FACTORS IN THE GROWTH OF AXILLARY BUDS IN CHRYSANTHEMUM MORIFOLIUM

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This is to certify that the

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ABSTRACT

FACTORS IN THE GROWTH OF AXILLARY BUDS IN *CHRYSANTHEMUM MORIFOLIUM*

by Harry W. Keppeler

Nine cultivars of *Chrysanthemum* were used to study the environmental factors affecting the growth of axillary buds. Plants were usually pinched above the 10th node and were grown under long days (16 hr. photoperiod) during the experimental period.

Increase in temperature increased bud elongation at the top three nodes of the plant. A similar effect was noted with the use of the red or far-red spectrum. Increase in light intensity initiated bud growth at the lower nodes.

Removal of the lower five leaves did not enhance bud growth in relation to the control plants. Excising the top five leaves induced increased growth in lower axillary buds and decreased growth of upper buds.

Decreasing the nutrient concentrations produced a decline in the number of buds initiating growth. This reduction in bud initiation proceeded in an acropetal direction. Calcium, magnesium, or potassium in decreased concentrations caused a growth decline similar to that experienced with decreasing concentrations of all nutrients.

With high soil nutrition, increased relative humidity induced elongation in the top three buds. There was no

comparable effect in lower buds. Higher light intensity decreased growth in the upper buds and stimulated growth in the lower buds. With low soil nutrition, increased relative humidity increased growth in the top two buds.

Selective excision of the of the upper five buds indicated nutrient rather than auxin control of bud growth. Severing of vascular tissue above a lower axillary bud induced growth in that bud.

Indoleacetic acid (10^{-2}M) in lanolin placed on the tip of the pinched plant inhibited growth in one case, but did not inhibit growth in another. Indoleacetic acid (10^{-2}M), indolebutyric acid (10^{-3}M), 2, 4-dichlorophenoxyacetic acid (10^{-2}M) and N-1-naphthyl phthalamic acid (10^{-2}M) inhibited growth in lower axillary buds when placed in notches above these buds. No consistent pattern of growth stimulation occurred with any of the growth substances utilized.

FACTORS IN THE GROWTH OF AXILLARY BUDS IN *CHRYSANTHEMUM MORIFOLIUM*

By

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INTRODUCTION

Apical dominance in Chrysanthemum morifolium has a wide range of expression. In many cultivars, few lateral branches develop after the terminal bud is removed while in others, more occur. The variation may be illustrated by the cultivars "Mermaid" and "Princess Anne." "Mermaid" will produce five to six lateral branches after terminal bud removal; "Princess Anne" three to four. These lateral branches arise from buds immediately below the point of terminal bud detachment.

This variation in apical dominance is noted throughout the plant world. One extreme form occurs in genera such as Philodendron where destruction of the terminal bud results in the growth of the next closest axillary bud. In general, only one axillary bud will grow. An opposite extreme form is found in Coleus where the terminal bud exhibits little apical dominance.

In this study, certain environmental factors involved in axillary bud growth have been investigated. Because of the vast research in the theoretical phyto-hormonal mechanism area, a considerable amount of time was spent investigating other environmental factors which might influence the growth of axillary buds. Simultaneously, an attempt would be made to correlate the phyto-hormonal system with these factors.

REVIEW OF LITERATURE

Apical dominance is defined by some authors as "correlative inhibition" and is explained as the inhibition of axillary bud growth by the terminal bud. When the terminal bud is destroyed, the development of the upper axillary buds induces inhibition of lower buds. This theory is recognized in this paper.

Theoretically, all axillary buds are released from inhibition at the moment of terminal bud destruction. A number of axillaries start growth during this non-inhibitive period. The re-establishment of inhibition by the topmost axillaries limits the number which continue growth.

Apical dominance has long been under investigation. Two early theories suggested either an internal hormone as the correlating agent or a nutritional explanation. In 1925, Snow (51) demonstrated an internal hormone's existence.

The development by Went (64) of the Avena test in 1928 enabled Kögl and Haagen-Smit (29) to isolate and purify auxin "A" from human urine. Later auxin "B" was isolated and purified from plant sources. Eventually, "heteroauxin" was isolated and purified from urine and was identified as B-indoleacetic acid. Later, Haagen-Smit

et al. (21,22) isolated B-indoleacetic acid in pure form from corn meal and corn germ. This work and other confirming data suggested that indoleacetic acid is the most important growth hormone in plants.

Apical dominance is usually mentioned with reference to auxin.[a] Thimann's (60) review in 1939 stated nine different mechanisms which might account for the inhibition. In 1956, Allsopp (1) summarized the nine mechanisms into three distinct theories: (a) auxin acts directly as an inhibitor of axillary buds; (b) auxin produces some process which gives rise to a special inhibiting influence; (c) auxin leads to a diversion of nutrients or growth factors.

Investigators (19, 57) have found the terminal bud rich in auxin; others (12, 50, 52, 58) discovered more in the young leaves. In a few cases (19, 62) the extending internodes of the stem have yielded more auxin than either the terminal bud or the young leaves.

Basipetal movement of auxin has been demonstrated. Le Fanu (35) observed that auxin-lanolin paste inhibited or stimulated growth of young internodes. The inhibition or stimulation depended upon the placement of the paste below or above the tissue involved. She concluded that there was more basipetal transport than acropetal transport. This

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[a]The terms auxin and IAA will both refer to B-indoleacetic acid unless otherwise specified.

conclusion has been verified (24, 34, 37, 39, 40, 41, 53, 54, 66, 70).

Wickson and Thimann (7) found that apical sections of Pisum stem transported more auxin than did older stem sections. Movement was largely basipetal and was reduced by conditions that favored axillary bud growth. McCready and Jacobs (39) verified this decline of basipetal movement with age. They associated it with a steady increase in acropetal auxin movement and with a progressive decrease in the ability of the sections to grow in length. Leopold and Guernsey (37) illustrated a changing ratio of basipetal/acropetal transport from a vegetative stem tip to a flowering stem tip. This occurred although basipetal transport decreased with stem age. McCready and Jacobs (41) indicated that the mechanism of transport may be different for the two directions involved. However, the data of Le Fanu (35) showed little auxin transport in either direction in a completely inhibited shoot of Pisum.

Thimann (59) was one of the first investigators to illustrate the control of axillary bud growth by auxin synthesis and transport. He applied auxin to either the stem above the axillary buds or directly to the axillary buds of Pisum seedlings. This resulted in an equal inhibitory effect on the growth of the axillary buds. Delisle (12) showed that auxin applied to the cut ends of Aster leaves inhibited axillary bud growth. Other investigators

(17, 25, 34, 36, 50, 62, 63, 66) have since confirmed this general reaction although the effectiveness of the inhibition varies greatly among species.

To resolve the direct auxin theory, many (25, 47, 58, 63, 70) have shown an increase in auxin content of axillary buds following terminal bud destruction. Others (50, 63) pointed out a corresponding decrease of auxin in the stem tissue. Wickson and Thimann (7) also found a linear relationship between the inhibition re-established by upper axillary buds and the content of externally applied IAA isotope in the axillary bud tissue of Pisum. They concluded that auxin produced in the terminal bud, leaves, or stem did reach the axillary buds.

Snow (53) and Went (66) favored Allsopp's (1) second theory and pointed out the phenomenon of increasing inhibition with increasing distance. This conclusion was disputed by Thimann (59).

Van Overbeek (63) found that the longer the time lapse between decapitation and application of external auxin, the less effective was the inhibition of axillary bud growth. Gordon (17), working with x-ray irradiation, showed an inconsistency in the time relationship. He found that irradiation of the terminal tip of Xanthium would cause subjacent axillaries to grow. In addition, external auxin applied to the irradiated terminal tip for two days caused postponement of axillary bud growth for two days.

However, external auxin application for two weeks following irradiation caused axillary buds to remain dormant. Auxin application had suppressed their growth during the two weeks.

Jacobs et al. (25) showed that 1% IAA in lanolin had no inhibiting effect on the growth of axillary buds. This amount of IAA exactly substitutes for the terminal tip in providing auxin through the second node from the apex. They had previously demonstrated apical dominance in a clone of Coleus blumei. Smith (50) and Snow (51) found inhibition interrupted by physiological shock (steam). Snow (51) illustrated inconsistencies in inhibition interruption by severing different tissues individually (xylem, phloem, pith). Severance of the phloem did not interrupt inhibition, but severance of both xylem and phloem did. Maintaining connections between axillary bud and main apex by only the xylem did not interrupt inhibition.

Snow (55) stated an indirect theory (1) in the following manner: auxin travels down the stem from the growing apex or leaves. The primary positive effect of auxin overrides the secondary inhibiting influence. Very little auxin travels acropetally into a lateral bud or shoot. The inhibiting influence moves upward and produces its effect. Went (65) postulated the presence of hormone-like factors (calines). These are formed in the roots and are required for the elongation of the stem or axillary buds. He also stated that auxin causes a redistribution of calines in the plant.

Kefford (27) apparently confirmed these theories by chromotographic separation of growth substances. Using etiolated bean shoots, he found IAA the predominating growth substance in the stem. Inhibitor B predominated in the first axillary bud.

Many chemical substances (5, 11, 47, 69) overcome auxin inhibition of axillary bud growth. Audus (5) stated that high concentrations of adenine would accomplish this purpose. Wickson and Thimann (69) reported the removal of auxin inhibition on isolated Pisum stem sections by kinetin, an adenine derivative. However, Davies et al. (11) showed an increase of auxin inhibition on axillary bud growth in bean by kinetin. Both Wickson and Thimann (69) and Sachs and Thimann (47) illustrated with Pisum that kinetin released axillary buds from inhibition by the intact apex. Buds released would not elongate as much as uninhibited buds. The bud would react normally with an auxin treatment. They (47) suggested that growing shoots are relatively insensitive to correlative inhibition because they synthesize two types of growth substances.

A possible partial explanation for the auxin-kinetin interaction was shown by Seth et al. (48) and Davies et al. (11). IAA promoted kinetin transport and kinetin promoted IAA transport.

Other substances have been shown to affect auxin transport. Niedergang-Kamien and Leopold (43) reported

that dinitrophenol (a classical respiration inhibitor) inhibited auxin transport at concentrations which stimulated respiration. They also reported transport inhibition by TIBA (2, 3, 5-Triiodobenzoic acid). Hay (23) found transport inhibition with 2, 4-D (2,4-Dichlorophenoxyacetic acid) and TIBA. Jacobs (26) showed increased auxin transport with gibberellic acid.

As a possible consequence of this auxin transport interaction, Asen and Hamner (3) found TIBA to be the most effective inductor of basal shoots on rose plants. However, regardless of the chemical used, 60% of the total number of basal shoots developing were on the outside rows. Brian et al. (9) have shown that gibberellic acid enhances apical dominance in the self-branching "Cupid" sweet peas. Wickson and Thimann (69) found that gibberellic acid promoted bud elongation and occurs only after inhibition has been released.

Other chemicals (7, 36, 38, 39) have been reported as affecting some phase of apical dominance. Leopold (36) observed the effect of auxin (Naphthaleneacetic acid) in reducing tillering in barley, while TIBA was effective in increasing it. Beach and Leopold (7) reported that maleic hydrazide broke apical dominance in Chrysanthemum. Mitchell et al. (39) showed the varying response of 64 phthalamic acids in controlling apical dominance. Libbert (38) found that NMSP (α-1-Naphthylmethylsulfide propionic acid)

stimulated uninhibited axillary buds of Pisum. It also stimulated correlatively inhibited buds. The above summary is conflicting and inconclusive.

The third theory (1), the nutrient theory, can be divided into two general sections: light effects and inorganic nutrition. Plant growth can be influenced by light quality or light intensity.

The effects of light quality and light intensity have been difficult to separate. Went (67) experimented with Pisum seedlings and found growth in length decreasing with small amounts of red light. Increasing intensity of light was more effective in decreasing the length than increasing duration. He suggested a dual effect of red light: (a) it caused excessive growth (red etiolation); (b) it decreased growth in length compared to dark etiolation. This conclusion has been supported by Dunn and Went (13) with utilization of the yellow region of the spectrum or increased amounts of incandescent light which is high in red and infra-red wave lengths. Arthur and Stewart (2) and Withrow and Withrow (71) also confirmed the dual effect with incandescent or other light sources having high proportions of infra-red.

There has been an attempt to correlate these results with growth substances. Thimann and Skoog (58) stated that the production of growth substance takes place only in light. However, he established no thresholds, nor did it

appear that there was a linear relationship between the two factors. Red and blue-violet light produced approximately the same amounts of growth substance, while far-red and yellow-green produced less. Thimann and Wardlaw (61) observed the accumulation of IAA under high light intensity which induced elongation. This was observed with both red and blue light. In contrast, Galston and Hand (15) found that, at any given auxin level, white light decreased the amount of growth produced. This was not due to differences in auxin content, but to a light-induced differential response to auxin.

There has been agreement in the few reports on the interaction of auxin and nutrient uptake, translocation and accumulation. Auxin enhanced the uptake of salt and water in potato slices (10) and was capable of preventing plasmolysis in hypertonic sucrose solutions. When applied to the third or fourth mature leaf from the apex, sucrose (^{14}C) moved in an acropetal direction (8). This movement was enhanced in plants with terminal bud intact or with IAA-lanolin paste substituted. There was less movement in plants with the terminal bud detached. Zaerr (72) found a direct correlation of IAA transport with the degree of sucrose (^{14}C) accumulation in the morphological base of stem sections.

Some authors (13, 33, 44) believed there was a direct correlation between increasing light intensity and plant

growth as measured by dry weight increase. There was disagreement as to which wave lengths of light are most efficient in dry weight production. Dunn and Went (13) found red wave lengths more effective. Rohrbaugh (46) observed nearly equal production in the red and blue regions. Shirley (49) showed the blue-violet region to be more efficient at low intensities and observed that the complete solar spectrum was more efficient per unit light intensity than any one portion of it.

As to inorganic nutrition, Kraus (31) outlined its relationship to organic nutrition and resulting vegetative growth. Gunckel et al. (20) suggested that the ability of long shoots to develop from uninhibited lateral buds in Gingko was a function of general nutrition. Gregory and Veale (18) concluded that the main factor in apical dominance in flax was nutrition. They thought it was not an inhibitor which induced less activity in buds but rather a competitive effect for a limited nutrient supply. Flax exhibits little apical dominance. An increase or decrease in the tillering of barley was controlled largely by nutrient supply (4). Goodwin and Cansfield (26) found nutrient supply not directly involved in inhibition of lateral buds on potato tubers, but high nutrient supply could partially offset the effect of the inhibitor.

Klebs (28) investigated interactions of light and nutrient factors. He found that the absolute values of several factors (light intensity, temperature, soil nutrients) were of little value. However, the relationship between factors was of consequence in the development of Sempervivum. Kwack and Dunn (32) observed no differences in dry weight of pods with Pisum grown under equal intensities with three different nutrient levels. The levels were all of high order (0.5X, 1X, 2X). In another experiment with equal light intensities, length of photoperiod caused marked differences in yields.

One example in the applied area was reported by Post (45) who found differences in branching with interactions between last pinch and start of short days. However, this involved the complications of the flowering apex. White (68) and Fries and White (14) have investigated branching differences obtained with changing watering frequencies and constant feed procedures. Tayama and Kiplinger (56) observed an effect of light intensity, caused by planting different numbers of Chrysanthemum cuttings in the same size pot. Kohl and Nelson (30) confirmed this effect (56) and showed differences from environmental factors which vary from month to month.

MATERIALS AND METHODS

Nine cultivars of Chrysanthemum morifolium used in this study were obtained as rooted cuttings from a commercial propagator or cuttings were propagated from stock plants grown in a greenhouse at Michigan State University. Stock plants and cuttings were grown at 60 F night temperature and under long photoperiods (14 hrs. or 16 hrs).

Each rooted cutting was placed in a 4" clay pot in a soil consisting of equal parts of a clay-loam, peat moss, and a soil conditioner ("Turface" or perlite).

Plants were usually severed at a height of ten nodes from the soil surface; however, several variations in heights were used. The plant height is indicated in the tables and figures by the number of nodes at which measurements were taken.

The node numbering system used in the tables and figures starts at the point in an internode where the terminal tip of the plant was removed and proceeds in a basipetal direction to the soil surface. The point of terminal tip detachment is considered as the top of the plant. Axillary buds are numbered by the same method.

Growth chambers were used for some experiments. Temperatures utilized were 60 F night and 70 F day unless otherwise

specified. The growth chambers contain a clear plastic barrier between the lights and the growing chamber. Controlled environmental light quality work was done by substituting a colored filter for the plastic barrier. In one experiment, colored cellophane was added to the plastic barrier.

In addition, two "growth chamber" boxes were constructed with approximate dimensions of 28" x 42" x 30". Fluorescent and incandescent lights were installed and an exhaust fan pulled air through the chamber. These boxes were placed in a thermostatically temperature controlled room.

Nutrient solutions (modified Hoagland[a]) for the nutritional levels experiments were formulated at the 1.0 X level as follows:

$Ca(NO_3)_2$	-- 1M -	15 ml per gal. solution
KNO_3	-- 1M -	15 ml per gal. solution
$MgSO_4$	-- 1M -	8 ml per gal. solution
NaH_2PO_4	-- 1M -	4 ml per gal. solution
FeNa EDTA	-- 0.1M -	4 ml per gal. solution
H_3BOs	-- 0.04M -	4 ml per gal. solution
$MnCl_2$	-- 0.008M -	4 ml per gal. solution
$ZnCl_2$	-- 0.0008M -	4 ml per gal. solution
$CuCl_2$	-- 0.0003M -	4 ml per gal. solution
MoO_3	-- 0.0003M -	4 ml per gal. solution

[a]Hoagland, D. R. and W. C. Snyder, 1933 Proc. Amer. Soc. Hort. Sci. 30:288-294.

Plants were grown in gallon jars with constant aeration. Distilled water was added to replace that lost by transpiration and evaporation. Plants were placed in fresh solutions every fifteen days.

Growth substances applied as sprays were dissolved in small amounts of 50% ethanol and diluted to the indicated concentrations with 50% ethanol. Substances were sprayed on leaves with a small, plastic, manually-operated sprayer. Spray was applied till run-off occurred. In some experiments plant leaves were immersed in the solutions for ten seconds. Growth substances utilized were indoleacetic acid, gibberellic acid, indolebutyric acid, kinetin, and N^6 benzyl adenine.

Growth substances for lanolin application experiments were added to lanolin as crystalline material. Where lower concentrations were used, the substances were dissolved in small amounts of 50% ethanol and diluted to the proper concentration before addition to lanolin. Lanolin was melted in a hot water (60 C) bath for proper mixing. Growth substances used were indoleacetic acid, N^6-benzyladenine, B995, thioracil, gibberellic acid, 2,4-dichloroanisole, AmChem #67-109, AmChem #66-329, 2,3,5-triiodobenzoic acid, 2,4-dinitrophenol, Alanap, 2,4-dichlorophenoxyacetic acid, and dichloropropionic acid.

The "notching" technique was accomplished by severing the vascular tissue at an internode. The notch was always

directly above an axillary bud and approximately 1/2" from it. Leaves were removed from the plant by severing the petiole not more than 1/4" from the stem. Axillary buds were excised with a small knife with no damage to other tissues.

Intermittent mist was regulated by the use of an artificial leaf. Relative humidity was increased with the use of a mist tent. Small areas of a propagation bench were enclosed with polyethylene plastic. A mist nozzle inside the tent (regulated by an artificial leaf) provided additional moisture. A 6" space was left open at the bottom of the tent on two sides. This space provided air circulation and partial temperature regulation.

Light energy was automatically recorded with an ISCO[a] Spectraradiometer and energy computations were made with polar planimeter measurements of the chart area.

A completely randomized statistical design was used. An analysis of variance table was computed for bud growth at each node. Experiments with more than two treatments required the use of orthogonal or non-orthogonal comparisons. Five millimeters was the shortest measurement observed and indicated a range from no visible elongation to a measurement of five millimeters.

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[a]Instrumentation Specialities Co., Lincoln, Nebr.

RESULTS

To determine the capacity for growth of the various axillary buds on the stem of the Chrysanthemum, the plant was severed between nodes and the node plus leaf was placed in a sand bench under intermittent mist. The growth of the axillary buds of a plant with 10 nodes was determined (Table 1). Several of the basal buds elongated as much or more than the upper buds.

Plants were grown at different temperatures to determine the temperature effect on axillary bud growth. A temperature increase from 50 F to 65 F increased growth; however, this increase was in the first three buds from the top (Table 2). In the interaction of temperature and light intensity, temperature stimulation is also illustrated (Figure 1). A combination of high night temperature (80 F) and a low light intensity (109,080 micro-watts/cm^2) produced similar growth when compared with a higher light intensity (359,900 micro-watts/cm^2) and lower night temperatures (started at 75 F, changed to 60 F after 7 days). Growth initiated by high temperature stimulation occurred at the top three nodes while buds at nodes 4 through 10 showed increased growth with the higher intensity-lower night temperature treatment.

TABLE 1.--Cultivar "Mermaid" severed at the internodes, and each node with leaf attached propagated in sand under intermittent mist for 50 days.

	Node from top of plant									
	1	2	3	4	5	6	7	8	9	10
Mean growth of axillary buds in mm.	19	12	17	25	22	18	12	24	28	40
Non-orthogonal[f] comparison F test.	a	a a a a a	a a a	a b	a b	a a	a a a a a	a b	a b	b

[f]Within a line, mean (8 plants) designated by (a) are significantly different from means designated by (b) at the 5% level.

TABLE 2.--Cultivar "Red Star" grown under two greenhouse temperatures for 26 days.

Treatment	Mean axillary bud growth in mm.							
	Node from top of plant							
	1	2	3	4	5	6	7	8
Temperature 65 F	116[a]	108[a]	103[a]	28[a]	10[a]	6[a]	5[a]	3[a]
Temperature 50 F	72[b]	84[b]	76[b]	23[a]	12[a]	9[a]	3[a]	4[a]

[a]Means (8 plants) within a column followed by different letters are significantly different at the 5% level by the F test.

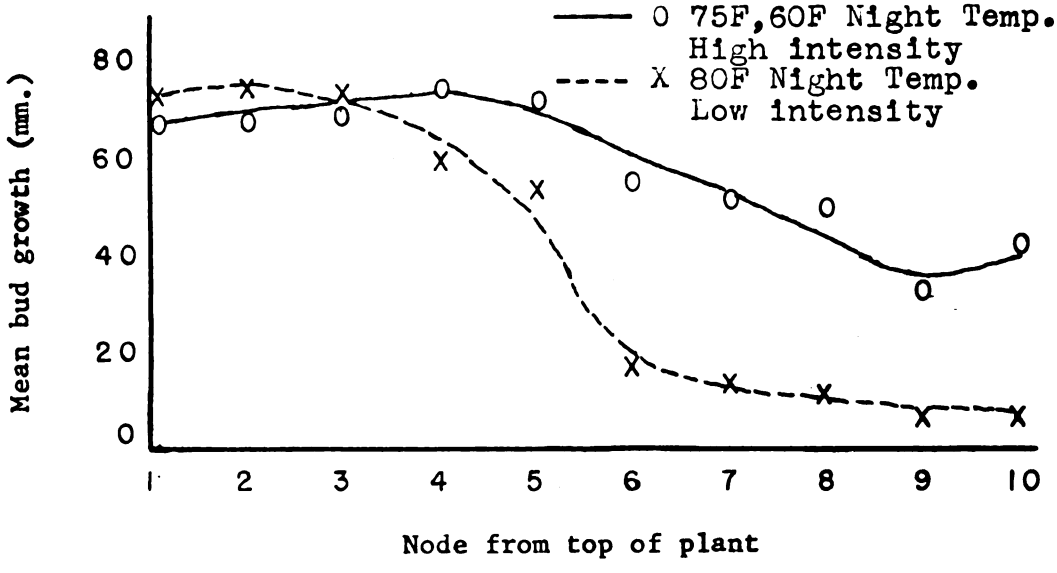

Figure 1 - Cultivar 'Starburst' grown for 21 days at two light intensities (359,900 micro-watts/cm^2 vs. 109,080 micro-watts/cm^2). Plants under high intensity light started at 75 F night temperature and changed to 60 F after 7 days.
The mean growth (10 plants) of the axillary buds at nodes 4 through 10 significantly different at the 5% level by the F test.

With the same night temperature (60 F) but two light intensities (109,080 micro-watts/cm^2 vs. 359,900 micro-watts/cm^2), significant differences in growth were noted only at nodes 4, 6, and 7 (Figure 2). This response was under long photoperiod (16 hrs.) (vegetative growth). Using the same cultivar and environmental conditions except for short photoperiods (8 hrs.) (reproductive growth), significant growth increases occurred at every node with high light intensity (Table 3). The growth pattern was changed under high light intensity. In this situation, the growth differences were less between upper and basal buds which was a variation from the usual apical to basal growth decline illustrated by low intensity. In another experiment with plants grown in the greenhouse in October, there were no significant differences in growth between plants grown under long days (16 hrs.) and short days (8 hrs.) (Table 1A, Appendix). With an additional increase in photoperiod (14 hrs. vs. 20 hrs.) under high light intensity (359,900 micro-watts/cm^2) and a 60 F night temperature, growth increases were obtained at nodes 5 and 8 with the longer photoperiod.

The growth increases obtained with increases in light intensity indicated that experiments with light quality might yield positive information. With differences in light intensity (red spectrum-18,450 micro-watts/cm^2; blue spectrum-12,320 micro-watts/cm^2), the red spectrum

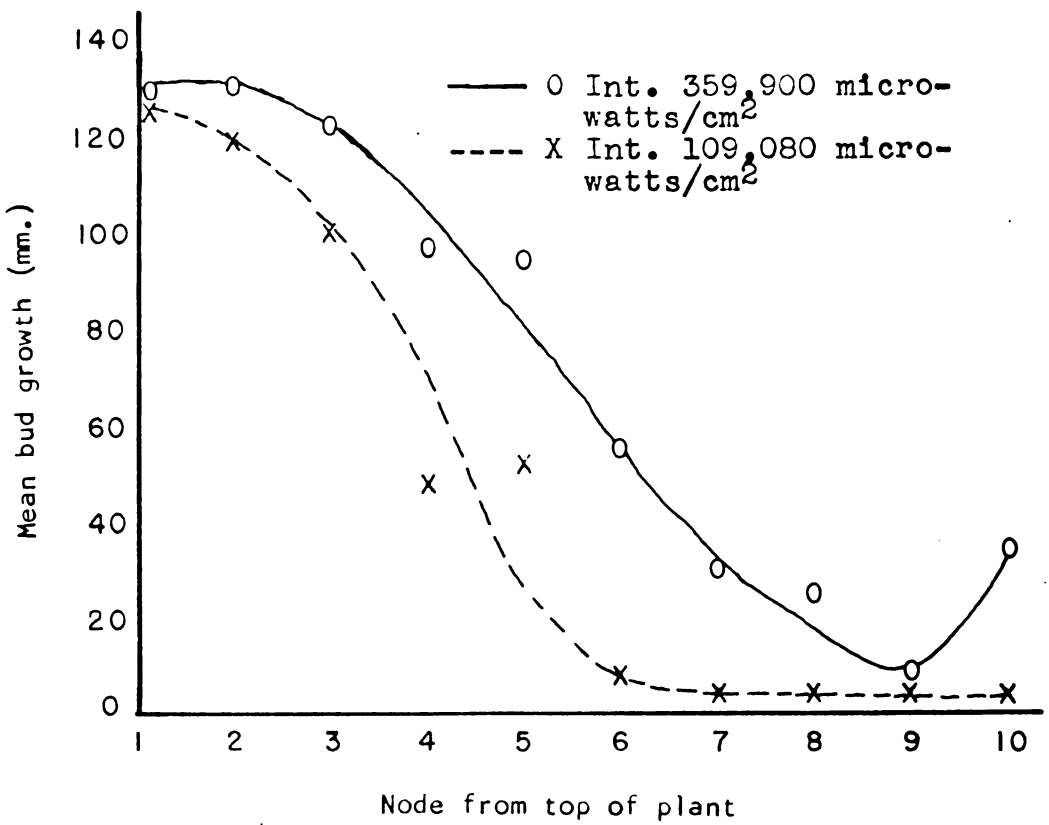

Figure 2 - Cultivar 'Mermaid' grown at two light intensities for 25 days.
The mean growth (6 plants) of the axillary buds at nodes 4, 6, and 7 significantly different at the 5% level by the F test.

TABLE 3.--Cultivar "Mermaid" exposed to short days (8 hr. photoperiods) and two light intensities (359,900 micro-watts/cm^2 vs. 109,080 micro-watts/cm^2) for 34 days.

Treatment	Mean axillary bud growth in mm.									
	Node from top of plant									
	1	2	3	4	5	6	7	8	9	10
High intensity	156[a]	160[a]	154[a]	142[a]	114[a]	75[a]	54[a]	65[a]	98[a]	89[a]
Low intensity	82[b]	87[b]	79[b]	34[b]	30[b]	10[b]	9[b]	9[b]	9[b]	9[b]

[a]Means (6 plants) within a column followed by different letters are significantly different at the 5% level by the F test.

increased growth at nodes 3 and 4 (Figure 4). However, with the blue spectrum, decreasing growth from node 1 through node 3 did not follow the usual curve (lesser differences in growth) for plants grown under white light. This curve was better illustrated by growth under the red spectrum. The use of red and blue spectra of higher intensities (32,100 micro-watts/cm^2 vs. 76,000 micro-watts/cm^2 respectively) obtained growth curves illustrated in Figure 5. Higher intensity of the blue spectrum produced more growth at every node with a different cultivar. The composition of the blue spectrum included other areas of the spectrum (Figure 7A, Appendix).

The use of two spectra which differed only in the infra-red (188, 350 micro-watts/cm^2 vs. 1350 micro-watts/cm^2) produced two different growth curves (Figure 6). The use of the infra-red spectrum induced excessive elongation at the top three nodes although there was less growth at nodes 7, 8, and 9. Excessive growth was noted again at the top three nodes with the use of a red spectrum (Figure 7). Spectrum, light intensity, and environmental factors were identical as with the plants treated in an earlier experiment (Figure 4) although another cultivar was used.

In an attempt to designate a particular portion of the plant as the initiator of growth stimulation or inhibition by light, two defoliation experiments were used. The two

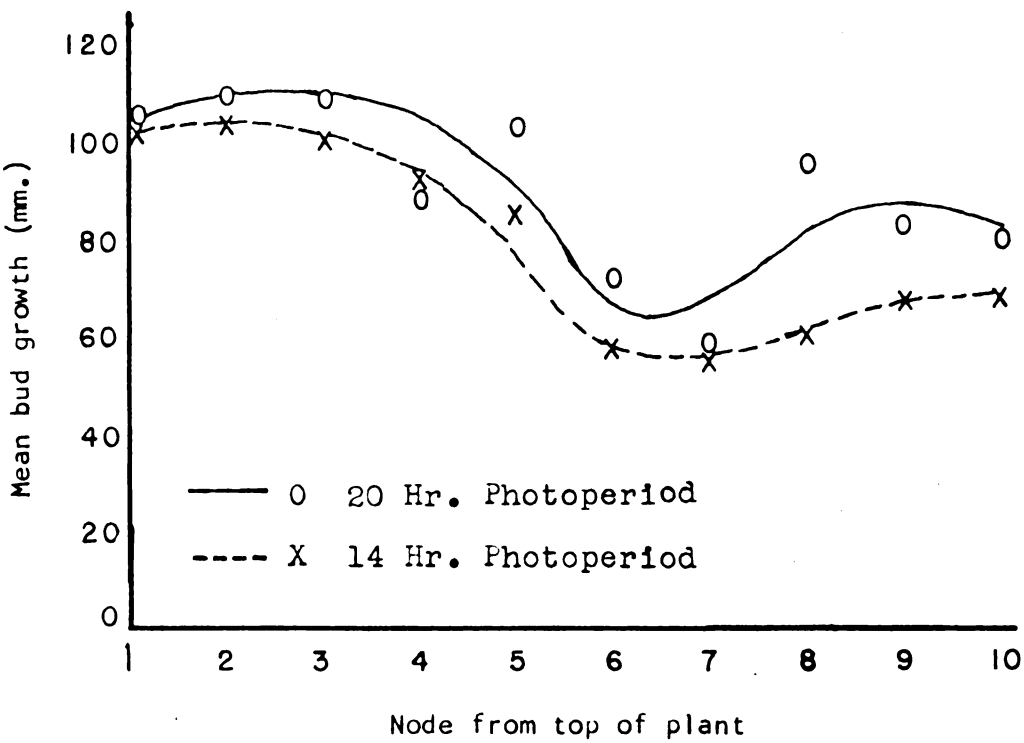

Figure 3 - Cultivar 'Mermaid' grown under 14 hr. and 20 hr. photoperiod for 20 days.
The mean growth (10 plants) of the axillary buds at nodes 5 and 8 significantly different at the 5% level by the F test.

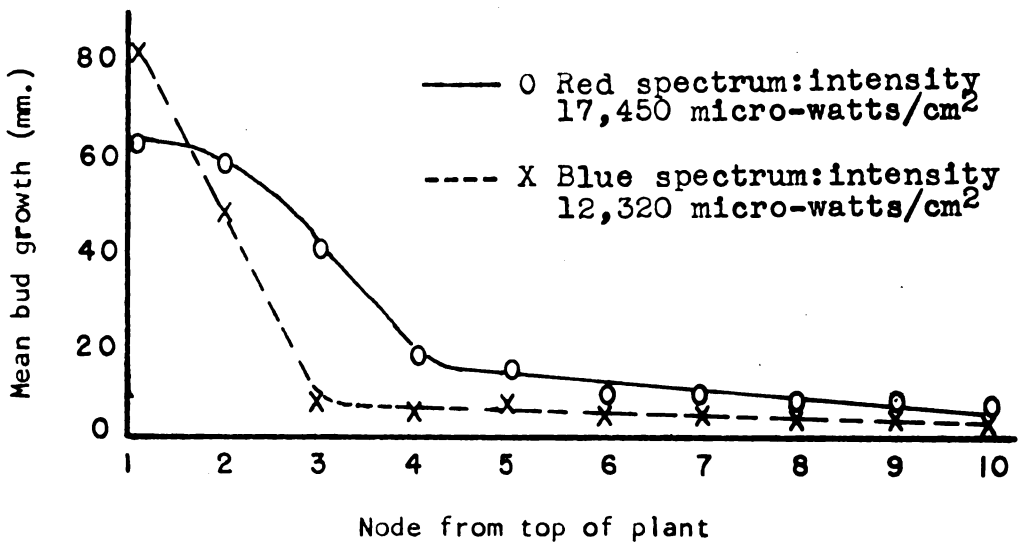

Figure 4 - Cultivar 'Winter Carnival' grown under two spectra for 21 days. Red spectrum (Figure 3A - Appendix); blue spectrum (Figure 2A - Appendix).
The mean growth (8 plants) of axillary buds at nodes 3 and 4 significantly different at the 5% level by the F test.

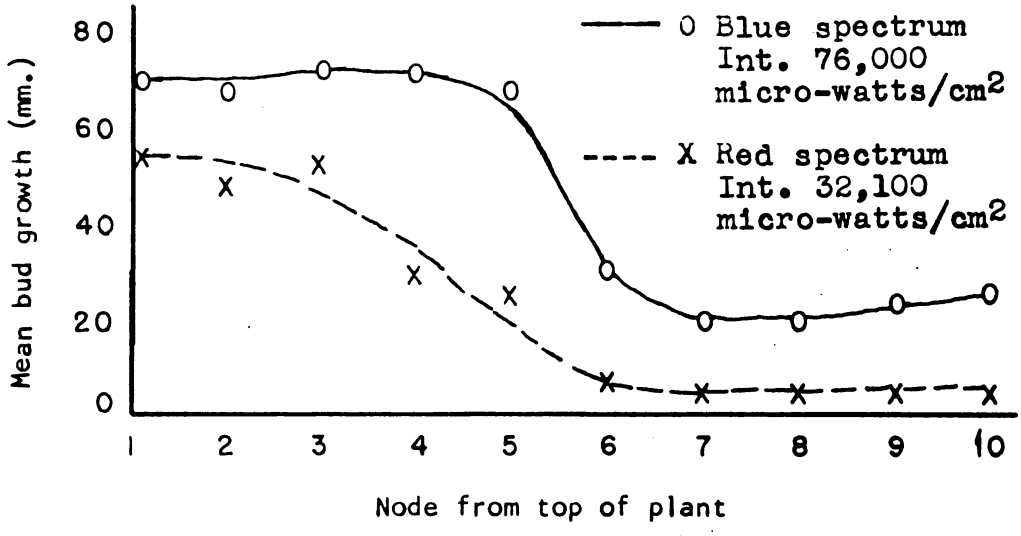

Figure 5 - Cultivar 'Stardust' grown under two spectra for 24 days. Red spectrum (Figure 6A - Appendix); blue spectrum (Figure 7A - Appendix).
The mean growth (10 plants) of the axillary buds at nodes 1 and 3 through 10 significantly different at the 5% level by the F test.

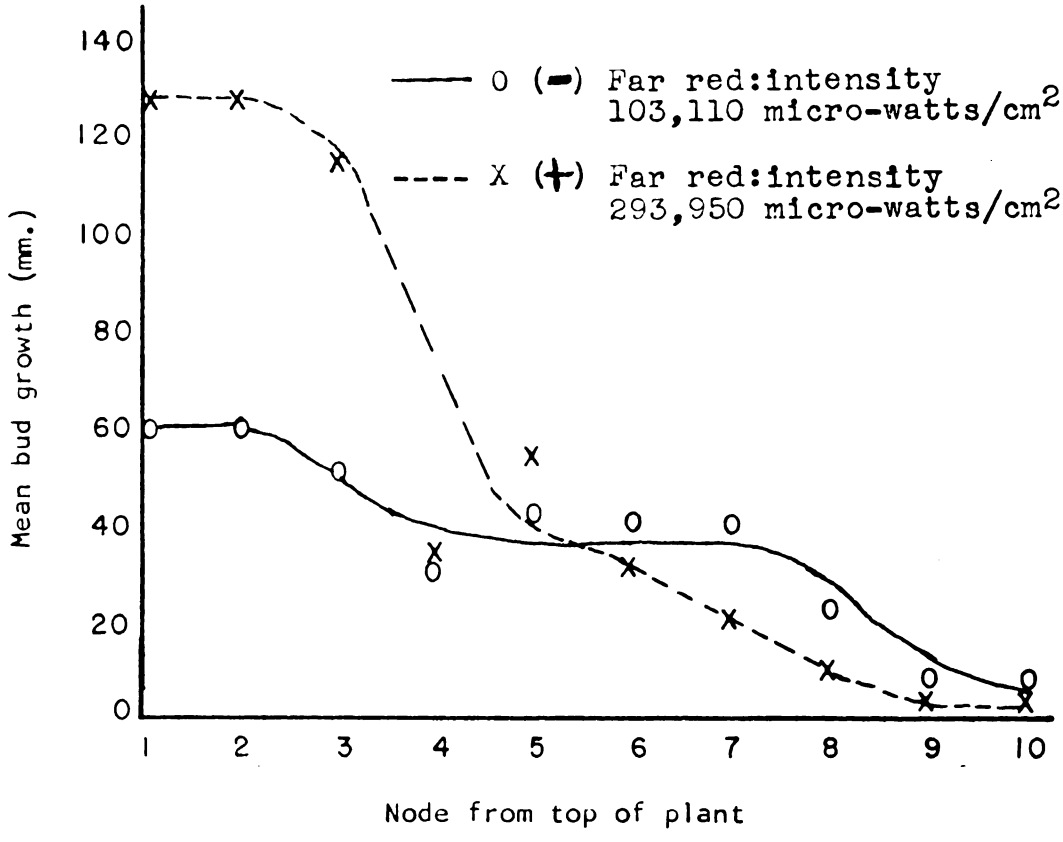

Figure 6 - Cultivar 'Bright Golden Anne' grown under two spectra for 18 days. (+) far red (Figure 4A - Appendix); (-) Far Red (Figure 5A - Appendix).
The mean growth (8 plants) of axillary buds at nodes 1, 2, 3, 7, 8, and 9 significantly different at the 5% level by the F test.

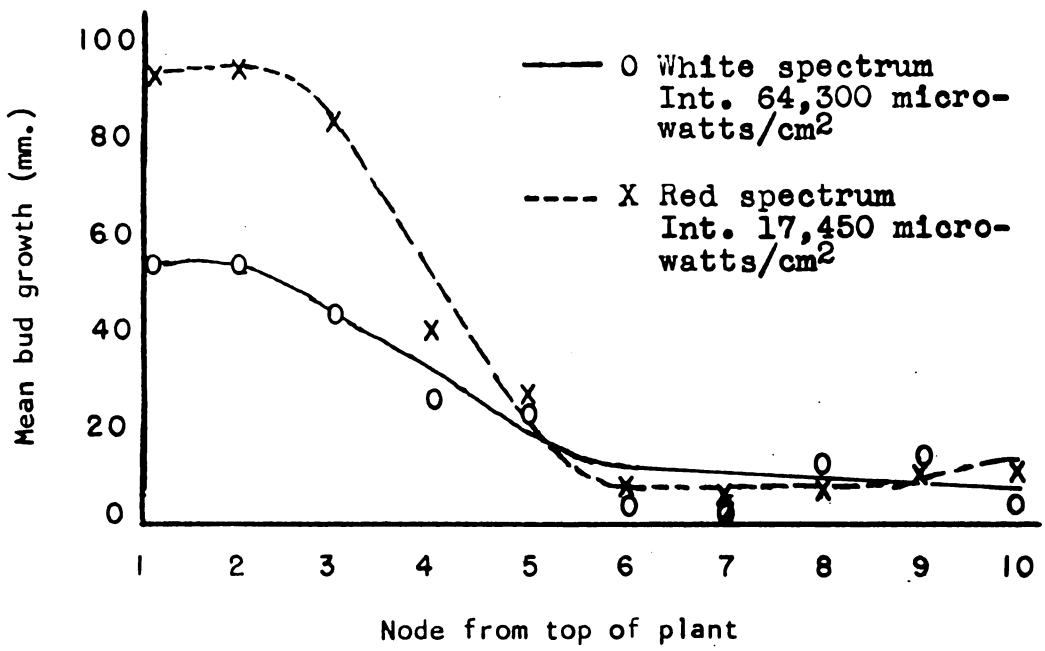

Figure 7 - Cultivar 'Mermaid' grown under two spectra for 21 days. Red spectrum (Figure 3A - Appendix); White spectrum (Figure 5A - Appendix).
The mean growth (10 plants) of axillary buds at nodes 1, 2, and 3 significantly different at the 5% level by the F test.

treatments of the first experiment restricted growth to the topmost five buds (Figure 8). Retaining the upper five leaves produced more growth in the top three buds with a steep decline in growth in buds 4 and 5. Growth was similar in buds 1 through 5 when all leaves were removed. Removal of the upper five leaves obtained comparable growth of axillary buds at 10 nodes (Figure 9). With a different cultivar, the growth curve--in comparison to the curve in Figure 8--was modified (less growth in buds 1 through 3, more growth in buds 6 through 9) when the lower five leaves were removed.

Investigations in the applied area (14, 68) have indicated nutrient influence in this problem. Using a 0.5X modified Hoagland solution induced differences in bud growth at nodes 2 and 3 (Figure 10). Use of 0.2X, 0.1X, and 0.05X solutions produced a corresponding decline in bud growth (Table 5). Buds at nodes 1 through 5 elongated when a 1.0X modified Hoagland was used; bud growth at the same node number declined progressively with decreasing concentration of the nutrient solution. At the 0.05X concentration, only buds 1 and 2 elongated.

Trial experiments attributed this growth decline to more than one element. Of the key elements tested, calcium and potassium decreased growth at nodes 1 through 5 (Table 6). Zinc, copper, and magnesium showed no significant growth decline until the fifth node.

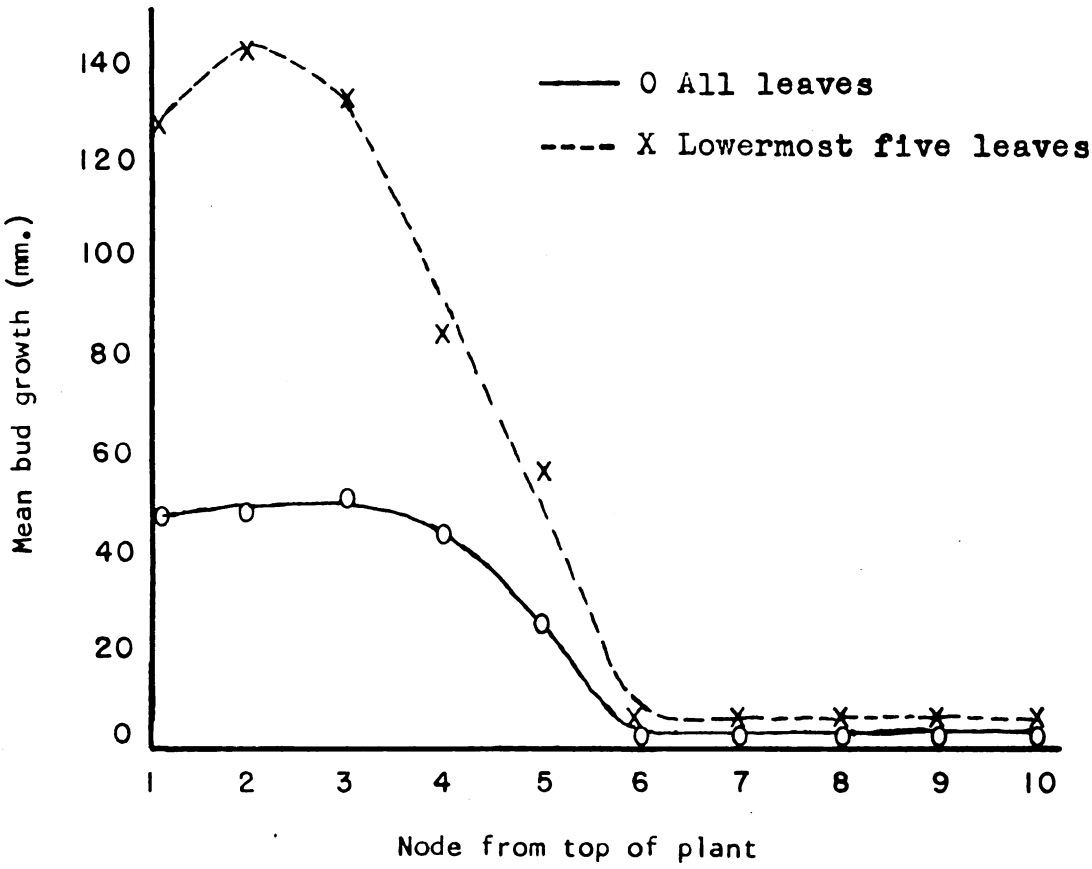

Figure 8 - Cultivar 'Winter Carnival' partially or fully defoliated and grown for 21 days.
The mean growth (5 plants) of the axillary buds at nodes 1, 2, and 3 significantly different at the 5% level by the F test.

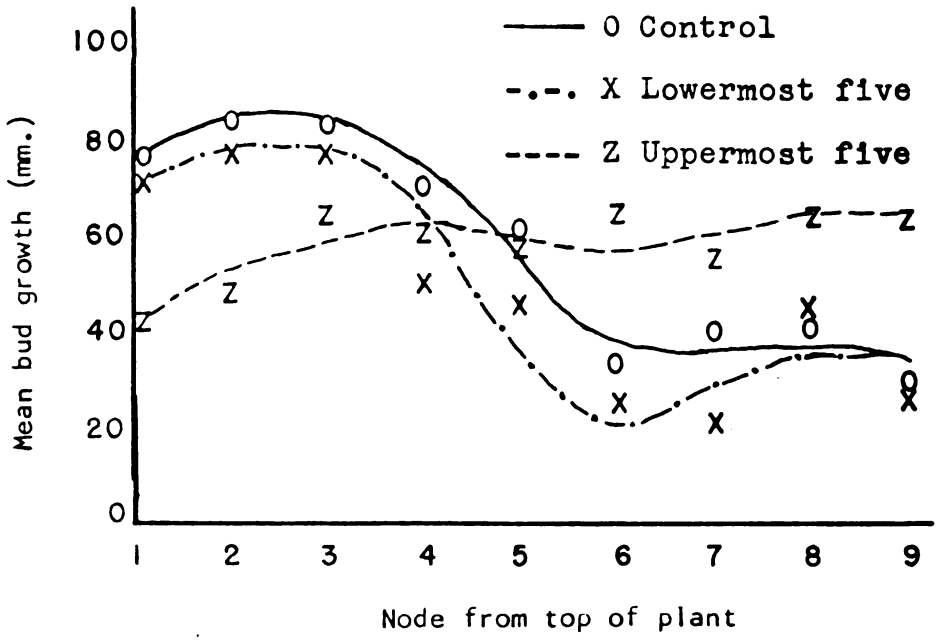

Figure 9 - Cultivar 'Mermaid' grown for 23 days with leaves removed as indicated.

TABLE 4.--Data analysis for Figure 9.

Orthogonal Comparison	Node from apex								
	1	2	3	4	5	6	7	8	9
Control vs lower 5 and upper 5	*	*	*	NS	NS	NS	NS	NS	NS
Lower 5 vs upper 5	*	*	*	NS	NS	NS	NS	NS	NS

*Means (6 plants) differ significantly within a column at the 5% level by the F test.

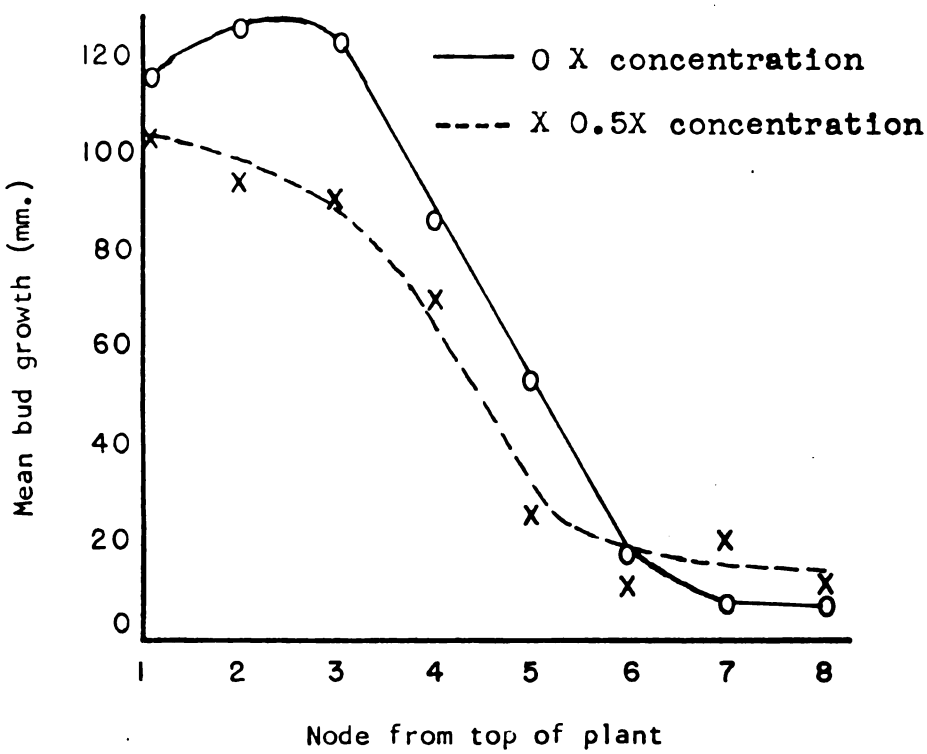

Figure 10 - Cultivar 'Winter Carnival' grown in nutrient solutions for 19 days.
The mean growth (9 plants) of axillary buds at nodes 2 and 3 significantly different at the 5% level by the F test.

TABLE 5.--Cultivar "Red Star" grown in nutrient solutions for 30 days.

Treatment	Mean axillary bud growth in mm.[a]							
	Node from top of plant							
	1	2	3	4	5	6	7	8
(A) X concentration	166	192	190	136	68	8	6	5
(B) 0.2X concentration	188	215	162	58	13	5	5	5
(C) 0.1X concentration	131	192	63	6	5	5	5	5
(D) 0.05x concentration	95	79	1	5	5	5	5	5
A vs. B through D	NS	**	**	**	**	*	NS	NS
B vs. C and D	**	**	**	*	NS	NS	NS	NS
C vs. D	NS	**	*	NS	NS	NS	NS	NS

[a]Each figure is the mean of 8 plants.

* and ** Orthogonal comparison significant within a column at the 5% or 1% level respectively by the F test.

TABLE 6.--Cultivar "Winter Carnival" grown in nutrient solutions for 18 days.

Treatment	Mean axillary bud growth in mm.[b]							
	Node from top of plant							
	1	2	3	4	5	6	7	8
Control[a] conc.	100	91	101	61	75	19	7	4
0.1 B conc.	105	109	91	46	47	6	4	2
-.Zn conc.	99	96	89	48	16**	17	3	2
0.1 Ca conc.	57**	58**	50**	13**	23**	9	5	4
0.05 Mg conc.	83	75	72	38	15	10	3	2
- Cu conc.	85	95	87	53	41*	13	4	1
0.1 K conc.	47**	36**	29**	10*	14**	2	1	2

[a]0.5X--Modified Hoagland solution.

[b]Each figure is a mean of 5 plants.

* and ** Mean differs significantly within a column from the control mean at the 5% or 1% level respectively by nonorthogonal F test.

Experiments covering the interaction of nutrition and light intensity demonstrated that increases in light intensity increased growth only at higher nutritional levels (Table 7). Significant differences were demonstrated at buds 1 through 3 with 1.0X and 0.2X modified Hoagland concentrations. There were no differences at the 0.05X concentration.

It has been a common observation for centuries that the relative availability of water can affect plant growth. An experiment designed to test the effect of reduced transpiration on axillary bud growth provided positive information. This experiment was run in the greenhouse with outside day temperatures above 90 F. Comparable growth of all buds was obtained when plants were grown under intermittent mist (Figure 11). Non-mist conditions produced more growth in the upper buds than in lower ones.

Since axillary bud growth was stimulated or inhibited by changes in light intensity, nutrition, or water relations, interactions between the three factors were determined. Under high soil nutritional conditions (fertilization rate at 1 oz. per 2 gallons water) an approximate increase in relative humidity from 65% to 80% produced more growth in buds 1 through 3 but affected growth little in the other buds (Table 8). Higher light intensity (909,700 micro-watts/cm^2) decreased growth in the top three buds but increased growth in buds 6 through

TABLE 7.--Cultivar "Red Star" grown in nutrient solutions for 35 days. Light intensity: high--226,230 micro-watts/cm^2; low--97,890 micro-watts/cm^2.

Treatment	Mean axillary bud growth in mm.						
	Node from top of plant						
	1	2	3	4	5	6	7
High light intensity-1.0X modified Hoagland	111[a]	114[a]	98[a]	36[a]	17[a]	3[a]	1[a]
Low light intensity-1.0X modified Hoagland	61[b]	58[b]	10[b]	3[a]	3[a]	2[a]	2[a]
High light intensity-0.2X modified Hoagland	98[a]	98[a]	91[a]	24[a]	20[a]	3[a]	1[a]
Low light intensity-0.2X modified Hoagland	40[b]	73[b]	30[b]	6[a]	3[a]	1[b]	1[a]
High light intensity-0.05X modified Hoagland	48[a]	68[a]	45[a]	11[a]	5[a]	2[a]	1[a]
Low light intensity-0.05X modified Hoagland	54[a]	61[a]	18[a]	3[a]	3[b]	1[a]	1[a]

[a]Means (6 plants) within each column of two figures followed by different letters are significantly different at the 5% level by the F test.

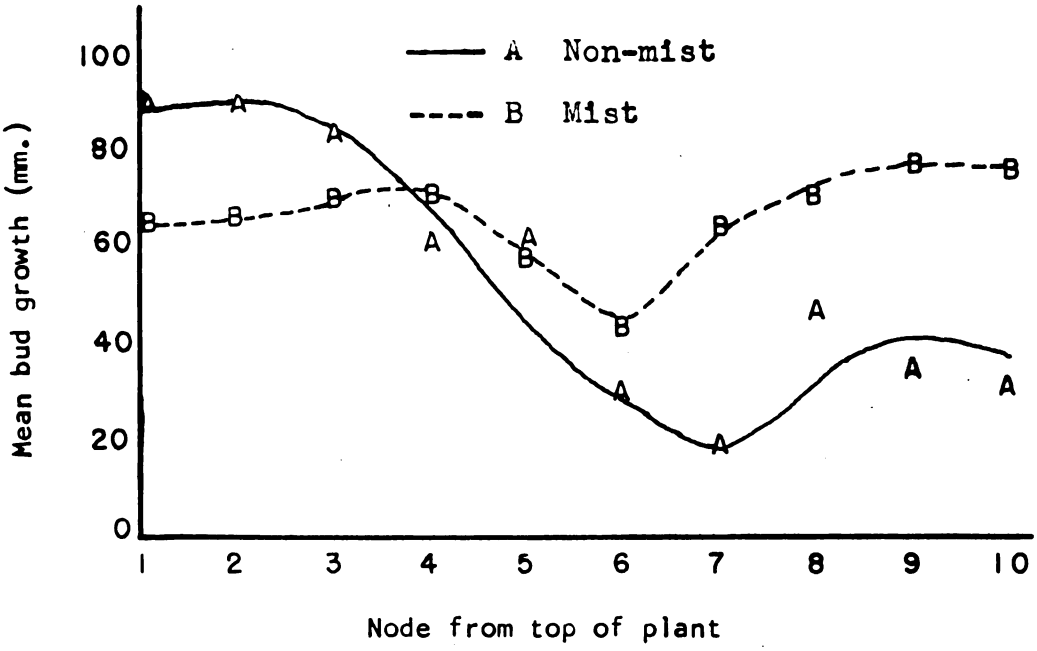

Figure 11 - Cultivar 'Mermaid' grown under intermittent mist and non-mist conditions for 21 days.
The mean growth (7 plants) of the axillary buds at nodes 2, 7, 8, and 9 significantly different at the 5% level by the F test.

TABLE 8.--Cultivar "Bright Golden Anne" grown under two relative humidities and four light intensities for 21 days.

Treatments All with fertilization rate 1 oz./2 gal. H_2O (25-5-20)	Mean axillary bud growth in mm.[a] Node from top of plant										Dry wt. per plant
	1	2	3	4	5	6	7	8	9	10	
(A) Int. 243,120 micro-watts/cm^2 Humidity 65% to 70%	128	123	117	84	90	44	42	27	5	3	1.48gm
(B) Int. 133,950 micro-watts/cm^2 Humidity 80% to 85%	144	140	141	86	75	60	42	10	5	3	1.31gm
(C) Int. 909,700 micro-watts/cm^2 Humidity 65% to 70%	96	101	98	88	80	68	90	47	18	6	3.14gm
(D) Int. 805,500 micro-watts/cm^2 Humidity 80% to 85%	132	134	135	115	102	119	133	37	26	35	3.23gm
A vs. B through D	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	
D vs. B and C	NS	NS	*	*	NS	*	*	NS	*	*	
B vs. C	**	**	**	NS	NS	NS	NS	**	NS	NS	

[a]Each figure is the mean of 6 plants.

* and **Orthogonal comparison significant within a column at the 5% or 1% level respectively by the F test.

9. With increases in both factors (80% relative humidity and 805,500 micro-watts/cm^2), significant increases in growth were observed at nodes 3, 4, 6, 7, 9, and 10.

Plants grown with low soil nutritional conditions (fertilization rate 1 oz. per 10 gal. water) produced an increase in growth in buds 1 and 2 with an increase in relative humidity (80%) (Table 9). The remaining buds were not affected. There was less growth in buds 1 through 3 under higher light intensity (898,700 micro-watts/cm^2) and no differences in growth at the remaining nodes. Increase in both factors (80% relative humidity and 805,500 micro-watts/cm^2) produced a growth decrease at node 2 and a growth increase only at node 6.

Various methods were used in attempting to correlate the environmental factors with a phyto-hormonal system. The excision of three combinations of axillary buds at nodes 2 through 5 showed significant increases in growth to the non-excised control at nodes 1 and 6 through 9 (Table 10). The excising of buds at nodes 2 through 5 versus bud excision at nodes 1 and 2 or 3 and 4 was also effective in increasing growth in buds 6, 7, and 8. No significance was found in excising buds at nodes 1 and 2 versus nodes 3 and 4.

Placing a notch above the axillary buds at nodes 5 and 7 stimulated growth in those buds whereas growth stimulation did not occur in buds at similar positions in

TABLE 9.--Cultivar "Bright Golden Anne" grown under two relative humidities and four light intensities for 21 days.

Treatments All with fertilization rate 1 oz./10 gal. H_2O (25-5-20)	Mean axillary bud growth in mm.[a] Node from top of plant										Dry wt. per plant
	1	2	3	4	5	6	7	8	9	10	
(A) Int. 243,100 micro-watts/cm^2 Humidity 65% to 70%	99	98	71	11	20	7	8	4	1	1	0.69gm.
(B) Int. 898,700 micro-watts/cm^2 Humidity 65% to 70%	68	68	59	21	14	8	9	3	1	1	1.03gm.
(C) Int. 133, 950 micro-watts/cm^2 Humidity 80% to 85%	114	111	70	32	29	8	7	5	2	3	0.69gm.
(D) Int. 805,500 micro-watts/cm^2 Humidity 80% to 85%	79	70	58	23	25	19	18	7	3	1	0.88gm.
A vs. B through D	NS	*	NS	*	NS	NS	NS	NS	NS	NS	
D vs. B and C	NS	**	NS	NS	NS	**	NS	NS	NS	NS	
B vs. C	**	**	NS	NS	NS	NS	NS	NS	NS	NS	

[a]Each figure the mean of 6 plants.

* and **Orthogonal comparison significant within a column at the 5% or 1% level respectively by the F test.

TABLE 10.--Cultivar "Winter Carnival" grown for 20 days with buds excised as indicated.

Treatment	Mean axillary bud growth in mm.[a]								
	Node from top of plant								
	1	2	3	4	5	6	7	8	9
(A) Control	124	133	153	161	113	16	7	14	5
(B) Excise buds 2, 3, 4, 5	95					109	89	86	43
(C) Excise buds 3, 4	101	120			125	78	25	36	23
(D) Excise buds 1,2			135	136	115	79	49	18	21
A vs. B through D	*	NS	NS	NS	NS	*	*	*	*
B vs. C and/or D	NS					*	*	*	*
C vs. D					NS	NS	NS	NS	NS

[a]Each figure is a mean of 9 plants.

*Orthogonal comparison significant within a column at the 5% level by the F test.

control plants (Table 11). Notching decreased total growth of plants. Differences in cultivars were noted in changing the gravitational orientation of the main stem (Tables 12 and 13). No significant growth changes were obtained with cultivar "Red Star"; while there were growth increases with "Mermaid" at nodes 1, 4, and 6 and more total growth in the upright-grown plants versus the horizontal-grown plants.

Indoleacetic acid (IAA) in lanolin (1 mg., 10 mg., and 100 mg. per gram lanolin) placed on the tip of the plant inhibited the growth of axillary buds (Table 14). Increases from 1 mg. IAA to 10 mg. and 100 mg. per gram lanolin gave no significant increases in inhibition whereas the increase from 10 mg. IAA to 100 mg. stimulated growth at nodes 4 and 6.

Dipping the top 5 leaves in N^6 benzyl adenine (100 ppm.), Anchem #66-329 (2000 ppm.), and B995 (5000 ppm.) inhibited growth in buds 1 through 4 (Table 15). There was no increase in growth in the lower buds. The use of other selected growth regulators by spray or dip technique gave no significant results (Tables 2A, 3A, 4A; Appendix).

IAA (10^{-2}M, 10^{-4}M, 10^{-7}M), gibberellic acid (GA) (10^{-2}M, 10^{-4}M, 10^{-6}M) and indolebutyric acid (IBA) (10^{-3}M, 10^{-7}M) in lanolin placed on the tip of the pinched plant gave little significance in either inhibition or stimulation (Table 16). With GA (10^{-2}M), growth stimulation was noted at nodes 1 and 3 and with GA (10^{-4}) at node 1. IBA (10^{-7}M) also stimulated growth at nodes 3 and 7.

TABLE 11.--Cultivar "Red Star" notched above buds 3, 5, and 7 and grown for 19 days.

Treatment	Mean axillary bud growth in mm.[b]							
	Node from top of plant							
	1	2	3	4	5	6	7	8
(A) Pinched and unnotched	128	128	141	91	13	5	5	16
(B) Pinched and notched	80	42	75	5	55	13	121	1
(C) Unpinched[a] and notched	22	5	103	10	93	12	102	26
A vs. B and C	*	**	*	**	*	NS	**	NS
B vs. C	NS	NS	NS	NS	NS	NS	NS	NS

[a]Terminal growth continued in the unpinched plants.

[b]Each figure is the mean of 4 plants.

* and **Orthogonal comparison significant within a column at the 5% and 1% level respectively by the F test.

TABLE 12.--Cultivar "Red Star" placed on sub-irrigation bench filled with sand, and grown for 25 days.

Treatment	Mean axillary bud growth in mm.						
	Node from top of plant						
	1	2	3	4	5	6	7
Grown upright	110[a]	115[a]	115[a]	95[a]	35[a]	24[a]	12[a]
Grown horizontal	123[a]	128[a]	128[a]	80[a]	23[a]	9[a]	6[a]

[a]Mean (6 plants) within a column followed by different letters are significantly different at the 5% level by the F test.

TABLE 13.--Cultivar "Mermaid" placed on a sub-irrigation bench filled with sand, and grown for 25 days.

Treatment	Mean axillary bud growth in mm.								
	Node from top of plant								
	1	2	3	4	5	6	7	8	9
Grown upright	113[a]	113[a]	113[a]	101[a]	105[a]	43[a]	24[a]	23[a]	15[a]
Grown horizontal	100[a]	101[a]	100[a]	86[b]	78[a]	5[b]	5[a]	5[a]	7[a]

[a]Means (6 plants) within a column followed by different letters are significantly different at the 5% level by the F test.

TABLE 14.--Cultivar "Red Star" treated with IAA-lanolin paste placed on the tip of the pinched plant, and grown for 16 days.

Treatment	Mean axillary bud growth in mm.[a]							
	Node from top of plant							
	1	2	3	4	5	6	7	8
(A) No lanolin	66	76	78	58	35	5	5	5
(B) 1 mg. IAA/gm. lanolin	36	50	39	36	7	5	5	5
(C) 10 mg. IAA/gm. lanolin	26	37	44	14	7	5	5	5
(D) 100 mg. IAA/gm. lanolin	28	38	43	35	11	16	5	5
A vs. B through D	**	**	**	**	**	NS	NS	NS
B vs. C and D	NS	NS	NS	NS	NS	*	NS	NS
C vs. D	NS	NS	NS	*	NS	**	NS	NS

[a]Each figure is the mean of 8 plants.

* and **Orthogonal comparison significant within a column at the 5% level respectively by the F test.

TABLE 15.--Cultivar "Mermaid" treated on pinch date and twice at 4-day intervals, and grown for 20 days.

Treatment	Mean axillary bud growth in mm.[a]								
	Node from top of plant								
	1	2	3	4	5	6	7	8	9
Not dipped	102	100	97	78	66	28	38	45	42
N^6BA-100 ppm.	61**	56**	61*	59	56	36	29	28	22
Anchem #66-329 2000 ppm.	69**	73*	67*	51*	57	23	31	46	11*
B995-5000 ppm.	66**	67*	59**	46*	47	35	8	38	28

[a]Each figure is the mean of 8 plants.

* and **Mean differs significantly within a column from the control mean at the 5% or 1% level respectively by non-orthogonal comparison F test.

TABLE 16.--Cultivar "Bright Golden Anne" treated with lanolin-chemical paste placed on the tip of the pinched plant and grown for 20 days.

Treatment	Mean axillary bud growth in mm.[a]									
	Node from top of plant									
	1	2	3	4	5	6	7	8	9	10
Control	64	69	61	57	64	56	57	36	15	5
IAA-10^{-2}M	60	59	64	59	67	50	61	32	13	3
IAA-10^{-4}M	71	71	68	72	70	65	68	39	9	6
IAA-10^{-7}M	73	76	72	70	75	47	75	23	7	3
GA -10^{-2}M	82*	80	76*	74	78	65	79	28	16	5
GA -10^{-4}M	79*	78	72	68	74	54	68	31	11	3
GA -10^{-6}M	70	70	64	63	57	52	67	41	22	5
IBA-10^{-3}M	64	58	63	63	70	54	80	18	12	5
IBA-10^{-7}M	73	80	75*	65	76	60	83*	40	11	6

[a]Each figure is the mean of 6 plants.

*Mean differs significantly within a column from the control mean at the 5% level by non-orthogonal comparison F test.

The growth regulators (same materials noted in the preceding paragraph) had inhibitory and stimulatory effects when placed in notches above buds at nodes 6, 8, and 10. (Table 17). IAA (10^{-2}M) inhibited growth in buds 8 and 10. Lower IAA concentrations had no effect at these nodes although IAA (10^{-7}M) gave stimulation at node 4. GA (10^{-4}M) stimulated growth at nodes 2, 4, and 5, while IBA (10^{-3}M) was effective in inhibiting growth at nodes 6, 8, and 10. No consistent pattern emerges with similar use of a number of other chemicals (Table 18). Only IBA (10^{-3}M) gave consistent inhibition at all nodes in the area where plants were treated.

Differences were noted between lanolin-chemical placement on the tip of the pinched plant (Table 19) or in notches above axillary buds at nodes 6, 8, and 10 (Table 20). When Alanap (N-1-naphthyl phthalamic acid) (10^{-2}) was placed on the plant tip, growth was inhibited at nodes 1 and 2 and stimulated at nodes 8 and 9. With notch placement, it inhibited at nodes 1, 2, 3, 5, and stimulated at nodes 7 and 9. 2, 4-Dichlorophenoxyacetic acid (10^{-2}M) inhibited at nodes 1 and 2 with tip placement and inhibited at nodes 3, 4, 5, 6, 8, and 10 with notch placement. Dichloropropionic acid (10^{-4}M and 10^{-6}M) caused inhibition at two nodes with tip placement. Alanap (10^{-4}M) induced inhibition at node 5 and stimulation at node 9. These responses were with notch placement.

TABLE 17.--Cultivar "Bright Golden Anne" notched above buds 6, 8, and 10. Lanolin-chemical paste placed in notches and plants grown for 20 days.

Treatment	Mean axillary bud growth in mm.[a]									
	Node from top of plant									
	1	2	3	4	5	6	7	8	9	10
Control	56	62	43	40	42	76	47	87	24	63
IAA-10^{-2}M	55	62	45	48	48	64	33	57**	7	31*
IAA-10^{-4}M	56	70	47	56	55	63	54	80	21	55
IAA-10^{-7}M	58	67	44	65**	60	77	69	90	20	56
GA -10^{-2}M	65	70	45	56	46	75	58	91	13	50
GA -10^{-4}M	60	75*	43	63**	64*	93	67	85	29	65
GA -10^{-6}M	51	59	39	54	42	76	45	74	18	54
GA -10^{-8}M	50	59	27*	60*	49	73	64	71	22	55
IBA-10^{-3}M	53	59	30	30	23	40**	37	23**	3	4**
IBA-10^{-7}M	53	71	51	59*	55	80	49	84	32	60
Pure lanolin	55	65	37	65**	55	75	50	63*	10	51

[a]Each figure is the mean of 6 plants.

* and **Mean differs significantly within a column from the control mean at the 5% and 1% level respectively by non-orthogonal comparison F test.

TABLE 18.--Cultivar "Winter Carnival" notched above buds 7, 9, and 11. Lanolin-chemical paste placed in notches and plants grown for 14 days.

Treatment	Mean axillary bud growth in mm.[c]						
	Node from top of plant						
	6	7	8	9	10	11	12
Control	30	40	9	43	5	26	3
Thiouracil 9 x 10^{-3}M	21	40	11	43	8	37	4
Gibberellic Acid--1.2 x 10^{-2}M	25	52	12	47	6	38	3
N^6Benzyl Adenine--6.2 x 10^{-5}M	30	53	14	57	5	40	2
Dichloro-Anisole--2.8 x 10^{-3}M	13*	57	13	33	15*	43	2
IAA --2.8 x 10^{-6}M	7**	54	8	29	7	36	3
IAA --2.8 x 10^{-4}M	7**	51	16	33	3	32	1
IBA --1 x 10^{-3}M	3**	6**	3	1**	1	1**	1
[a]N^6BA+IAA, 2.8 x 10^{-6}M	19	60	16	50	7	47*	2
Anchem 67-109-1350 ppm.	22	61	10	50	4	45*	1
Anchem 66-329-1350 ppm.	19	56	17	47	14*	40	12*
Triiodobenzoic Acid--1 x 10^{-3}M	13*	28	17	20	17**	35	9
[a]N^6BA+[b]GA	11**	75	10	60	4	56**	3
2, 4-Dinitrophenol--1 x 10^{-3}M	11**	35	17	40	36**	50*	0
[a]N^6BA+IAA, 2.8 x 10^{-4}M	20	55	7	49	5	42	1

[a]N^6BA conc., 6.2 x 10^{-5}M

[b]GA conc., 1.2 x 10^{-2}M

[c]Each figure is the mean of 6 plants.

* and **Mean differs significantly within a column from the control mean at the 5% or 1% level respectively by non-orthogonal comparison F test.

TABLE 19.--Cultivar "Bright Golden Anne" treated with lanolin-chemical paste placed on the tip of the pinched plant and plants grown for 20 days.

Treatment	Mean axillary bud growth in mm.[d]									
	Node from top of plant									
	1	2	3	4	5	6	7	8	9	10
Control	105	95	85	56	62	34	47	22	6	4
[a]Alanap-10^{-2}M	41**	63*	71	69	63	56	75	60**	27**	4
Alanap-10^{-4}M	93	78	85	64	69	59	73	25	6	2
Alanap-10^{-6}M	83	72	75	52	59	56	63	22	6	1
[b]2, 4-D-10^{-2}M	10**	35**	69	80	71	54	60	27	3	1
2, 4-D-10^{-4}M	86	74	76	63	50	54	31	17	4	1
2, 4-D-10^{-6}M	88	83	70	50	60	40	24	18	4	2
[c]DPA -10^{-2}M	83	96	87	55	55	35	31	9	4	1
DPA -10^{-4}M	94	76	65*	62	57	42	44	21	2	2
DPA -10^{-6}M	67**	76	86	71	70	50	40	21	6	3

[a]N-1-Naphthyl phthalamic acid.

[b]2, 4-Dichlorophenoxyacetic acid.

[c]Dichloropropionic acid.

[d]Each figure is the mean of 6 plants.

* and **Mean differs significantly within a column from the control mean at the 5% or 1% level respectively by non-orthogonal comparison F test.

TABLE 20.--Cultivar "Bright Golden Anne" notched above buds 6, 8, and 10. Lanolin-chemical paste placed in notches and plants grown for 20 days.

Treatment	Mean axillary bud growth in mm.[d]									
	Node from top of plant									
	1	2	3	4	5	6	7	8	9	10
Control	67	80	47	69	65	81	35	79	8	43
[a]Alanap-10^{-2}M	40**	45**	21**	44	26**	55	66*	34*	43**	40
Alanap-10^{-4}M	62	70	30	45	36*	72	47	73	32	49
Alanap-10^{-6}M	75	85	55	69	61	82	40	84	18	74*
[b]2, 4-D-10^{-2}M	71	70	9**	3**	3**	5**	27	5**	7	12*
2, 4-D-10^{-4}M	74	75	50	60	40	82	36	84	17	48
2, 4-D-10^{-6}M	65	70	41	47	46	74	45	67	23	46
[c]DPA -10^{-2}M	60	73	37	64	40	70	30	76	13	59
DPA -10^{-4}M	72	79	45	50	52	66	33	84	10	39
DPA -10^{-6}M	69	75	46	42	49	60	43	71	9	50

[a]N-1-Naphthyl phthalamic acid.

[b]2, 4-Dichlorophenoxyacetic acid.

[c]Dichloropropionic acid. [d]Each figure is the mean of 6 plants.

* and **Mean differs significantly within a column from the control mean at the 5% or 1% level respectively by non-orthogonal comparison F test.

DISCUSSION

A temperature difference of 15° (50 F - 65 F) increased bud elongation at nodes 1 through 3. A similar temperature trend was noted when the inhibitory effect of low light intensity was reduced by temperature increase (65 F - 80 F) and more growth occurred in the upper axillary buds. These temperature experiments indicated that the influence of temperature was confined to the upper portion of the plant.

The data (Figure 6) supported Went's theory of red etiolation (67); however, this effect occurred at nodes 1 through 3.

The use of red wave lengths or excessive amounts of the red spectrum obtained a growth curve which showed a steep decline at nodes 4 and 5. Growth initiated by the use of blue or white light produced a more gentle slope in the curve at this particular region with variations depending upon light intensity and cultivar. Increase in temperature and use of the red spectrum demonstrated a similar effect--stimulation of growth in the top three buds and no increase of growth in the lower buds.

Post (45) observed an increased number of axillary buds initiating growth when the time between pinch and

short days was reduced. This has not been supported (Table 1A, Appendix). A possible explanation for the disagreement is shown (Table 3). High intensity data agreed with his observations; low intensity did not. Short days induced flowering and the upper buds were non-inhibitive; therefore uninhibited axillary buds were dependent upon other factors for increased growth. High light intensity enhanced the capacity for growth.

Added support against photoperiodic involvement was indicated by small differences in growth between 14 hr. and 20 hr. photoperiods. The data agreed with the results of Kwack and Dunn (32), although they observed greater differences in growth.

In contrast to small differences with increase in photoperiod, greater changes in growth were obtained by selective defoliation. The similar growth curve produced by removal of five lowermost leaves and of no leaves (control) suggested that top leaves determined the comparative growth of upper and lower buds. Removal of the five topmost leaves added support to this theory. These data also suggested some basic difference between top and bottom leaves. Younger leaves are more efficient in photosynthesis and roots utilize sucrose from the basal portion; therefore, uppermost buds may be closer to a constant source of organic compounds. A second basic difference might have been the production of auxin and its influence on sucrose movement

(8, 72). Excision of upper leaves removed a major source of auxin in the top portion of the plant. Loss of this auxin influence retained more sucrose in the lower portion; hence, more growth there.

The data did not support Kwack and Dunn's (32) work with nutrient concentrations. There were small growth differences at 1.0X modified Hoagland concentration vs. 0.5X concentration; however, the growth differences became greater as the discrepancy between concentrations increased. Especially relevant was the growth of more axillary buds in a basipetal direction as the nutrient concentration increased. The nutrient concentration effect can be attributed to one or a combination of elements in low supply (Table 5).

In the interaction of nutrition and light intensity, certain limiting factors developed. When nutrition was not limiting, a response was obtained by increasing light intensity; at low nutrient levels (0.05X modified Hoagland) no growth increase was noted with light intensity increase.

The involvement of plant-water relations was illustrated (Figure 11). Since a part of the growth period coincided with very hot weather, the response might have been different with cooler temperatures.

The interactions between nutrition, light intensity, and humidity have been especially interesting. At low soil nutritional levels, increased light intensity decreased

overall elongation with a corresponding increase in dry weight (Table 7). Under high soil nutritional conditions with increasing light intensity, there was less growth at the top three nodes; however, a growth increase occurred at nodes 6, 7, and 8 and an increase in dry weight was noted. It appeared that under both nutritional regimes the main effect of increased humidity was increased elongation in the uppermost three buds.

Growth curves of treatments 2 and 3 (Table 8) closely paralleled growth curves expected by commercial growers under midwinter and midsummer environmental conditions. Winter conditions of low intensity and high relative humidity produced more top and less bottom growth. Summer conditions reversed these two factors with resultant increase in bottom growth.

Results from Table 9 added support to Gregory and Veale's (18) theory of nutrient control. The observed growth of basal buds with the excision of upper buds indicated a transfer of growth factors to the basal portion of the plant. The excision of buds 1 and 2 vs. buds 3 and 4 produced no significant differences and tended to indicate that growth substances synthesized by particular upper buds was not a critical factor. The translocation distance also had little effect and the conclusions indicated nutrient control. However, the notching results (Table 10) suggested a phyto-hormonal mechanism since it worked equally well with pinched or unpinched plants.

Data in Table 13 showed that IAA applied to the tip of the plant inhibited axillary bud growth and agreed with other investigators (12, 17, 25, 34, 36, 50, 62, 63, 66). Data in Table 13 did not agree with those in Table 15 where no inhibition occurred with IAA (10^{-2}M), a comparable concentration with 1 mg. per gm. lanolin (Table 13). Data in Table 13 were taken in midwinter while those of Tables 15 and 16 were taken in midsummer. An explanation for the discrepancy might be attributed to Sachs and Thimann's (47) suggestion that a growing apex is less sensitive to correlative inhibition. In this response, the growth rate regulated the sensitivity.

Data from Table 16 indicated inhibition in basal buds with notched plants when using lanolin-IAA (10^{-2}M) and lanolin-IBA (10^{-3}M) in the notches. If it is assumed that basal buds had a slower growth rate, the explanation would still be valid. Since these growth substances did not inhibit basal buds with tip placement, it appeared that transport in inhibitive concentrations did not occur in a basipetal direction.

The response received from Alanap (10^{-2}M) (Table 18) indicated two possibilities: (1) inhibition of the upper buds and stimulation of the lower ones; (2) by the significant inhibition of the upper buds, there was a translocation of growth factors to lower buds resulting in growth. The first possibility was eliminated by inspection of the raw

data. The response was uniform; if there was more inhibition at nodes 1 and 2, there was more growth at 8 and 9. Less inhibition at 1 and 2 produced less growth at 8 and 9. 2, 4-Dichlorophenoxyacetic acid (2, 4-D) inhibited at the first 2 nodes, but a growth increase was not observed in basal protions. Total growth was less than the control with all concentrations of 2, 4-D.

With notch placement (Table 19), acropetal transport of Alanap and 2, 4-D occurred readily although it did not occur beyond three nodes with 2, 4-D. The growth stimulation at nodes 7 and 9 with Alanap (10^{-2}M) placed below these nodes cannot be explained since no stimulation occurred at node 5 with Alanap (10^{-2}M) in a similar position.

SUMMARY

The data indicated that the number of axillary buds which elongate following terminal tip detachment was dependent upon the environmental factors existing during the growth period. This did not account for the variation between cultivars. The response by all cultivars was reasonably uniform to changes in environmental factors. This observation indicated that the efficiency of overall plant growth processes would explain the difference between cultivars relative to the number of axillary buds which grow.

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APPENDIX

TABLE 1A.--Cultivar "Bronze Princess Anne" exposed to variable daylength for 26 days.

Treatment	Mean axillary bud growth in mm.									
	Node from top of plant									
	1	2	3	4	5	6	7	8	9	10
Short days--8 hr. photoperiod	138[a]	150[a]	144[a]	120[a]	95[a]	21[a]	13[a]	5[a]	4[a]	3[a]
Long days-- 16 hr. photoperiod	153[a]	149[a]	143[a]	85[a]	65[a]	10[a]	5[a]	5[a]	5[a]	5[a]

[a]Means (10 plants) within a column followed by different letters are significantly different at the 5% level by the F test.

TABLE 2A.--Cultivar "Hurricane" treated on pinch date and twice at 5-day intervals, and grown for 25 days.

Treatment--Top 5 leaves immersed	Mean axillary bud growth in mm.[a]							
	Node from top of plant							
	1	2	3	4	5	6	7	8
Not dipped	146	135	100	35	45	7	9	5
IAA--20 ppm.	94*	122	86	58	66	24	18	21
GA--75%K--20 ppm.	113	131	103	46	51	22	8	2
Kinetin--20 ppm.	113	121	100	51	50	8	6	26

[a]Each figure is the mean of 8 plants.

*Mean differs significantly within a column from the control mean at the 5% level by non-orthogonal comparison F test.

TABLE 3A.--Cultivar "Orchid Queen" treated by spraying and grown for 20 days.

Treatment	Mean axillary bud growth in mm.[a]							
	Node from top of plant							
	1	2	3	4	5	6	7	8
No spray	53	81	71	30	14	6	6	5
N^6BA--20 ppm.	69	93	87	32	15	9	7	8
Kinetin--20 ppm.	58	69	52	25	9	7	6	5
GA--75% K--20 ppm.	66	84	55	22	13	7	7	5
IAA--100 ppm.	83*	93	70	27	5	7	5	5

[a]Each figure is the mean of 6 plants.

*Mean differs significantly within a column from the control mean at the 5% level by non-orthogonal comparison F test.

TABLE 4A.--Cultivar "Mermaid treated by spraying at pinch and twice at 3-day intervals, and grown for 20 days.

Treatment	Mean axillary bud growth in mm.[a]									
	Node from top of plant									
	1	2	3	4	5	6	7	8	9	10
No spray	74	76	79	75	73	34	22	14	21	43
Kinetin--1 ppm.	76	78	79	75	55	41	17	18	33	27
N^6BA--1 ppm.	79	78	74	72	55	25	20	28	37	34
GA + N^6BA	75	77	76	66	68	33	5	9	40	40
GA--75%K--0.1 ppm.	82	90	85	73	60	16	15	20	30	47
IAA--0.01 ppm.	70	77	79	64	64	19	12	22	26	27

[a]Each figure is the mean of 6 plants.

No significance between means within a column by non-orthogonal comparison F test.

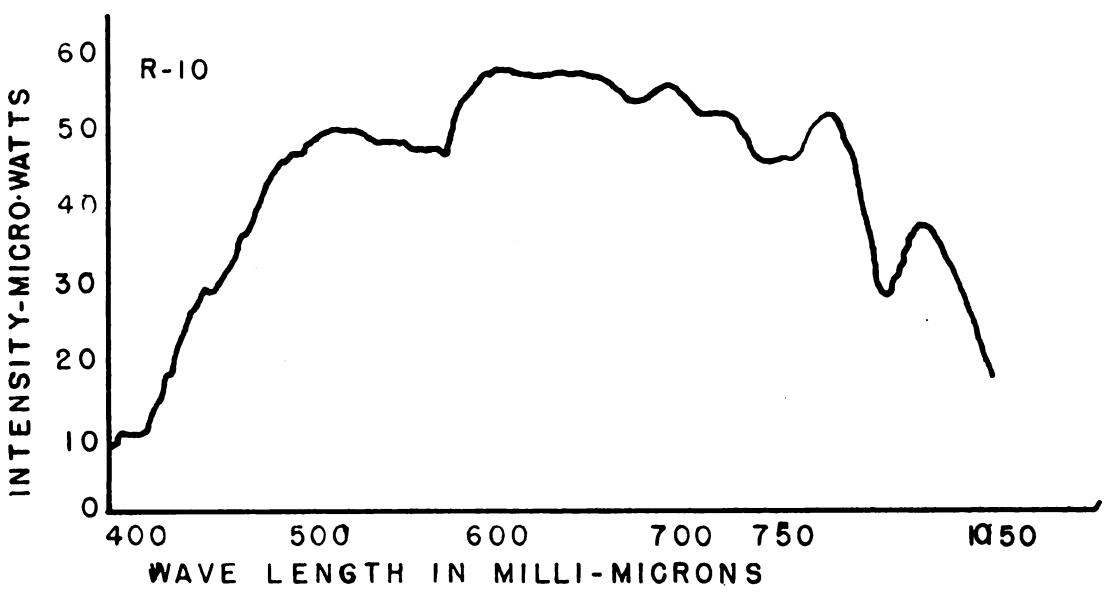

Figure 1 A - Typical light spectrum as recorded in a greenhouse at noon on a bright day in August.

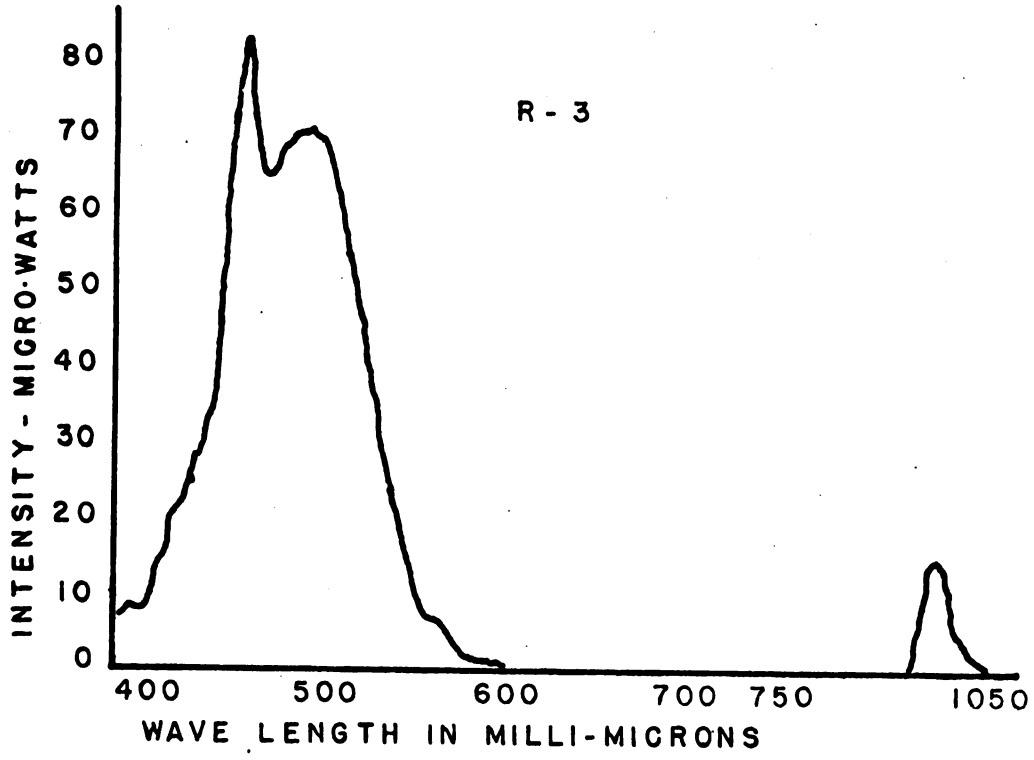

Figure 2 A - Light spectrum resulting from the use of cool white fluorescent tubes with a blue Rohm and Haas (2424) filter.

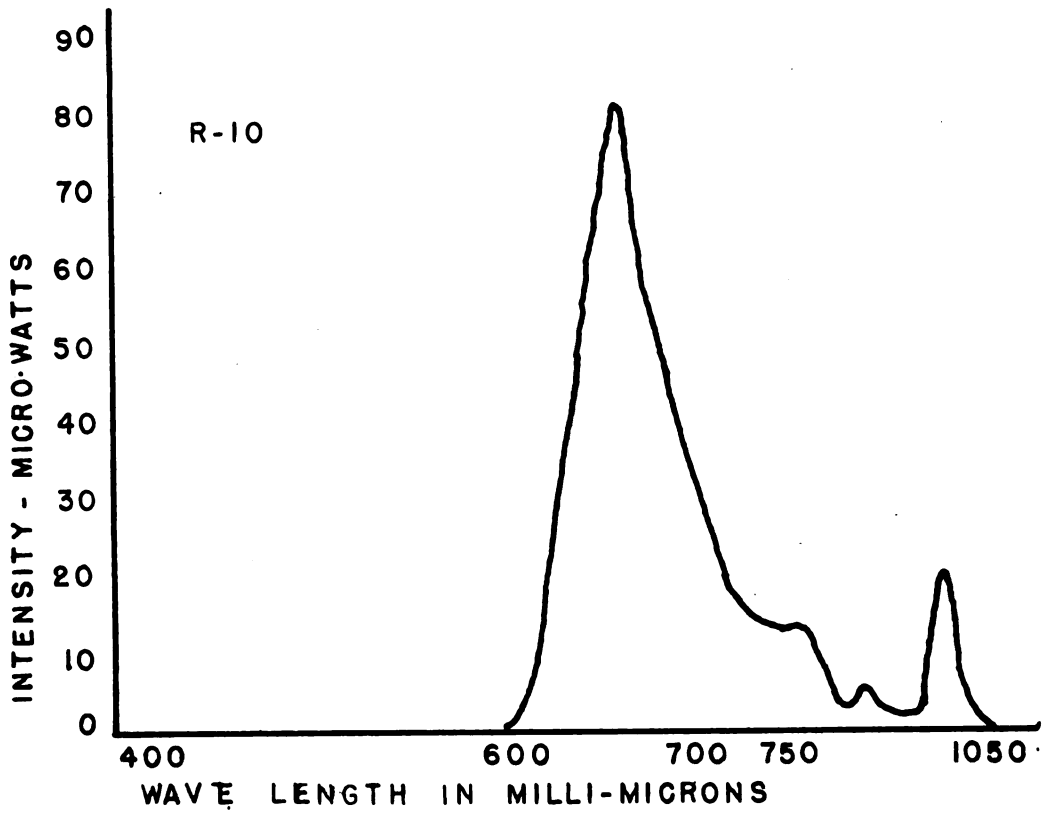

Figure 3 A - Light spectrum resulting from the use of cool white fluorescent tubes with a red Rohm and Haas (#2423) filter.

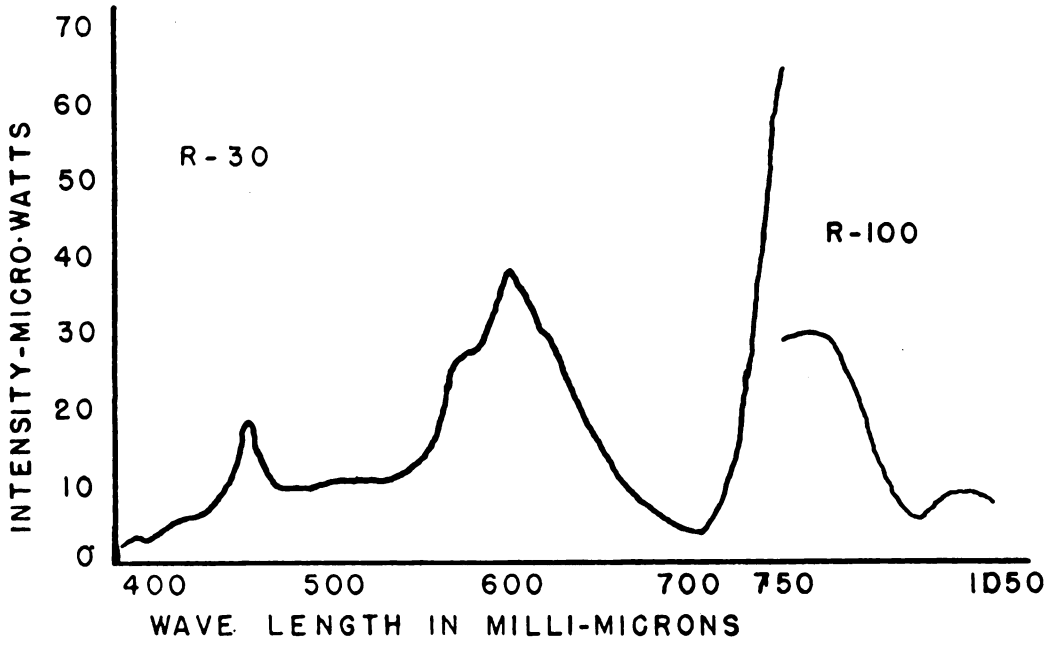

Figure 4 A - Light spectrum resulting from the use of cool white fluorescent tubes with the addition of incandescent flood bulbs filtered by a FR 700 filter.

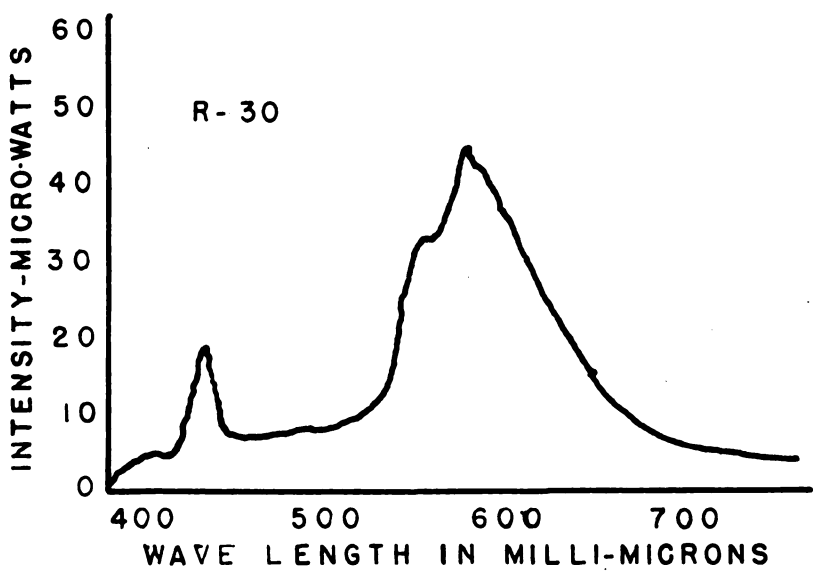

Figure 5 A - Light spectrum using cool white fluorescent tubes as the main source with the addition of two 25 W incandescent bulbs.

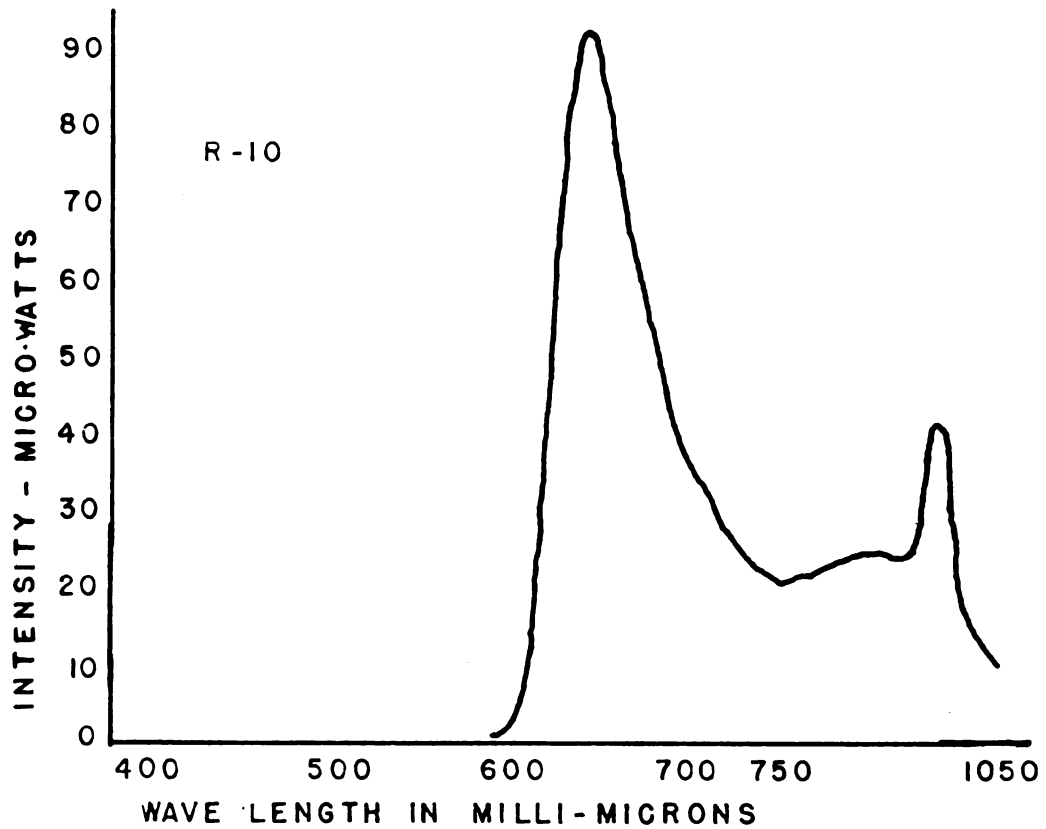

Figure 6 A - Light spectrum resulting from two layers of red cellophane (Dennison) as a filter and using cool white fluorescent tubes as the main light source.

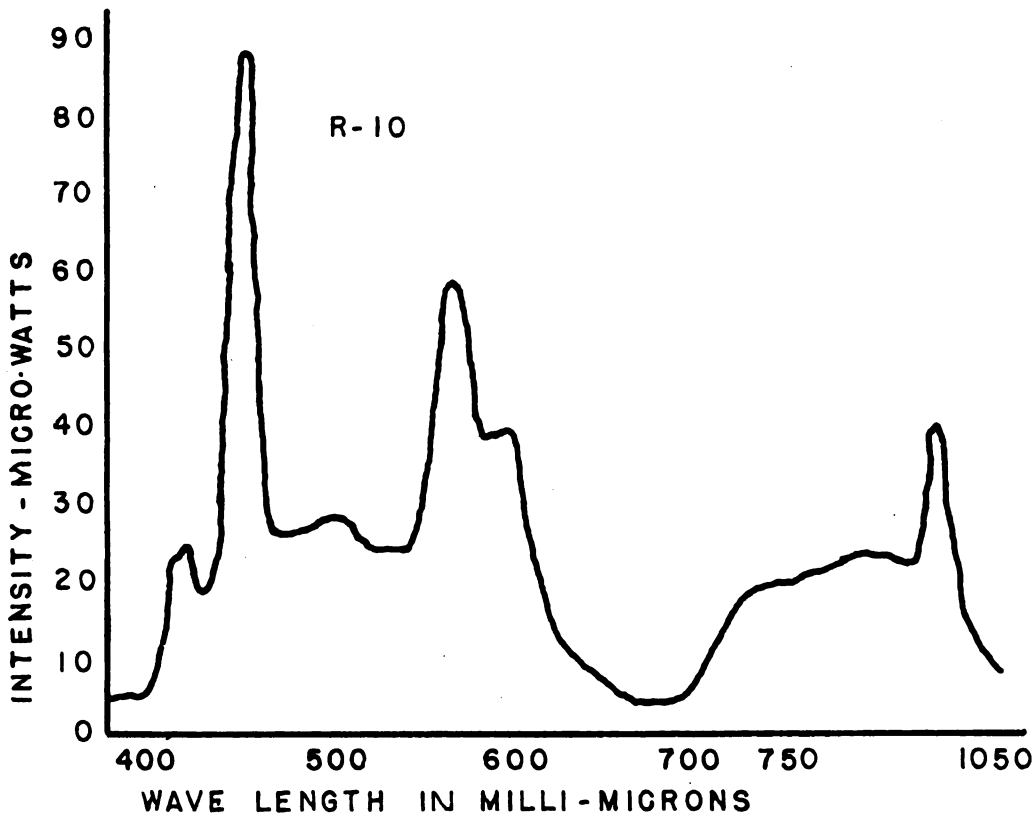

Figure 7 A - Light spectrum resulting from two layers of blue cellophane (Dennison) as a filter and using cool white fluorescent tubes as the main light source.