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GROWTH AND DEVELOPMENT OF FORCED
TUBEROUS-ROOTED DAHLIAS

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GROWTH AND DEVELOPMENT OF FORCED TUBEROUS-ROOTED DAHLIAS

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ABSTRACT

GROWTH AND DEVELOPMENT OF FORCED TUBEROUS-ROOTED DAHLIAS

By

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Dahlias are grown for cut flower production and as garden plants, but there is limited use of dahlias as flowering pot plants. This study evaluates various aspects of the growth and development of pot dahlias which might affect the variation in the number of flowers produced and the time of flowering.

Flower development of tuberous-rooted Dahlia 'Park Princess' and 'Miramar' was studied during 2 forcing seasons using scanning electron and light microscopy techniques. Each cultivar had a flat, rectangular (0.2 x 0.1 mm) vegetative meristem which domed and increased in diameter as the last leaf primordia developed. Subsequently, 8 outer involucrate bract primordia were formed and the meristem became round with a diameter of approximately 0.35 mm. The first visible sign of floral initiation was the formation of inner involucrate bract primordia. The floret primordium developed after the subtending bract primordium. The first unpinched plants of 'Park Princess'

were reproductive 20 days after planting and 100% were reproductive after 30 days. 'Miramar' was reproductive 10 days later with a corresponding delay in anthesis. Unpinched 'Park Princess' and 'Miramar' were reproductive when the 4th and 6th leaf pairs had separated, respectively. When pinched, over 80% of the lateral branches of 'Park Princess' and 'Miramar' were reproductive after 12 days.

For the first 35 days, the dry weights of the tuberous roots (TR) of 'Park Princess' and 'Miramar' decreased, but simultaneously the dry weights of the fibrous roots (FR) and shoots increased. During the 2nd half of the forcing period shoot and TR dry weights increased rapidly. In addition, new TR developed from adventitious roots which formed at the basal nodes of the stem. Ancymidol (0.75 mg/plant) reduced shoot dry weight as well as total height but did not alter TR or FR growth. Plant quality measured by shoot dry weight was reduced when the distal half of each TR was removed before planting. It was not reduced where some of the TR were left intact or when only 1 cm was removed from each TR. The number of days to flower was inversely correlated with plant height measured at 14 and 28 days after planting but not with clump fresh weight.

Pinching was evaluated as a method for increasing flower production and plant quality. Pinched plants

produced more flowers, flowered later, had smaller flowers, and were taller than unpinched controls.

On an individual plant basis, pinching at node 4 generally gave the best results, while pinching at node 2 resulted in the greatest delay and fewest flowers. 'Park Princess' produced more shoots per clump and more lateral branches after pinching than 'Miramar'. The more distal the pinch, the greater the number of laterals formed on both cultivars and the higher the percent of laterals flowering on 'Park Princess'. On a population basis, pinching only those plants with a single strong shoot at node 3 or 4 resulted in the best compromise between increased flower production and the deleterious delayed flowering and increased plant height. Pinching experiments with 3 cultivars in combination with growth retardants ancymidol, daminozide, and chlormequat were inconclusive.

To James E. Barrett, Jr.
for all he has taught me.

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INTRODUCTION

Plants with attractive flowers are valued in gardens for their beauty. Suitable plants with showy flowers are either grown indoors or used indoors for short periods, while in flower. Also, the flowers of some plants are utilized in arrangements as cut flowers.

Since their introduction into Europe from Central America in the late 18th Century, dahlias have become popular garden plants in many parts of the world. This was due to the ease with which they were grown and to the beauty and diversity of their flowers. Normally, they flower in late summer and early fall. However, to obtain flowers in early summer, they are sometimes started in greenhouses in late winter or early spring and transplanted to the garden after the last frost. Along with garden usage, dahlias are valued as cut flowers and can be grown either outdoors or in greenhouses. High quality show flowers must be selectively pinched and disbudded.

The limited usage of dahlias as flowering pot plants has primarily involved the forcing of seed propagated dwarf dahlia cultivars (17,41,69,70). Recently, trials have been conducted which utilized plants grown from vegetatively

propagated tuberous-rooted clumps (27,31). When suitable cultivars were treated with ancymidol as a growth retardant and grown under proper temperature, light, and fertilization regimes; 30 to 40 cm plants were produced. The appealing characteristic of the cultivars used as pot plants in these studies is that they could be initially used indoors for 2 to 4 weeks and then transplanted to the garden where they would continue flowering until frost. The development of techniques for forcing pot dahlias that would not only be appealing to the consumer but also economical for the grower would provide the floriculture industry with a new and unique product. Presently, many of the popular greenhouse grown flowering plants have no useful garden life after their indoor flowering period.

The two major problems with pot dahlias forced from clumps were the variability in the number of flowers produced and the time of flowering both within and among cultivars. The research reported herein was designed to evaluate various aspects of the growth and development of pot dahlias which might affect this variability. In addition, selective pinching was evaluated as a means of improving the overall quality of the forced plants.

SECTION I

GENERAL LITERATURE REVIEW

GENERAL LITERATURE REVIEW

Dahlia History

Dahlias are endemic to the highlands (1500 to 4300 m) of Mexico and Central America, and in a revision of the genus, Sorensen (80) describes 27 species. These vary from 40 cm perennial herbs (D. scopigera), to tall arborescent plants which may ascend to eight or nine meters (D. imperialis). The genus even includes scrambling epiphytic vines which sprawl among the treetops in rain forests (D. macdougallii). With the exception of one species, D. coccinea, each species has an extremely restricted range.

Sorensen (81) published an early history of the dahlia in which he suggested that they were first domesticated by the Aztecs and used as ornamental and medicinal plants. Dahlias were introduced into Europe in the late 18th Century when Antonio José Cavanilles of Madrid grew them from seeds obtained from Mexico. In 1791, Cavanilles described Dahlia pinnata, naming the genus for Andreas Dahl, a Swedish botanist and a pupil of Linnaeus. The use of dahlias quickly spread throughout Europe. Both horticultural and botanical histories have been confused because

many hybrid variants have been given formal taxonomic ranking and because erroneous information has been introduced into the literature and passed on when authors did not check the original references (76,80,81).

The present day garden dahlias are hybrids probably between D. coccinea and D. pinnata (35,57,80). Sorenson (80) argued that the original hybridization occurred after the two species were introduced into Europe because Cavanilles described the flowers of D. pinnata as being purple and not the wide range of colors that would have resulted from an interspecific cross or from a plant which had been derived from such a cross.

There is some confusion over the scientific name for cultivated dahlias. Many American authors designate it as D. pinnata (17,21,41,71), while some American authors and most others use D. variabilis (8,11,19,27,66). The name D. pinnata is incorrect because there are obvious morphological and genetic differences between the cultivated dahlia and the species D. pinnata as pointed out by Sorensen (80) and Giannasi (35).

Giannasi (35) and Lawrence (57) favored the name D. variabilis partially because of the great deal of variability in cultivated dahlias as compared to other Dahlia species. However, both Sherff (76) and Sorensen (80) included D. variabilis in their list of synonyms for

D. pinnata. Sorensen (80,81) indicated that the name, D. variabilis, arose from the efforts of Willdenow who, in 1809, grouped all forms with purple, lilac, or rosaceous ligules under the name Georgina variabilis. Willdenow's error was later recognized, but the species name was retained by many workers. In 1829, Desfontaines offered the combination D. variabilis (Willd.) Desf. in the synonymy of which he placed Georgina variabilis.

Sorensen (80) stated that the development of modern dahlia cultivars involved repeated hybridization between existing hybrids and between hybrids and wild species, and it would therefore be incorrect to designate them as D. coccinea x pinnata. He concluded that it is best to utilize cultivar names for all dahlias that are not clearly selections from a wild species.

Horticultural Usage

Dahlias are principally used as late summer and fall flowering garden plants. With many plant forms and various flower sizes and colors, they are versatile plants in the garden (18,45). Most dahlias are propagated and sold as tuberous-rooted clumps which are planted in late spring. Some dahlias are grown from seed as bedding plants which provide late spring and early summer flowers (36). Cut flowers can be obtained from plants growing in fields,

gardens, or greenhouses (45,69). However, Post (69) stated that the flowers did not open much after being cut and that they have a vase life of only four or five days.

The minor use of dahlias as flowering pot plants has been limited to the dwarf cultivars. Post (69) suggested that some of them make excellent pot plants for spring sale. The sixth edition of Commercial Flower Forcing (55) indicated that there was a very limited demand for pot dahlias, and the seventh edition (56) did not mention them at all.

Potter (70) indicated that either seeds or clumps of 'Unwin' and 'Coltness' dahlias could be started during the fall or winter for spring sales. Laurie et al. (55) also suggested that seeds or clumps could be used and that 'Easter Greeting' took about 100 days from potting to flowering.

The photoperiodic requirements for producing pot plants using either seed dahlias or cuttings from asexually propagated cultivars was investigated by Botacchi (17). He reported that 'Unwin' and 'Coltness' seeded in October or November flowered at a height of approximately 46 cm in 100 to 140 days using 16°C and 13.5 hour photoperiods. Plants grown at 10°C were delayed 10 to 20 days, and fewer plants flowered. At 16°C and 13 hour photoperiods, plants of the four cultivars started from cuttings flowered in

90 to 100 days with average heights of 63 to 87 cm.

More recently, Haliburton (41) examined the photoperiodic requirements of dwarf 'Redskin' grown from seed as pot plants. Under either 13 hour photoperiods or increasing photoperiods (nine hours the first week and increasing 30 minutes each week thereafter) the average time to first flower was approximately 62 days, but the spread from the first to the last plant to flower was 66 and 88 days, respectively. In both cases, about 80 percent of the plants flowered between the 50th and 70th days. At the time of flowering, plants in each treatment had approximately 20 flowers and buds, and the average flower diameter was about 6.2 cm. Average plant height was 29 and 34 cm for the increasing and 13 hour photoperiods, respectively.

The Ball Red Book (4) recommended starting seed dahlias in early December to produce plants in 10 cm pots for Mother's Day. It stated that the dwarf strains have produced an abundance of brightly colored, semidouble and double, 5 to 7.5 cm flowers on plants 38 to 61 cm in height.

The work by De Hertogh and co-workers (26,27,31) evaluated the production of pot plants from tuberous root clumps of asexually propagated garden cultivars. The goal of this research was to force pot dahlias which would

flower at approximately 30 to 40 cm in 12 weeks or less. De Hertogh et al. (27) reported that plant height could be controlled using ancymidol applied as a soil drench two weeks after planting. When planted in early February and given 0.5 mg ancymidol per 15 cm pot, 'Park Princess' averaged flowering in 71 days with 8.6 cm flowers at a height of 31 cm. There were noticeable differences in plant height, days to flower, and flower size among the cultivars.

The influence of various greenhouse environmental factors on ancymidol treated dahlias was investigated by Durso and De Hertogh (31). Using 'Kolchelsee' and 'Park Princess', they showed that proper fertilization was essential and that one of several slow-release formulations of Osmocote or weekly applications of 20N-8.8P-16.6K (200 ppm N) as a soluble fertilizer produced high quality plants which flowered in approximately 70 days. The highest quality plants and best height control was obtained with 25°C day and 16°C night temperatures. Flowering was delayed at 24/12°C day/night and accelerated at 28/17°C and 29/20°C day/night temperatures, but the latter two treatments adversely affected plant quality. When planted on either January 30th or February 20th, decreased light intensity increased plant height and tended to delay flowering. Plants under a 50 percent shade were greater than 40 cm in

height at flowering. Also, they reported that the naturally increasing spring photoperiods (43° N latitude) were optimal for forcing.

After extensive cultivar evaluation, De Hertogh et al. (26) recommended five cultivars for commercial usage as pot dahlias. Because of the variation in the time to flower within a cultivar, they indicated that plants of each cultivar would come into flower over a two week period.

Propagation

Dahlias can be propagated by either seeds, division of the clump, or herbaceous cuttings. Seed propagation is used in breeding programs (45,84); as well as in the production of bedding plants using some of the dwarf cultivars (36). Due to self-incompatibility, dahlias are highly heterozygous, which results in the variability found in sexually propagated material (80,84).

Commercial production of clones is largely by cuttings taken from clumps started in greenhouses during the winter and early spring (53,84). The cuttings are rooted and then transplanted to the field in late spring to produce tuberous roots. The clumps are lifted in the fall, stored at 5 to 10°C and marketed during the next winter and spring.

Dutch propagators leave a heel (section of crown) on the base of the cutting. They feel that this insures that

the clump produced from that cutting will have viable buds on the crown the next year (53). Dean et al. (25) and Lebar (58) indicated however that heel cuttings may be slower to root than cuttings without a heel. Also, Wildon (84) and others (25,45,59) explained that cuttings made with the cut just below a node (1 mm) produced viable clumps. In addition, Wildon (83,84) described the techniques for propagation by leaf bud cuttings which increased the number of cuttings obtained, but produced clumps of equal size as compared to those produced by stem cuttings.

Biran and Halevy (11,12,13) investigated various factors influencing the rooting of dahlia cuttings. They reported that actively growing buds inhibited rooting and that reproductive buds were more inhibitory than vegetative buds. Also, they found no difference in the levels of auxin or rooting cofactors between easy-to-root and hard-to-root cuttings. However, they did find a higher level of an inhibitor in the hard-to-root cuttings. This inhibitor was also found in root exudates of 'Orpheo', a hard-to-root cultivar. Thus, they concluded that the inhibitor was produced by the roots. In addition, they found that shading stock plants increased rooting of cuttings in two of three cultivars.

Shoots are not formed on dahlia tuberous roots. Thus, when propagated by division of the clump it is

important that a bud is present at the crown of each section of clump (42,84). Few studies have evaluated the contribution of the tuberous roots to the growth of the new shoots. Hartmann and Kester (42) and Lebar (58) indicated that old tuberous roots are consumed in the development of the shoot and replaced by new tuberous roots. Contrarily, Krijthe (54) illustrated a clump with tuberous roots, formed the first year, still present after the second year of growth. Wildon (84) stated that if the distal half of exceptionally large tuberous roots are removed when the clumps are divided the resulting plant would produce a larger clump in the ensuing growing season.

In other species with underground storage organs, the size of the storage organ effects the growth and development of the shoot. Hartsema (43) and Rees (72) reported that below a critical size bulbs of tulips (Tulipa spp.), hyacinths (Hyacinthus orientalis L.), and iris (Iris hollandica Hoog) will not form flowers. De Hertogh et al. (28) indicated that there was a direct relationship between the Easter lily (Lilium longiflorum Thumb.) bulb size and the number of flowers formed. Edmond (33) indicated that small sweet potato (Ipomoea batatus Lam.) roots produce more shoots per unit weight than larger roots. Coursey (24) stated that for yam (Dioscorea spp.) the largest tubers are produced from the largest sets. Bishop and Wright (16)

found that increased yields of potatoes (Solanum tuberosum L.) could be achieved by using larger seed pieces. Jones and Borthwick (46) reported increasing seed piece size caused potatoes to flower earlier with increased flower numbers. Birecki and Roztropowicz (15) demonstrated that increased yield was due to an increased number of shoots produced from larger seed pieces.

Tuberous Root Development

The dahlia storage organ is a true tuberous root with all the external and internal structures of roots. Unlike the sweet potato, buds are produced only at the proximal end of the tuberous roots where the root merges with the stem (crown) (42,54,84). Fibrous roots are produced primarily at the distal end of the tuberous roots (42). On seedlings, adventitious roots which later become the tuberous roots are formed at the cotyledonary node and at the lower nodes on the stem (2,87).

Garner and Allard (34) were the first to indicate that tuberization is influenced by photoperiod. They reported that two cultivars did not form tuberous roots under long days. Zimmerman and Hitchcock (87) conducted experiments with seven different cultivars and reported that plants started from either cuttings or clumps and grown under natural summer photoperiods formed mostly

fibrous roots, while plants under seven or nine hour photoperiods formed large storage roots. Cuttings taken from October 15 to 28 and given natural days formed only a few tuberous roots or formed no roots, with a stem structure becoming a storage organ. Also, they reported that plants started from seeds in November produced tuberous roots unless given long days in which case they produced only fibrous roots.

Wasscher (82) reported that four weeks of short days during August increased tuberous root development of cultivars which normally formed poor storage roots. Likewise, growing plants in pots or cutting them back stimulated tuberous root development.

Moser and Hess (66) found that tuberous root development in the cultivar 'Sneezy' had a critical day length between 11 and 12 hours and that five inductive cycles were required to initiate the process. Subsequently, tuberization responded quantitatively as the number of inductive cycles increased. Under short days, tuberization was greater at 16 and 21°C than at 10 or 27°C night temperatures. At all four temperatures, the process was inhibited by long days. Furthermore, they demonstrated that gibberellic acid (GA_3) inhibited tuberization of plants grown under long or short photoperiods, while daminozide promoted the process under long photoperiods. Read et al. (71) confirmed the

daminozide response and showed that chloremequat also increased the number and size of tuberous roots of two cultivars under short photoperiods.

In a series of studies, Halevy and co-workers (10,14, 38) examined the hormonal regulation of the tuberization process. They found that under long days daminozide and ethephon promoted tuberization in whole plants, but inhibited it in budless leaf cuttings. They concluded that the effects of synthetic growth retardants were indirect, resulting from their reduction of shoot growth. In addition, they found that the evolution of endogenous ethylene peaked between the second and third week after initiation of short days after which it decreased to the level evolved from plants grown under long days. This peak corresponded to the cessation of shoot growth and preceded onset of tuberization by approximately one week. In their experiments, short day conditions, which promoted tuberization, increased the endogenous levels of abscisic acid (ABA)-like inhibitors in intact plants. Exogenous ABA enhanced and GA_3 inhibited tuberization in both whole plants and budless leaf cuttings, but GA_3 promoted thickening at the petiole base of budless leaf cuttings. They proposed that GA_3 and ABA control the tuberization process by controlling the site of the sink for assimilates.

Dormancy in the tuberous-rooted clumps was studied by Konishi and Inaba (52). They started clumps in the greenhouse at intervals from the end of October until the end of December and found that from the end of October to the end of November the percent of clumps sprouting decreased with time. Until mid-December, sprouts that were formed had very low vigor and often stopped growing. When clumps were harvested on November 20th and given 40 days of 0°C prior to planting, the shoots grew normally.

Zimmerman and Hitchcock (88) stored clumps at 4.5, 10, or 25°C from November 1 to May 12. They found that those stored at the lower temperature were in better condition and had higher survival rates than ones stored at 22.5°C. However, they stated that the storage temperature did not effect the vigor of the surviving plants.

Allen (1) reported that when the relative humidity (RH) was held at 75 percent for clumps stored from November to mid May at temperatures of 2, 10, or 18°C there was approximately 33 percent weight loss during storage. However, clumps held at 27°C lost 60 percent and were mostly rotted. At both 10 and 18°C, some clumps sprouted during storage, and at 18°C some did not survive. After planting, the sprouting of clumps held at 2°C was slightly delayed. In addition, they stored clumps under varying RH at 7.5°C and found that satisfactory growth was

obtained for those stored at RH above 50 percent.

Flower Development

The inflorescence of the compositae is a capitulum surrounded by at least one series of involucral bracts (phyllaries). The compound receptacle is formed by coalescence of the individual receptacles of the disk florets in the center and the ray florets on the outside. Each disk floret has an inferior ovary, five coalescent petals (corolla), and five anthers coalesced into a tube around the style. The corolla of each ray floret is laid out in an elongated flat structure (ligule) simulating a single petal (3,7).

In the genus Dahlia, the capitulum is born on a long slender naked peduncle and contains three types of bracts. The outer series of involucrates contains four to seven fleshy green bracts. Subtending each ray floret is an inner involucrate which is membranous and many lined. Each disk floret is subtended by a chaff bract (palea). The chaff bracts closely resemble the inner involucrates. The ray florets are either neutral or pistillate, often sterile. Disk florets are hermaphrodite and fertile. The pappus (calyx) is missing or consists of two minute rudiments (76, 80).

Krijthe (54) published excellent detailed line drawings of flower organogenesis in 'L'Innocence', a mignon

dahlia, which has a single row of ray florets. She reported that flower initiation started two to two and one-half weeks after planting in the greenhouse and anthesis began 10 weeks after planting. Konishi and Inaba (49) also made line drawings of flower development and described seven stages of development: (a) vegetative, (b) dome forming, (c) early involucre and bractlet formation, (d) late involucre and bractlet formation, (e) early floret formation, (f) middle floret formation (petal formation), and (g) late floret formation (petal elongation).

Both Krijthe (54) and Konishi and Inaba (49) reported that the vegetative meristem was fairly flat and it became enlarged and domed as it started the transition to the reproductive state. Konishi and Inaba (49) stated that the cultivar they were working with produced eight outer involucrates, but they could not detect a difference between the outer and inner involucrate primordia. However, the mignon dahlia (54) produced five outer involucrates, eight inner involucrates, and eight ray florets acropetally in that order. The inner involucrates elongated, covered over the center of the captiulum and became the outer covering of the flower bud. Subsequent to the formation of the ray floret primordia, multiple series of disk

floret primordia and subtending chaff bract primordia were formed.

Philipson (68) studied the development of the inflorescence of D. gracilis, now D. coccinea (80), and reported that there were five outer and 11 inner involuctates that were arranged in pairs. The first few pairs of bracts, like the leaves, were arranged in a decussate phyllotaxis. He explained that the bract and floret primordia arose at the periphery of the meristematic mantle. The first sign of the bract primordium was a slight swelling due to periclinal and anticlinal divisions in the inner of the two tunica layers. Immediately adaxial to this swelling, the earliest indication of floret primordium, was a plate of narrow cells resulting from anticlinal division in both tunica layers.

Effects of Photoperiod and Temperature on Flower Initiation and Development

There is variation among cultivars in their specific photoperiod requirements, but, in general, cultivated dahlias are short day plants for flower initiation and long day plants for flower development. Normally, continued short days produces the fastest flowering for the plants that do reach anthesis, but in most cases, the flowers abort. Garner and Allard (34) first reported the photoperiodic response of dahlias. They reported that

'John Ehlich' flowered in late September when given natural days, but flowered in early July under 10 hour photoperiods. Then, Zimmerman and Hitchcock (87) using seven cultivars which form tuberous roots under short days demonstrated that the tuberization and flowering processes were separate photoperiod responses. Compared to plants grown in natural summer photoperiods, four of these seven cultivars also flowered earlier under short days (seven or nine hour photoperiods), but the other three did not flower earlier.

As part of a series of reports on various factors controlling flowering in dahlias grown from cuttings for cut flowers, Konishi and Inaba (47,49) reported that the Japanese cultivars 'Akane' and 'Futarishizuka' grown under photoperiods less than 12 hours produced less shoot weight, shoot height and percent of plants flowering than plants grown under 13 hour photoperiods. For 'Akane', as photoperiods increased above 13 hours the percent of plants flowering decreased, but 'Futarishizuka' was not effected until photoperiods reached 16 hours. Subsequently, they found that 10 hour or less photoperiods were optimal for initiation, and as the flower developed the critical photoperiod was 12 hours and the optimum was 13 hours. After initiation, flower bud abortion occurred in plants given less than 12 hour photoperiods.

Botacchi (17) reported that 'Unwin' and 'Coltness', grown from seed, did not flower under nine hour photoperiods and that 13.5 or 14.5 hour days were the most favorable for flowering. At longer photoperiods, he found that the percent of plants flowering decreased. Using 'Redskin' dahlias grown from seed, Haliburton (41) found that at nine hour photoperiods the average time to anthesis was 56 days, but only 63 percent of the plants flowered. Her 13 hour photoperiod treatment and increasing photoperiod (from 9 to 13 hours) treatment resulted in plants averaging approximately 62 days from planting to anthesis with 98 percent of the plants flowering. Both a 17 hour photoperiod and a four hour night break caused a delay in flowering of about 10 days.

Durso and De Hertogh (31) obtained similar results using 'Kolchelsee' and 'Park Princess' grown from clumps. Under an eight hour photoperiod, 'Kolchelsee' did not flower, and only 78 percent of the 'Park Princess' plants flowered in an average time of 56 days. All plants of both cultivars flowered when given natural increasing spring photoperiods, 16 hour photoperiods, or four hour night breaks with average time to anthesis for 'Kolchelsee' being 65, 67, and 72 days, respectively, and for 'Park Princess' 68, 70, and 71 days, respectively. In her M.S. Thesis, Durso (30) reported that in eight hour photoperiods both

cultivars formed flower buds, but they often failed to develop.

Mathur et al. (63) grew D. palmata from seeds under photoperiods from 8 to 24 hours and found that 100 percent flowered at 13.5 hours or less and none of the plants flowered at 20 to 24 hours. The time to anthesis decreased with decreasing photoperiods. When plants at the three to four leaf stage and under different photoperiods were sprayed with 200 ppm GA_3, flowering of plants under inductive was enhanced, but it failed to induce flowering of plants under non-inductive photoperiods.

Mastalerz (62) evaluated 18 cultivars for use as cut flowers and found that in six of these flower initiation and development were not regulated by day length and that in the other 12 photoperiod did regulate initiation and development. Plants in the latter group did not flower under photoperiods longer than 16 hours. When grown under nine hour photoperiods, the number of ray florets was reduced to the point that in some cultivars the flowers were classified as singles rather than doubles. He found that normal flowers were obtained with these cultivars when they were given 14 days of nine hour photoperiods and then 24 hour photoperiods until anthesis. When less than 14 cycles of short days were given, some plants did not flower. If more than 25 short days were used a reduction in the number of ray florets was obtained.

This "open eye" or "daisy eye" syndrome has been observed by other workers. Durso and De Hertogh (31) indicated that 'Park Princess' under eight hour photoperiods exhibited flowers with "open eye" centers, while those subjected to natural increasing photoperiods (from 10 to 14 hours) did not. Canham (19) in England observed that flowers formed by 'Newby' under natural fall photoperiods and those formed under two hour night breaks had similar numbers of disk florets, but they had an average of 56 and 166 ray florets, respectively. Konishi and Inaba (47,50) reported that for two cultivars the number of disk florets decreased and the number of ray florets and total florets increased with increasing photoperiods. However, Okada and Horada (67) indicated that photoperiod did not affect the total number of florets per inflorescence but did alter the ratio of ray to disk florets in six cultivars.

Mastalerz (62) indicated that night temperatures from 10 to 21°C in the winter and from 16 to 27°C in the summer did not affect flower initiation, but that temperature did influence the rate of flower development resulting in more rapid flowering at higher temperatures. Durso and De Hertogh (31) also reported that higher temperatures caused more rapid flowering but with a marked reduction in overall pot plant quality.

Konishi and Inaba (51) grew dahlias at 5, 10, and 15°C finding that lower temperatures caused delayed but

more uniform flowering. In addition, they reported that the critical photoperiod for flower development was between 11 and 12 hours for plants at 5 or 15°C, but it was between 12 and 13 hours for plants at 10°C. Botacchi (17) also observed an interaction between photoperiod and temperature in the percent of plants flowering, but the results were variable from one experiment to another.

Growth Regulators

The growth regulators chlormequat ((2-chloroethyl)trimethylammonium chloride), daminozide (succinic acid-2, 2-dimethylhydrazide), and ancymidol (α-cyclopropyl-α-(p-methoxyphenyl)-5-pyrimidine methanol) are the three most widely used compounds for height control on floricultural crops (21,37). These compounds reduce plant height by reducing internode length rather than killing or altering meristematic function of the terminal bud as is the case with some other height controlling growth regulators such as the fatty acid esters (73).

The effect of chlormequat and daminozide has been attributed to their inhibition of GA synthesis (29,85). Leopold (60) concluded that ancymidol acted as an antagonist of GA action; however, others (23,77) indicated that it can function as an inhibitor of GA synthesis.

Heins et al. (41) and Gortzig (37) suggested using chlormequat on poinsettias (Euphorbia pulcherrima Willd.)

and geraniums (Pelargonium hortorum Bailey) at rates of 2000 to 3000 ppm as a foliar spray or up to 6000 ppm as a soil drench (180 ml/15 cm pot). They suggested the use of daminozide on azaleas (Rhododendron spp.), bedding plants, chrysanthemums (Chrysanthemum morifolium Ramet.), hydrangeas (Hydrangea macrophylla Ser.), and kalanchoes (Kalanchoe blossfeldiana Poellnitz) as a spray at 2500 to 5000 ppm. Also, they suggested that ancymidol could be used on bedding plants, chrysanthemums, clerodendron (Clerodendron thomsoniae Balf.), Easter lilies, geraniums, poinsettias and tulips as a drench at 0.125 to 0.5 mg per 15 cm pot in 120 to 180 ml of water or as a spray at 25 to 200 ppm.

Along with their effect on internode elongation these compounds often affect other developmental processes. All three compounds produce an increased greening of leaves in some species, and ancymidol and daminozide inhibit leaf expansion (21). Daminozide alters the size and arrangement of both the palisade and spongy mesophyll cells (22,39,65).

Chlormequat and ancymidol caused more and earlier flowering on Hibiscus rosa-sinenis Linn. (75) and earlier flowering on seed geraniums (20). Also with geraniums, Semeniuk and Taylor (74) found that chlormequat stimulated growth of lateral branches. Increased growth of laterals of petunia (Petunia hybrida Vilm.) also resulted from applications of daminozide, and stomates on treated plants

were slightly closed compared to untreated plants (22). On marigold (Tagetes erecta L.), daminozide delayed flowering; reduced shoot dry weight; increased leaf thickness and root diameter; and reduced cell wall thickness of stem phloem fibers (64,65). Reported effects of daminozide on apple (Malus domestica Borkh.) include thicker leaves, fewer nodes, decreased shoot/root ratio, reduced shoot dry weight, reduced net assimilation rate, increased chlorophyll per unit fresh weight, and larger stem diameter due to increased thickness of pith, cortex and phleom (5,39,40). Cathey (21) reported that daminozide and chlormequat caused an undesirable yellowing of the flowers of chrysanthemum.

Shoub and De Hertogh (78) reported that ancymidol on 'Paul Richter' tulips reduced internode elongation, with the basal internode being affected the most. The ancymidol caused a reduction in the rate of cell division in the basal internode, along with shorter and radially expanded cells. Also, they found a reduction in the stem fresh weight of treated plants.

Bhattacharjee et al. (8) tested the effects of chlormequat and daminozide on 10 dahlia cultivars grown from cuttings. When the plants were 12 to 16 cm tall, they applied daminozide twice with a 12 day interval as a spray at 2500, 5000 or 10,000 ppm and chlormequat as a spray at

1000, 2000, or 4000 ppm; and as a drench at 2000, 4000, or 8000 ppm (200 ml/18 cm pot). They obtained variable results with chlormequat, some cultivars were reduced in height and others were stimulated. Daminozide reduced the height of all cultivars with increased inhibition occurring as the concentration was increased. With two cultivars, earlier flowering resulted from chlormequat application, but daminozide delayed flowering of four cultivars. In addition, they indicated that daminozide delayed leaf senescence and abscission; and increased drought resistance, flower size, number of ray florets, and cut flower post-harvest life. In later work, Bhattacharjee et al. (9) substantiated these results for daminozide and reported that chlormequat, as a spray or drench at 1000 to 2000 ppm, stimulated height by 0.6 to 12.0 percent and at 4000 or 8000 ppm reduced height by 1.5 to 12.6 percent.

Mastalerz (62) found that both ancymidol (132 or 264 ppm) and daminozide reduced peduncle length if applied just as the flower bud began to extend above the foliage. The effect of daminozide was variable. In one experiment 10,000 to 20,000 ppm was required to achieve the same degree of inhibition previously obtained with 5000 ppm.

Cathey (21) reported that chlormequat, daminozide and ancymidol were all active on the seed dahlia 'Unwin's Mix'. De Hertogh et al. (27) evaluated the usefulness of all

three compounds for height control of dahlias forced from clumps. They found that only ancymidol as a drench at 0.5 to 2.0 mg/15 cm pot provided consistent height control, and that application two weeks after planting gave more consistent results than application after four weeks.

Pinching

The principle purpose of pinching, which is practiced on many greenhouse crops, is to force the growth of lateral buds which can increase the number of flowering shoots. Ball (4) and Williams and Bearce (86) reported that pinching chrysanthemums delayed flowering and that pinched plants should be started two to three weeks earlier than unpinched. They recommended using a "roll out" or "tip pinch" because this procedure removed only the very tip of the shoot and the more of the shoot removed with the pinch, the longer it took for the remaining lateral buds to develop.

Ecke and Matkin (32) and Sink (79) reported that after pinching some poinsettia cultivars a lateral branch developed at each remaining node. This enabled them to pre-determine the number of flowers on a plant by leaving a given number of nodes after the pinch and was termed "precision pinching". Ball (4) and Love (61) indicated that pinching azaleas at approximately eight week intervals produced larger plants with more flowers. They stated that

the timing of the last pinch was important to achieve flowering at the desired time.

Baumgardt (6) and James (45) described the method for growing exhibition dahlias in gardens where the size of the flower is dependent upon the number of laterals that are allowed to develop following pinching. They recommended pinching at the third or fourth node. For greenhouse production of cut flowers, Mastalerz (62) pinched rooted cuttings two weeks after planting and then disbudded permitting only two branches to develop per plant. To increase branching and flowering of dahlia pot plants, Potter (70) suggested pinching after six nodes were formed. Haliburton (41), growing seed propagated dwarf 'Redskin' as pot plants, found that photoperiods of 9 to 17 hours did not influence the number of laterals developed after pinching at nodes three or four. Konishi and Inaba (48) pinched rooted cuttings above the third node and found that the laterals from node one flowered earlier and produced higher quality flowers than laterals from the third node.

LITERATURE CITED

LITERATURE CITED

1. Allen, R. C. 1937. Temperature and humidity requirements for the storage of dahlia roots. Proc. Amer. Soc. Hort. Sci. 35:770-773.

2. Aoba, T., S. Watanobe, and K. Soma. 1961. Studies on the formation of tuberous root in dahlia II. Anatomical observation of primary root and tuberous root. J. Japan Soc. Hort. Sci. 30:82-88.

3. Bailey, L. H. 1949. Manual of cultivated plants most commonly grown in the continental United States and Canada. The Macmillan Co., New York. 1116 pp.

4. Ball, V., ed. 1975. The ball red book. Geo. J. Ball, Inc., USA. 501 pp.

5. Barden, J. A. 1968. Effects of alar on the growth and distribution of the growth increment in one year old apple trees. Proc. Amer. Soc. Hort. Sci. 93:33-39.

6. Baumgardt, J. P. 1970. Bulbs for summer bloom. Hawthorn Books, Inc., New York. 232 pp.

7. Benson, L. 1957. Plant classification. D. C. Heath and Company, Boston. 688 pp.

8. Bhattacharjee, S. K., K. Das Gupta, and T. K. Bose. 1971. B-Nine, an effective growth retardant on Dahlia; ineffectiveness of CCC. Phyton 28:61-65.

9. Bhattacharjee, S. K., T. Mukhopadhay, and T. K. Bose. 1974. Experiments with growth retardants on Dahlia. Indian J. Hort. 31:86-90.

10. Biran, I., I. Gur, and A. H. Halevy. 1972. The relationship between exogenous growth inhibitors and endogenous levels of ethylene, and tuberization of dahlias. Physiol. Plant. 27:226-230.

11. Biran, I. and A. H. Halevy. 1973. Stock plant shading and rooting of dahlia cuttings. Scientia Hort. 1:125-131.

12. Biran, I. and A. H. Halevy. 1973. The relationship between rooting of Dahlia cuttings and the presence and type of bud. Physiol. Plant. 28:244-247.

13. Biran, I. and A. H. Halevy. 1973. Endogenous levels of growth regulators and their relationship to the rooting of dahlia cuttings. Physiol. Plant. 28: 436-442.

14. Biran, I., B. Leshem, I. Gur and A. H. Halevy. 1974. Further studies on the relationship between growth regulators and tuberization of dahlias. Physiol. Plant. 31:23-28.

15. Birecki, M. and S. Roztropowicz. 1963. Studies on seed potato size and productivity. Eur. Potato J. 6:1-13.

16. Bishop, J. C. and D. N. Wright. 1959. The effect of size and spacing of seed pieces on the yield and grade of 'White Rose' potatoes in Kern County, California. Amer. Potato J. 36:235-240.

17. Botacchi, A. C. 1958. Photoperiodic response of Dahlia pinnata, Cav. M. S. Thesis. The Pennsylvania State Univ. 69 pp.

18. Bush-Brown, L. and J. Bush-Brown. 1948. Dahlia. Pages 555-561 in L. Bush-Brown and J. Bush-Brown, America's Garden Book. Charles Scribner's Sons, New York. 1241 pp.

19. Canham, A. E. 1969. An effect of daylength on the flowering of dahlias. Acta Hort. 14:109-115.

20. Carlson, W. H. 1976. How growth retardants affect seed geranium varieties. Mich. State Univ. Agri. Expt. Sta. Res. Rpt. 302. 8 pp.

21. Cathey, H. M. 1975. Comparative plant growth-retarding activities of ancymidol with ACPC, phosfon, chlormequat and SADH on ornamental plant species. HortScience. 10:204-216.

22. Cathey, H. M. and H. E. Heggestad. 1972. Reduction of ozone damage to Petunia hybrida Vilm. by use of growth regulating chemicals and tolerant cultivars. J. Amer. Soc. Hort. Sci. 97:685-700.

23. Coolbaugh, R. C. and R. Hamilton. 1976. Inhibition of ent-kaurene oxidation and growth by α-cyclopropyl-α-(p-methoxyphenyl)-5-pyrimidine methyl alcohol. Plant Physiol. 57:245-248.

24. Coursey, D. E. 1967. Yams. Longmans, Green and Co., LTD., London. 230 pp.

25. Dean, R., R. File, J. Ballantyne, S. Jones, W. Cuthbertson, and L. Barron. 1903. The dahlia: its history and cultivation. Macmillan and Co., London. 120 pp.

26. De Hertogh, A., J. Barrett, and N. Blakely. 1978. Guidelines for greenhouse forcing of dutch-grown tuberous-rooted dahlias as pot plant. Holland Flower Bulb Tech. Services Bull., No. 5.

27. De Hertogh, A. A., N. Blakely, and W. Szlachetka. 1976. The influence of ancymidol, chlormequat and daminozide on the growth and development of forced Dahlia variabilis Willd. Scientia Hort. 4:123-130.

28. De Hertogh, A. A., H. P. Rasmussen, and N. Blakely. 1976. Morphological changes and factors influencing shoot apex development of Lilium longiflorum Thumb. during forcing. J. Amer. Soc. Hort. Sci. 101:463-471.

29. Dennis, D. T., C. D. Upper and C. A. West. 1965. An enzymatic site of inhibition of gibberllin biosynthesis by AMO-1618 and other plant growth retardants. Plant Physiol. 40:948-952.

30. Durso, M. 1976. Influence of greenhouse environmental factors on the forcing of Dahlia variabilis Willd. M. S. Thesis. Michigan State Univ. 86 pp.

31. Durso, M. and A. A. De Hertogh. 1977. The influence of greenhouse environmental factors on forcing Dahlia variabilis Willd. J. Amer. Soc. Hort. Sci. 102-314-317.

32. Ecke, P., Jr. and O. A. Matkin, eds. 1976. The poinsettia manual. Paul Ecke Poinsettias, Encinitas, California. 205 pp.

33. Edmond, J. B. and G. R. Ammerman. 1971. Sweet potatoes: production, processing, marketing. AVI Publishing Co., Westport, Connecticut. 334 pp.

34. Garner, W. W. and H. A. Allard. 1923. Further studies in photoperiodism, the response of the plant to relative length of day and night. J. Agr. Res. 23:871-920.

35. Giannasi, D. E. 1975. The flavonoid systematics of the genus Dahlia (Compositae). Mem. N. Y. Bot. Garden 26:1-125.

36. Goldsmith, G. A. and A. Wilson. 1976. Sun plants. Pages 271-298 in J. W. Mastalerz, ed. Bedding plants. Pennsylvania Flower Growers, University Park. 516 pp.

37. Gortzig, C. F., ed. 1974. Cornell recommendations for commercial floriculture crops, Part I: Cultural practices and production programs. Cornell Univ., Ithaca, New York. 60 pp.

38. Halevy, A. H. and I. Biran. 1975. Hormonal regulation of tuberization in dahlia. Acta Hort. 47:319-329.

39. Halfacre, R. G. and J. A. Barden. 1968. Anatomical responses of apple leaf and stem tissues to succinic acid 2, 2-Dimethylhydrazide (Alar). Proc. Amer. Soc. Hort. Sci. 93:25-32.

40. Halfacre, R. G., J. A. Barden, and H. A. Rollins, Jr. 1968. Effects of alar on morphology, chlorophyll content and net CO_2 assimilation rate of young apple trees. Proc. Amer. Soc. Hort. Sci. 93:40-52.

41. Haliburton, M. A. 1976. Effects of photoperiod on growth and flowering of Dahlia pinnata, Cav. 'Redskin' pot plants. M. S. Thesis. Oklahoma State Univ. 59 pp.

42. Hartmann, H. T. and D. E. Kester. 1975. Plant propagation: principles and practices, 3rd ed. Prentice Hall, Englewood Cliffs, New Jersey. 662 pp.

43. Hartsema, A. M. 1961. Influence of temperature on flower formation and flowering of bulbous and tuberous plants. Handbuch der Pflanzenphysiologie 16:123-167.

44. Heins, R. D., R. E. Widmer, and H. F. Wilkins. 1976. Growth regulator recommendations for floriculture crops. Florists' Rev. 158 (4107):36-37.

45. James, H. 1963. Dahlias for garden and exhibition, John Gifford Limited, London. 192 pp.

46. Jones, H. A. and H. A. Borthwick. 1938. Influence of photoperiod and other factors on the formation of flower primordia in the potato. Amer. Potato J. 15:331-336.

47. Konishi, K. and K. Inaba. 1964. Studies on flowering control of dahlia I. On optimum day-length. J. Japan Soc. Hort. Sci. 33:171-180.

48. Konishi, K. and K. Inaba. 1965. Studies on flowering control of dahlia II. Effects of mature leaves of main stem upon the growth and flowering of lateral shoots. J. Japan Soc. Hort. Sci. 34:71-76.

49. Konishi, K. and K. Inaba. 1966. Studies on flowering control of dahlia III. Effects of day-length on initiation and development of flower bud. J. Japan Soc. Hort. Sci. 35:73-79.

50. Konishi, K. and K. Inaba. 1966. Studies on flowering control of dahlia IV. Effect of day-length at the early stage of shoot growth upon the flowering time and the quality of cut-flowers. J. Japan Soc. Hort. Sci. 35:195-202.

51. Konishi, K. and K. Inaba. 1966. Studies on flowering control of dahlia V. Effects of night temperature and amount of light on flowering. J. Japan Soc. Hort. Sci. 35:317-324.

52. Konishi, K. and K. Inaba. 1967. Studies on flowering control of dahlia VII. On dormancy of crown-tuber. J. Japan Soc. Hort. Sci. 36:131-140.

53. Krabbendam, P. and A. A. Baardse. 1967. Bloembollenteelt VII. Bijgoed. W. E. J. Tjeenk Willink, Zwolle. 401 pp.

54. Krijthe, N. 1938. De ontwikkeling der knoppen van enkele voorjaarsgwassen I. (The development of the meristem of several spring crops I. Mignon, Dahlias and Lilium regale). Meded. Landbouwhoogesch. Wageningen. 42:1-51.

55. Laurie, A., D. C. Kiplinger, and K. S. Nelson. 1958. Commercial flower forcing, 6th ed., McGraw-Hill Book Co., New York. 509 pp.

56. Laurie, A., D. C. Kiplinger, and K. S. Nelson. 1968. Commercial flower forcing, 7th ed., McGraw-Hill Book Co., New York. 514 pp.

57. Lawrence, W. J. L. 1932. The origin and genetics of the garden Dahlia. Proc. Linn. Soc. London 145:49-51.

58. Lebar, T. R. H. 1955. Dahlia growing. Dover Publications, New York. 70 pp.

59. Lebar, T. R. H. 1961. Dahlias for everyone. Blandford Press, London. 208 pp.

60. Leopold, A. C. 1971. Antagonism of some gibberellin actions by a substituted pyrimidine. Plant Physiol. 48:537-540.

61. Love, J. W. 1975. Vegetative growth. Pages 47-51 in A. M. Kofranek and R. A. Larson, eds. Growing azaleas commercially. Division of Agr. Sci. Univ. of California. 108 pp.

62. Mastalerz, J. W. 1976. Garden dahlias may have potential as a greenhouse crop: daylength controls flower initiation. Pennsylvania Flower Growers Bull. 287(3): 1,4-6.

63. Mathur, S. N., R. A. Sharma, and S. P. Mittal. 1970. Interaction of gibberellic acid and daylength in flowering of dahlia. Indian J. Plant Physiol. 13:72-75.

64. McConnell, D. B. and B. E. Struckmeyer. 1970. Effect of succinic acid 2, 2-dimethydrazide on the growth of marigold in long and short photoperiods. HortScience 5:391-392.

65. McConnell, D. B. and B. E. Struckmeyer. 1971. The effect of succinic acid 2, 2-dimethylhydrazide on the anatomy of Tagetes erecta L. J. Amer. Soc. Hort. Sci. 96:70-73.

66. Moser, B. C. and C. E. Hess. 1968. The physiology of tuberous root development in dahlia. Proc. Amer. Soc. Hort. Sci. 93:595-603.

67. Okada, M. and H. Harada, 1955. Effects of daylength and photoperiod on ratio of ray-flowers to disk-flowers in dahlia flower heads. J. Japan Soc. Hort. Sci. 23:259-263.

68. Philipson, W. R. 1948. Studies in the development of the inflorescence IV. The capitula of Hiesacium boreale Fries and Dahlia gracilis Ortg. Ann. Bot. 12:65-75.

69. Post, K. 1949. Florist crop production and marketing. Orange Judd Publ. Co., New York, New York. 891 pp.

70. Potter, C. H. 1954. Flowering pot plants. Florists' Rev. 113 (2930):39.

71. Read, P. E., C. W. Dunham, and D. J. Fieldhouse. 1972. Increasing tuberous root production in Dahlia pinnata Cav. with SADH and chlormequat. HortScience 7:62-63.

72. Rees, A. R. 1966. The physiology of ornamental bulbous plants. Bot. Rev. 32:1-23.

73. Sachs, R. M. and W. P. Hackett. 1972. Chemical inhibition of plant height. HortScience 7:440-447.

74. Semeniuk, P. and R. Taylor. 1970. Effects of growth retardants on growth of geranium seedlings and flowering. HortScience 5:393-394.

75. Shanks, J. B. 1972. Chemical control of growth and flowering in hibiscus. HortScience 7:574.

76. Sherff, E. E. 1955. Compositae-Heliantheae-Coreopsidinae. N. Amer. Flora. II 2:1-190.

77. Shive, J. B. and H. D. Sisler. 1976. Effects of ancymidol (a growth retardant) and triarimol (a fungicide) on the growth, sterols and gibberellius of Phaseolus vulgaris (L.). Plant Physiol. 57:640-644.

78. Shoub, J. and A. A. De Hertogh. 1974. Effects of ancymidol and gibberellins A_3 and A_{4+7} on Tulipa gesneriana L. cv. Paul Richter during development in the greenhouse. Scientia Hort. 2:55-67.

79. Sink, K. C. 1972. Growing precision pinched multiflowered poinsettias. Florists' Rev. 150(3899):26-27, 62-64.

80. Sorensen, P. D. 1969. Revision of the genus Dahlia (Compositae, Heliantheae-Coreopsidinae). Rhodora 71:309-416.

81. Sorensen, P. D. 1970. The Dahlia: An early history. Arnoldia 30:121-138.

82. Wasscher, J. 1955. De invloed van een kortedagbehandeling op de knolvorming by dahlia's, knolbegonia's en gesneria's. Meded. Dir. Tuin. 18:342-352.

83. Wildon, C. E. 1934. A method for rapid propagation of dahlias. Mich. Agr. Exp. Sta. Quart. Bull. 16: 253-254.

84. Wildon, C. E. 1935. Dahlias: culture, history and classification. Pages 1-57 in Dahlias their history, classification, culture, insects and diseases. Agr. Exp. Sta. Mich. State Coll. Spec. Bull. No. 266.

85. Wiley, A. W., K. Ryugo, and R. M. Sachs. 1970. Effects of growth retardants on biosynthesis of gibberellin precursors in root tips of peas, Pisum sativum L. J. Amer. Soc. Hort. Sci. 95:627-630.

86. Williams, C. and B. Bearce. 1964. Pinching and disbudding. Pages 38-45 in R. W. Langhans. Chrysanthemums. New York Ext. Ser. Chrysanthemum School.

87. Zimmerman, P. W. and A. E. Hitchcock. 1929. Root formation and flowering of dahlia cuttings when subjected to different day lengths. Bot. Gaz. 87:1-13.

88. Zimmerman, P. W. and A. E. Hitchcock. 1932. Dahlia root storate at different temperatures. Bull. Amer. Dahlia Soc. 13:44-45.

SECTION II

COMPARATIVE INFLORESCENCE DEVELOPMENT OF TWO CULTIVARS OF FORCED TUBEROUS-ROOTED DAHLIAS

Comparative Inflorescence Development of Two Cultivars of Forced Tuberous-Rooted Dahlias

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Additional index words: scanning electron and light microscopy, Dahlia

Abstract: Flower development of tuberous-rooted Dahlia 'Park Princess' and 'Miramar' was studied during 2 forcing seasons using scanning electron and light microscopy techniques. Each cultivar had a flat, rectangular (0.2 x 0.1 mm) vegetative meristem which domed and increased in diameter as the last leaf primordia developed. Subsequently, 8 outer involucrate bract primordia were formed and the meristem became round with a diameter of approximately 0.35 mm. The first visible sign of floral initiation was the formation of inner involucrate bract primordia. The floret primordium developed after the subtending bract primordium. The first unpinched plants of 'Park Princess' were reproductive 20 days after planting and 100% were reproductive after 30 days. 'Miramar' was reproductive 10 days later with a corresponding delay in anthesis. Unpinched

'Park Princess' and 'Miramar' were reproductive when the 4th and 6th leaf pairs had separated, respectively. When pinched, over 80% of the lateral branches of 'Park Princess' and 'Miramar' were reproductive after 12 days.

INTRODUCTION

In past studies on the forcing of tuberous-rooted dahlias, considerable variation in the time to flower was observed both within and among cultivars (1,2,8). In order to determine the cause of this variation, the developmental sequence of the flowering process must be known. Krijthe (14) with line drawings followed flower initiation in 'L'Innocence' which occurred in the field when 7 pairs of foliage leaves had formed. This was 2-2.5 weeks after planting. With an early March planting date in a 15°-16°C greenhouse, initiation occurred after 5 leaf pairs had formed. In both studies flowering began 10 weeks after planting. Later, Konishi and Inaba (13) described and illustrated 7 stages in flower development during a study on the effects of photoperiod on flower initiation and development. Philipson (18) detailed the development of individual bracts and floret primordia with medium longitudinal section photomicrographs of D. gracilis meristems.

This study was undertaken to follow the process of flower initiation and development in the dahlia with the use of the scanning electron microscope (SEM), to compare the development of two cultivars which reach anthesis at different times when forced as pot plants (1), and to clarify the species designation of the cultivated dahlia.

MATERIALS AND METHODS

Cultural procedures. In all experiments, 'Park Princess' and 'Miramar' were No. 2 size tuberous root clumps produced in The Netherlands. Clumps were shipped on December 17, 1975 and January 10, 1977, respectively, and received on January 10, 1976 and February 15, 1977, respectively. The clumps were held at 5°C both during and after shipping.

Each clump was planted in 15 cm azalea pots with the crown just above the media (equal parts of soil, peat, sand, and Perlite). Plants were grown under natural photoperiods (43°N latitude) with 17°C min night temp. Ancymidol (0.5 mg/pot) was applied as a drench 14 days after planting using 100 ml of solution; Osmocote (14N-6.2P-11.6K) at 9 g/pot was surface applied 15-20 days after planting.

Microscopy techniques. Apices were prepared either fresh or in formalin, glacial acetic acid, ethanol, and

water (10:5:45:40) (FAA) for examination with a binocular light microscope with a calibrated occular eyepiece. For SEM viewing the apices were placed in FAA after removal of 1 or 2 pairs of unexpanded leaves. Large reproductive apices were first cut into cubes of 5 mm or smaller and placed in FAA. The tissues were stored in FAA for a min of 24 hr before dehydration in a graded ethanol series (50%, 70%, 90%, 100%, 100%). After approx 8 hr in 100% ethanol, the tissues were critical point dried using liquid CO_2 in a Denton DCP-1.

When required, the removal of inner involucrate bracts (IB) or chaff bracts (CB) was performed while the apices were in ethanol. When not required, the final isolation of the meristem was performed after critical point drying. The tissues were mounted on SEM stubs with Tube Koat (G. C. Electronics Co., Rockford, Ill.), sputter coated with gold, and viewed with an International Scientific Instrument Co. Super-Mini SEM using a 15 kv accelerating potential.

1976 experiments. 'Park Princess' and 'Miramar' were planted on February 25 and 26, respectively. To determine plant size effects on the time of flower initiation, 22 days after planting 7-10 plants each of 'Park Princess' with either 2, 3, or 4 leaf pairs separated were randomly selected and the stage of meristem development was determined. The same was done 30 days after planting with

10-14 plants each of 'Miramar' with either 0, 1, 2, 3, 4, 5, or 6 leaf pairs separated. Expanding leaf pairs were considered separated when the edges of the blades were no longer in contact.

1977 experiments. 'Park Princess' and 'Miramar' were planted on February 17, and no more than 3 shoots were allowed to develop from a single clump. Starting on the 10th day, 10 samples of each cultivar were taken at 5 day intervals. The days to flowering was determined for an additional 10 plants (5 replications of 2 pots each) of each cultivar.

Another group of 'Park Princess' and 'Miramar', planted February 17, were pinched above the 3rd or 4th node 25 days after planting. The apex of the longest of the 2 laterals at the highest remaining node was collected from 10 plants of each cultivar at 3 day intervals beginning on the day of pinching.

RESULTS AND DISCUSSION

Morphological development. Prior to planting, the shoot consisted of the apical meristem and 5 to 8 pairs of bud scales and/or leaf primordia with associated axillary meristems. The apical meristem was flat and rectangular (0.1 x 0.05 mm). The bud scales and leaf primordia were arranged in a decussate phyllotaxy, and it was difficult to

distinguish them. Krijthe (14) identified any structure with brown coloration on the abaxial side to be a bud scale and found 3-4 pairs.

The leaf primordia did not closely overlap the meristem (Fig. 1A & B) and the resulting open space above the meristem was filled with trichomes developing on the adaxial side of the leaf primordia (Fig. 1A). Thus, one function of trichomes in Dahlia may be protection of the meristem. After separation of 2 leaf pairs, the meristem measured 0.2 x 1.0 mm. As the transition from the vegetative to the reproductive stage began, the meristem became domed and enlarged rapidly. It then measured approx 0.3 x 0.25 mm (Fig. 1D). The dome stage was also characterized by a breakdown of the decussate phyllotaxy (Fig. 1D). This phyllotactic rearrangement was particularly evident in 'Miramar' in which the last few leaf primordia can be formed individually rather than in pairs. Philipson (18) indicated that in D. gracilis the first few bracts are arranged in pairs and continue the decussate pattern found in the leaves. This was not observed in the cultivars in this study.

Normally, 'Miramar' and 'Park Princess' formed 8 outer involucrate bracts (OB), but observations of other cultivars indicated that the no. can vary from 5 to 8. Sherff (21) and Sorensen (22) stated that wild species form

4 to 7 OB but 5 is most common. At the end of the OB formation stage, the meristem was round with a diam of approx 0.35 mm (Fig. 1E).

In another study (1) it was shown that the last leaves formed prior to OB formation could be simple leaves. These are distinguishable from the OB primordia because leaf primordia are pointed at the apex, usually have trichomes, and have a broad base. The OB primordia are rounded at the apex, do not possess trichomes, and have narrow bases (Fig. 1F). Furthermore, lateral meristems (LM) were observed in the leaf axials (Fig. 1E).

The 2nd type of bract produced on the Dahlia inflorescence was the IB, and one subtended each ray floret (RF) (Fig. 1E and Fig. 2). At anthesis, the OB and IB can be easily distinguished (21,22), but the primordia can not (13). Using the system of Konishi and Inaba (13), we designated the 9th bract primordium as the first IB. Normally, the first IB arises on the same side of the meristem as and distal to the first OB. Therefore, in a topographic view it was hidden by the enlarging OB (Fig. 1E).

Philipson (18) reported that in D. gracilis the first indication of the floret primordium was a narrow plate of cells formed by anticlinal cell divisions in both tunica layers when the subtending bract primordium was becoming visible. Therefore, we considered a meristem to be

reproductive when the first IB primordium appeared.

A 3rd type of bract on the Dahlia inflorescence was the CB which subtended each disk floret (DF) (Fig. 2E). In the fully double flowered dahlias studied, there appeared to be no morphological differences between the IB and CB, and Sherff (21) and Sorensen (22) indicated a similarity in the single flowered wild species.

Initially, there were only a few IB primordia on the periphery of the meristematic mantle (Fig. 2A), but after further development many IB primordia were formed almost simultaneously (Fig. 2C). The meristematic mantle, which was measured between the innermost series of bract primoria, enlarged until it was approx 0.5 mm in diam and it remained that size until it decreased as the last CB and DF primordia were produced.

The IB and CB primordia elongated rapidly, became imbricated, and overlapped the more distal parts of the capitulum. The floret primordia elongated after being covered by the subtending bract (Fig. 2). Krijthe (14) reported that in 'L'Innocence', a mignon dahlia which produced only 1 row of RF, the DF were well formed with various organ primordia visible before it was covered by the subtending CB. Durso and De Hertogh (10) have shown that short days caused 'Park Princess' to produce flowers with few RF and many DF. In flowers with open eye centers, we

observed a development of the CB and DF very similar to that described by Krijthe (14).

The first structure formed by both RF and DF was the corolla. In RF, corolla enlargement occurred on the abaxial and lateral sides of the apex without the formation of distinct corolla lobes (Fig. 2D). Sattler (20) has shown that in marigolds 5 distinct lobes are formed, but only the lateral 2 and the one on the abaxial side develop to form the ligule. Whereas in salsify (Tragopogon pratensis L.), 5 lobes are formed on the corolla, but the ligule is formed by enlargement of the portion of the corolla below the lobes (20).

In dahlias, the DF formed 5 corolla lobes with the abaxial one being the last to arise (Fig. 2E). Inception of the 5 anther primordia occurred rapidly after the corolla lobes were formed (Fig. 2E). Through enlargement of the abaxial and lateral lobes the corolla enclosed the apex (Fig. 2F). The gynoecium developed in the center of the androecium after the apex was covered by the corolla (Fig. 2F).

By anthesis of the first RF, 'Park Princess' had produced 150-300 RF and 50-100 DF, while 'Miramar' had 150-200 RF and 69-90 DF. In both cultivars some meristems were still forming DF at this time. Often, the inflorescence terminated by forming a single large floret with

abnormally large no. of corolla lobes, anthers, and gynoecia. The most distal florets often did not reach anthesis because they aborted or the entire capitulum senesced prior to their anthesis.

Instead of remaining round throughout inflorescence development, the meristematic mantle of 'Park Princess' often was elongated due to differential rates of floret primordia formation at the periphery. Some 'Park Princess' inflorescences reverted back to producing RF after several series of DF had been formed.

1976 experiments. The no. of leaf pairs separated 30 days after planting had a marked effect on meristematic development (Table 1). 'Miramar' with 0-3 leaf pairs separated were vegetative, but plants with 4-5 pairs separated were mostly in the prefloral stages. Meristems were considered prefloral from doming until the first IB formed. Ninety-one percent of plants with 6 pairs separated were reproductive. In contrast, when 'Park Princess' had 4 leaf pairs separated they were reproductive (data not presented). These results indicate that when grown under inductive photoperiods dahlias from clumps must reach a certain shoot size before flower initiation occurs. In plants grown from cuttings, plant size was not a factor in flower initiation, because plants with 4-5 and plants with 15-18 leaf pairs flowered simultaneously after receiving inductive photoperiods (16).

1977 experiments. The development of unpinched 'Miramar' plants was approx 10 days behind 'Park Princess' (Table 2). For 'Park Princess', the first meristems were prefloral and reproductive at 15 and 20 days after planting, respectively; however, 'Miramar' reached the same stages after 25 and 30 days, respectively. Similarly, the majority of plants were reproductive after 25 and 35 days for 'Park Princess' and 'Miramar', respectively. In this experiment, the average days to flower for 'Miramar' was 4 days longer than 'Park Princess'. In other studies (1,8), 'Miramar' was 7-10 days later than 'Park Princess'.

These data suggest that the difference between the 2 cultivars in the no. of days to anthesis results from the difference in time of flower initiation. This varies from the chrysanthemum in which variation in the days to flower is due to differences in the rate of development after initiation (9).

When samples of these cultivars were forced in The Netherlands, 'Miramar' flowered before 'Park Princess' (Freriks, personal communication). The reason for this discrepancy is unclear. Although flowering in most dahlia cultivars is partially controlled by photoperiod (5,6,10, 12,13,14), there is no indication that the photoperiodic differences between The Netherlands and the northern part of the United States during the spring would cause a

difference in the time of flowering. Possibly, the washing and shipping of clumps utilized in the United States affected subsequent shoot growth.

When plants were pinched above node 3 or 4 and the meristems of the most vigorous growing laterals at the distal nodes were examined at 3 day intervals, 80% of 'Park Princess' and 'Miramar' were reproductive 12 days after pinching (Table 3). The main shoot apex on 'Park Princess' with 3 or 4 leaf pairs separated would have been either prefloral or reproductive at the time of removal, but with 'Miramar' at the same stage of leaf development the apex would have been primarily vegetative (Table 1). At the time of pinching, 25 days after planting, the lateral buds at nodes 3 and 4 on both cultivars were vegetative and measured approx 0.15 x 0.08 mm. When the main shoot of unpinched plants flowered, the lateral buds at nodes 3 and 4 were still vegetative.

There has been some confusion over the correct scientific name for cultivated dahlias. Many American authors have designated them as D. pinnata (5,7,12,19), while others have used D. variabilis (3,4,6,10,17). D. variabilis is an incorrect designation, because it is a synonym for D. pinnata (21,22). We observed differences in the leaf morphology and the flower colors between cultivated dahlias and herbarium specimens of the wild species D. pinnata.

Giannasi (11) and Sorensen (22) studied the morphological and genetic differences between the 2 and concluded that the cultivated dahlia should not be classed as *D. pinnata*. Modern dahlia cultivars have evolved from repeated crosses between wild species and cultivated forms (11,15,22). We agree with Sorensen (22) that it is best to utilize cultivar names for all dahlias that are not clearly selections from a wild species.

Table 1. Meristem stage of 'Miramar' with varying leaf pair separation, 30 days after planting, 1976.

No. of leaf pairs separated	Meristem stage (%)			
		Prefloral		
	Vegetative	Dome	Bract	Reproductive
0	100	-	-	-
1	100	-	-	-
2	100	-	-	-
3	100	-	-	-
4	36	46	18	-
5	8	34	50	8
6	-	9	-	91

Table 2. Meristem development of unpinched 'Park Princess' and 'Miramar' at different time intervals after planting, 1977.

Cultivar and days to flower[z]	Days after planting	Meristem stage (%)		
		Vegetative	Prefloral	Reproductive
Park Princess (65)	10	100	-	-
	15	70	30	-
	20	30	60	10
	25	-	10	90
	30	-	-	100
Miramar (69)	20	100	-	-
	25	40	60	-
	30	40	40	20
	35	-	30	70

[z]Days to flower significantly different at the 1% level.

Table 3. Stage of lateral meristem development from 'Park Princess' and 'Miramar' at intervals after pinching, 1977.[z]

Cultivar	Days after pinching	Meristem stage (%)		
		Vegetative	Prefloral	Reproductive
Park Princess	3	100	-	-
	6	60	40	-
	9	10	40	50
	12	10	10	80
Miramar	3	100	-	-
	6	90	10	-
	9	20	60	20
	12	-	20	80

[z]Plants pinched above node 3 or 4, 25 days after planting.

Fig. 1. Scanning electron micrographs of main shoot apices from Dahlia 'Miramar'. A. Vegetative apex, leaf (L) primordia at 3 nodes present (L1-L3), viewing adaxial side of L3 and abaxial side of L1, 0° tilt, x 50. Plant had 3 leaf pairs separated. B. Vegetative apex, topographic view, note decussate insertion of L1 and L2, 0° tilt, x 93. Plant had 2 leaf pairs separated. C. Vegetative apex, note trichome development on adaxial surface of L2, 50° tilt, x 105. Plant had 3 leaf pairs separated. D. Prefloral apex, meristem enlarged, domed, insertion of leaf primordia (L) not decussate, cut surface (CS) after removal of leaf primordium, 0° tilt, x 84. Plant had 5 leaf pairs separated. E. Reproductive apex, all leaf primordia removed, 8 outer involucrate bract primordia (OB) present, 4 inner involucrate bract primordia (IB) visible, 0° tilt, x 63. Plant had 6 leaf pairs separated. F. Reproductive apex, 3 leaf primordia present, some OB and IB obscured, 0° tilt, x 48. Plant had 6 leaf pairs separated.

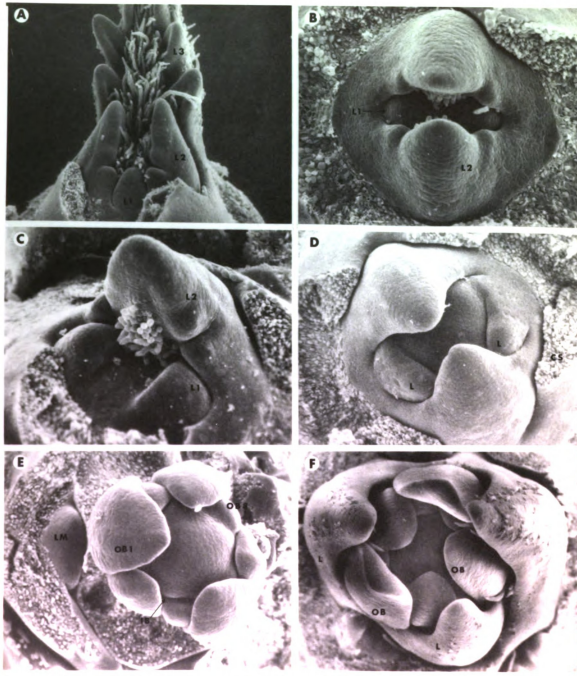

Figure 1

Fig. 2. Scanning electron micrographs of reproductive shoot apices from Dahlia 'Miramar'. A. Inner involucrate bract primordia (IB) being formed, all outer involucrate bract primordia (OB) removed, x 61. Plant had 7 leaf pairs separated. B. Imbricate IB, all OB removed, x 49. Plant had 7 leaf pairs separated. C. IB on periphery of meristematic mantle, large no. compared to A, outer IB removed, x 80. Plant had 8 leaf pairs separated. D. Ray floret (RF) formation, capitulum apex in lower left, larger IB removed, cut surface (CS), corolla (C) forming on outer RF, x 41. Approx 8 mm bud. E. Disk floret (DF) formation, apex at left, note that few chaff bract (CB) primordia are forming, larger CB removed, corolla lobes (CL) and anthers (A) present on some DF, x 81. 22 mm bud. F. Same capitulum as E, most proximal DF at top, apex is out of picture at bottom, all CB removed, 3 CL removed from DF at top to reveal gynecium (G), x 48.

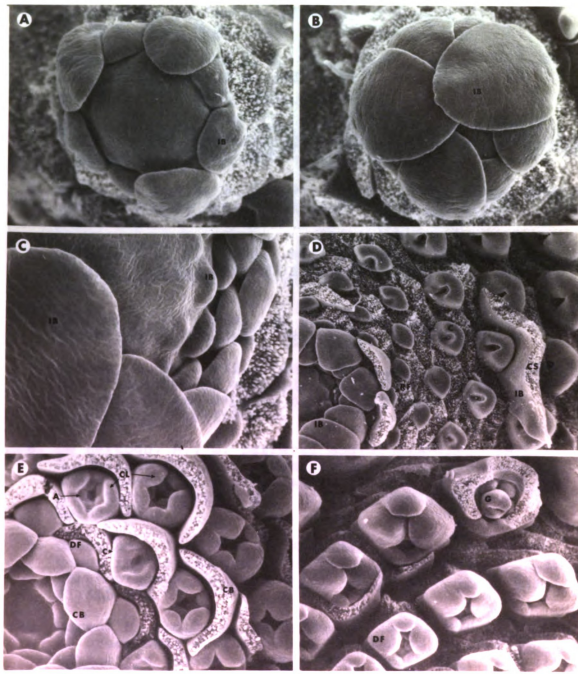

Figure 2

LITERATURE CITED

1. Barrett, J. E. and A. A. De Hertogh. 1978. Effects of pinching on forcing of tuberous-rooted dahlias. J. Amer. Soc. Hort. Sci. Submitted.

2. Barrett, J. E. and A. A. De Hertogh. 1978. Growth and development of forced tuberous-rooted dahlias. J. Amer. Soc. Hort. Sci. Submitted.

3. Bhattacharjee, S. K., K. Das Gupta, and T. K. Bose. 1971. B-Nine, an effective growth retardant on Dahlia; ineffectiveness of CCC. Phyton 28:61-65.

4. Biran, I. and A. H. Halevy. 1973. Stock plant shading and rooting of dahlia cuttings. Scientia Hort. 1:125-131.

5. Botacchi, A. C. 1958. Photoperiodic response of Dahlia pinnata, Cav. M. S. Thesis. The Penn. State Univ.

6. Canham, A. E. 1969. An effect of daylength on the flowering of dahlias. Acta Hort. 14:109-115.

7. Cathey, H. M. 1975. Comparative plant growth-retarding activities of ancymidol with ACPC, phosfon, chlormequat and SADH on ornamental plant species. HortScience 10:204-216.

8. De Hertogh, A., J. Barrett, and N. Blakely. 1978. Guidelines for greenhouse forcing of dutch-grown tuberous-rooted dahlias as pot plant. Holland Flower Bulb Tech. Services Bul. No. 5. Hillegom, The Netherlands.

9. Doorenbos, J. and A. M. Kofranek. 1953. Inflorescence initiation and development in an early and late chrysanthemum variety. Proc. Amer. Soc. Hort. Sci. 61:555-558.

10. Durso, M. and A. A. De Hertogh. 1977. The influence of greenhouse environmental factors on forcing Dahlia variabilis Willd. J. Amer. Soc. Hort. Sci. 102:314-317.

11. Giannasi, D. E. 1975. The flavonoid systematics of the genus Dahlia (Compositae). Mem. N. Y. Bot. Gard. 26:1-125.

12. Haliburton, M. A. 1976. Effects of photoperiod on growth and flowering of Dahlia pinnata, Cav. 'Redskin' pot plants. M. S. Thesis. Oklahoma State Univ.

13. Konishi, K. and K. Inaba. 1966. Studies on flowering control of dahlia III. Effects of day-length on initiation and development of flower bud. J. Jap. Soc. Hort. Sci. 35:73-79.

14. Krijthe, N. 1938. De ontwikkeling der knoppen van enkele voorjaarsgwassen I. (The development of the meristem of several spring crops I. Mignon, Dahlias and Lilium regale). Meded. Landbouwhoogesch. Wageningen 42:1-51.

15. Lawrence, W. J. L. 1932. The origin and genetics of the garden Dahlia. Proc. Linn. Soc. London 145:49-51.

16. Mastalerz, J. W. 1976. Garden dahlias may have potential as a greenhouse crop: daylength controls flower initiation. Penn. Flower Growers Bul. 287(3):1,4-6.

17. Moser, B. C. and C. E. Hess. 1968. The physiology of tuberous root development in dahlia. Proc. Amer. Soc. Hort. Sci. 93:595-603.

18. Philipson, W. R. 1948. Studies in the development of the inflorescence IV. The capitula of Hiesacium boreale Fries and Dahlia gracilis Ortg. Ann. Bot. 12:65-75.

19. Read, P. E., C. W. Dunham, and D. J. Fieldhouse. 1972. Increasing tuberous root production in Dahlia pinnata Cav. with SADH and chlormequat. HortScience 7:62-63.

20. Sattler, R. 1973. Organogenesis of flowers: a photographic text-atlas. Univ. of Toronto Press, Toronto.

21. Sherff, E. E. 1955. Compositae-Heliantheae-Coreopsidinae. N. Amer. Flora. II 2:1-190.

22. Sorensen, P. D. 1969. Revision of the genus Dahlia (Compositae, Heliantheae - Coreopsidinae). Rhodora 71:309-416.

SECTION III

GROWTH AND DEVELOPMENT OF FORCED TUBEROUS-ROOTED DAHLIAS

Growth and Development of Forced Tuberous-Rooted Dahlias

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Additional index words: Dahlia, ancymidol

Abstract: For the first 35 days, the dry weights of the tuberous roots (TR) of Dahlia 'Park Princess' and 'Miramar' decreased, but simultaneously the dry weights of the fibrous roots (FR) and shoots increased. During the 2nd half of the forcing period shoot and TR dry weights increased rapidly. In addition, new TR developed from adventitious roots which formed at the basal nodes of the stem. Ancymidol (0.75 mg/plant) reduced shoot dry weight as well as total height but did not alter TR or FR growth. Plant quality measured by shoot dry weight was reduced when the distal half of each TR was removed before planting. It was not reduced where some of the TR were left intact or when only 1 cm was removed from each TR. The number of days to flower was inversely correlated with plant height measured at 14 and 28 days after planting but not with clump fresh weight.

INTRODUCTION

Within a cultivar the rate of early shoot growth of tuberous-rooted (TR) dahlias is variable, and the shoots must reach a certain min size before flower initiation occurs (2). Thus, the 2 week variation in the time of flowering of a population of plants within a cultivar (5) may be related to the variation in early shoot growth.

In other bulbous species, the size of the storage organ can affect the growth and development of the shoot. Below a critical size, tulip, hyacinth, and iris bulbs will not form flowers (13,20). There is a direct relationship between Lilium longiflorum bulb size and the number of flowers and leaves produced (6). Also, the larger the potato (Solanum tuberosum L.) seed piece the earlier the flowering with a greater no. of shoots and flowers (3,14). Small sweet potato roots produce more shoots per unit wt than larger roots (7). The effects of photoperiod and growth regulators on TR development in dahlias have been studied (9,18,19,23,25), but no detailed studies have been reported on the relationship of the storage organs to shoot growth and flowering. This latter aspect was investigated in this study.

MATERIALS AND METHODS

Cultural procedures. Unless otherwise noted, the shipping, handling, and forcing of clumps were the same as previously described (2). In experiments 1 and 4, the planting medium consisted of equal parts of soil, peat, sand, and Perlite; and 0.5 mg of ancymidol was applied to each pot in 100 ml of solution 14 days after planting. In experiments 2 and 3, the planting medium was soil, peat, sand, and Turface (1:1:1:6); and ancymidol at 0.75 mg/pot was applied 13 and 14 days after planting, respectively.

Experiment 1. In order to determine the changes during forcing in the dry wt of the TR, fibrous roots (FR), shoots, and total plant; 90 uniformly sized clumps each of 'Park Princess' and 'Miramar' were planted on April 9, 1976. Dry wt determinations were made on 15 randomly selected plants of each cultivar at 0, 14, 21, 35, 49, and 63 days after planting.

Experiment 2. Two hundred randomly selected 'Park Princess' clumps were planted March 8, 1977 to determine the effect of ancymidol on the growth of the various plant parts. At intervals, the dry wt and plant ht were determined for 20 plants either with or without ancymidol.

Experiment 3. During harvesting, handling, and shipping clumps are often damaged to varing degrees. Sometimes,

a portion of a TR must be removed before the clumps will fit into a pot. To determine how much of the clump can be removed without affecting shoot growth, 90 randomly selected 'Park Princess' clumps with varying amounts of the clumps removed (Table 1) were planted on April 14, 1977. There were 3 five plant replicates of each of the 6 treatments arranged in a randomized complete block design. As a precaution against root rot disease, all clumps were given a 30 min preplanting dip in a benomyl solution (2 g of 50% WP per liter of H_2O).

Experiment 4. To evaluate the importance of clump size and the rate of the early shoot growth, 25 clumps each of 'Park Princess' and 'Miramar' were planted on February 25 and 26, 1976, respectively; and 32 of each cultivar were planted on February 17, 1977. Plant ht and stem diam 25 days after planting, ht at flowering and no. of days to flower were recorded in 1976. In 1977, plant ht was measured at 14 and 28 days and at flowering. Also, the no. of days to flower, clump fresh wt at planting, and the shoot dry wt at 95 days were determined. The linear correlation coefficients between each of the parameters for each cultivar in each year were calculated.

RESULTS AND DISCUSSION

Experiment 1. At planting, 'Park Princess' and 'Miramar' clumps had average dry wt of 35.1 and 29.7 g, respectively, which was 27 and 21%, respectively, of the fresh wt. One and 3%, respectively, of the dry wt was FR. During the first 35 forcing days, 'Park Princess' total plant and TR dry wt decreased as the shoot and FR dry wt increased slowly (Fig. 1). The TR dry wt at 35 days was 73% of the initial planting wt. From 35 to 63 days, the total plant dry wt increased by 32 g and shoot growth accounted for 50% and TR growth was 44%. The basic growth and development patterns for 'Miramar' were similar to those for 'Park Princess' and are not shown.

The increase in TR wt during the 2nd half of the forcing period (Fig. 1) was at least partially due to the development of new TR. They formed as advantitious roots from the nodes, at the base of the stem, that bore the bud scales. In dahlia seedlings, TR develop adventitiously at the stem base (1,25). Normally, TR are formed only when the plants are under short photoperiods (8, 18, 23, 25), but growing dahlias in pots (23) or applying daminozide or ethephon (9) stimulated TR development.

Hartmann and Kester (12) and Lebar (16) reported that old TR were consumed in shoot development and are replaced

by new TR. However, Krijthe (15) indicated that the replacement of old TR is a process requiring more than a year. We have observed that on 1 year old plants an occasional TR will senesce but most TR are retained on the clump at least through the 2nd year.

Experiment 2. In 1977, with or without ancymidol, 'Park Princess' had growth patterns similar to those in 1976, therefore only shoot growth is reported (Fig. 2).

Ancymidol was applied 13 days after planting, and its effect on plant ht was detectable 27 days later (Fig. 2). Compared to controls, ancymidol caused a reduction in the rate of dry wt accumulation, but this was not apparent until 73 days after planting. Shoub and De Hertogh (22) reported that ancymidol reduced cell division and cell length in the tulip scape. These effects were observed 48 hr after drench application. The tulip normally flowers in 21 days after being placed in the greenhouse. With both tulip (22) and Phaseolus vulgaris (21) ancymidol reduced stem fresh wt. In contrast, Coolbaugh and Hamilton (4) reported that ancymidol increased fresh wt/cm of stem of Pisum sativum. However, their data indicate that the total stem fresh wt on ancymidol treated plants was reduced compared to untreated plants. A reduction in the dry wt of marigold (17) and apple (10) has been reported with daminozide.

Experiment 3. Normally, new FR developed from the distal end of intact TR and from the remaining healthy FR. This agrees with Hartmann and Kester (12). On TR with 1 cm removed from the distal end, new FR developed at the end of the remaining TR. On clumps with all TR cut in half, the FR developed primarily from the crown.

Clumps from which all the old FR were removed produced more flowers and greater shoot dry wt than did the unpruned controls (Table 1). The removal of half of each TR resulted in plants with the least shoot and root dry wt and was the only treatment that reduced overall plant quality. This difference was apparent only during the 2nd half of the forcing period since early shoot growth was similar in all treatments.

In the propagation of dahlias by division of clumps, a single TR is left to support shoot and root growth (12, 24). These results indicate that shoot growth during forcing is not affected as long as half of the TR of a clump are left intact. Therefore, the removal of FR and/or large portions of some TR either in lifting and handling or for fitting into a container does not affect overall plant quality.

Experiment 4. An important problem in the forcing of pot dahlias has been the variation in the time of flowering. Haliburton (11) indicated that in 2 populations of

seed propagated 'Redskin' approx 80% of the plants flowered in a 20 day period, but the spread for 98% of the plants was 66 and 88 days. In 1976 and 1977, the flowering span from the first to last of 'Park Princess' was 16 and 22 days, respectively, and with 'Miramar' it was 22 and 34 days, respectively.

In 1977, there was a high negative linear correlation between plant ht at 28 days and no. of days to flower with coefficients of -0.80 and -0.77 for 'Park Princess' and 'Miramar', respectively (Table 2). There was a high negative correlation in 1976 between time to flower and plant size at 25 days, using either plant ht or stem diam. Additionally, the taller plants at 14 and 28 days tended to be the shorter plants at flowering (Table 2).

In a random sample of 250 'Park Princess' clumps, the average fresh wt was 126 g with a range from 31 to 308 g. However, there was no relationship between clump size and time of flowering, shoot dry wt, or no. of shoots per plant. The size of the storage organ in dahlias is not important to shoot growth as in other species with underground storage organs (3,6,7,13,14,20).

Flower initiation in dahlias forced from clumps does not occur until the shoot has reached a certain min size (2). The more vigorous plants reach the required size first and, thus, are the first to flower. This indicates

that if uniform shoot growth could be obtained, uniform flowering would result. For a better understanding of this variable shoot growth, more research is needed on genetic and/or environmental factors that might control it.

Table 1. Effects of fibrous and tuberous root removal on development of 'Park Princess', 1977.

Portion[z] of clump removed	Days to flower	No. of flowers	Flower diam (mm)	Ht to flower (mm)	Dry wt (g) Shoot	Dry wt (g) Root
None	65a[x]	1.6bc	145a	305a	34.1c	8.7ab
All FR	64a	2.4a	146a	313a	39.9a	10.5a
1 cm from 50% of the TR	67a	2.0abc	142a	318a	34.3c	8.0ab
1 cm from each TR	64a	2.1ab	145a	273a	36.2bc	8.1ab
½ of 50% of the TR	64a	2.0abc	146a	313a	37.9ab	10.3a
½ of each TR	65a	1.5c	142a	274a	30.1d	7.3b

[z]Portion removed from distal end of each tuberous root (TR). Fibrous roots (FR) were not removed from uncut TR.

[x]Mean separation within columns by Duncan's multiple range test, 5% level.

Table 2. Linear correlation coefficients for days to flower and for plant ht in relation to other parameters for 'Park Princess' and 'Miramar', 1977.

Parameter	Park Princess		Miramar	
	Days to flower	Plant ht	Days to flower	Plant ht
Days to flower	1.0**[z]	0.69**	1.0**	0.76**
Clump fresh wt[y]	-0.28	-0.25	-0.09	0.19
Ht at 14 days	-0.48**	-0.37*	-0.66**	-0.65**
Ht at 28 days	-0.80**	-0.60**	-0.77**	-0.82**
Shoot dry wt[x]	-0.67**	-0.27	-0.34	-0.32

[z]Significance at the 5% (*) and 1% (**) levels.

[y]At planting.

[x]105 days after planting.

Fig. 1. Dry wt changes of tuberous roots, fibrous roots, shoots, and total plant during forcing of 'Park Princess', 1976.

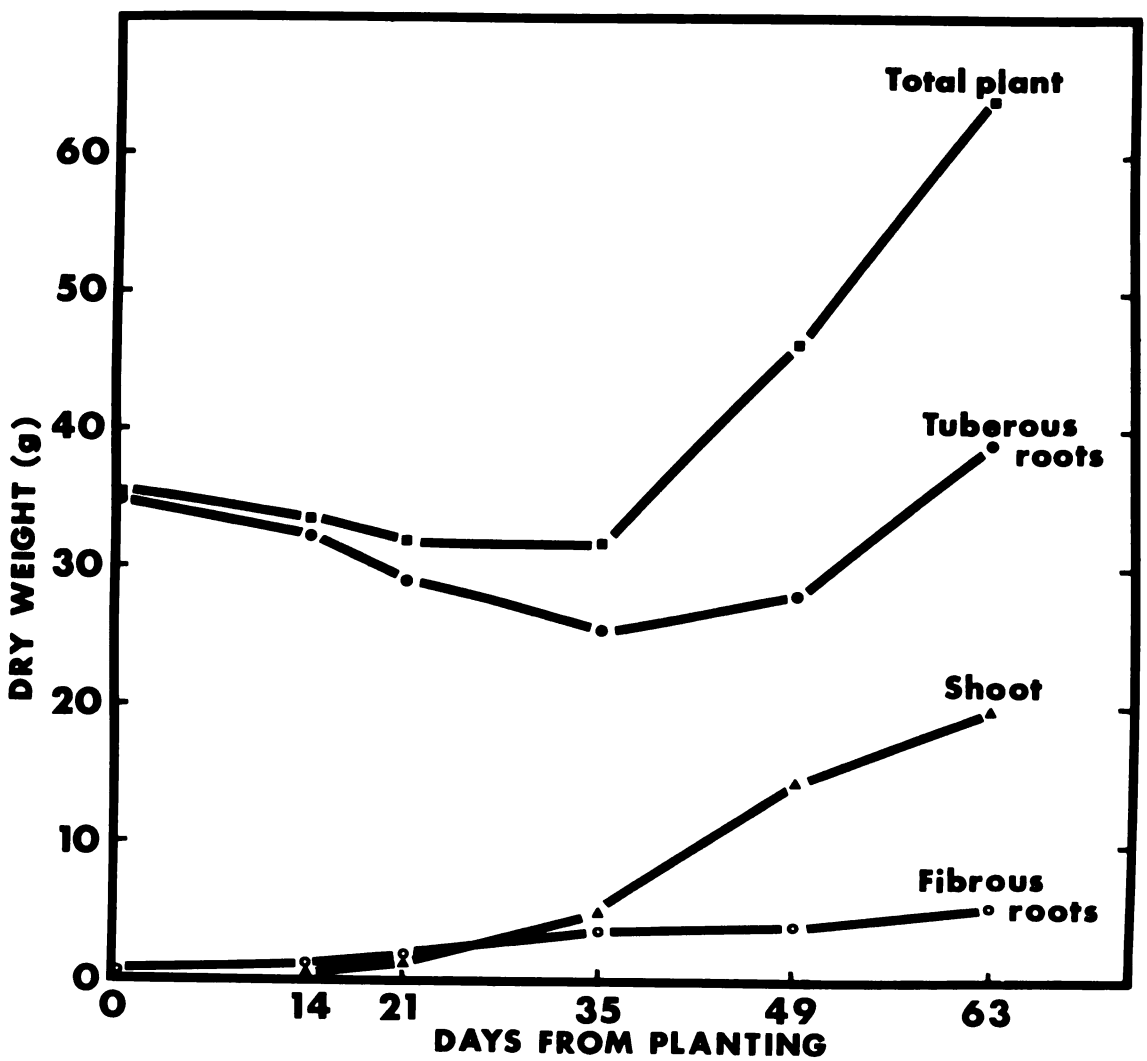
Total plant
Tuberous roots
Shoot
Fibrous roots
DRY WEIGHT (g)
0
10
20
30
40
50
60
0
14
21
35
49
63
DAYS FROM PLANTING

Figure 1

Fig. 2. Effects of ancymidol on shoot growth of 'Park Princess', 1977.

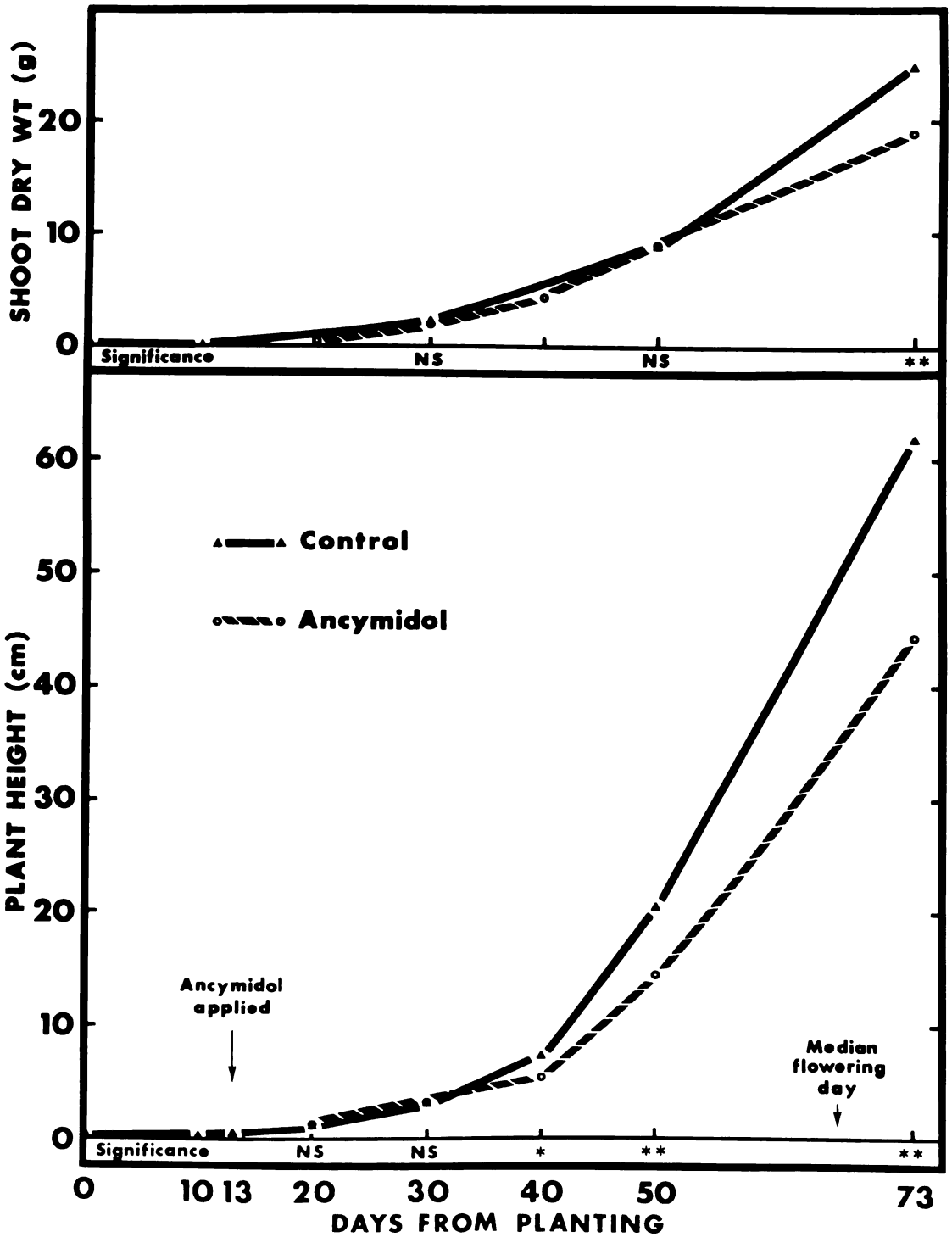
SHOOT DRY WT (g)
20
10
0
Significance
NS
NS
**
60
50
40
30
20
10
0
PLANT HEIGHT (cm)
Control
Ancymidol
Ancymidol applied
Median flowering day
Significance
NS
NS
*
**
**
0
10
13
20
30
40
50
73
DAYS FROM PLANTING

Figure 2

LITERATURE CITED

1. Aoba, T., S. Watanobe, and K. Soma. 1961. Studies on the formation of tuberous root in dahlia II. Anatomical observation of primary root and tuberous root. J. Japan Soc. Hort. Sci. 30:82-88.

2. Barrett, J. E. and A. A. De Hertogh. 1978. Comparative inflorescence development of two cultivars of forced tuberous-rooted dahlias. J. Amer. Soc. Hort. Sci. Submitted.

3. Birecki, M. and S. Roztropowicz. 1963. Studies on seed potato size and productivity. Eur. Potato J. 6:1-13.

4. Coolbaugh, R. C. and R. Hamilton. 1976. Inhibition of ent-kaurene oxidation and growth by α-cyclopropyl-α-(p-methoxyphenyl)-5-pyrimidine methyl alcohol. Plant Physiol. 57:245-248.

5. De Hertogh, A., J. Barrett, and N. Blakely. 1978. Guidelines for greenhouse forcing of dutch-grown tuberous-rooted dahlias as pot plants. Holland Flower Bulb Tech. Services Bul. No. 5. Hillegom, The Netherlands.

6. De Hertogh, A. A., H. P. Rasmussen, and N. Blakely. 1976. Morphological changes and factors influencing shoot apex development of Lilium longiflorum Thumb. during forcing. J. Amer. Soc. Hort. Sci. 101:463-471.

7. Edmond, J. B. and G. R. Ammerman. 1971. Sweet potatoes: production, processing, marketing. AVI Publishing Co., Westport, Connecticut.

8. Garner, W. W. and H. A. Allard. 1923. Further studies in photoperiodism, the response of the plant to relative length of day and night. J. Agr. Res. 23:871-920.

9. Halevy, A. H. and I. Biran. 1975. Hormonal regulation of tuberization in dahlia. Acta Hort. 47:319-329.

10. Halfacre, R. G., J. A. Barden, and H. A. Rollins, Jr. 1968. Effects of alar on morphology, chlorophyll content and net CO_2 assimilation rate of young apple trees. Proc. Amer. Soc. Hort. Sci. 93:40-52.

11. Haliburton, M. A. 1976. Effects of photoperiod on growth and flowering of Dahlia pinnata, Cav. 'Redskin' pot plants. M. S. Thesis. Oklahoma State Univ.

12. Hartman, H. T. and D. E. Kester. 1975. Plant propagation: principles and practices, 3rd ed. Prentice Hall, Englewood Cliffs, New Jersey.

13. Hartsema, A. M. 1961. Influence of temperature on flower formation and flowering of bulbous and tuberous plants. Handbuch der Pflanzenphysiologie 16:123-167.

14. Jones, H. A. and H. A. Borthwick. 1938. Influence of photoperiod and other factors on the formation of flower primordia in the potato. Amer. Potato J. 15:331-336.

15. Krijthe, N. 1938. De ontwikkeling der knoppen van enkele voorjaarsgwassen I. (The development of the meristem of several spring crops I. Mignon, Dahlias and Lilium regale). Meded. Landbouwhoogesch. Wageningen, 42:1-51.

16. Lebar, T. R. H. 1955. Dahlia growing. Dover Publications, New York.

17. McConnell, D. B. and B. E. Struckmeyer. 1970. Effect of succinic acid 2,2-dimethylhyrazide on the growth of marigold in long and short photoperiods. HortScience 5:391-392.

18. Moser, B. C. and C. E. Hess. 1968. The physiology of tuberous root development in dahlia. Proc. Amer. Soc. Hort. Sci. 93:595-603.

19. Read, P. E., C. W. Dunham, and D. J. Fieldhouse. 1972. Increasing tuberous root production in Dahlia pinnata Cav. with SADH and chlormequat. HortScience 7:62-63.

20. Rees, A. R. 1966. The physiology of ornamental bulbous plants. Bot. Rev. 32:1-23.

21. Shive, J. B., Jr. and H. D. Sisler. 1976. Effects of ancymidol (a growth retardant) and triarimol (a fungicide) on the growth, sterols, and gibberellins of Phaseolus vulgaris (L.). Plant Physiol. 57:245-248.

22. Shoub, J. and A. A. De Hertogh. 1974. Effects of ancymidol and gibberellins A_3 and A_{4+7} on Tulipa gesneriana L. cv. Paul Richter during development in the greenhouse. Scientia Hort. 2:55-67.

23. Wasscher, J. 1955. De invloed van een kortedagbehandeling op de knolvorming by dahlia's, knolbegonia's en gesneria's. Meded. Dir. Tuin. 18:342-352.

24. Wildon, C. E. 1935. Dahlias: culture, history and classification. Pages 1-57 in Dahlias their history, classification, culture, insects and diseases. Agr. Exp. Sta. Mich. State Coll. Spec. Bul. No. 266.

25. Zimmerman, P. W. and A. E. Hitchcock. 1929. Root formation and flowering of dahlia cuttings when subjected to different day lengths. Bot. Gaz. 87:1-13.

SECTION IV

EFFECTS OF PINCHING AND GROWTH REGULATORS ON FORCED TUBEROUS-ROOTED DAHLIAS

Effects of Pinching and Growth Regulators on Forced Tuberous-Rooted Dahlias

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Abstract: Pinching of forced tuberous-rooted Dahlia 'Park Princess' and 'Miramar' was evaluated as a method for increasing flower production and plant quality. Pinched plants produced more flowers, flowered later, had smaller flowers, and were taller than unpinched controls.

On an individual plant basis, pinching at node 4 generally gave the best results, while pinching at node 2 resulted in the greatest delay and fewest flowers. 'Park Princess' produced more shoots per clump and more lateral branches after pinching than 'Miramar'. The more distal the pinch, the greater the number of laterals formed on both cultivars and the higher the percent of laterals flowering on 'Park Princess'. On a population basis, pinching only those plants with a single strong shoot at node 3 or 4 resulted in the best compromise between increased flower production and the deleterious delayed flowering and

increased plant height. Pinching experiments with 3 cultivars in combination with growth retardants ancymidol, daminozide, and chlormequat were inconclusive.

INTRODUCTION

Until recently, only seed propagated dwarf cultivars have been used to produce pot dahlias (1,6,12,18). Efforts to develop techniques for forcing dahlias from tuberous-root clumps of asexually propagated, established garden cultivars have shown that ht control can be achieved with ancymidol (9), and several cultivars have been suggested for commercial use (8). Durso and De Hertogh (10) reported that proper fertilization and temperature regimes were required to produce quality plants and that naturally increasing spring photoperiods were optimal for flowering.

During these studies (8,9,10), the no. of shoots developing from each clump varied and each shoot formed a terminal flower and a few lateral flower buds. Therefore, while some plants had several flowers and buds, others had only a single flower and a few buds.

Increasing the no. of flowers on a plant by pinching to increase the number of lateral branches is a common floricultural practice (11,16,19). Garden dahlias are often pinched to increase the number of flowers (13). The objective of this study was to evaluate the effects of

pinching and growth regulators on the tuberous-rooted dahlia under greenhouse forcing conditions.

MATERIALS AND METHODS

General procedures. Shipping, handling, and forcing of clumps were the same as previously described (2). Except where specified, ancymidol (0.5 mg/15 cm pot) was applied in 100 ml of solution 14 days after planting.

The no. of days from planting to flowering, no. of visible flower buds, and plant ht (except experiment 1) were determined when the first flower opened. Flower diam, no. of open flowers and plant ht in experiment 1 was determined 7 days later. A flower was considered open when a series or a few florets around the outside of the capitulum had reflexed enough that the midportion of the ligule was pulling back from the inner florets. This was approx 1 day prior to anthesis of the outer florets. Heights were measured from the crown to the base of the highest capitulum.

Experiment 1. In 1976, 500 clumps each of 'Park Princess' and 'Miramar' were planted February 25 and 26, respectively. The rate of shoot growth after planting was variable, but as the plants reached the stage where 2 leaf pairs had separated, they were segregated according to plant size and no. of shoots per plant. Based on shoot no. the groupings for 'Park Princess' were single (1 shoot), double

uneven (2 shoots, 1 more vigorous than the other), double even (both shoots approx same size), and triple (shoot size more uniform than double uneven). The groupings for 'Miramar' were single, double uneven, and double even.

Each test was a randomized complete block. The treatments were no. of shoots per plant and location of the pinch. Blocking was against the reported effects of the varying early shoot growth (3). There were 5 pots per replication with 3 and 4 replicates, respectively, for 'Miramar' and 'Park Princess'. Single shooted 'Park Princess' were pinched at node 2, 3 or 4; and the multishooted plants pinched at node 3 or 4. 'Miramar' singles were pinched at node 2, 3, 4, or 5; and multishooted plants were pinched at node 4. In the pinched double uneven treatments only the largest shoot in each pot was pinched, but all shoots were pinched in the pinched double even and triple treatments. There were unpinched controls in each grouping and cultivar.

Experiment 2. In 1977, 'Park Princess' and 'Miramar' were planted on February 17. A max of 3 shoots were allowed to develop on any plant. Each cultivar was analyzed separately with 32 plants per treatment in a randomized complete block design with 4 replications. Pinching was performed 27 and 30 days after planting, and the tests were terminated after 95 and 100 days for 'Park Princess'

and 'Miramar', respectively. The 5 treatments were (A) all shoots unpinched, (B) all shoots pinched, (C) only shoots pinched were those that could be pinched at node 3 or 4, (D) all shoots on single and double uneven plants were pinched, and (E) only shoots pinched were those on single and double uneven plants that were large enough to be pinched at node 3 or 4.

Experiment 3. In 1976, 'Park Princess' was planted May 12, and only the first shoot was allowed to develop on each plant.

The treatments (Table 6) were a combination of an ancymidol drench, an ancymidol spray, and/or a pinch at node 3. Only plants which were large enough to be pinched at node 3, 26 days after planting, were used. The spray was applied 33 days after planting at the rate of 0.3 g/pot as a 100 ppm solution. There were 15 plants per treatment in a randomized complete block design with 3 replications.

Experiment 4. In 1977, 'Miramar', 'Purple Gem', and 'Park Princess' were planted February 22, 23, and 28, respectively. Only one shoot was allowed to develop per plant. Each test was a randomized complete block with 16 treatments. 'Miramar' and 'Purple Gem' were replicated 3 times with 5 pots per replication. 'Park Princess' was replicated 4 times with 4 pots each.

The treatments are described in Table 7. Plants in treatments 2-16 were pinched on day 27 for 'Miramar' and 'Purple Gem' and day 25 for 'Park Princess'. Treatments 1, 2, 5-16 received an ancymidol drench at 0.5 mg/pot for 'Miramar' and 'Park Princess' and at 1.0 mg/pot for 'Purple Gem'. Treatments 3 and 4 received an ancymidol drench at 0.75 and 1.0 mg/pot, respectively, for 'Park Princess' and 'Miramar' and at 1.25 and 1.50 mg/pot, respectively, for 'Purple Gem'. The postpinch foliar sprays were as follows: ancymidol (treatments 5-8) at 0.25 mg/pot, daminozide (treatments 9-12) at 5000 ppm, or chlormequat (treatments 13-16) at 3000 ppm. A 2nd spray of daminozide was applied 2 weeks after the first.

RESULTS AND DISCUSSION

Experiment 1. The leaf type at each node of the unpinched single and the major shoot on double uneven plants was determined (Table 1). After initially forming simple leaves, both cultivars progressively formed more complex leaves until only leaves with 5 or 7 primary leaflets were formed. Less complex leaves were formed at the most distal 1 or 2 nodes. For 'Park Princess', 40% of the plants initiated compound leaves at node 3; the rest produced the first compound leaves at node 4. The first compound leaf

appeared at node 4 on 87% of the 'Miramar' plants and at node 5 on the rest (data not shown). This variation in the change from simple to compound leaves resulted in determining the position of the pinch by node no. rather than leaf type.

The first leaf-like structure at the base of the stem of both cultivars was small, and Krijthe (15) considered it to be a bud scale and not a foliage leaf. We counted this as the first leaf if there was a distinct internode below it or if it was 1 cm or longer. After this leaf, the simple and compound leaves became progressively larger (15).

Regardless of shoot no. or pinch position, pinched 'Park Princess' were approx 8-10 cm taller and 8-12 days later in flowering then unpinched plants (Table 2). There was little difference in the ht of pinched plants, but unpinched triples were taller than the unpinched double uneven plants.

Flowering of unpinched triples was delayed compared to the unpinched single and double uneven plants (Table 2). Flowering of the pinched triples was delayed compared to singles pinched at node 3 or 4. The time from planting to flower and pinch to flower was greater for pinched triples than singles pinched at node 3 or 4. Furthermore, the time to flower from planting and pinching was delayed by pinching singles at node 2 compared to node 3.

In all cases, pinching 'Park Princess' at node 3 or 4 resulted in approx twice as many open flowers per plant compared to unpinched plants (Table 2). Single shooted plants pinched at nodes 2, 3, and 4 bore an average of 3.4, 4.4, and 5.5 flowers, respectively. The no. of flower buds per plant was increased by pinching single and double uneven plants at node 4 and pinching double even and triple plants at nodes 3 and 4. Pinching resulted in smaller flowers. Only flowers from pinched and unpinched double even plants were not significantly different. James (13) reported that pinched garden dahlias produced smaller flowers and flower size was increased by limiting the no. of flowers allowed to develop.

Pinching single and multishooted 'Miramar' delayed flowering (Table 2). Pinching at nodes 2 and 5 resulted in a 15 and 9 day delay in flowering, respectively, but only a 4 and 5 day delay resulted from pinching at nodes 3 and 4, respectively. Compared to all other pinch treatments, the time from pinch to flower was longest for singles pinched at node 2. Even though all pinch treatments increased plant ht, the only significant increase was from pinching single plants at node 2.

Unpinched double even plants produced an average of 2.9 flowers per plant. This was significantly more than the 2.0 produced by unpinched single and double uneven

plants, and the same as pinched double even plants. There was an increase in the no. of flower buds from pinching single plants at nodes 4 and 5 and double even plants at node 4. Flower diam was slightly reduced on single plants pinched at node 5 compared to unpinched or pinched single plants at node 3 or 4.

After pinching single and double uneven plants of both cultivars, the more distal the pinch the more laterals that developed (Table 4). 'Park Princess' pinched at nodes 2, 3, and 4 averaged 3.3, 3.5, and 4.2 branches per plant, respectively; whereas, 'Miramar' pinched at nodes 2, 3, 4, and 5 averaged 2.0, 2.2, 2.7, and 3.3 branches per plant, respectively.

'Miramar' formed branches at the 2 most distal nodes only, while 'Park Princess' produced some branches at the 3rd node below the pinch (Table 4). In all cases 2 branches developed at the most distal remaining node. Therefore, the within and between cultivar differences in the no. of branches developed were caused by the differences in the no. of branches produced at the 2nd and 3rd nodes below the pinch.

With 'Miramar', the more distal the pinch the higher the % of laterals flowering at the most distal node, but the position of the pinch did not affect the flowering of the laterals at the 2nd node below the pinch (Table 4).

The opposite was true for 'Park Princess'. The position of the pinch did not affect the flowering of laterals at the most distal remaining node, but the more distal the pinch the higher the % of laterals flowering at the 2nd node below the pinch.

Konishi and Inaba (14) pinched rooted cuttings above the 3rd node and by disbudding allowed only laterals from node 1 or 3 to develop. They found that the laterals from node 1 flowered earlier and produced higher quality flowers than the laterals from node 3. However, our data indicate that for pinched dahlias grown from clumps the highest quality plants are formed by laterals from nodes 3 and 4.

Unpinched 'Park Princess' formed 7-8 nodes and 'Miramar' formed 9-10 nodes before flower initiation. Lateral branches on 'Park Princess' pinched at node 3 or 4 initiated flowers after producing 4-5 nodes, whereas pinching at node 2 required 5-7 nodes. On 'Miramar', laterals at nodes 2, 3, and 4 or 5 generally formed 7-10, 5-7, and 5-6 nodes, respectively, before flower initiation.

On most pinched plants the first flower to open was on a lateral arising from the most distal node, but occasionally with 'Park Princess' the first lateral to flower was at the 2nd note below the pinch. For both cultivars, pinching the strongest growing shoot of a double uneven plant resulted in the unpinched shoot often flowering before the

pinched shoot; however, both shoots flowered within 7 days of the first flower. For an unpinched double uneven plant, the less vigorous shoot seldom flowered within 7 days of the vigorous shoot.

Experiment 2. In experiment 1, the effects of the location of the pinch and shoot no. were determined. The effects of the variable initial shoot growth was negated through blocking. In experiment 2, no constraints were imposed except that no more than 3 shoots per clump were allowed to develop, and the effects of pinching only selected plants in a population were determined.

'Park Princess' unpinched control and the single and double uneven plants pinched at node 3 or 4 flowered in 71.5 and 73.3 days, respectively, but the other 3 treatments flowered in approx 78-79 days (Table 5). The unpinched 'Miramar' control flowered in 80.5 days. In the pinched treatments, as the no. of pinched plants within a population increased the no. of days to flower increased from 82.8 to 88.0.

With both cultivars, pinched plants were taller than unpinched plants. The smallest increase came from pinching only the single and double uneven plants which were large enough to be pinched at node 3 or 4. Also with both cultivars, pinching increased the no. of flowers produced per plant (Table 5).

In experiment 1, the single and double uneven plants normally produced the fewest flowers, and plants pinched at node 2 were delayed more than those pinched at nodes 3 or 4 (Tables 2 and 3). The results of this experiment indicate that pinching only single and double uneven plants large enough to be pinched at node 3 or 4 provides an increase in flowering of these plants, which produce the fewest flowers, with a min increase in the average plant ht and time to flower for the population.

Over all treatments, 'Miramar' and 'Park Princess' averaged 1.5 and 2.1 shoots per clump, respectively. In experiment 1, 'Park Princess' formed more lateral branches after pinching than did 'Miramar' (Table 4). This indicates a possible correlation between the no. of shoots a cultivar produces initially and its branching after pinching.

Experiment 3. Because of increased plant ht due to pinching, ancymidol applied as a drench and/or a foliar spray was evaluated on both pinched and unpinched 'Park Princess'. Unpinched plants flowered in approx 57 days, and pinched plants flowered in approx 71 days (Table 6). Ancymidol applied as either drench or spray did not affect the days to flower.

Unpinched plants receiving only an ancymidol drench (treatment 3) averaged 23.6 cm in ht, while pinched plants

(treatment 4) were 36.3 cm in length. However, pinched plants given a postpinch spray (treatment 5) averaged 31.3 cm. The ht of the unpinched and pinched plants not given ancymidol (treatments 1 and 2) averaged 45.8 and 59.3 cm, respectively. The peduncle length generally reflected the differences between treatments in plant ht. Pinching increased peduncle length in all cases, and the ancymidol drench reduced peduncle length on pinched (treatments 4 vs. 2) and unpinched (treatments 3 vs. 1) plants.

Since pinched plants were taller than unpinched plants with or without ancymidol (Table 6), the elongation of the laterals, which resulted in the increased ht, appeared to be a natural growth response to pinching rather than a lowering of the amount of ancymidol per growing shoot.

Experiment 4. In 1977, the no. of growth retardants and applications were increased (Table 7). With all 3 cultivars the time from planting to flower was longer for the pinched plants than the unpinched controls. Neither growth regulator sprays nor increased amounts of ancymidol as a drench affected time to flower.

With 'Park Princess', all the pinched plants were taller than the unpinched controls. The application of 1.0 mg of ancymidol (treatment 4) as a drench produced the shortest pinched plants (Table 7). All pinched 'Purple Gem' given a growth regulator spray (treatments 5-16) were

shorter than the plants given only an ancymidol drench (treatments 2-4) (Table 7). Unpinched 'Miramar', which received 0.5 mg of ancymidol, averaged 37.5 cm; and the pinched plants receiving 0.5, 0.75, and 1.0 mg as a drench averaged 42.3, 37.4, and 38.1 cm, respectively.

The effectiveness of the growth regulator postpinch sprays in reducing pinched plant ht was variable (Tables 6 and 7). Daminozide (5000 ppm) has been effective in ht control of unpinched rooted cuttings of several dahlia cultivars (4,5). In addition, Mastalerz (17) reported that both ancymidol (132 or 264 ppm) and daminozide reduced peduncle length if applied just as the flower bud began to extend above the foliage, but the concn of daminozide required to achieve the same degree of inhibition in each experiment varied from 5000 to 20,000 ppm. Evaluating effects of growth regulators on shoot growth of dahlias grown from clumps, De Hertogh et al. (9) found that chlormequat as a drench was ineffective, but daminozide as a foliar spray was slightly effective on unpinched plants planted February 8 but ineffective on pinched plants planted March 9. On plants in the February 8 planting, a soil drench of ancymidol was effective both 2 and 4 weeks after planting, but on the March 9 plants it was only effective if applied 2 weeks after planting (9). Cathey (7) reported all 3 growth regulators were active on seed dahlias. In our studies,

postpinch sprays reduced the ht of 'Park Princess' in experiment 3, but not in experiment 4. None of the growth regulator treatments on the 3 cultivars provided uniform results. The use of growth regulators to control ht of pinched dahlias needs further investigation to determine the reasons for the variation and the rate, time, and method of application for an effective chemical required to give uniform results.

Table 1. Leaf types at each node of 'Park Princess' with single strong shoot, 1976.

Node[z]	Leaf types (%)			
	Simple	Trifoliolate	Five primary leaflets	Seven primary leaflets
1	100	-	-	-
2	100	-	-	-
3	60	30	10	-
4	-	22	78	-
5	-	-	80	20
6	-	-	60	40
7[y]	5	15	75	5
8[y]	28	72	-	-

[z]Numbering starts with the proximal node.

[y]The terminal flower was at node 7 on 75% of the plants and node 8 on 25% of the plants.

Table 2. The effects of shoot no. and pinching node on the development of 'Park Princess', 1976.

Shoot Number	Pinched above node	Days to flower	Plant ht (cm)[z]	No. of flower buds per plant	No. of flowers per plant[z]	Diam of first flower (cm)[z]	Days from pinch to flower
1	No pinch	59.2g[w]	39.5cd	16.2de	2.4fg	14.1a	-
	2	71.3bc	47.6a	16.7cde	3.4ef	13.3bc	46.5a
	3	68.2d	46.4ab	16.8cde	4.4cd	12.9cd	41.7ef
	4	70.2cd	46.2ab	20.0ab	5.5b	12.8cd	40.4fg
2 uneven[y]	No pinch	61.2fg	37.0d	15.5e	2.2g	14.1a	-
	3	69.0d	47.4a	15.7e	4.5cd	13.1bcd	42.6de
	4	69.2cd	48.2a	18.2bcd	4.2de	13.1bcd	39.4g
2 even[x]	No pinch	61.8ef	39.6cd	15.1e	3.2f	13.7ab	-
	3	70.3bcd	49.2a	18.7bc	5.7ab	13.0bcd	43.8cd
	4	71.9b	48.6a	19.5ab	6.4a	13.0bcd	42.2def
3[x]	No pinch	63.4e	42.6bc	15.6e	3.0fg	14.0a	-
	3	72.4ab	47.5a	20.3ab	5.1bc	12.5d	45.9ab
	4	74.3a	48.5a	21.6a	5.7ab	12.6d	44.6bc

[z]Determined 7 days after opening of first flower.

[y]Only the strongest shoot was pinched.

[x]All shoots were pinched.

[w]Mean separation within columns by Duncan's multiple range test, 5% level.

Table 3. The effects of shoot no. and pinching on the development of 'Miramar', 1976.

Shoot Number	Pinched above node	Days to flower	Plant[z] ht (cm)	No. of flower buds per plant	No. of[z] flowers per plant	Diam of[z] first flower (cm)	Days from pinch to flower
1	No pinch	70.3d[w]	49.3c	11.5c	2.0bc	14.7a	-
	2	85.5a	58.5ab	11.1c	1.8c	14.4ab	59.5a
	3	75.1c	54.0abc	11.0c	2.0bc	14.9a	47.8b
	4	74.6c	54.6abc	13.9ab	2.7ab	14.6a	44.9b
	5	79.3b	54.4abc	13.6ab	3.1a	13.7b	44.2b
2 uneven[y]	No pinch	71.9d	51.9abc	10.7c	2.0bc	15.0a	-
	4	76.0b	55.0abc	11.7c	2.7ab	14.4ab	46.3b
2 even[x]	No pinch	72.0d	53.9abc	12.1bc	2.9a	14.2ab	-
	4	75.4c	59.5a	14.7a	3.1a	14.4ab	47.5b

[z]Determined 7 days after opening of first flower.

[y]Only strongest shoot was pinched.

[x]All shoots were pinched.

[w]Mean separation within columns by Duncan's multiple range test, 5% level.

Table 4. Development of lateral branches at each node after pinching 'Park Princess' and 'Miramar', 1976.[z]

Cultivar and node pinched above	Avg no. of laterals per node at node 1	2	3	4	5	No. of laterals per plant	% of laterals flowering at node[y] 1	2	3	4	5	% of laterals flowering
Park Princess												
2	1.3	2.0	-	-	-	3.3	29	94	-	-	-	68
3	0.1	1.4	2.0	-	-	3.5	0	52	97	-	-	78
4	0	0.3	1.9	2.0	-	4.2	-	8	71	94	-	83
Miramar												
2	0.1	1.9	-	-	-	2.0	0	62	-	-	-	58
3	0	0.3	1.9	-	-	2.2	-	25	79	-	-	72
4	0	0	0.7	2.0	-	2.7	-	-	30	93	-	76
5	0	0	0	1.3	2.0	3.3	-	-	-	20	97	66

[z]Data from single and double uneven plants.

[y]Seven days after opening of first flower.

Table 5. Effects of pinching selected plants of 'Park Princess' and 'Miramar', 1977.

Plants pinched	Cultivar: Park Princess Days to flower	Park Princess Plant ht (cm)	Park Princess No. flowers[z]	Miramar Days to flower	Miramar Plant ht (cm)	Miramar No. flowers[z]
None	71.5b[x]	31.3d	1.5c	80.5c	41.6b	1.8b
All	79.3a	44.0a	3.4a	88.0a	48.3a	2.6a
All at 3 or 4[y]	78.0a	39.1b	2.0bc	85.5ab	47.7a	3.2a
Singles and double uneven	78.0a	37.3bc	2.9ab	83.8abc	48.7a	2.7a
Signles and double uneven at 3 or 4	73.3b	34.3cd	2.5abc	82.8bc	45.2ab	2.7a

[z]Determined 7 days after opening of first flower.

[y]Those that could be pinched at node 3 or 4. The other plants were unpinched.

[x]Mean separation within columns by Duncan's multiple range test, 5% level.

Table 6. Effects of pinching and ancymidol on development of single shooted 'Park Princess', 1976.

No.	Treatments: Ancymidol[z] Drench	Ancymidol[z] Postpinch spray	Pinch	Days to flower	Plant ht (cm)	Peduncle length (cm)
1	No	No	No	56.8b[y]	45.8b	13.2b
2	No	No	Yes	70.7a	59.3a	17.0a
3	Yes	No	No	55.7b	23.6e	6.6de
4	Yes	No	Yes	72.0a	36.3c	10.7bc
5	Yes	Yes	Yes	71.7a	31.3d	8.6c
6	Yes	Yes	No	57.3b	21.2e	5.9e

[z]Drench at 0.5 mg/15 cm pot; spray at 0.3 mg/pot.

[y]Mean separation within columns by Duncan's multiple range test, 5% level.

Table 7. Effects of ancymidol, daminozide, and chlormequat on plant ht of single shooted 'Park Princess', 'Miramar', and 'Purple Gem', 1977.

Treatment no.	Spray		Plant ht (cm)		
	Chemical[z]	Applied wk postpinch	Park Princess	Purple Gem	Miramar
1[yx]	None	-	31.1e[v]	28.8d	37.5e
2[x]	None	-	39.8bcd	40.2abc	42.3bcde
3[w]	None	-	40.3bcd	43.8ab	37.4e
4[w]	None	-	36.5d	44.5a	38.1e
5	Ancymidol	0	41.6bc	33.8cd	39.8de
6	Ancymidol	1	42.0abc	34.7cd	45.1abcd
7	Ancymidol	2	38.8cd	34.3cd	42.5bcde
8	Ancymidol	3	38.7cd	36.1c	41.6cde
9	Daminozide	0 & 2	42.3abc	39.0abc	45.7abcd
10	Daminozide	1 & 3	43.8ab	37.5abc	46.6abc
11	Daminozide	2 & 4	41.8bc	34.3cd	45.3abcd
12	Daminozide	3 & 5	39.5bcd	37.2bc	49.1a
13	Chlormequat	0	42.8abc	35.6cd	45.8abcd
14	Chlormequat	1	42.1abc	37.3bc	48.0ab
15	Chlormequat	2	46.2a	34.7cd	43.4bcde
16	Chlormequat	3	43.6ab	36.8bc	45.2abcd

[z]Rates of ancymidol, daminozide, and chlormequat were 0.3 mg/pot, 5000 ppm, and 3000 ppm, respectively; [y]plants in treatment 1 were unpinched, all others were pinched; [x]plants in treatments 1, 2, 5-16 were drenched with ancymidol at 0.5 mg/pot for 'Park Princess' and 'Miramar' and at 1.0 mg/pot for 'Purple Gem'; [w]plants in treatments 3 and 4 were drenched with ancymidol at 0.75 and 1.0 mg/pot, respectively, for 'Park Princess' and 'Miramar' and at 1.25 and 1.50 mg/pot, respectively, for 'Purple Gem'; [v]mean separation within columns by Duncan's multiple range test, 5% level.

LITERATURE CITED

1. Ball, V., ed. 1975. The ball red book. Geo. J. Ball, Inc., U.S.A.

2. Barrett, J. E. and A. A. De Hertogh. 1978. Comparative inflorescence development of two cultivars of forced tuberous-rooted dahlias. J. Amer. Soc. Hort. Sci. Submitted.

3. Barrett, J. E. and A. A. De Hertogh. 1978. Growth and development of forced tuberous-rooted dahlias. J. Amer. Soc. Hort. Sci. Submitted.

4. Bhattacharjee, S. K., K. Das Gupta, and T. K. Bose. 1971. B-Nine, an effective growth retardant on Dahlia; ineffectiveness of CCC. Phyton 28:61-65.

5. Bhattacharjee, S. K., T. Mukhopadkay, and T. K. Bose. 1974. Experiments with growth retardants on Dahlia. Indian J. Hort. 31:86-90.

6. Botacchi, A. C. 1958. Photoperiodic response of Dahlia pinnata, Cav. M. S. Thesis. The Penn. State Univ.

7. Cathey, H. M. 1975. Comparative plant growth-retarding activities of ancymidol with ACPC, phosfon, chlormequat and SADH on ornamental plant species. HortScience 10:204-216.

8. De Hertogh, A., J. Barrett, and N. Blakely. 1978. Guidelines for greenhouse forcing of dutch-grown tuberous-rooted dahlias as pot plant. Holland Flower Bulb Tech. Services Bul. No. 5. Hillegom, The Netherlands.

9. De Hertogh, A. A., N. Blakely, and W. Szlachetka. 1976. The influence of ancymidol, chlormequat, and daminozide on the growth and development of forced Dahlia variabilis Willd. Scientia Hort. 4:123-130.

10. Durso, M. and A. A. De Hertogh. 1977. The influence of greenhouse environmental factors on forcing Dahlia variabilis Willd. J. Amer. Soc. Hort. Sci. 102:314-317.

11. Ecke, P., Jr., and O. A. Matkin, eds. 1976. The poinsettia manual. Paul Ecke Poinsettias, Encinitas, California.

12. Haliburton, M. A. 1976. Effects of photoperiod on growth and flowering of Dahlia pinnata, Cav. 'Redskin' pot plants. M. S. Thesis. Oklahoma State Univ.

13. James, H. 1963. Dahlias for garden and exhibition. John Gifford Limited, London.

14. Konishi, K. and K. Inaba. 1965. Studies on flowering control of dahlia II. Effects of mature leaves of main stem upon the growth and flowering of lateral shoots. J. Japan Soc. Hort. Sci. 34:71-76.

15. Krijthe, N. 1938. De ontwikkeling der knoppen van enkele voorjaarsgwassen I. (The development of the meristem of several spring crops I. Mignon, Dahlias and Lilium regale). Meded. Landbouwhoogesch. Wageningem 42:1-51.

16. Love, J. W. 1975. Vegetative growth. Pages 47-51 in A. M. Kofranek and R. A. Larson, eds. Growing azaleas commercially. Division of Agr. Sci. Univ. of California.

17. Mastelerz, J. W. 1976. Garden dahlias may have potential as a greenhouse crop: daylength controls flower initiation. Penn. Flower Growers Bul. 287(3):1,4-6.

18. Potter, C. H. 1954. Flowering pot plants. Florists' Rev. 113(2930):39.

19. Williams, C. and B. Bearce. 1964. Pinching and disbudding. Pages 38-45 in R. W. Langhans. Chrysanthemums. New York State Ext. Ser. Chrysantheum School.