Chapter 2

Review of Literature

Chan (1955) mentioned that the factors affecting the flower bud initiation and the development of flower bud in chrysanthemums were the temperatures at which stock plants were held, temperatures before and after induction of flower buds, photoperiods and light intensities before and during induction, and the age of plants at the time of induction.

Vernalization. (A period of low temperature)

Schwabe (1950) reported that a period of low temperature hastened inflorescence bud initiation in the chrysanthemum, as measured by the time until the macroscopic appearance of the bud and also by the number of leaves produced. This effect was found under both long- and short-day conditions. A vernalization period of only three weeks at 5-7°C. was effective in stimulating flowering. Although the low temperature treatment might be given discontinuously, it was more effective if given during the dark phase than during the light phase. Vernalization of the apices alone was sufficient to cause greatly accelerated flowering, whereas chilling of the other plant parts did not affect flowering (Schwabe,1954). Little or none of the stimulus was carried over from one

year to another (Schwabe,1950).

According to Vince (1955) a period of low temperature was not found to be necessary in the variety 'Charm'; any period of low temperature during growth actually delayed flowering. In the 'Magnet' variety the effect of a low temperature treatment of the parent stools was carried over to the cuttings, even though these were produced at high temperatures. There was no difference in response to temperature between plants raised from stem cuttings and those raised from basal cuttings.

Mason (1957) also found that cuttings taken from the stems of vernalized stock plants were themselves fully varnalized and required no further chilling. However, under conditions of high temperatures and low light intensity the winter plants became devernalized and remained vegetative.

Schwabe (1957) confirmed the importance of the interaction between temperature and low-light intensity treatment in the devernalization of the chrysanthemum. Low intensity light caused no de-vernalization at, or just above 18°C., but at 23°C. four weeks of low light gave a considerable de-vernalization response, and at 28°C. it was practically complete.

Temperatures.

Post (1939-1942) and Roberts and Struckmeyer (1938) investigated the effects of high and low temperature on the flowering response of the chrysanthemum. Both investigations led to the conclusion that in addition to a short photoperiod, high temperatures were required for the rapid flowering of this plant. Post laid a special stress on night temperatures, which he claimed should be kept above 60°F.

Okada (1953) investigated the effects of day lengths and temperatures on the flowering of the summer- and August-flowering chrysanthemums, Although both were day-neutral, they differed in flowering seasons owing to different temperature requirements for flower bud formation (8°C. for summer-flowering and 12-15°C. for August-flowering chrysanthemums). High night temperatures delayed flower bud development in the Chrysanthemum Sea Gull (Furuta and Nelson, 1953).

Cathey (1954b, 1954d) classified chrysanthemum varieties on the basis of temperature responses into three groups: (1) thermozero- in which flowering was not inhibited within the range 50 to 80°F. (2) thermopositive- in which a temperature of 60°F. or more was needed for initiation of flower buds, (3) thermonegative- in which a temperature of 60°F. or less was needed for initiation and development.

Cathey (1954c) studied the effects of night, day

and mean temperatures upon the thermopositive chrysanthemum variety Encore. Night temperatures affected the flower development more than day temperatures did. The higher the night temperature, the shorter was the time required for bud initiation and the greater was the number of flowers produced. A medium night temperature (60°F.) resulted in flowering in the shortest time. The mean growing temperature (average night and day) was not correlated with flowering time. Cathey (1954e) studied further on the effect of temperatures. Stock plants from which cuttings were taken were grown at 50, 60 and 80°F., and later at three stages from the time of propagation onwards, batches of plants from each of the stock temperatures were transfered to temperatures of 50 and 60°F. Minimum flowering time was obtained with all three varieties when 60°F. was continued throughout the life of the plants. Growing plants at 80°F. in the first phase inhibited flowering in the thermonegative variety and delayed it in the others. An initial temperature of 50°F. delayed flowering slightly in the thermonegative variety and inhibited it in the thermopositive variety. A continuous temperature of 50°F. reduced the number of flowers per spray on both thermonegative and thermozero varieties. Shifting the thermopositive variety from 50 to 60°F. resulted in more flowers per spray than when plants were grown continuously at 60°F.*Thermozero variety

The

Shasta flowered in the range of 50 to 80°F., but both these temperatures produced an equal delay in the flowering as compared with the time taken by plants grown at 60°F. Cathey (1955f) reported that there was a straight line relationship between temperature and flower initiation; At low temperatures the photoperiod required for flower development was slightly less than that required for flower initiation. When the apical region was held at 80°F. while the leaves were at a minimum night temperature of 50°F., flowering occurred at the same time as in plants grown with all their organs at 80°F. By lowering the temperature the rate of bud initiation was delayed basipetally down the stem. Spray formation was altered by low temperatures. The rate of flower development was affected by temperature changes from 80° to 50° or to 60°F.; after initiation at a low temperature (50°F.), there was a greater accelerated flower bud development. Day temperatures partially overcame the effects of short periods of low temperature during the dark period, but could not counteract the effect of low temperatures during the entire dark period. Flowering of the Encore variety was delayed by growing cuttings at temperatures below 60°F. and was further delayed by reduced light intensity and by storage of the cuttings at 31°F. Delayed flowering was nullified by treatment at 45°C. for 5 minutes. Cathey (1955a) studied the effect of temperature

Shifts upon the spray formation and flowering time of the thermopositive variety Satellite and the thermonegative variety Revelation. At various stages of development, the type of spray produced could be controlled by the magnitude and time of temperature reduction. Reduction of temperature from 80 to 60°F. at the start of long nights or when buds were just visible produced crown sprays with elongated terminal sprays. Reduction of temperature from 80 to 50°F. produced crown sprays with elongated peduncles. The later the change occurred, the greater the elongation of the lateral shoots. Flowering could be either accelerated or delayed by reduction in temperature, depending on the variety and the magnitude and time of temperature reduction. Cathey (1955b) investigated the effect of the date of starting SDT on the flowering of the thermonegative chrysanthemum variety Revelation. Under short-day treatment bud initiation occurred throughout the year, but flower development did not occur until the temperature dropped to 60°F. or lower for a large part of the night. Higher temperatures at the beginning of short-day treatment resulted in compound sprays with a large number of flower buds. High light intensity during short-days had little effect on flowering when night temperatures were controlled at 55°F.

Samman (1958) studied how low temperatures affected

chrysanthemum flowering at the beginning of short-day treatment. A gradual increase in stem length and in number of mature leaves occurred as temperatures were decreased. The average number of flowers which developed did not appear to be affected by low temperatures. The delay in flower development was considerable with decreasing temperatures (the maximum delay occurring around 40°F.) and also with increasing duration of low temperatures. There was evidence that flower initiation did not take place under a combination of short-days and low temperatures. Flower initiation was faster at 60°F. than at the other experimental temperatures.

Doorenbos (1959) studied the after-effects of temperature and light intensity on chrysanthemums. The growth and flowering of plants propagated from the various temperature-treated plants showed marked after-effects, and in many cases the number of internodes to the terminal inflorescence was greater in plants from cuttings formed at the higher temperatures. In several cases too the internodes were shorter after high temperature treatment.

Vince (1960) revealed that low night temperatures of 40-50°F., given before the bud was visible, were found to delay flowering in several glasshouse varieties when compared with steady temperatures of 60°F. Low night

temperaturee given during long-day treatment usually caused an increase in the number of leaves to the bud, but when given during short-day induction no such increase was evident. Flower diameter was increased by low night temperatures and was primarily determined by the temperature after the buds became visible macroscopically.

Tayama and Miller (1963) found that optimum night temperatures for growth and efficiency of chrysanthemums depended upon plant age. Young chrysanthemum plants ranging in age from 6 to 10 weeks held under short-day and long-day conditions, and exposed to various night temperature treatments for a period of four weeks. Optimum night temperatures for growth of plants in short days dropped from about 65 to 40°F. as the plant aged, and in long days dropped from 72 to 40°F. as the plants aged.

Temperatures and photoperiods.

The critical photoperiod (minimum night length) necessary for flowering was shown by Long (1939) to vary according to the growing temperature. As the plants grew older, they became more sensitive to a photoperiodic treatment and a shorter critical photoperiod was required for flowering. Iwai (1954), and Iwama and Iwai (1954) concluded that of 17 chrysanthemum varieties studied, flowering was influenced mainly by temperature in 3

varieties and by day-length in 14 others, in which flower buds differentiation occurred when day-length was reduced to 14.5 hours and their development followed when it was reduced to 13.5 hours or less. Among these 14 varieties influenced by day-length, 4 flowered earlier when the temperature was increased, and 7 were retarded by increased temperature.

According to Cathey (1957) temperatures altered the critical photoperiod necessary for the initiation and development of a flower in all varieties studied; the longer the normal period required to bring a given variety to flower under natural fall conditions, the shorter the photoperiod required for flower bud formation and development. The photoperiod required for the initiation of the inflorescence was shortened by lowering the temperature (from 80 to 50°F.). The photoperiod required for the development of the flower was shortened by raising the temperature (from 50 to 80°F.) At low temperature (50°F.), there was no difference in the critical photoperiod for initiation and development of the flower. When flower buds were initiated, they developed slowly.

Miller and Kiplinger (1962) studied the effect of day length and temperature on the production of tubular florets (Quills). Exposure of the plants to short periods of artificial light during the night after short-day treat-

ment had begun, to 11-hour days, or to interrupted short days did not improve the form or reduce quilling, but 15 to 32 % more florets per flower were produced by the last treatment. More desirable flowers were obtained and quilling was nearly eliminated by growing the plants at 67°F. instead of 62°F., the critical period for the temperature treatment being from 3 weeks after the start of the short-day treatment up to flowering time.

Photoperiods.

Quite early in the history of the study of photoperiodism the chrysanthemum was classified by Gardner and Allard (1923) as a typical short-day plant. Since then the chrysanthemum has been employed in experiments on photoperiodism by several investigators (Cajlachjan, 1936 and 1937; Moshkov, 1935 and 1937), who demonstrated that the lengtb of day was perceived by the leaves, and flowering was included when as few as the upper 4 mature leaves were exposed to short days. But earlier flowering resulted when the entire plant or a half of the plant was exposed to short-day conditions. Using the chrysanthemum, Weise and Seeley (1964) also showed that the stimulus can be translocated to the main shoot and other branches of the plant. Similarly short-day treatment of the Shasta stock portion of grafted plants caused flower bud initiation

and development in Indianapolis Bronze scions receiving a long-day treatment. Earliness of visible flower buds and the number of flower buds on the receptor branch and scion were stimulated by defoliation of the receptor.

Post (1934) showed that the time of flowering was dependent on the number of short days in proportion to long days in a period of treatment. Flower buds developed less rapidly when long days were interspaced in the short day treatment than when short days were given in succession. In 1943 he showed, long day intervals of 5 to 20 days given 28 or 35 days after the start of short days delayed the date of bloom a maximum of 8 days in comparision with the continuous short day treatment. The size of the flower was increased slightly and the individual flower heads were on longer peduncles, allowing in individual flowers to stand farther apart when the long day interval was given. Crown buds (topmost flower bud on the stem) were found on chrysanthemums as a result of a few short days followed by long days (Post, 1934). Progressive budding down the stem would result if the number of short photoperiods were increased in the cycle.

Post and Kamemoto (1950a) showed that the older stems required as many short days to bud as did the younger stems. When a long photoperiod was given contimuously, no crown buds formed during 3 months of growth (Post, 1948b),

showing that a relative short photoperiod was necessary for the crown bud to form. Five short days caused the crown bud on the stem to form and lateral vegetable growth occurred (Post, 1954). Kiplinger and Alger (1948) produced branched sprays with short stems suitable for packaging by given seven short photoperiods followed by 20 long photoperiods, then short photoperiods until flowering. In this case, crown buds resulted in from the first short photoperiod and the branches developed during the long photoperiods which followed.

= Earlier experiments dealing with short cycles of short and long photoperiods (Post, 1943) showed that seven short photoperiods were sufficient to bud completely to the ground in some varieties, while in other varieties the treatment formed two to five buds only. Pedicel length increased as the number of long photoperiods in the cycle was increased. Singleness of flowers of the variety Princeton was associated with seven short photoperiods followed by 10 to 20 long photoperiods. Increase in doubleness of Yellow Fellow resulted when 14 short photoperiods were followed by 15 to 20 long photoperiods.

= Post (1950b) showed that chrysanthemum pompon spray formation was controlled by changing the photoperiod during flower bud induction and development. Crown buds were induced by three to five short photoperiods followed by

five or more long photoperiods. The number of long photoperiods governed the length of the lateral vegetative shoots which developed. Twelve short photoperiods completely budded the plant forming a terminal spray. The length of pedicel, following the complete budding, was dependent on the length of the long photoperiod which followed. Ten exposure gave a good spray with all buds well placed on long pedicels. Fifteen and 20 long photoperiods gave undesirably long pedicels and some malformed flowers. Two types of sprays appear most valuable for florists' use. Terminal sprays with crowned buds were produced by giving 12 short and 10 long photoperiods. Crowned sprays with terminal clusters were produced to best advantage with 4 or 5 short then 15 or 20 long photoperiods. The latter spray is excellent for disbudding, the former appears as a disbudded spray. Both types are probably supsrior in quality to the normal terminal spray produced by a continuous short photoperiod.

Post and Kamemoto (1950a, 1950b, 1950c) reported that short photoperiods did not cause flower buds formation during the rooting period of chrysanthemum cutting. Four short pbotoperiods were sufficient to cause crown buds formation in the variety Gold Coast. Crown buds formed on plants, after the cutting was rooted, developed a considerable distance from the ground. All stock plants

of Arcadia formed crown flower buds after four photoperiods if shoots remained on the plants. The buds developed on all cuttings removed 10 or more days after four short photoperiods. As the interval of long photoperiods was reduced before taking the cutting, after four short photoperiod treatment, less buds formed. The growth of the crown bud decreased with time after the treatment.

Furuta (1954) studied the influence of photoperiods on flower bud initiation and development. His findings are as followed: (1) Photoperiods over 14 hour duration did not cause flower bud initiation. Flower buds initiated in photoperiods over 14 hour duration but this was correlated with growth. Photoperiods under 14 hours duration caused flower bud initiation. (2) A shorter photoperiod was needed for maximum rapidity of flowering than was needed for flower bud initiation. Flower bud development was delayed by photoperiods of 13 hours or over. (3) Varietal differences were noted. The later a variety flowers (longer response groups), the shorter the photoperiod necessary for both initiation of flower buds and maximum rapidity in flower bud development. (4) At photoperiods near the maximum limit, full open flowers and smaller flower buds were present on the same stem. This condition was not true under shorter photoperiods.

Capreal (1954) applied a formula of days from

planting to bloom comprising: on the average, 15 long days from planting to pinching root stock, 30 long days for vegetative growth and 60 short days for bud initiation and development. The third phase will, in fact, range from 7 to 14 weeks depending on variety. Once the short-day response of any given variety has been worked out, the date of blooming can be controlled by applying a short-day timing schedule.

Love (1963): The optimum photoperiod was found to be 12 hours for 4 tested varieties, whether the supplementary illumination was provided at 2 f.c. or at 10 f.c. Photoperiods longer than the optimum resulted in the stage of flower development being quantitatively reduced; more advanced stages of floral ontogeny were consistently found in the plants receiving 2 f.c. of supplementary light than in plants receiving 10 f.c.

Griffin and Carpenter (1964): The clone of chrysanthemum maximum Ester Read flowered at photoperiods in exceas of 13 hours and remained vegetative at one of 12 hours. T.E. Killian flowered at a 15-hour photoperiod, but remained vegetative under shorter periods. Extension beyond the critical photoperiod improved flower height, weight and diameter for Ester Read and increased monthly flower production. The growth habit of both clones varied with the photoperiod. With short photoperiods the stems

developed horizontally for considerable distances from the main stem before bending vertically. This growth habit was progressively reduced at longer photoperiods. The 15-hour photoperiod produced upright stems. Measurements of excised basal leaves showed progressive increased in leaf length, width and weight as photoperiods increased.

Seeley and Weise (1965) studied photoperiodic responses of garden and greenhouse chrysanthemums. The greenhouse cultivars had a shorter critical photoperiod than the garden cultivars. The greenhouse cultivars, Indianapolis Bronze and Forty Niner, flowered when exposed to 9- and 13½-hour photoperiods. Photoperiods of 14½-hour caused both varieties to form crown buds which did not flower. Grown under longer periods, Forty Niner similarly formed crown buds, but Indianapolis Bronze remained vegetative. All the garden cultivars had visible flower buds with photoperiods up to and including 24 hours. With a 9-hour photoperiods all cultivars flowered, but with longer photoperiods the cultivars varied in the degree of flowering response. For example, Dr. Longley and Rosa flowered with 24-hour photoperiods, whereas W.P. Snyder flowered only with photoperiods of 17½-hours or less. Photoperiod had a significant effect on rate of development, with increments in photoperiod delaying the appearance of flower color and anthesis.

Light intensity.

Watson and Andrew (1953) studied the effect of light intensity on the flowering of chrysanthemum variety Gold Coast. Under a light intensity totaling 1,848,797 f.c. (equivalent to normal day light) with temperatures of 51°F. by night and 61°F. by day and of 61°F. by night and 74°F. by day, 100 % of the plants initiated flower buds in 11 and 10 short days respectively. Under a light intensity of 270,000 f.c. with temperatures of 60°F. by night and 70°F. by day, 99 % of the plants had initiated flower buds after 27 short days, but no initiation occurred under this lower light intensity when the temperatures were 50°F. by night and 58°F. by day.

Yasuda and Korematsu (1958) studied the effect of light intensity under lamps of various watts. 10 and 60 W. fluorescent lamps and 40 and 200 W. incandescent lamps all effectively prevented flower bud differentiation in the late-flowering chrysanthemum varieties Kanbotan and Unzen. Flower bud differentiation began 10-15 days after the lighting was discontinued and by the 20th day flower bud formation was completed in all the plants. Differences were found in the length of flowering stems but these could not be attributed to the type of lighting.

Vince's work (1960) showed that reduced light intensity markedly delayed flowering if it occurred during

long days. Light intensity and temperature had a marked effect on flower sizes. The flower diameter was greater when a short-day induction consisted of 14-hour, followed by 13-hour, photoperiods than when 8-hour photoperiods were provided; the former day-length treatment, however, delayed flowering.

Yasuda and Tsukutani (1961) grew chrysanthemum cuttings from August to September under lamps of 10, 20 30 or 60 watts. There were no distinct differences in stem elongation due to the treatments. Delay in flower bud formation and flowering increased with higher light intensity. Flowering time was the same, however, for both the 30 W. and 60 W. treatments.

Carpenter (1964) studied the response of chrysanthemums to supplemental reflective sunlight. An increase in mid-winter light intensities, due to the use of aluminium foil reflectors, increased stem lengths and fresh and dry weights. Maximum light increase occurred close to the reflectors and measurable differences in illumination were recorded 32 in. from the reflectors.

Swain (1964) studied the effect of supplementary illumination by mercury lamps during periods of low natural light intensity. Plants grown from 29 September to 3 January under mercury vapour (MV) lamps produced significantly more and heavier cuttings than the unlighted

controls. Plants grown from 12 January to 13 April under MV lamps produced significantly heavier cuttings than the controls, but the number of cuttings was not increased. Stock plants under MV lamps grew to the pinch stage 1 to 3 days eralier and produced satisfactory cuttings.

Tsukamoto (1957) and Tsukamoto and Tanaka (1964) studied the effect of light intensity and plant regulators on flowering. Applications of NAA to December King as a partial substitute for light in retarding flowering. In control plants the effect of light in retarding flowering declined as light intensity decreased, but the reduction was much less in plants treated with 50 and 100 p.p.m. of NAA. In Shintoa chrysanthemums grown under short days, flower bud formation was inhibited at light intensities of 8-12 lux without the addition of growth substances, and at only 2 lux when growth substances were applied. The inhibitory effects of NAA at 100 p.p.m. were similar to those of about 40 lux light intensity. NAA at 50 p.p.m. caused little formative damage and was only slightly inhibitory. However, when this dosage was combined with a light intensity of 2-3 lux, the effects were similar to those produced by a light intensity of 40 lux. NAA at 25 p.p.m. plus ascorbic acid or urea had an inhibiting effect similar to that of NAA at 50 p.p.m. The effects of thiamine resembled those of ascorbic acid but were less

pronounced. Tryptaphane at 100 and 200 p.p.m. inhibited flower bud differentiation but it did not have appreciable effects when applied as a combined spray with ascorbic acid. A synergistic relationship was apparent between gibberellin and auxin; NAA at 50 p.p.m. and GA at 50 p.p.m. inhibited flower bud differentiation when applied at 3-day intervals under a low light intensity of 2 lux. Flower bud development was retarded in the variety Okayamaheiwa only if shading was given before the flower buds were initiated, but the varieties Matsunohomare and Shintoa were affected when shading was applied after flower bud initiation had started. A very low light intensity of 6-7% delayed growth and flowering in Okayamaheiwa except when they were applied 15 days after budding. NAA at 50 p.p.m. alone or combined with gibberellin at 50 p.p.m. delayed flowering most markedly at a reduced light intensity of 25-30%, but gibberellin alone was ineffective. Growth was promoted but flowering was unaffected at a light intensity of 33-38% even when the treatment was applied before bud initiation. When sprays of NAA or NAA+gibberellin were applied at this light intensity, however, flowering was much delayed. Under natural light, gibberellin accelerated flowering. Fewer ray florets were produced under a reduced light intensity.

Age of plants.

It is known that when chrysanthemums are grown in the shade the height of the plant at the time when short-day treatment starts bears a close relationship to flower formation. If the plants are small at the beginning of a short-day treatment, they are very late in flowering. Okada (1952), experimenting with the early variety Ginteki, the mid-season variety Honen, and the late variety Shanozakura, showed that the plants should first have been grown to a height of at least 18-20 cm. with Ginteki, 22-24 cm. with Honen, and 18 cm. with Shanozakura at the time when the short-day treatment started. Reduction of leaf area by removing 1-7 leaves per plant retarded flower formation in the shade culture, but its effects were far less severe than those due to smallness of the plants at the beginning of the short-day treatment. It may be said, therefore, that the retardation of flowering in small plants subjected to short days is not due to their small leaf area.

Cathey (1953) maintained that the different ages of vegetating stems had no effect on the time taken to flower after short days were started with either single stem or pinched plants.

Furuta and Kiplinger (1955) studied the chronological age of cuttings; the plants were not pinched;

the height of the crown bud varied with the age of the shoot; the older the shoot the lower the crown bud. On similar plants that were pinched there was no correllation between the height of the crown bud and the age of the parent shoot. It was concluded that variations in flower spray formation on unpinched pompons could be caused by using shoots of varying ages as a source of cuttings.