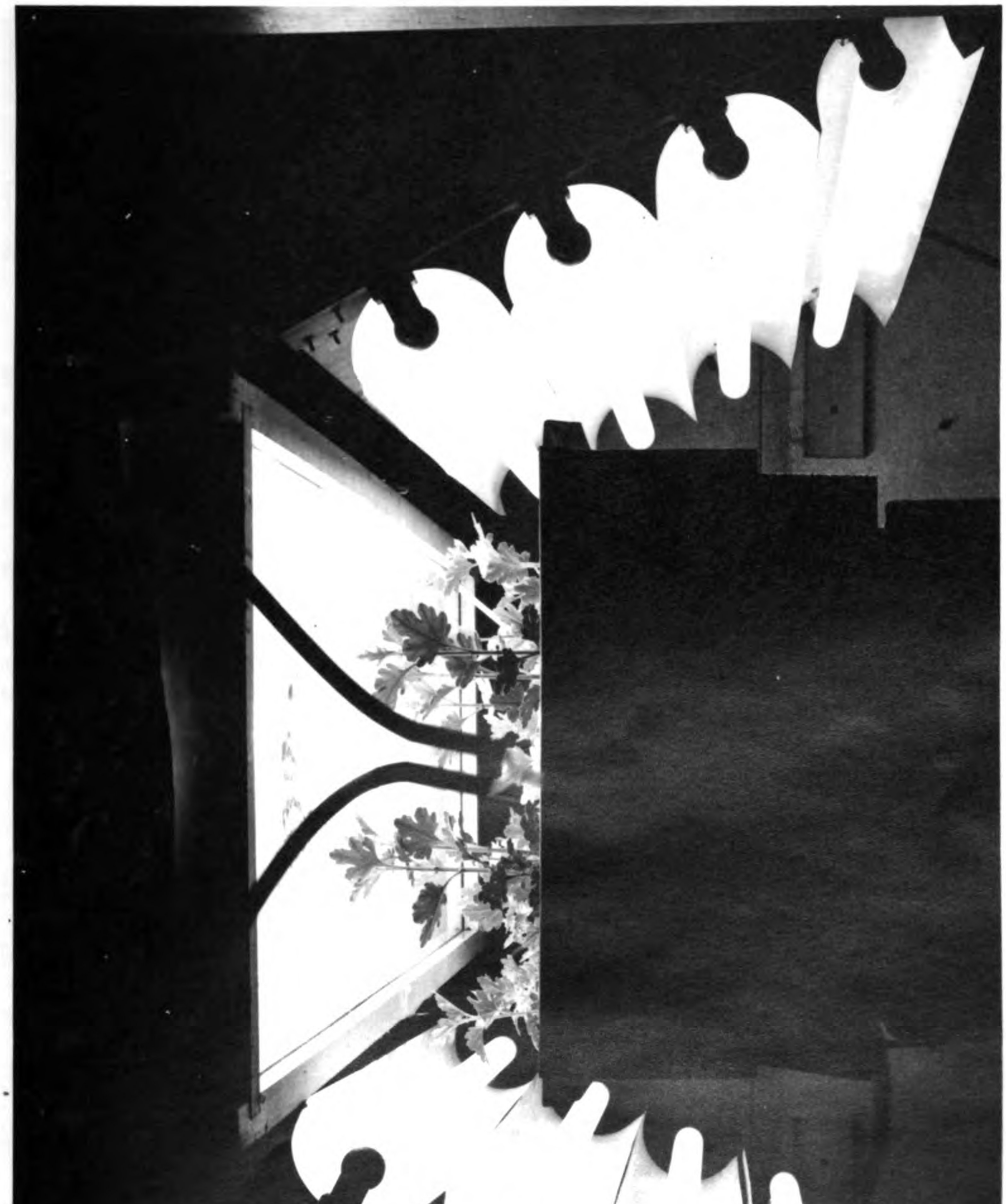
Popham and Chan (1950), described the vegetative shoots of certain varieties of Chrysanthemum morifolium by dividing them into five distinct zones (See diagram Popham and Chan 1950). They designated zone one as the overlying mantle of regularly formed cells, two to five layers deep, covering the apex of the shoot. Below the center of this mantle, or tunica, was located the area which they called zone two. This zone was recognized by its cone shaped arrangement; being three to six cells tall in the center, one or two cells thick at the top, and five to eight cells in diameter at the base. Zone three was represented by a cup shaped area of cells, situated below zone two and extending upward to the periphery of the apex cutting across part or all of the layers of the tunica. The larger cells, below zone three and in the central portion of the stem apex, were designated as zone four. The cells which comprise zone five were situated peripheral to zone four, not so definitely arranged in longitudinal rows, and were observed to be much smaller.

Arber (1933) reported that the differences between the flower and vegetative shoot in many plants are recognized by: A change in the leaf type, a change in the relationship of the leaves to the shoot apex, and a telescoping of the floral axis.

Sharman, while studying the developmental morphology of the shoot apex of Agropyron repens, observed that the change over from a purely vegetative to the reproductive stage was extremely rapid and he was unable to photograph many intermediate stages made visible by a dissection technique. He suggested, from studying microtomed material, that the initiation of floral parts was evidenced by periclinal division of the dermatogen and hypodermis.

EXPERIMENTAL PROCEDURE

Controlled temperature chambers: In May 1950, 84 rooted cuttings, variety Gold Coast, were planted two inches on the square in garden soil in each of two galvanized pans 30x18x7 inches in size, coated on the inside with asphalt paint. A space was left unplanted at each end of the pans to insure uniform illumination of the plants when placed in the refrigerators. One pan was placed in a greenhouse with an average night temperature of 50°F., and the other in a greenhouse with an average night temperature of 60°F. Since Kiplinger and Hasek (1939), reported that temperatures below 60°F, retarded flower bud initiation and Post (1949), maintained that flower buds do not form in most varieties at temperatures as low as 50°F., these two temperatures were selected for comparison. Ten days later all plants were pinched, leaving three leaves on each plant. Forty-five days from the date of planting, both pans were moved into 50°F. and 60°F. refrigerators respectively. These refrigerators were 3?6 cubic feet in size and were equipped with thermostatically controlled temperature units. Each pan of plants was lighted with eight 40 watt fluorescent and four 300 watt incandescent lights, giving a total illumination of 1000 foot candles at the tip of the plants, (Fig. 1). A constantly flowing water bath was hung directly below the incandescent lights to minimize the temperature differential between the light and dark periods.



Seven days after the plants were moved to the refrigerator, the light period was reduced from 16 to 10 hours per day and collections of the stem tips were begun. At this time those plants in the 50°F. refrigerator averaged 84 mm. in height. The plants in the 60°F. refrigerator averaged 108 mm. in height.

Collections were made of the stem apexes, 3 from each temperature, every 3 days for 36 days. These apexes were then killed in chrom-acetic acid and embedded in paraffin, employing the technique described in Johansen's "Plant Microtechnique". Serial sections were cut 12 microns in thickness, with a rotary microtome, stained with Haidenhain's haematoxylin and safranin, then mounted in balsam for examination of the developing apical meristems.

All the stem apexes were removed and hand sectioned after the last collection was made. In the hand sectioning and examining technique, tweezers, a razor, and low power binoculars were used. The stem apex was stripped of its larger leaves, placed horizontally on a firm surface and held steady with the tweezers while a median longitudinal cut was made with a sharp razor blade. The cut surfaces were then examined under 30X wide field magnification to determine the presence of floral parts.

<u>First greenhouse crop</u>: On September 10, 1950, sixty uniform, rooted cuttings of the following three varieties: Gold Coast, Mary L. Hall, and Sea Gull were planted in a homogeneous soil mixture, using a raised bench in one house of the range of the Plant Science Greenhouses at Michigan State College in East Lansing. A replicat-

ion was planted in a ground bench in another house. The night temperatures of these two houses were 50°F. and 60°F. respectively and the plants were treated similarly to those grown by commercial growers in the same region. The plants were spaced six inches apart in each direction and the tops cut off 18 days later, removing all but 3 leaves and 1 shoot from each plant. A system of lights consisting of 100 watt lamps, 4 feet apart, hung 3 feet above the tips of the plants was used from the time of planting until November 26th (77 days) to interrupt the dark period with one hour of light each night at midnight and keep the plants in a vegetative condition. Six stem apexes of each variety from both the 50°F. and 60°F. night temperatures were collected for studies of flower bud initiation every second day through December 5th.

Second greenhouse crop: A replication of the temperature experiment under greenhouse conditions was started on the 7th of January 1951. The same number of cuttings, taken from the plants used in the first experiment, were rooted, planted and grown as previously using the same controlled temperatures and daylength. Because much of this phase of the experiment was conducted during the winter months, more accurate temperature control in the greenhouse was possible. The daylength was increased by a system of lights, similar to that used in the first crop, to keep the plants in a vegetative condition until April 2nd (85 days). At this time black sateen shade cloth was used to hold the daylength below the critical period and continued until the development of flower buds was evident to the naked eye. The tips of the plants were removed February 6th to induce branching and all the resulting shoots were allowed to develop to maturity. Collection of the shoot apexes was begun on April 4th and continued daily, until April 19th at which time examination by the previously described dissection technique showed flower buds evident in all varieties from both temperatures.

FIG. II

Fig. II. Diagram of chrysanthemum leaf with dark areas to show location of areas removed to examine thickness, number and size of chloroplasts (actual size).

RESULTS

Anatomical Comparison of Leaves

Comparison of leaf thickness and size of chloroplasts: The leaves appeared thicker and a darker shade of green on plants growing in the low temperature than on those growing in a temperature ten degrees higher. To compare their structure, matched leaves were collected from similar locations on plants growing in the 50 and 60°F. greenhouses. Ten cross sections, taken from each of 3 different leaves, and from 3 similar positions on each leaf (Fig. II) were examined microscopically to measure leaf thickness and size of chloroplasts in leaves taken from plants grown in 50 and 60°F. temperatures. The leaf thickness varied from 240 to 270 microns and the size of chloroplasts ranged from 6.0 to 7.5 microns along their longest diameter on all leaves from both temperatures. This examination revealed no significant difference in either leaf thickness or size of chloroplasts as a result of the influence of temperature.

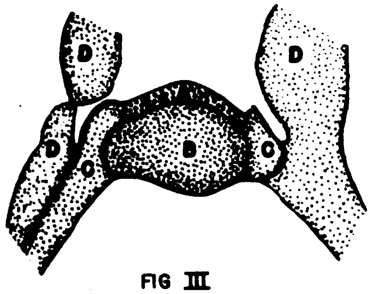


FIG III

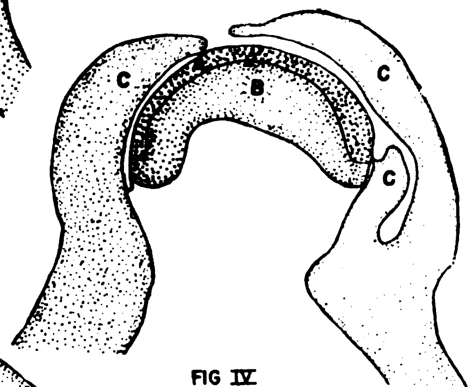


FIG IV

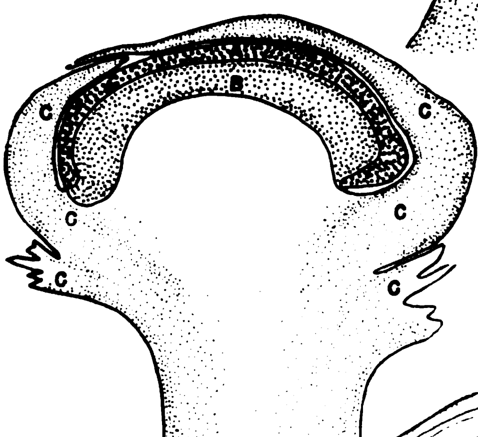


FIG V

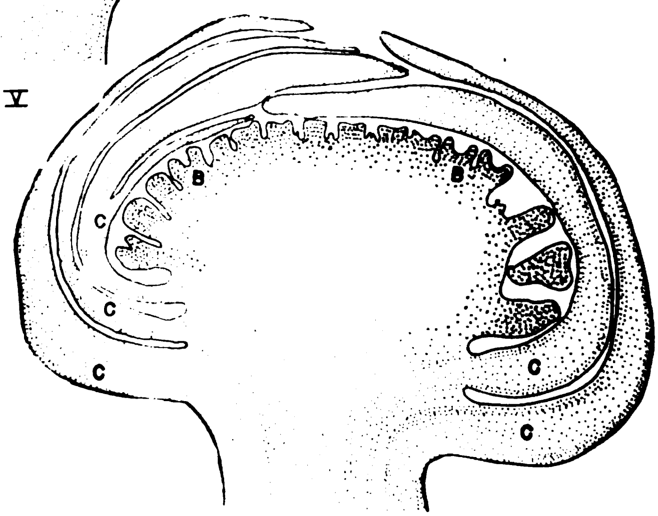


FIG VI

FIG. VII

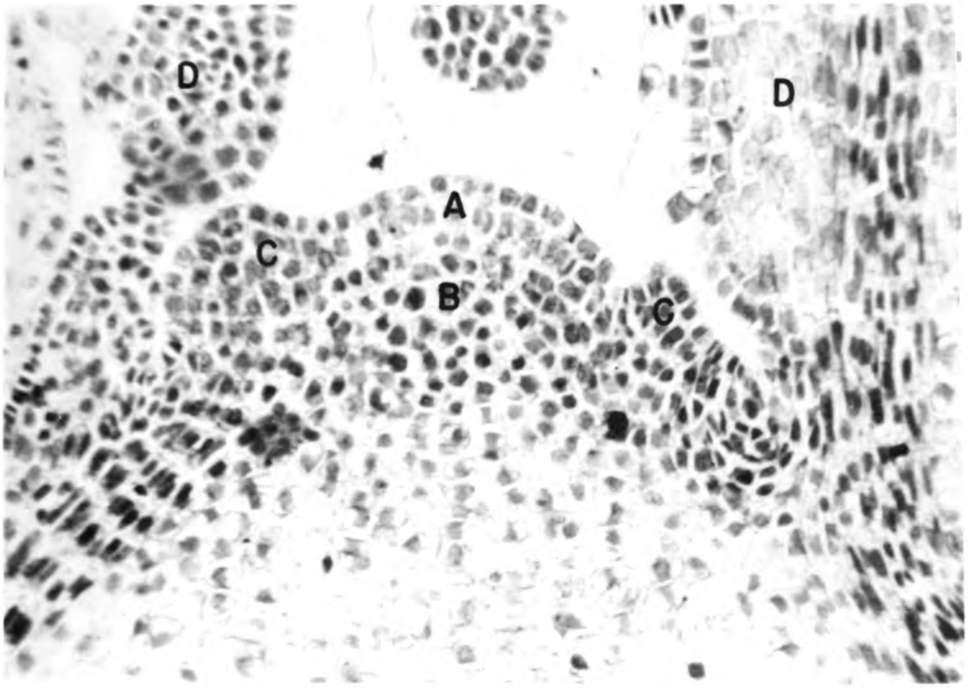
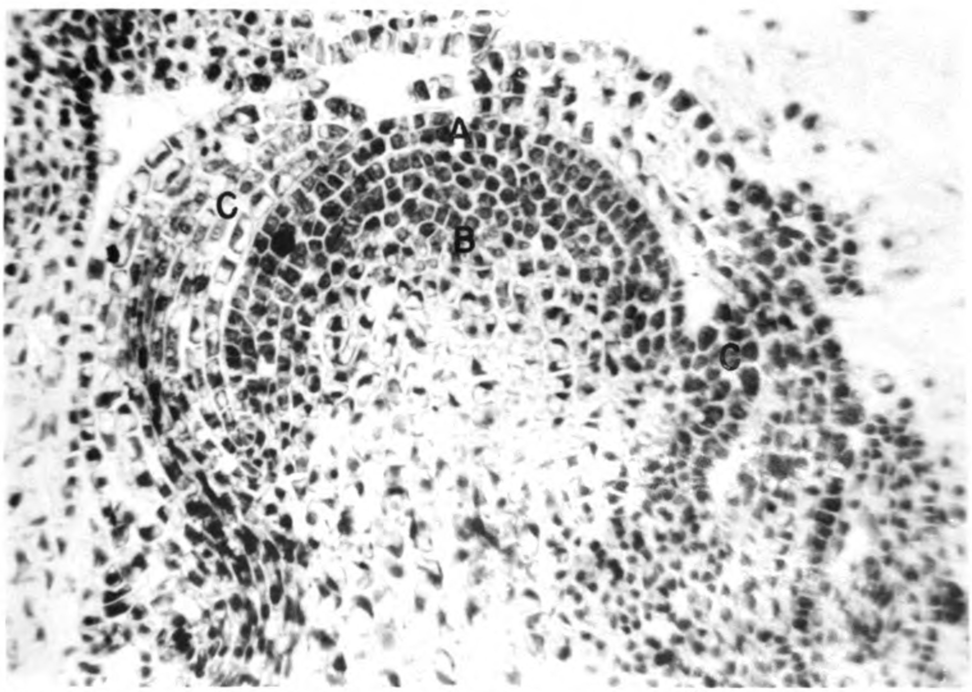


FIG. VIII



Photomicrographs of long. sections of chrysanthemum apexes; plants grown in 60°F. temp., 16 hrs. light per day. Fig. VII, vegetative tip collected at time short days were begun, showing: A, tunica; B, upper corpus; C, bracts; and D, leaves; (x260). Fig. VIII, transitional stage after 18 short days, showing: A, tunica; B, upper corpus; and C, bracts; (x195).

FIG. IX

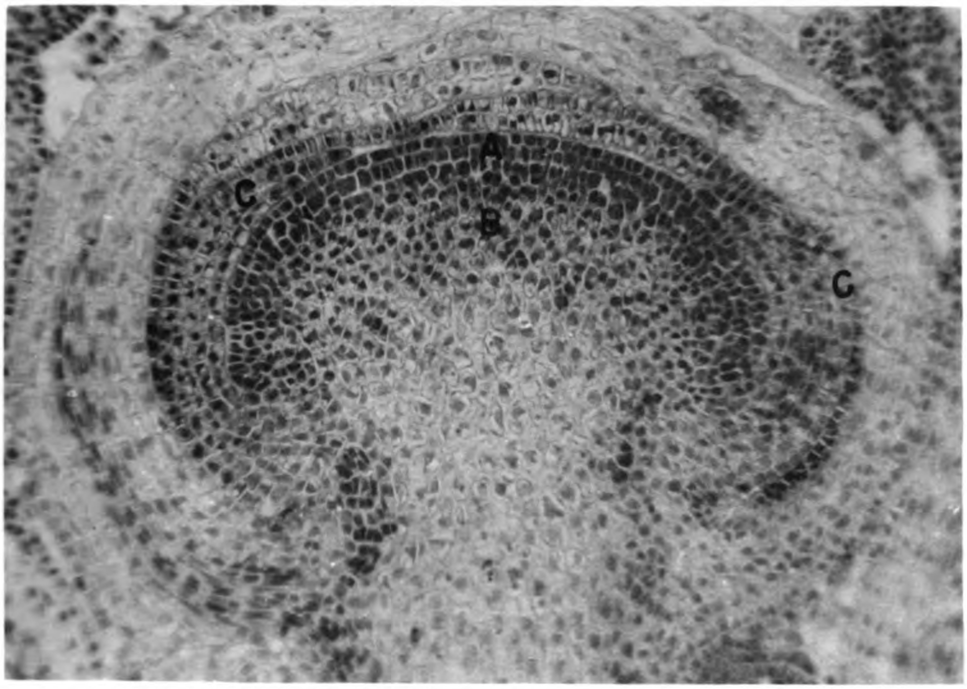
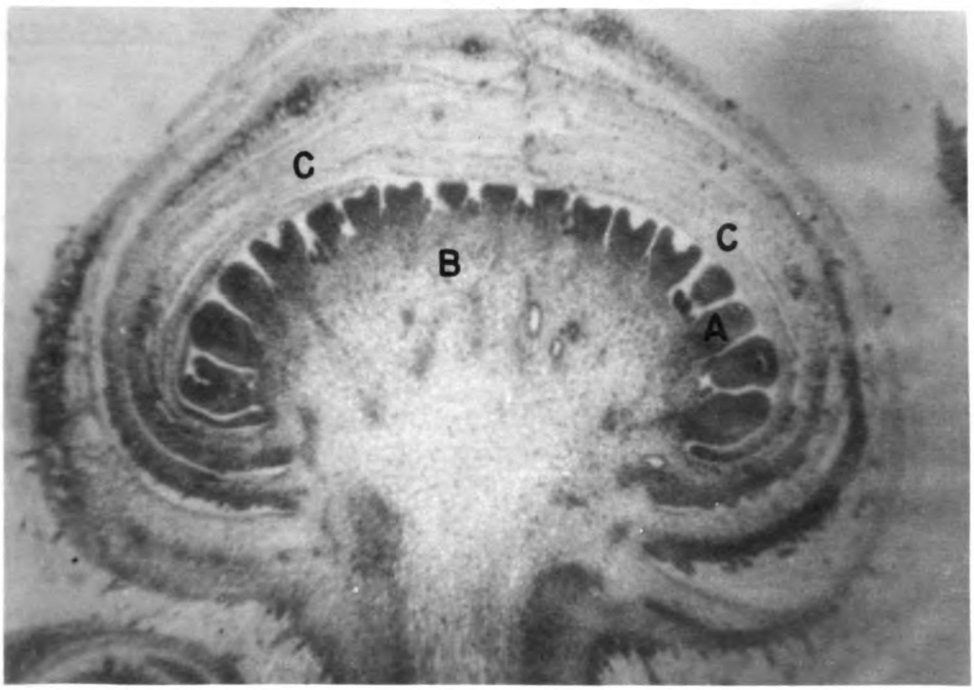


FIG. X



Photomicrographs of long. sections of chrysanthemum apex; plants grown in 60°F. temp., 10 hours light per day. Fig. IX, young reproductive tip after 27 short days, showing: A, tunica; B, upper corpus; and C, bracts; (x155). Fig. X, further developed reproductive stage collected after 26 short days, showing: A, flower primordia; B, upper corpus; and C, bracts; ([illegible]).

Anatomical Description of Shoot Apex

A series of four stages in the development of the flower head is illustrated by diagrams (Figs. III through VI) which are presented to clarify the regions described in photomicrographs of the same stages (Figs. VII through X).

Young vegetative tip: It is clearly shown in Figs. III and VII that on the basis of cellular form and arrangement, the tissues in the vegetative shoot apex can be segregated into four arbitrary regions; A, B, C, and D. The tunica (A) is two cell layers in depth. The regularity of cell arrangement, and location of the nuclei indicate that anticlinal divisions are most frequent. Immediately below the tunica a mass of polyhedral cells, approximately ten cells deep and fifteen cells in width, is evident (B). This upper corpus region is characterized by: irregular cell arrangement, much periclinal and anticlinal cell division, and cytoplasm exhibiting a highly meristematic condition. The bract primordia (C) are characterized by their highly meristematic cells. At the left of the figure they extend farther down the cylinder than at the right where the cut is non-median. Below the grouping at the tip of the bracts, the cells are regularly elongate. Exterior to the bract primordia is found tissue of developing leaves (Figs. III and VII, D). At the left of the figure are shown parts of two separate leaves or parts of two lobes of the same leaf. The leaf on the right is intact and a row of elongated cells four to six cells in width, is continuous through the center of the leaf. In places, these procambium cells are developing into protophloem and protoxylem, the beginning of vascular tissues.

Transitional stage: Figs. IV and VIII are illustrations of a longitudinal section through the shoot apex eighteen days after the short days were begun. The apex is larger and more highly arched or mushroom-like in shape. The two-cell layered tunica (A), extending over the arched apical meristem is present as in the earlier stage. The corpus is larger but similar in structure to that illustrated in the early vegetative bud. The increased meristematic activity in this corpus region suggests that it is in the earliest stages of floral initiation. A group of longitudinal cells is present in each of the two large bracts (C) which enclose the developing flower head. The tissue in each of the arbitrary regions is similar in nature to that found in Figs. III and VII and at the right of the apex a young bract primordium is comparable to those found in the apex eighteen days earlier.

Young reproductive tip: Figs. V and IX show the stage collected twenty-seven days after short days were begun. It has been chosen as a criterion for identification of a flower head in the established dissection technique. No floral parts are recognizable. The

FIG. XI

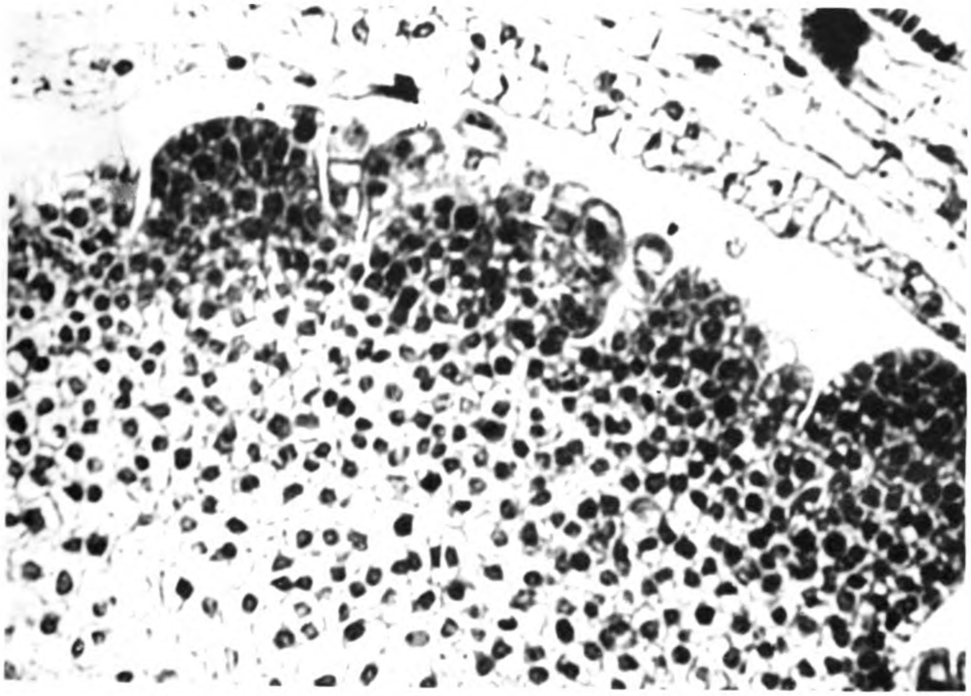
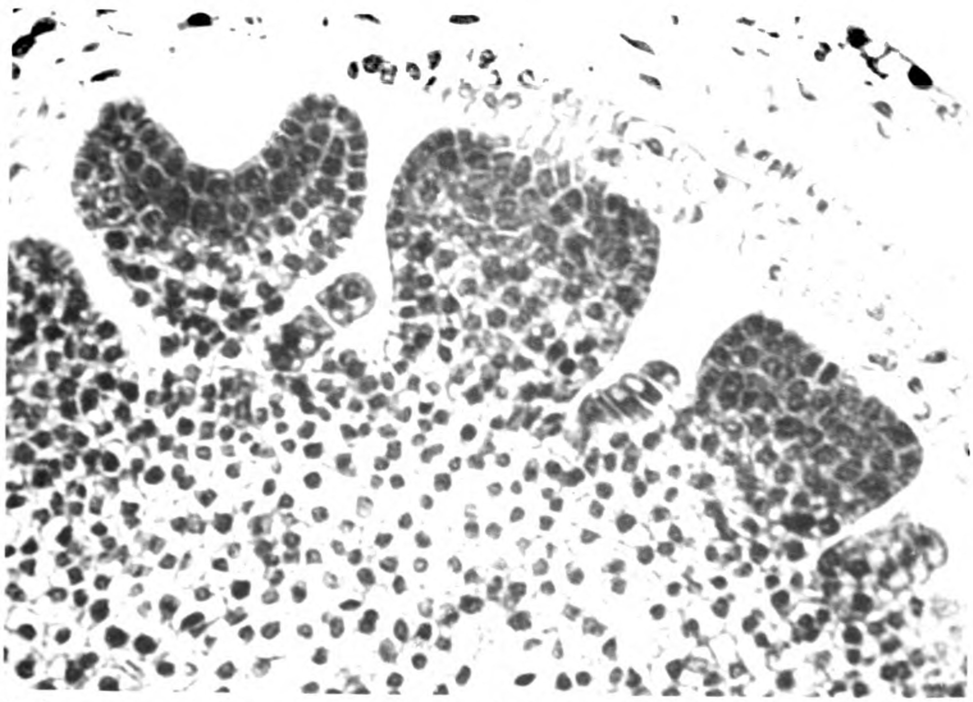


FIG. XII



Photomicrographs of several individual flower primordia; plants grown at 60°F., 10 hrs. light per day, after 36 short days. Fig. XI, flower primordia near periphery of flower head; (x310). Fig. XII, later stages of flower primordia near top center of same flower head; (x310).

apex has a flattened appearance and experimental observation has shown that flowers develop from this structure. It is at a stage sufficiently large to be recognized and distinguished from a vegetative bud and consequently serves to establish the initiation at an early stage of flower development. The tunica (A) through numerous anticlinal divisions has expanded along with the inner tissue and continues to cover the enlarged corpus (B). Many periclinal and anticlinal divisions of the cells in the corpus have resulted in the tightly packed and mushroomed-like appearance of the apex. The cytoplasm is more dense and fills a larger proportion of the cell than previously. Five bracts envelop the apex in contrast to the two shown in Figs. IV and VIII. It is apparent, that as the bracts mature, the cells become larger, more vacuolate, and intercellular spaces develop.

Further developed reproductive tip: At least eight over-lapping bracts, enclosing numerous floral primordia, are shown in Figs. VI and X. The tissues cannot be as easily divided into the corpus and tunica areas in this stage of development although the tunica cells still appear on the periphery of the individual primordia. Figure XI, an enlargement of an early stage of development of some of these primordia, indicates that the early initiation of floral parts is evidenced by localized rapid cell division resulting in protruding masses of cells. Unicellular chains of globose cells arise between these protrusions. A later stage in the development showing three individual primordia as well as the inter-primordial structures is illustrated in Fig. XII. The tip of the flower primordia at the left of this photograph is cupped, in contrast to the other two, indicating that the form of the flower at this stage is not uniformly cylindrical. Numerous serial sections would be necessary to make an accurate morphological determination of the individual flower development. The unicellular chains of cells that are evident between the flower primordia apparently develop into the pointed hairlike, multicellular structures (chaff of the receptacle) found between the florets of the mature flower head. Pistils may be seen forming in the flowers where differentiation is most advanced. These are located on the lower regions of the periphery of the flower head (Fig. X). Meristematic activity in the apex of the flower head is concentrated mainly in the developing flowers.

Bud Initiation

Controlled temperature crop: Flower buds were initiated in 99 percent of the stems on the plants in this experiment that were grown at 60°F. The night temperature was held constantly at 60°F. and the temperature during the daylight period rose to 70°F. and held very constantly. Only 1 percent of the stems on the plants in the experiment that were grown at 50°F. initiated flower buds. Buds on plants grown at 60°F. became reproductive after 27 short days according to the arbitrary stage described previously under "young reproductive tip" and illustrated in Figs. V and IX. At this time there were no buds in a reproductive condition in any samples of stems from the plants grown at 50°F. After 36 short days when the remaining 48 plants were hand sectioned, there was only one plant in each treatment that was not in the same condition as the others in the same treatment.

TABLE I

FLOWER BUD INITIATION

First Greenhouse crop

Number of short days	Gold Coast 50°	Gold Coast 60°	Mary L. Hall 50°	Mary L. Hall 60°	Sea Gull 50°	Sea Gull 60°
1*	00000	00000	00000	XX000	XX000	XX000
3	X0000	XXXX0	XXXXX	XXXXX	00000	XXX00
5	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX
7	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX
9	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX

Second Greenhouse Experiment

Number of short days	Gold Coast 50°	Gold Coast 60°	Mary L. Hall 50°	Mary L. Hall 60°	Sea Gull 50°	Sea Gull 60°
1**	000	000	000	000	000	000
2	000	000	000	000	000	000
3	000	000	000	000	000	000
4	000	000	000	000	000	000
5	0000	0000	0000	0000	0000	X000
6	00000	00000	00000	00000	00000	XX000
7	000000	000000	000000	000000	XX0000	XXXXXX
8	000000	X00000	000000	XX0000	XXX000	XXXXXX
9	X00000	XX0000	000000	XXXXX0	XXXXXX	XXXXXX
10	XX0000	XXXX00	XX0000	XXXXXX	XXXXXX	XXXXXX
11	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX

*First Collection Nov. 27, 1950 — 0 - vegetative bud

** First Collection April 4, 1951 — x - flower bud

First greenhouse crop: Using the hand sectioning dissection technique described previously and the flower bud criterion (Figs. V and IX) it was possible to record the data presented in Table I (First Greenhouse Crop). The stem apexes were removed from plants of the first greenhouse crop at two day intervals following short day treatment during November and December of 1951. Flower heads in the early bud stage were present in two of the three varieties after one short day in the 60°F. temperature. Flower buds had been found in all of the varieties from both temperatures after three days and by five or more days none of the samples taken were in a vegetative condition. In order to supplement these results stem apexes were collected from the second greenhouse crop in April of 1951.

Second greenhouse crop: These collections were made at daily intervals using the same technique for examination and identification of flower heads. In general, flower initiation was not as rapid in this crop. The first occurrence of flower initials in stem apexes was in the samples of Sea Gull from the 60°F. house examined five days after short days were begun (Table I, Second Greenhouse Crop). There was a definite variety difference, Sea Gull being slightly more rapid in its response than Gold Coast or Mary L. Hall. All varieties did produce flower buds one or two days earlier in the 60°F. than in the 50°F. temperature. The latest occurrence of flower initials in stem apexes was in the samples of Mary L. Hall from the 50°F. house ten days after short days were bugun. It required eleven short days for samples from all varieties at both temperatures to form flower buds.

TABLE II

AVERAGE HEIGHT OF PLANTS IN CENTIMETERS
(168 Plants)

	50°F.	60°F.
At time plants were placed in controlled temperatures.	61.4	79.6
Seven long days later.	84.0	108.7
After 36 short days.	109.8	123.4

TABLE III

WEIGHT AND HEIGHT OF PLANTS

First Greenhouse Crop

Gold Coast				Mary L. Hall				Sea Gull			
50°		60°		50°		60°		50°		60°	
oz.	in.	oz.	in.	oz.	in.	oz.	in.	oz.	in.	oz.	in.
1.00	18	1.50	33	1.25	28	1.75	44	1.50	20	2.25	41
1.00	19	1.00	30	1.75	30	1.00	39	0.50	17	2.00	44
1.00	19	0.75	27	0.75	22	0.75	37	1.25	21	2.00	44
0.75	21	1.50	32	1.00	26	0.75	33	1.50	23	3.00	43
1.25	21	1.25	31	0.75	22	1.00	34	1.25	21	1.25	38
1.00	21	0.50	26	1.00	28	1.25	38	1.00	21	2.25	41
2.00	26	0.75	28	0.75	31	0.75	33	1.75	24	2.00	37
1.00	21	2.00	36	1.00	27	1.25	37	2.00	24	1.50	40
1.00	23	1.50	32	1.25	26	1.00	34	1.50	25	2.25	38
0.75	20	0.75	26	1.00	27	1.75	45	1.25	21	1.75	42
0.50	18	2.00	35	1.25	34	1.00	37	1.25	26	2.00	38
1.25	22	1.50	32	0.50	20	0.75	36	1.25	22	1.50	41
1.50	24	1.25	31	1.00	27	1.25	40	0.75	21	1.75	37
1.00	21	1.25	33	2.00	30	0.50	24	1.00	21	1.00	31
1.50	22	1.50	32	1.00	30	0.75	35	1.00	21	1.25	35
1.00	23	2.00	36	1.50	26	1.25	37	0.75	18	1.25	38
1.00	21	1.50	32	0.50	24	2.00	43	1.25	25	1.25	39
1.00	21	1.25	34	0.50	20	1.00	35	1.00	19	1.25	40
1.75	24	1.25	31	1.25	29	2.50	46	1.25	23	1.25	41
2.50	26	1.50	32	0.25	22	1.25	36	0.75	19	3.00	45
0.75	16	1.25	30	1.00	28	1.50	37	1.25	23	0.75	25
0.75	21	1.00	31	1.50	38	1.25	38	1.00	19	1.50	41
1.25	25	1.25	30	----	--	0.75	35	0.75	19	1.50	40
1.00	22	2.00	36	----	--	0.75	37	1.50	24	1.25	39
0.75	18	1.25	33	----	--	0.75	31	1.00	20	1.75	36
28.25	533	33.25	789	22.75	587	28.50	921	29.25	537	42.50	974

Averages

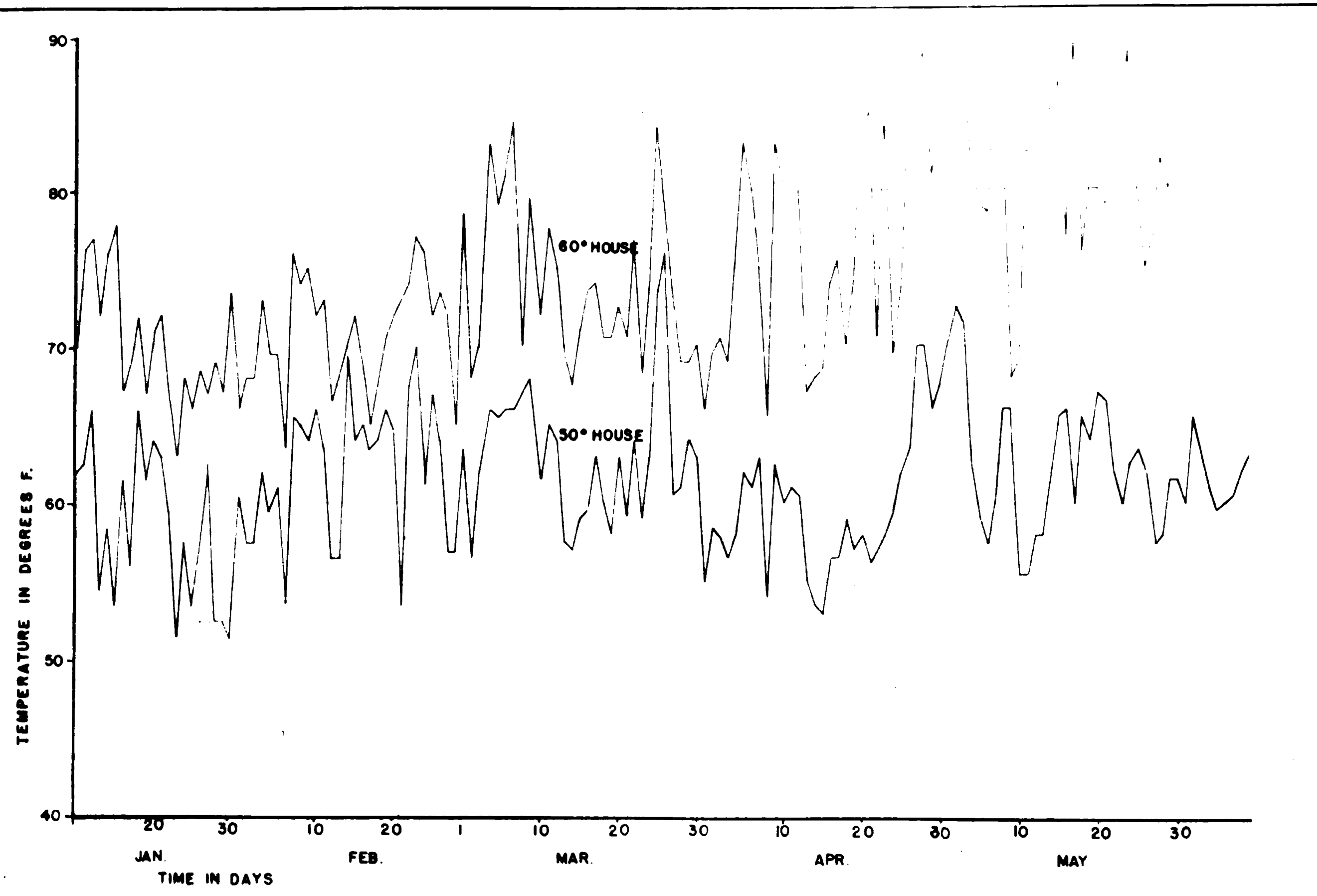
1.13	21.3	1.33	31.5	1.03	26.6	1.14	36.8	1.17	21.4	1.70	38.9

Growth and Quality

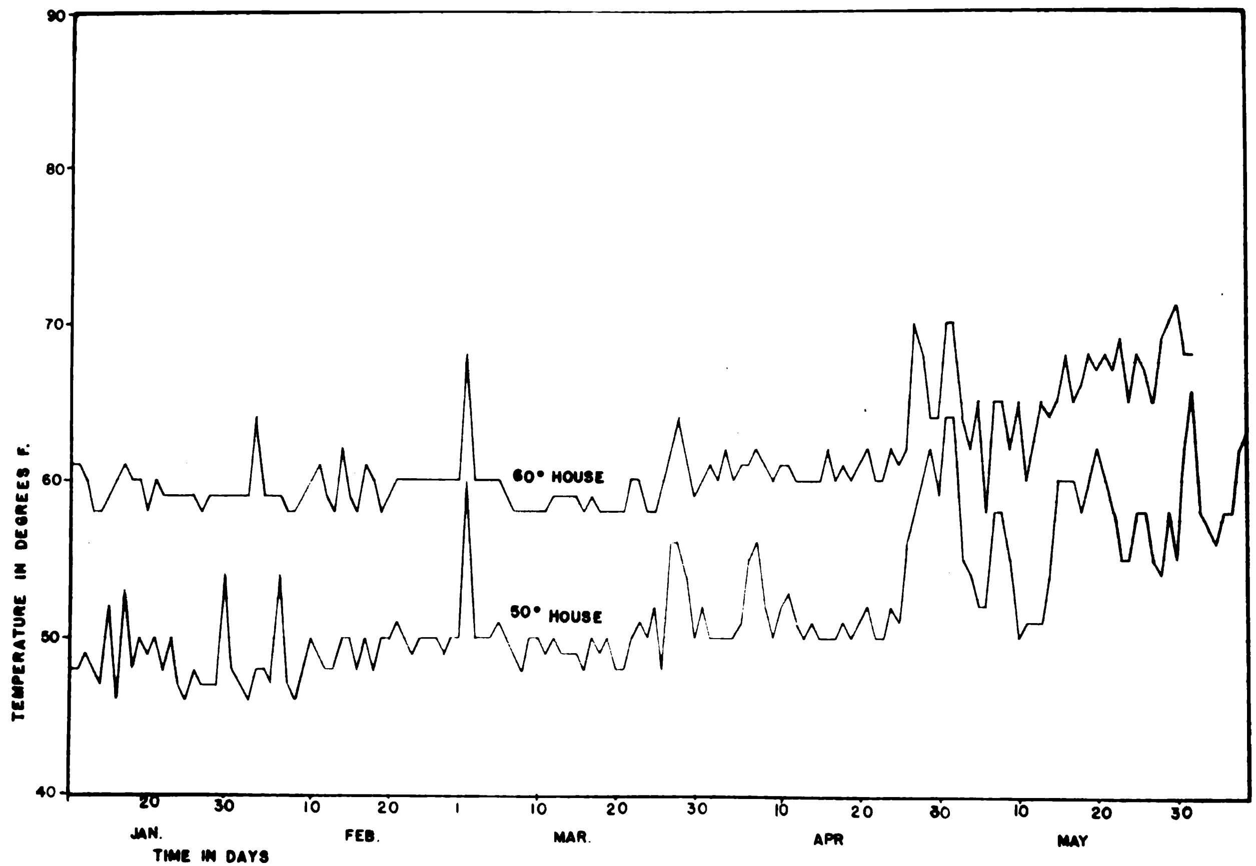
Rate of growth in controlled temperature: Measurements of the height of the plants grown in the controlled temperatures were made at 3 different times: when they were removed from the greenhouse and placed in the controlled temperatures under long days, at the time the short days were begun, and 36 days later when all plants were removed and dissected for examination. The average height of the plants in the 60°F. chamber was approximately 2 cm. greater than the average height of those grown in the 50°F. chamber at each time measurements were recorded (Table II). The average gain in height during the 7 long days was greater for plants from both temperatures than the total average gain during the following 36 short days.

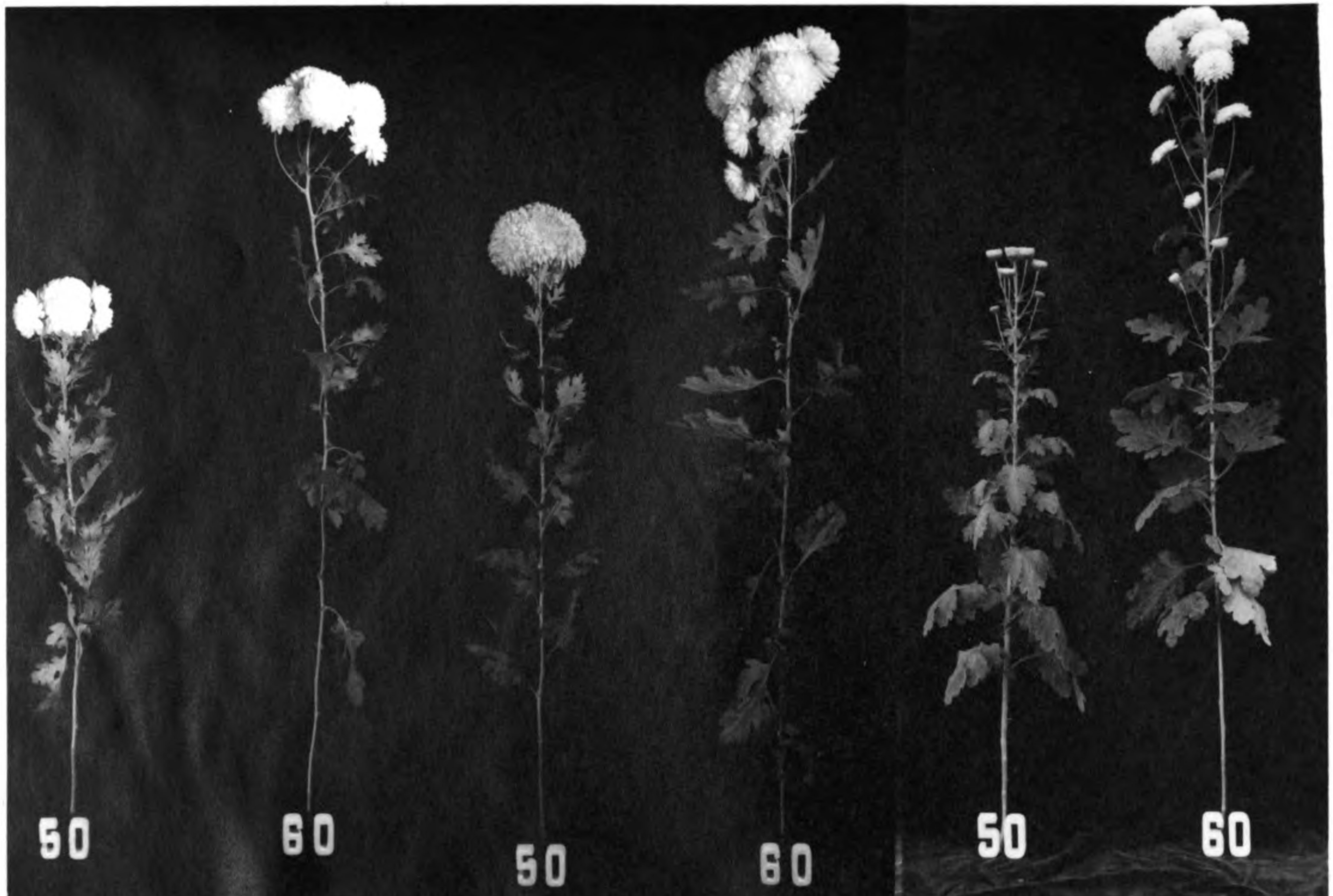
Weight and height of first crop of cut flowers: Fig. XV shows the difference in size and quality of growth of the three varieties grown at 50 and 60°F. night temperatures. The data presented in Table III record the weight and height of 25 plants of the varieties Gold Coast and Sea Gull and 22 plants of the variety Mary L. Hall from each of the same two temperatures in the first greenhouse crop. In each variety the stem length is greater in plants grown at 60 than at 50°F. night temperatures. The average differences vary from a minimum of 10 inches in the varieties Gold Coast and Mary L. Hall to a maximum of 17 inches in the variety Sea Gull

MEAN DAY TEMPERATURES IN 50 AND 60° F. GREENHOUSES



MEAN NIGHT TEMPERATURES IN 50 AND 60° F. GREENHOUSES




50
60
50
60
50
60

(Table III). The average weight per stem for all varieties is greater at 50 than at 60°F. Although this difference ranges only from 0.53 ounces in the variety Sea Gull to 0.11 ounces in the variety Mary L. Hall it can be sufficient to raise the grade of many of the stems. The leaves are smaller and appear more thick on plants grown at the lower temperature. They are not any thicker by measurement (See Anatomical Comparison of Leaves) but possibly appear thicker as a result of the concentration of carbohydrates causing a darker green color and greater turgidity. The difference in spray formation (Fig. XV) as a result of temperature difference is of interest, the longer pedicel on the plants from the 60°F. temperature making a more attractive flower.

The length of the growing period from the time the rooted cuttings were planted in the bench until the first crop was cut was 9 days longer for the variety Gold Coast and 12 days longer for the variety Sea Gull at the lower temperature than for the same varieties at the higher temperature (Table V). The stems were cut when there were at least three flowers open on each stem. This stage was considered to be of good commercial quality (See Fig. XV). Both plantings of the variety Mary L. Hall matured at the same time and were cut after 141 days of growth in the bench.

The average weight per inch, which is indicative of quality, was greatest for all varieties from the 50°F. samples. The average difference for the same variety at the 50 and 60°F. temperatures

TABLE IV

WEIGHT AND HEIGHT OF PLANTS

Second Greenhouse Crop

Gold Coast				Mary L. Hall				Sea Gull			
50°		60°		50°		60°		50°		60°	
oz.	in.	oz.	in.	oz.	in.	oz.	in.	oz.	in.	oz.	in.
0.75	18	1.25	23	0.75	27	1.00	24	1.50	33	1.25	27
0.50	16	0.50	18	1.00	26	2.25	37	2.50	30	1.75	21
0.50	18	1.00	19	1.00	23	1.50	32	2.25	28	2.00	29
1.00	17	1.00	20	1.00	28	0.50	19	2.00	27	1.00	22
0.75	19	0.75	18	0.75	23	1.00	30	2.00	26	2.00	25
1.25	18	1.50	23	0.50	18	0.50	18	1.25	24	1.00	23
0.50	18	0.75	19	4.00	36	1.00	27	1.25	28	2.25	29
0.50	15	1.00	19	1.50	23	1.25	27	2.00	28	1.75	24
1.50	17	1.25	18	1.50	27	1.50	28	1.50	24	0.75	21
0.75	15	1.00	21	1.50	29	1.50	25	0.75	27	1.25	27
1.25	18	0.75	20	1.75	28	1.00	24	1.25	28	1.25	26
1.25	19	0.25	12	1.50	28	0.75	23	1.50	30	1.50	29
1.50	24	0.50	16	1.50	27	0.75	19	2.00	24	1.25	26
0.75	16	0.25	14	1.25	22	1.00	24	2.00	24	1.25	31
1.00	19	0.50	17	0.75	29	1.00	29	1.25	24	1.75	33
0.50	17	0.50	13	1.00	24	0.75	22	1.25	22	1.25	32
1.50	18	0.75	16	3.25	32	1.00	24	1.00	18	1.00	27
3.00	25	0.50	14	1.00	21	1.00	22	2.75	33	2.50	34
0.75	17	0.50	13	1.75	25	2.00	31	1.00	21	1.00	26
0.50	17	1.25	19	1.50	30	1.00	23	2.00	26	1.50	27
0.50	14	1.25	20	2.50	21	1.00	23	1.75	30	1.25	23
1.25	17	0.50	15	1.00	27	1.25	27	2.50	27	1.25	26
1.25	19	0.25	14	1.25	29	1.25	28	1.75	21	0.50	24
2.00	21	1.00	20	1.50	28	2.75	37	1.50	24	1.50	29
1.25	22	1.50	22	1.25	27	1.50	27	2.00	26	2.00	27
1.00	18	0.50	16	2.00	27	1.00	22	2.00	27	1.50	23
1.75	20	0.50	14	1.00	26	1.00	25	1.75	25	1.00	25
1.00	17	0.50	13	1.50	28	0.75	17	1.00	18	3.25	35
1.00	17	0.50	14	1.25	19	1.00	24	3.00	31	1.50	30
2.00	21	0.25	13	1.25	28	1.25	27	2.00	21	1.75	25
0.75	14	0.50	14	1.50	25	1.75	27	1.50	26	1.25	23
2.00	26	0.75	16	2.00	34	2.00	28	1.50	27	1.25	27
1.25	20	0.50	12	1.00	19	1.00	24	2.25	26	0.50	25
1.00	23	0.75	15	1.50	20	1.00	23	1.75	23	1.75	31
1.00	16	0.75	17	1.25	21	1.50	26	0.75	22	0.75	25
0.50	15	0.50	17	0.75	19	1.00	25	1.50	28	1.50	29
1.25	23	0.50	14	1.25	30	1.00	20	1.25	25	1.25	22
0.50	16	0.50	14	0.75	26	1.00	18	1.00	21	1.00	28
1.00	20	0.50	13	1.50	26	1.00	23	1.50	22	2.00	31
1.25	20	0.50	15	1.25	22	1.00	26	1.00	24	2.00	32
44.50	739	29.25	660	56.00	1045	45.70	1178	66.50	1019	59.00	1124
Averages											
1.11	18.5	0.73	16.5	1.40	26.1	1.14	29.4	1.66	25.5	1.88	28.1

was 0.01 ounces heavier in all varieties. The average grade was established by the Cornell Standard Weight (CSW) System (Post 1949) and with the exception of the variety Mary L Hall where the quality also appeared better, the grade was improved by growing the plants in the 60°F. temperature. From grades of individual stems it was found that over 50 percent of the flowers in each variety were advanced at least one grade by being grown at 60 rather than at 50°F. night temperature.

<u>Weight and height of second crop of cut flowers</u>: All of the stems of the variety Gold Coast in the second greenhouse crop were abnormally short (Table IV) either as a result of poor nutrition or from chrysanthemum stunt. While the average height of stems was two inches greater in the 50 than in the 60°F. night temperature, the poor growth of these plants does not warrant much consideration being given to this difference.

As in the first crop, the varieties Mary L. Hall and Sea Gull produced longer stems when grown at the higher temperature. The average stem length was only 3 inches greater for both varieties in contrast to the 7 inch average difference in the first crop.

In the second crop as in the previous crop the average weight per stem was greater in those from the 50 than from the 60°F. environment. The difference ranges from 0.18 ounces in the variety Sea Gull to 0.26 ounces in the variety Mary L. Hall, omitting the poorly grown plants of the variety Gold Coast. This difference is not as great as previously and is not consistent for varieties but the weight per stem is again greater at the lower temperature in each variety for both crops.

All varieties required a greater number of days to produce mature flowers under the low winter light intensities during the second than during the first greenhouse crop. This difference varied from 17 to 25 days at the low temperature compared to from 9 to 22 days at the high temperature (Table V). There was greater uniformity in cutting time in the second crop. All three varieties were ready to cut after 150 days in the 60°F. greenhouse while those in the 50°F. greenhouse required from 7 to 16 additional days to mature.

As in the previous crop all varieties grown at the low temperature weighed more per inch of linear growth than respective samples from the high temperature. The average difference for the same variety at the two temperatures ranged from 0.01 ounces for the varieties Sea Gull and Mary L. Hall to 0.02 ounces heavier for Gold Coast. The 0.01 ounce difference is in agreement with that found for the first crop and because of the poor growth in the variety Gold Coast, not too much significance is attached to the higher figure.

The average grade was not sufficiently different to conclude as previously, that the plants grown at 60°F. were uniformly better than those grown at a 50°F. night temperature.

TABLE V

LENGTH OF GROWING PERIOD AND QUALITY OF FLOWERS

	Gold Coast 50°	Gold Coast 60°	Mary L. Hall 50°	Mary L. Hall 60°	Sea Gull 50°	Sea Gull 60°
First Greenhouse Crop						
Number of days from benching to harvest.	137	128	141	141	149	137
Wt. per inch in ounces.	0.05	0.04	0.04	0.03	0.05	0.04
Grade-(CSW) Average of 25 stems.	First	Extra	Extra	Extra	First	Fancy
Second Greenhouse Crop						
Number of days from benching to harvest	157	150	166	150	166	150
Wt. per inch in ounces.	0.06	0.04	0.05	0.04	0.06	0.05
Grade-(CSW) Average of 40 stems.	First	First	Extra	Extra	Fancy	Fancy
Average For Both Crops						
Number of days from benching to harvest.	147	139	154	146	158	144
Wt. per inch in ounces.	0.055	0.040	0.045	0.035	0.055	0.045
Grade-(CSW)	First	Extra	Extra	Extra	First	Fancy

DISCUSSION OF RESULTS

The cellular arrangement in the vegetative shoot of the variety Gold Coast did not conform to the zonal regions described by Popham and Chan (1950) for the variety Bittersweet. Zones 1 and 2, in their description, correspond very closely to the tunica and upper corpus (A and B, Figs. III through X). It was difficult to segregate zones 3, 4, and 5 and the area which comprises these zones in Popham and Chan's description was referred to in this investigation as bract and leaf primordia (C and D, Figs. III through X). Early flower bud initiation was observed to be in conjunction with a "mushrooming" or strongly arched effect in the apical meristem, similar to that reported by Philipson (1946) in the Bellis perennis and Chan (1950) in Chrysanthemum morifolium. The actual change from a vegetative to reproductive state in the chrysanthemum apparently occurs rapidly and few buds were sectioned during this transitional stage, which is similar to the condition in the Gramineae (Sharman, 1946). Evidence of many periclinal divisions was observed in the upper corpus region immediately preceding the occurrence of flower buds. This substantiated Philipson's (1946) belief that the primary change leading to flowering was "an elongation of the cells immediately below the apical meristem".

It was of special interest to find that the number and size of chloroplasts as well as the thickness of leaves was not affected by the temperatures used in this investigation.

The overall picture of influence of temperature on flower bud initiation can only be summarized by combining and interpreting the data from each of the three crops grown in this investigation. The plants grown in a condition for which the temperature and light intensity were more constant, did substantiate Post's (1939) conclusions that at, or below, 50°F. initiation of flower buds was unlikely. It had been felt that by using 1000 foot candles of light in contrast to 500 used by Post, the results on the formation of flower buds might be different.

Growing a crop of pompon chrysanthemums in a greenhouse with less uniform temperatures is an entirely different procedure to growing the same plants in controlled temperature chambers where they are not subjected to vast fluctuations from the heat of solar radiation.

It is not felt that the data for time of initiation of flower heads from the first greenhouse crop is as indicative as that for the second greenhouse experiment. Temperature controls were not as accurate and temperature records were not complete for the first crop. The plants were grown from cuttings, some of which may have had daylengths shorter than the critical light period while in the cutting bench. After the first two weeks of growth in the bench the illumination source was changed from 60 to 100 watt incandescent bulbs because it was thought that on the lower, somewhat shaded plants, the intensity of light might have been too low to prevent bud formation.

Complete temperature records in the form of mean, night and day temperatures for the 50 and 60°F. greenhouse during the second greenhouse crop are presented in Figs. XIII and XIV. These figures show that during the period from the time that initiation of flower buds started until all apexes showed flower buds (From April 8th to 14th), the mean daily temperature in the 50°F. greenhouse reached a high of 64°F. but never fell below 53°F. The mean night temperature during this same period was more constant, never varying more than 3°F. above or below 50°F. (Fig. XIV). It is likely that the high day temperatures, during this critical period, in the 50°F. greenhouse were responsible for flower buds being initiated almost as soon as in the 60°F. greenhouse (Table I).

Contrary to time of flower bud initiation, data presented in Tables III, IV, and V arranged to show the quality of growth, is more representative for the first than for the second greenhouse crop. Poor growth of the variety Gold Coast combined with a slightly chlorotic condition of all of the plants indicated that the first crop may have been most representative. For an accurate conclusion however, an average of both crops is presented at the end of Table V.

These data show that in general, the 60°F. night temperature is to be reccommended. In each variety the number of days from benching to harvest is less, and while the weight per inch of linear growth is consistently lower, the stem length is sufficiently greater to produce a crop of higher quality.

SUMMARY

Eighty-four plants of *Chrysanthemum morifolium* variety Gold Coast were grown at 50 and 60°F. temperatures using 1000 foot candles of artificial light. The temperature during the light period rose consistently to 62 and 70°F. respectively, as a result of the heat from the lights. One percent of the stems on plants in 50 and 99 percent of the stems on the plants in the 60°F. temperature had initiated flower buds after 36 short days. It required 27 short days to produce flower buds at the higher temperature.

Photomicrographs, diagrams and descriptions are presented to show the stage of development of flowers in buds: at the time short days were begun, 18, 27, and 36 days later. Anatomical examination of the leaves revealed that the temperature had not influenced the thickness of leaves, size or number of the chloroplasts.

Two crops using varieties Gold Coast, Mary L. Hall, and Sea Gull, were grown in the greenhouse at 50 and 60°F. night temperatures. Using a hand sectioning dissection technique described previously and a flower bud criterion (established from the previous experiment after 27 short days) it was shown that these varieties formed flower buds in from 5 to 8 short days. There was a definite difference in varieties, all varieties producing flower buds one or two days earlier in the 60 than in the 50°F. greenhouse. It required eleven

short days for samples from all varieties at both temperatures to form flower buds.

Measurements of weight and height for both crops indicated that the 60°F. night temperature was to be preferred. In each variety the number of days from benching to harvest was less, and while the weight per inch of linear growth was consistently lower, the stem length was sufficiently greater to produce a crop of higher quality.

LITERATURE CITED

Arber, A. 1931. Studies in Floral Morphology. New Phyt. 30: 317-319.

Arber, A. 1933. Floral Anatomy and its Morphological Interpretations. New Phyt. 32: 231-242.

Bonner, J. 1947. Flower Bud Initiation and Flower Opening in Camellia. Proc. Amer. Soc. Hort. Sci. 50: 401-408.

Borthwick, H. A. and Parker, M. W. 1938. Influence of Photoperiods Upon Differentiation of Meristems and the Blossoming of Biloxi Soy Beans. Bot. Gaz. 99: 825-839.

Chan, A. P. 1950. The Development of Crown and Terminal Flower Buds of Chrysanthemum morifolium. Proc. Amer. Soc. Hort. Sci. 55: 461-465.

Garner, W. W. and Allard, H. A. 1923. Further Studies in Photoperiodism; Response of the Plant to Relative Length of Day and Night. Jr. Agr. Res. 23: 871-878.

Hamner, K. C. and Bonner, J. F. 1939. Photoperiodism in Relation to Hormones as Factors in Floral Initiation and Development. Bot. Gaz. 100: 388-431.

Kiplinger, D. C. and Hasek, R. 1949. Spring Flowering Chrysanthemums. Proc. Amer. Soc. Hort. Sci. 53: 437-439.

Link, C. 1936. Preliminary Studies on Flower Bud Differentiation in Relation to Photoperiodic Response. Proc. Amer. Soc. Hort. Sci. 34: 621-623.

Miller, H. and Wetmore, R. H. 1946. Studies on Developmental Anatomy of Phlox drummondii. Amer. Jour. Bot. 33: 1-9.

Philipson, W. R. 1946. Studies in Development of Inflorescence. I. Ann. of Bot. 10: 257-270.

________ 1947. Studies in Development of Inflorescence. II. Ann. of Bot. 11: 285-290.

________ 1948. Studies in Development of Inflorescence. IV. Ann. of Bot. 12: 65-72.

Poesch, G. H. 1931. Studies of Photoperiodism of the Chrysanthemum. Proc. Amer. Soc. Hort. Sci. 28: 389-392.

Popham, R. A. and Chan, A. P. 1950. Zonation in the Vegetative Stem Tip of Chrysanthemum morifolium. Amer. Journ. Bot. 37: 476-483.

Post, K. 1931. Reducing the Daylength of Chrysanthemums for the Production of Early Blooms by Use of Black Sateen Cloth. Proc. Amer. Soc. Hort. Sci. 28: 382-388.

______ 1939. Relationship of Temperature to Flower Bud Formation in Chrysanthemums. Proc. Amer. Soc. Hort. Sci. 37: 345-347.

______ 1942. Effects of Daylength and Temperature on Growth and Flowering of Some Florists Crops. New York Agr. Exp. Sta. Bull. #787.

______ 1943. The Effect of an Interval of Long Days in Short Day Treatment on the Flowering of Chrysanthemums. Proc. Amer. Soc. Hort. Sci. 43: 311-315.

______ 1949. Florist Crop Production and Marketing. Orange Judd. New York.

Sharman, B. C. 1946. The Biology and Developmental Morphology of the Shoot Apex in the Gramineae. New Phyt. 46: 21-34.

Tincker, M. H. 1925. The Effect of Length of Day Upon the Growth and Reproduction of Some Economic Plants. Ann. of Bot. 39: 721-754.

ROOM USE ONLY