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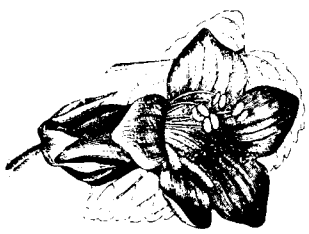


POTASSIUM

Debra Schwarze
University of Minnesota

Potassium is a macronutrient vital for plant growth. It is absorbed by plants in larger amounts than any other mineral element except nitrogen. Potassium acts as a catalyst to aid in many of the reactions vital to plant growth. Among the many physiological processes that potassium is involved in are:

1) Cell division.
2) Photosynthesis - formation of carbohydrates.
3) Translocation of sugars.
4) Reduction of nitrates and subsequent protein synthesis.
5) Enzyme activity.

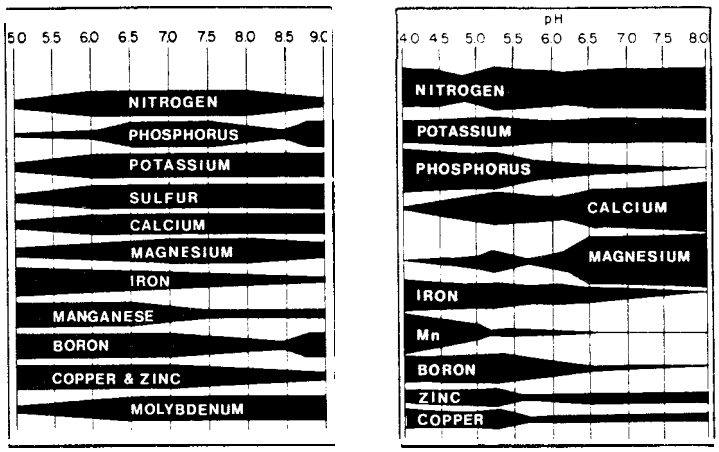
It is also generally accepted that potassium is involved in the carbon dioxide assimilation. Potassium level in plants has a direct impact on the carbohydrate level; potassium deficient plants have a lower carbohydrate level than plants with adequate potassium levels in the media.

Potassium also influences cell wall development. Stem stiffness is related to potassium level in plants. This 'makes sense' because lignin and cellulose development, which are important cell wall components, is directly related to the level of carbohydrate accumulation which, as mentioned above, is associated with potassium level.

Lack of potassium is also related to lodging. Lodging, or falling over, of plants due to stem weakness, is thought to be due to impaired lignification of vascular bundles. Sometimes carbohydrates are used in protein synthesis as rapidly as they are produced. This can happen when nitrate levels are high in the plant. If this occurs, cell walls may be thin and plant stems very weak because potassium uptake cannot keep up with plant demand. This is one of the reasons why the ratio of nitrogen to potassium in the plant is so important. On the tests which we have at the U of M, the nitrogen to potassium ratio should be 3:1.

Potassium is also important in maintaining internal plant pH, allowing the plant to maintain normal growth functions. Even a small shift in normal pH can disrupt normal metabolism (Figure 1).

Figure 1. *The influence of pH on the availability of essential nutrients in (a) a mineral soil (from Truog, 1948), and (b) a soilless root medium containing sphagnum peat moss, composted pine bark, vermiculite, perlite and sand (from Peterson, 1982).*



a b

Potassium is characterized as being highly mobile, not only in distance transport via the xylem and phloem, but also within individual cells and tissues.

In general, potassium contributes to the overall vigor of plants.

Potassium is also required for enzyme activation and membrane transport processes. More than 50 enzymes depend partially or completely on potassium for activation. Protein synthesis is reliant on sufficient potassium availability. For example, tobacco plant given sufficient potassium converted three times the nitrogen into protein five hours following a potassium application compared to untreated plants.

Potassium is characterized as being highly mobile, not only in distance transport via the xylem and phloem, but also within individual cells and tissues. Potassium is the most abundant cation in the cytoplasm and potassium salts make a major contribution to the osmotic potential of cells and tissues in many plants. Cell extension, stomatal regulation and other turgor-related processes are related to potassium concentration in plant vacuoles.

Plants require varying levels of potassium during different stages of growth.

Potassium also increases the resistance of some plants to diseases, plants deficient in potassium are generally more susceptible to fungal attack due to changes in enzyme activity and organic compounds present; and improves and helps plants overcome adverse environmental conditions, plants deficient in potassium are generally more susceptible to frost damage. In general, potassium contributes to the overall vigor of plants. It is for this reason that potassium nitrate fertilization is recommended, particularly at the end of a bedding plant production process.

Potassium deficiency symptoms will show up on the older leaves first.

Potassium Requirements of Plants

Plants require varying levels of potassium during different stages of growth. Many seeds contain from 0.1 to 1.0 percent potassium. This level will allow the seed to germinate and grow briefly. As the plants begin to grow they require the addition of potassium to the growing media. Often increasing amounts are needed as the plant continues growth.

There are a variety of potassium fertilizers that are available for use. Depending on other nutrient requirements of plants that you are growing you may select different fertilizers (Table 1).

Plant Growth and Deficiency Symptoms

For most plants, approximately 2-5% of the dry weight of the vegetative parts of the plant should be potassium, for optimal growth.

Potassium is a very mobile element at all levels, as mention previously. Therefore, potassium will move to the growing, or meristematic, regions of the plant. Potassium deficiency symptoms will show up on the older leaves first. Typical symptoms of potassium deficiency are:

- Retardation of growth.
- **Chlorosis on the edges** of older leaves.
- **Necrosis may result**, first around the edges and tips of the leaves and eventually moving in toward the midrib.
- If the deficiency is not corrected, younger leaves will show symptoms such as chlorosis.
- A sharp contrast between chlorotic necrosis and healthy green areas of the leaves of many crops.
- In later stages of potassium deficiency and starvation, leaf edges become necrotic, the tissue disintegrates and the leaf presents a ragged appearance. This condition is often called leaf scorch.

Potassium deficiency results in 1) a greater accumulation of soluble carbohydrates, decreased levels of starch and 2) increased amounts of soluble nitrogen compounds. Because of these changes, the activation and effectiveness of many plant processes may be affected.

Both calcium and magnesium compete with potassium for uptake sites on a root. Therefore, if your media contains high levels of calcium or magnesium, you may need to provide more potassium to insure that potassium deficiency will not occur.

Forms of Potassium in Soils

While the total amount of potassium in the soil is usually many times greater than the amount taken up by a plant, generally only a small portion of that potassium is available for plant growth.

Based on degree of availability, soil potassium can be grouped into three categories (Figure 2):

1) Difficultly available.
2) Slowly available.
3) Readily available.

The difficultly available portion is found in the in crystalline structures of primary minerals, such as orthoclase feldspars and muscovite mica. Weathering of these materials causes a gradual decomposition of the material over time. This decomposition brings about the release of potassium that may be:

1) Lost in drainage waters.
2) Taken up by living organisms.
3) Held as an exchangeable ion on surrounding clay particles.
4) Converted to one of the slowly available forms of soil potassium.

Difficultly available potassium is only slightly soluble and makes up 90 to 98 percent of the total soil potassium.

Slowly available potassium comprises about 2 to 10 percent of the total potassium in soils. Slowly available potassium is commonly found in biotite mica and illite.

Readily available potassium makes up about 1 percent of the potassium in soil. It is made up of exchangeable potassium and potassium in the soil solution.

Slowly available potassium and readily available potassium have an equilibrium in the soil. Weak acids and exchangeable cations allow the readily available potassium to be taken up by plants. While slowly available potassium is not readily available to the plants, strong acids can be used to extract it from the soil.

Both calcium and magnesium compete with potassium for uptake sites on a root.

While the total amount of potassium in the soil is usually many times greater than the amount taken up by a plant, generally only a small portion of that potassium is available for plant growth.

Readily available potassium makes up about 1 percent of the potassium in soil.

Table 1. *Analysis of representative samples of potash materials. From: Jones, U.S. 1982. Potassium - the catalyst. In:Fertilizers and soil fertility. Reston Publishing, Reston, VA.*

Constituent	Muriate of Potash (KCl) Percent	Potassium Nitrate (KNO_3) Percent	Sulfate of Potash (K_2SO_4) Percent	Sulfate of Potash-Magnesia ($K_2SO_4 \cdot 2MgSO_4$) Percent	Potassium Carbonate (K_2CO_3) Percent
Potash (K_2O)	60-62.5	44-45	50-52	21-22	63-64
Potassium	50.34	36.94	41.34	18.14	52.91
Sodium	1.13		0.76	1.08	
Sulfur	0.11	0.29	17.66	22.73	variables
Magnesium	0.11	0.23	0.70	11.19	variables
Chlorine	47.39	1.14	2.07	1.54	0.42
Nitrogen		12.96			
Moisture	0.21	2.01	0.52	0.30	variables
Other	0.71	46.43	36.95	45.02	46.61
Total	100.00	100.00	100.00	100.00	100.00

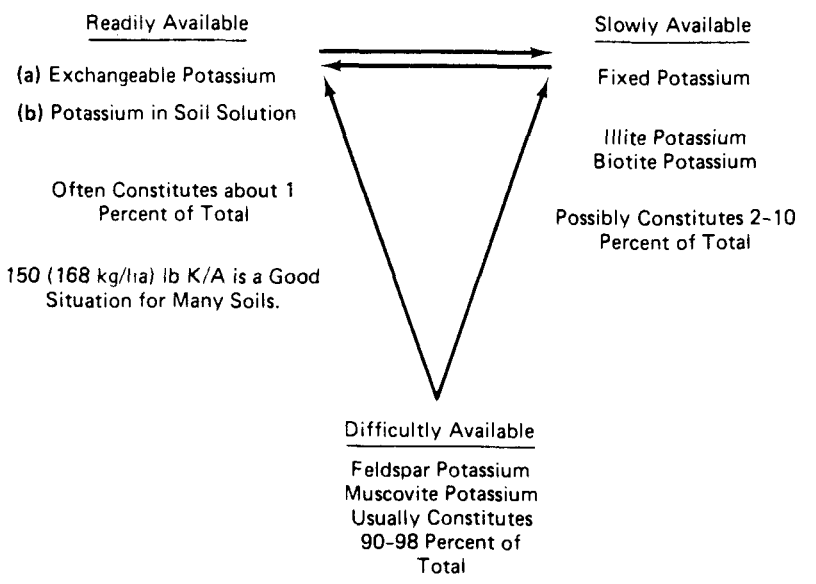


Figure 2. *Three availability categories of potassium in soils. From: Jones, U.S. 1982. Potassium - the catalyst. In:Fertilizers and soil fertility. Reston Publishing, Reston, VA.*

The majority of potassium comes from Canada, the United States, the former Soviet Union, Germany and France.

Where Potassium Fertilizers Come From

Due to the vast amounts of potassium in Canada, the majority used in the U.S. is mined there.

The majority of potassium comes from Canada, the United States, the former Soviet Union, Germany and France. Smaller producers of potassium come from Israel, Spain and the Congo.

Large scale mining of potassium was begun in the U.S. in the mid 1910's at Searles Lake, CA. About 10 to 15 year later deposits were found near Carlsbad, New Mexico. Since 1950 further deposits have been found near Moab, Utah and in Saskatchewan, Canada. Due to the vast amounts of potassium in Canada, the majority used in the U.S. is mined there.

In most cases potassium is mined through shaft mining (solid ore recovery), and solution mining. Shaft mining is similar to coal mining, however, new machinery has been developed to reduce the amount of undercutting necessary and directly extracting the potassium ore from the mine face. Solution mining pumps controlled brines into a bed of potassium and dissolved the potassium salts and the solution is then pumped to the surface. This is done where the potassium deposits are found over 5,000 feet below the earths surface.

In most cases potassium is mined through shaft mining (solid ore recovery), and solution mining.

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DETERGENTS INCREASE THE VASE LIFE OF CUT SUNFLOWERS (*Helianthus annuus* L.)

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Cut sunflowers have become a popular minor cut flower in the U.S., but suffer from poor vase life as the flowers may open poorly and leaves tend to wilt and discolor within 3 to 5 days of harvest. Furthermore, leaf desiccation seems to be accelerated by dry storage and transport so that flowers transported dry for more than 24 hours often have very short vase lives.

In an effort to alleviate this problem, we pulsed cut sunflowers with a non-ionic detergent, Triton X-100. Treatment of cut roses, Chrysanthemum and Gypsophila with non-ionic detergents has proved so successful that a pre-treatment with the detergent Agral LN is not mandatory in the Dutch auction system for these flowers.

In our trials, cut sunflowers were pulsed with solutions containing between 0.01 and 0.10% Triton X-100 for 30,60 or 180 minutes before simulated transport (3 days dry storage at 8C). Longest vase life was achieved with a 1 h pulse with 0.01% Triton X-100. The pre-storage Triton pulse worked in three ways: by increasing solution uptake during the 1 h pulse, minimizing weight loss during the dry storage period, and significantly improving the uptake of water after dry storage, resulting in greater leaf turgidity and longer vase life.

Sunflower could be stored (or transported) at 8C (46F) for up to 7 days after a pulse in Triton X-100 without a significant decline in vase life (Figure 1). It is also possible to keep sunflowers at lower temperatures than 8C. It is not beneficial to place sunflowers in a detergent solution for more than 3 hours, as this results in leaf damage and reduced vase life.

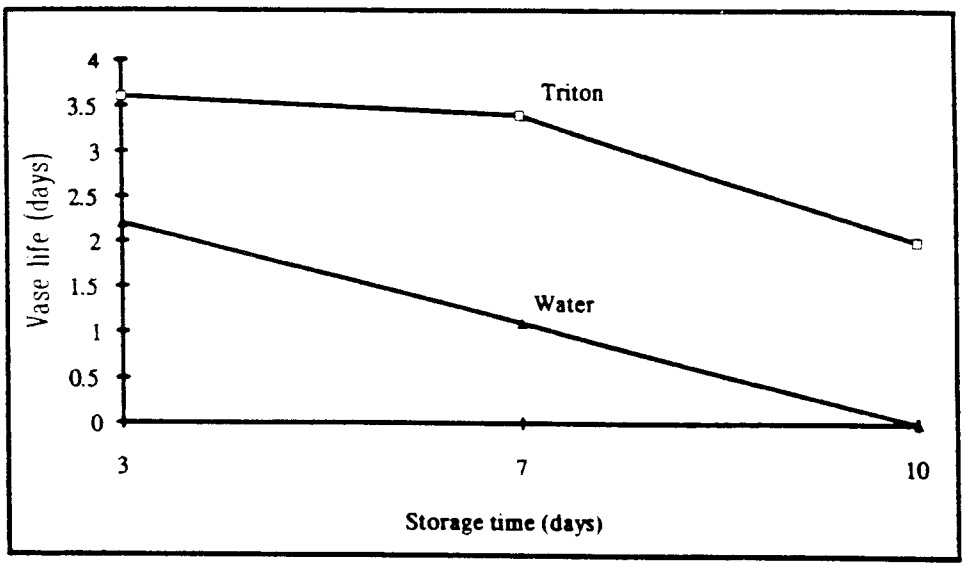

Figure 1. *Changes in vase life of cut sunflowers after dry storage at 8°C (46°F) for 3, 7 or 10 days. Stems were pulsed before storage with : A) distilled water or B) 0.01% Triton X-100.*

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RESEARCH REPORT: TEMPERATURE MANIPULATION OF VEGETABLE STEM ELONGATION AND FLOWERING

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Commercial management of vegetable transplant stem elongation has relied heavily on the use of synthetic plant growth retardants.

Abstract

Commercial management of vegetable transplant stem elongation has relied heavily on the use of synthetic plant growth retardants. Concern over the impact of these compounds on the environment and human health has limited their use and may limit their availability (Bidinotto, 1990). Indeed, the approval for use of daminozide (Alar) has been removed for all food crops. It is, therefore, imperative that methods for manipulating plant stem elongation which do not involve the application of chemical be developed.

Stem elongation is greatly affected by the day (DT) and night temperature (NT) plants are grown under.

Stem elongation is greatly affected by the day (DT) and night temperature (NT) plants are grown under (Went, 1952; Tageras, 1979; Karlsson, 1986). Stem elongation increases as the DT increases and NT decreases (Went, 1952; Tageras, 1979; Karlsson, 1986). Recent research identified that plant stem elongation was primarily a function of the difference (DIF) between DT and NT when temperatures ranged from 10 to 30C on *Lilium* (Erwin et al., 1989a; Erwin, 1991; Moe et al., 1991). Stem elongation increased linearly as DIF increased from -15 to +15C (Erwin et al., 1989a; Moe et al., 1991).

Stem elongation sensitivity to temperature varies within the photoperiod (Erwin et al., 1989b). Stem elongation was particularly sensitive to a cool temperature drop during the first 2-3 hours of the morning on *Lilium* (Erwin et al., 1989a). Almost as much inhibition of stem elongation occurred when plants were cooled to temperatures below the NT during the first 3 hours of the morning as if plants were cooled all day on *Lilium* (Erwin et al., 1989a; Erwin, 1991). Similar reductions in stem elongation from a -DIF during the first 3 hours of the morning have been reported on *Salvia* and *Impatiens* (Erwin, 1991).

Control of stem elongation via temperature manipulation has been applied on ornamental pot and bedding plants, but not vegetable crops.

Control of stem elongation via temperature manipulation has been applied on ornamental pot and bedding plants, but not vegetable crops. The reasons for this are twofold: 1) the concept of temperature manipulation for control of stem elongation is relatively new and was developed in the ornamentals industry first and 2) uncertainty as to how temperature manipulations for control of stem elongation during the seed to transplant stage may affect subsequent field production. The objectives of the research presented in this paper were to: 1) determine the potential for application of temperature manipulation for control of stem elongation on vegetable crops, 2) gain some insight into the physiological mechanism underlying responses of stem elongation to temperature and 3) determine the affect of temperature manipulations on other aspects of vegetable plant development such as flowering and sex expression.

Materials and Methods

Experiment 1: Seedlings of *Zea maize* 'Snow Bell', *Pisum sativum* 'Mars', *Citrullus lanatus* 'Crimson Sweet', *Phaseolus vulgaris* 'Blue Lake', *Lycopersicum esculentom* 'Sunny' and *Cucumis sativus* were planted in a soilless medium composed of 50% sphagnum peat, 25% perlite and 25% vermiculite and were placed in a controlled environment chamber maintained at constant 22C. When seedlings reached the first true leaf stage of development, they were moved into growth chambers maintained at: 1) continuous light, constant 20C, 2) 12 hr photoperiod, constant 20C, 3) 12 hr photoperiod, 23 DT/17C NT, or 4) 12 hr photoperiod, 17 DT/ 23C NT. All growth chambers had the same average daily temperature. Irradiance was maintained at 250 μmol $s^{-1}m^{-2}$ supplied with fluorescent (75% total wattage) and incandescent lamps (25% total wattage). Data were collected on internode length, flowering characteristics and leaf morphology after 3 months.

Experiment 2: *Lycopersicum esculentum* cv 'Money Maker' seed were germinated in a soilless medium composed of 50% sphagnum peat, 25% perlite and 25% vermiculite and were placed in a controlled environment chamber maintained at constant 22C. When seedlings reached the first true leaf stage of development, they were moved into growth chambers maintained at constant 20C, 23 DT/17C NT, or 17 DT/23C NT. Irradiance and photoperiod were maintained at 250 $u$mol $s^{-1}m^{-2}$ and 12 hr, respectively. Plants were grown under fluorescent (75% total wattage) and incandescent lamps (25% total wattage).

At the 2nd true-leaf stage, plants in each chamber were divided into 3 groups of 5 plants each to receive growth regulator treatments. Growth regulator treatments consisted of spray applications of either ancymidol (52 ppm), GA_3 (12 ppm) or distilled water applied every 3 days for 21 days. Measurements were taken on internode length after 21 days.

Experiment 3: *Cucumis sativum* seed from EG11812-1 (gynoecious), EG29417-1 (androgenous), and EG6701-1 (hermaphroditic) lines were obtained from Dr. Jack Staub at the University of Wisconsin in 1990. Seed were germinated in a soilless medium composed of 50% sphagnum peat, 25% perlite and 25% vermiculite and were placed in a controlled environment chamber maintained at constant 22C on Feb. 14, 1990. Seedlings were moved into growth chambers maintained at constant 20C, 23 DT/17C NT, or 17 DT/23C NT at the first true leaf stage of development. Irradiance and photoperiod were maintained at 250 $u$mol $s^{-1}m^{-2}$ and 12 hr, respectively. Plants were grown under fluorescent (75% total wattage) and incandescent lamps (25% total wattage).

Data were collected on internode length, male flower number, female flower number and hermaphroditic flower number after 4 weeks. Data were collected on each plant on each of 3 representative nodes starting 2 nodes down from the shoot tip.

Results

Stem Elongation: Internode length increased as DT increased and NT decreased (Table 1). The

Table 1. The interaction between thermoperiod vs photoperiod on internode elongation of *Zea maize* 'Snow Belle', *Pisum sativum* 'Mars', *Citrullus lanatus* 'Crimson Sweet', *Phaseolus vulgaris* 'Blue Lake', *Lycopersicum esculentom* 'Sunny' and *Cucumis sativum*.

Crop	Cont. Light Fluct. Temp.	Cont. Temp. Fluct. Light (0C DIF)	23C Day 17C Night (+6C DIF)	17C Day 23C Night (-6C DIF)
Zea maize 'Snow Bell'	1.7 ± 0.5 [z]	3.9 ± 1.5	5.5 ± 0.8	1.7 ± 0.4
Pisum sativum 'Mars'	3.4 ± 0.4	2.0 ± 0.3	2.4 ± 0.3	2.3 ± 0.3
Citrullus lanatus 'Crimson Sweet'	3.7 ± 1.0	2.6 ± 1.1	2.5 ± 0.6	0.4 ± 0.1
Phaseolus vulgaris 'Blue Lake'	5.3 ± 0.6	4.2 ± 1.0	4.8 ± 0.8	3.6 ± 0.6
Lycopersicum esculentom 'Sunny'	2.3 ± 0.4	2.6 ± 0.3	4.6 ± 0.9	2.0 ± 0.3
Cucumis sativus	4.2 ± 2.2	7.6 ± 1.1	7.6 ± 1.4	4.7 ± 0.4

	r^{2} [y]	P	Significance
Zea	0.79	0.000	***
Pisum	0.03	0.455	n.s.
Citrullus	0.32	0.030	*
Phaseolus	0.32	0.020	*
Lycopersicum	0.78	0.000	***
Cucumis	0.51	0.001	***

z Numerals represent treatment means and standard deviations.
y Represents multiple r square of DIF response only.

***Lycopersicum esculentum* cv 'Money Maker' seed were germinated in a soilless medium composed of 50% sphagnum peat, 25% perlite and 25% vermiculite and were placed in a controlled environment chamber maintained at constant 22C.**

At the 2nd true-leaf stage, plants in each chamber were divided into 3 groups of 5 plants each to receive growth regulator treatments.

Table 2. The effect of fluctuating temperatures and light on vegetable plant flowering on *Pisum sativum* 'Mars', *Cucurbita pepo var. melopepo, Phaseolus vulgaris* 'Blue Lake' and *Lycopersicum esculentom* 'Sunny'.

Crop	Cont. Light Fluct. Temp.	Cont. Temp. Fluct. Light	23C Day 17C Night	17C Day 23C Night
Pisum sativum 'Mars'				
Flowers/node	1.7 + 0.5 [z]	2.0 + 0.0	2.0 + 0.0	1.2 + 0.4
Cucurbita pepo var. *melopepo*				
Male flowers	5.6 + 2.3	1.3 + 0.8	5.6 + 2.1	2.0 + 1.4
Female flowers	2.7 + 2.1	1.7 + 0.5	0.4 + 0.5	2.0 + 0.7
male/female ratio	2.07	0.8	14.0	1.0
Phaseolus vulgaris 'Blue Lake'				
Flowers/node	2.5 + 0.6	3.6 + 0.5	1.8 + 0.8	1.3 + 0.5
Lycopersicum esculentom 'Sunny'				
Flowers/cluster	4.7 + 1.0	4.7 + 1.0	4.3 + 0.5	4.0 + 0.0

[z] Numerals represent treatment means and standard deviations about the treatment mean.

Species responded differently to DIF.

effect of DT and NT on internode elongation could best be described as a function of the difference (DIF) between DT and NT (DT-NT) (Table 1, Table 2, Figure 1). Internode length increased linearly as DIF increased from -6 to +6C when temperatures ranged from 12 to 24C in Experiment 1 and 2 (Figure 1). For instance *Zea* internode length increased from 1.7 to 5.5 cm as DIF increased from -6 to +6C in Experiment 1 (Table 1). Similarly, *Lycopersicum* internode length increased from 1.4 to 2.1 cm as DIF increased from -6 to +6C in Experiment 1 (Table 1; Figure 1) and increased from 1.0 to 2.1 cm as DIF increased from -6 to +6C in Experiment 2 (Table 2).

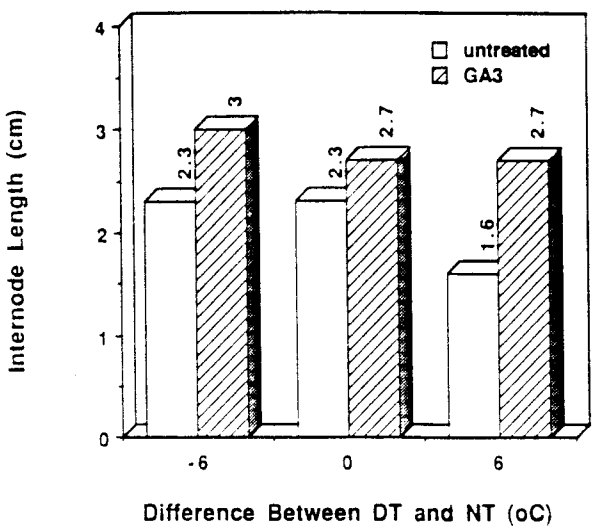


Figure 1. Stimulation of elongation of *Lycopersicum* internode elongation of plants grown in 23 DT/17C Nt versus 17 DT/23C NT environment before and after GA_3 application (Erwin and Pierson, 1992).

The response of *Cucumis* to DIF varied among experiments and among different genetic lines.

Species responded differently to DIF. The degree of correlation of internode length data with DIF (r^2) was greatest on *Zea* and *Lycopersicum* and least on *Pisum*, *Citrullus* and *Phaseolus* (Table 1). *Pisum* showed no response to DIF (r^2 = 0.03; P = 0.455) (Table 1). *Cucumis* elongation showed an intermediate response to DIF; although correlation was not high (r^2 = 0.51) a significant trend between DIF and internode length was evident (P=0.001) (Table 1).

The response of *Cucumis* to DIF varied among experiments and among different genetic lines (Tables 1 and 3). *Cucumis* internode length increased linearly as DIF increased from -6 to +6C in Experiment 1 (Table 1). Internode lengths on plants from the gynoecious line of *Cucumis* responded to DIF as in Experiment 1, i.e. internode length increased linearly as DIF increased (Table

3). In contrast, internode length was greatest in androgenous and hermaphroditic lines when DT and NT were constant (Table 3), i.e. the standard increasing linear response to DIF was not evident.

Continuous light and alternating thermoperiod promoted internode elongation on some species but not others (Table 1). For instance, *Zea*, *Lycopersicum* and *Cucumis* elongation was inhibited by continuous lighting whereas *Pisum*, *Citrullus* and *Phaseolus* elongation were promoted by continuous lighting (Table 1). Interestingly, elongation on those crops which were most responsive to DIF were most inhibited by continuous lighting (Table 1). In contrast, elongation on species which were not responsive to DIF was promoted by continuous lighting. In fact, percent stimulation of elongation by continuous lighting was highly correlated with responsiveness of species to DIF (Figure 2). Experiments are currently underway studying the relationship between thermo- versus photosensitivity of plants with respect to stem elongation.

Continuous light and alternating thermoperiod promoted internode elongation on some species but not others.

Flower Development: Flower formation was affected by the DT/NT environment which plants were grown under and plant species. For instance, *Cucumis* sex expression was dramatically altered by DT/NT regime. Maleness was promoted by a +DIF environment whereas femaleness was promoted by a 0 or -DIF environment in Experiment 1 (Table 3; Figure 3). These findings are consistent with data which suggests that +DIF environments promote gibberellin biosynthesis. Increased levels of gibberellins have been associated with promotion of maleness in *Cucurbitae*.

Conflicting results were found in Experiment 3 (Table 3). Maleness was promoted in an androgenous line in Experiment 3 on *Cucumis* when plants were grown under constant 20C. Hermaphroditic flowers were promoted when temperatures fluctuated with a + or -DIF compared to plants grown at constant 20C (0C DIF) (Table 3). Gynoecious lines of *Cucumis* produced female flowers regardless of DT/NT environment (Table 3).

Flower formation was affected by the DT/NT environment which plants were grown under and plant species.

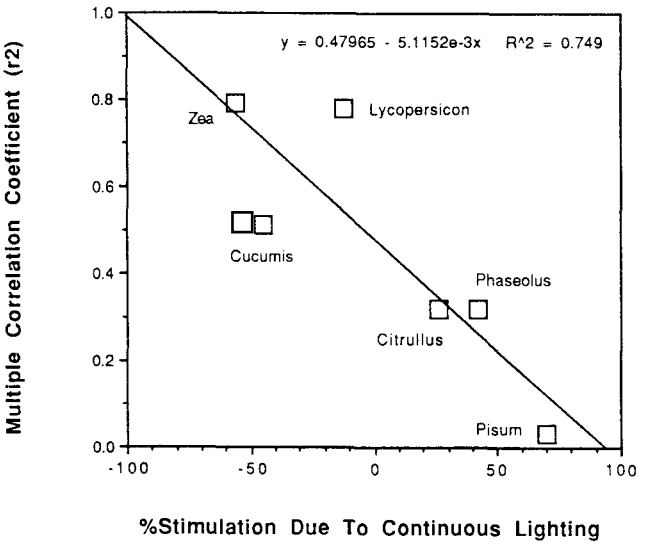
Table 3. The effect of day/night temperature relationship on flower sex expression of *Cucumis sativum* EG11812-1, EG29417-1 and EG6701-1 lines. Data were collected on internode length, male flower number, female flower number and hermaphroditic flower number after 4 weeks. Data were collected on each plant on each of 3 representative nodes starting 2 nodes down from the shoot tip.

	Temperature Treatment		
Cultivar Characteristic	**+ DIF**	**0 DIF**	**- DIF**
EG11812-1 (gynoecious)			
Internode length	5.3 ± 1.2 [z]	4.7 ± 1.5	3.4 ± 1.0
Female flowers	1.0 ± 0.0	1.0 ± 0.0	1.0 ± 0.0
Male flowers	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Hermaphroditic	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
EG29417 -1 (androgenous)			
Internode length	4.9 ± 0.7	8.5 ± 0.8	3.8 ± 1.2
Female flowers	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Male flowers	0.0 ± 0.0	5.6 ± 0.9	0.0 ± 0.0
Hermaphroditic	4.8 ± 1.0	0.7 ± 0.6	5.3 ± 1.0
EG6701-1 (hermaphroditic)			
Internode length	5.3 ± 1.1	7.7 ± 1.3	5.1 ± 1.2
Female flowers	0.0 ± 0.0	0.0 ± 0.0	0.0 + 0.0
Male flowers	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Hermaphroditic	6.4 ± 1.9	9.6 ± 2.4	8.6 ± 2.2

[z] Numerals represent treatment means and standard deviation about the mean.

Gynoecious lines of *Cucumis* produced female flowers regardless of DT/NT environment.

Figure 2. *P*ercent stimulation due to continuous lighting of *Zea maize* 'Snow Bell' *Lycopersicum esculentom* 'Sunny', *Cucumis sativus*, *Citrullus lanatus* 'Crimson Sweet', *Phaseolus vulgaris* 'Blue Lake' and *Pisum sativum* 'Mars' when compared with DIF treatments.



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Lycopersicum flower number per cluster was unaffected by temperatures between 12 and 24C.

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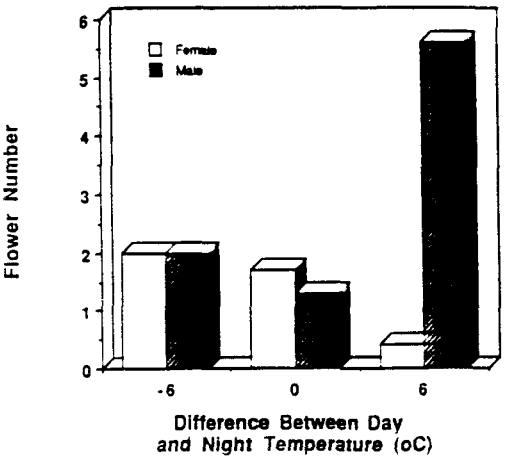

Figure 3. Effect of difference (DIF) between DT and NT on *Cucurbita* of male versus female flower number (Erwin, 1991).

MEDIA TEST REVIEW

Debra Schwarze
University of Minnesota

Test Parameter or Nutrient	Actual	Recommended	Acceptable	Toxic
pH	6.3	6.2-6.8	6.0-7.0	>7.4
Soluble Salts (SS)	123	70-90	60-100	>120
Nitrates (NO_3)	104	150-250	100-350	>400
Ammonium (NH_4)	1	0-10	0-15	>15
Phosphorus (P)	8	10-15	5-20	>80
Potassium (K)	53	50-100	30-120	-
Calcium (Ca)	126	50-200	25-300	>400
Magnesium (Mg)	33	40-50	30-60	-
Sodium (Na)	13	10-40	5-60	>70
Iron (Fe)	.26	.20-.50	.10-.70	>5.0
Manganese (Mn)	.24	.50-1.50	.30-1.75	>5.0
Zinc (Zn)	.17	.10-.50	.05-.75	>2.0
Boron (B)	.09	.05-.25	.02-.50	>1.0

This particular media test is from a hanging fuchsia basket. Since most hanging baskets will require more time in your greenhouse than other bedding plants, the nutritional requirements will be greater. Generally, fertilizer with 200 ppm of nitrogen and potassium from the time the baskets are planted. This will provide adequate nutrition for most baskets throughout the growing season.

One other point on hanging baskets. Since most growers raise their hanging baskets in the upper portions of the greenhouse, you need to take into account the warmer temperatures and additional water that the baskets will require. Because of this it is important to monitor the media and run media tests on a regular basis to make sure the appropriate nutrition is being maintained.

On this media test, of a soilless mix, the soluble salts are rather high. High soluble salts, generally over 100, can cause damage to the roots and this damage can lead to problems with the above ground portions of the plant. Typical damage will be die-back and browning of the roots followed by necrosis of leaf edges. To help remedy the problem, leach the plants thoroughly to reduce the salts level.

While the salts are high, nitrogen and potassium levels are not. This is not unusual for media early in the fertilization schedule. After leaching to reduce the salts levels, the nutrient levels will drop even lower. Therefore, follow up the leaching with a heavier fertilizer application. If you generally feed your hanging baskets with 200 ppm N and K, a single follow-up feeding of 300 ppm N and K will be beneficial. Following this watch the N:K ratio to try to keep it about 3:1. The 3:1 ratio will help make the nitrogen and the potassium available to the plants in the proper proportion.

The 3:1 ratio is also important when evaluating levels of Ca and Mg. In the case of this test, it looks like the plants are about due for an application of epsom salts to help raise the Mg level so that is about 1/3 that of the Ca. The rate of application for epsom salts is 8 ounces per 100 gallons of water. Often micronutrients are applied at half rate at the same time. Remember not to mix the epsom salts with other fertilizers (other than micronutrients) to avoid precipitation in your stock tank. In this case the micronutrients are in the acceptable range and addition is not necessary at this point. Since the plants are actively growing, micronutrients may be needed before the crop is ready to go out.

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It is important to monitor the media and run media tests on a regular basis to make sure the appropriate nutrition is being maintained.

GREENHOUSE COOLING

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Cooling is a fundamental requirement of almost any greenhouse operation, yet the process is not very well understood by most growers (and some researchers).

Cooling is a fundamental requirement of almost any greenhouse operation, yet the process is not very well understood by most growers (and some researchers). At NCSU, we have conducted several cooling studies over the past few years and the results have given us some insight as to what is going on.

Heat loss from a greenhouse can be either good or bad, depending upon the temperature. During periods of cold weather, heat loss is undesirable and steps are taken to minimize it wherever possible. During periods of hot weather, heat loss is essential to the cooling process and should be maximized, if at all possible.

All surfaces in the greenhouse lose heat through radiative and convective cooling; however, most of the heat loss comes from the canopy and the ground.

The fundamental mechanisms available for cooling a greenhouse are radiation, convection and the evaporation of water (Figure 1).

All surfaces in the greenhouse lose heat through radiative and convective cooling; however, most of the heat loss comes from the canopy and the ground. Further, only the canopy and the ground lose heat through the evaporation of water.

Radiative cooling is generally a minor factor during warm weather (the period of prime interest) but convection and evaporative cooling are major factors and are, in fact, inter-related. If convection were not present, the air around the leaf would soon become saturated and transpiration would effectively cease. One way to relate to this is to compare it to a sweat box (Figure 2). If you cannot get rid of the water no cooling will take place.

Transpiration

Plants evaporate water through the process of transpiration, which is controlled, in part, by openings (stomata) in the surfaces of the leaves.

Plants evaporate water through the process of transpiration, which is controlled, in part, by openings (stomata) in the surfaces of the leaves. Generally speaking, the stomata are completely open during daylight hours, allowing moisture to evaporate at a rate governed by the flow of air over the leaves (convection), and the content of water in that air. In a full greenhouse, canopy transpiration is generally the largest single fac-

Figure 1. *The basic mechanisms for cooling are radiation, convection and water evaporation (or transpiration.*

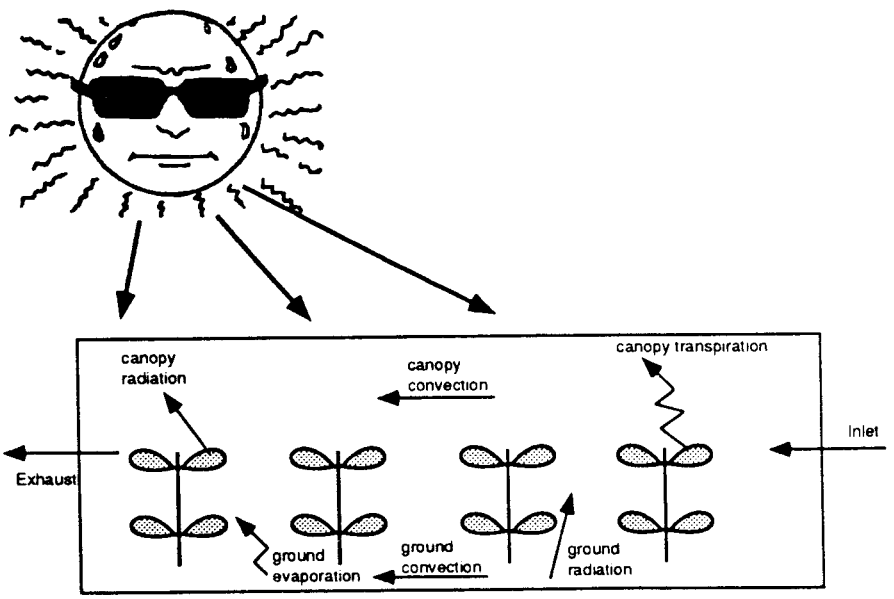
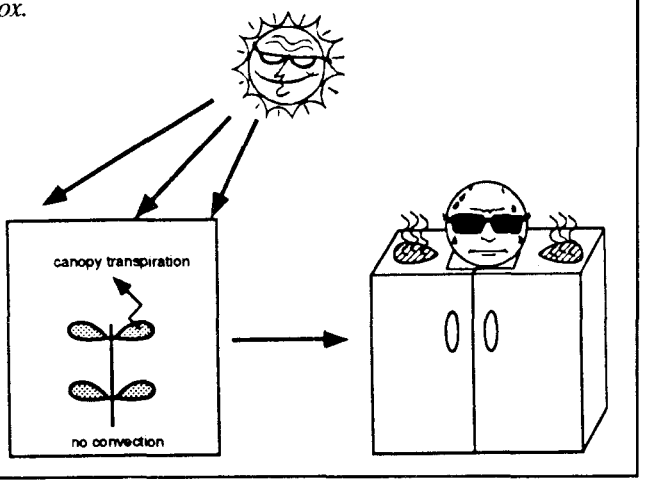


Figure 2. *A closed greenhouse can quickly become a sweat box.*



tor affecting temperature, with ground evaporation coming in a distant second. In an empty, or nearly empty, greenhouse the lack of transpiration can make it very difficult to control temperature.

Cooling Alternatives

Cooling equipment available for greenhouses is generally limited to multiple speed exhaust fans installed in one end of the greenhouse with evaporative pads installed at the other. Fogging systems are also available, but should be used with reservation, depending upon the operation.

Full Houses. Implementation of any cooling scheme should be based, in part, on the amount of transpiration present and, in part, on the expected outside conditions. In a full greenhouse (e.g., mature chrysanthemums on the benches with hanging baskets over the aisles), the crop evaporates large quantities of water into the air and little, if any, additional evaporation can be accomplished, especially if outside conditions are humid as they generally are in this part of the country.

Table 1. *Estimated inlet and exit temperatures for a full greenhouse on a 90°F day.*

System type	Inlet temp.	Exit temp.
Exhaust fan	90°F	93°F
Evap. pad	78°F	90°F
Fog + fan	80°F	90°F

Table 1 shows that for outside temperatures of 90°F, evaporative pads only provide exit temperatures about 3°F below that produced by exhaust fans alone. Average temperatures are much lower, however, because the temperature at the inlet end is substantially lower than that without pads. In this part of the country, fogging would be expected to perform no better than evaporative pads, although the temperature difference from end-to-end would probably be somewhat less.

Empty Houses. In an empty, or nearly-empty, house (a house full of immature plants or partially rooted cuttings qualifies as a nearly empty house) a different approach may be required. Since very little moisture is available for evaporation inside the house almost any that can be evaporated will affect temperatures greatly. With exhaust fans only, exit temperatures might be expected to reach 110°F on a 90°F day (Table 2). Evaporating water at the inlet of the house (as with evaporative pads) will help, but the temperature will still rise rapidly as the air moves through the house, because little additional water is available for evaporation. Exit temperatures can reach 100°F.

Table 2. *Estimated inlet and exit temperatures for a nearly empty greenhouse on a 90°F day.*

System type	Inlet temp.	Exit temp.
Exhaust fan	90°F	110°F
Evap. pad	78°F	100°F
Fog + fan	80°F	90°F

Fogging is probably the best solution where little transpiration is available, even in this area of the country. Performance would be expected to approximate that of evaporative pads used with a full crop. Fogging should be considered for rooting and seedling houses, houses with young plants and houses with small plants (i.e., houses full of small 4" material such as African violets.).

System Selection

Table 3 presents some of the current design recommendations for greenhouse cooling. Typi-

Cooling equipment available for greenhouses is generally limited to multiple speed exhaust fans installed in one end of the greenhouse with evaporative pads installed at the other.

Implementation of any cooling scheme should be based, in part, on the amount of transpiration present and, in part, on the expected outside conditions.

Fogging is probably the best solution where little transpiration is available, even in this area of the country.

Table 3. *Some recommendation for greenhouse cooling systems.*

System type	Airflow (chgs/min)	Pad velocity (fpm)	Water flowrate (gpm/ft)*	Water bleedrate (gpm/1000 cfm)	Sump capacity (gal/sq.ft.)
Aspen pad	1 to 1.5	150	0.30	0.05	0.50
4" pad	1 to 1.5	250	0.50	0.05	0.75
6" pad	1 to 1.5	350	0.75	0.05	1.00
Fog	1 to 1.5		0.03-0.04 gph/sq.ft.		

*Water flowrates for evaporative pads are per lineal foot of pad. Water flowrates for fogging systems are per square foot of floor area.

To determine the quantity of air that needs to be moved we must estimate the volume of the house.

cally, for this area if the country, an air flow of 1 to 1.5 air changes per minute should be provided via exhaust fans, regardless of any additional method of cooling used. Evaporative pads, if used, should be sized so that the air velocity through them ranges from 150 fpm for aspen pads to 350 fpm for 6" corrugated pads. Water flowrate for evaporative pads is not critical, but should be above the minimums listed. Most of the water is simply recirculated and only a small portion (approximately equal to the bleedrate) is evaporated into the air. The excess water is used to insure that the pads remain fully wet. Water flowrates for fogging systems should be roughly the same for a given house as the recommended bleedrate for evaporative pads.

Example. As an example, consider a 30 ft by 110 ft Quonset house located in North Carolina (Figure 3). Let's assume that is will generally contain a full crop during periods of the year when cooling will be required, so let's choose an evaporative pad as the supplementary cooling method.

The primary deciding factor should be the expected outside temperatures and the potential damage to the crop if inside temperatures rise too high.

To determine the quantity of air that needs to be moved we must estimate the volume of the house. We do that by assuming that the cross-section of the house is semi-circular (which it really isn't--but it's very close). This allows us to approximate the volume as that of ½ that of a cylinder with a diameter equal to the width of the house. This gives:

$$\text{Vol} = \frac{0.5 \times L \times (3.1416 \times W^2)}{4}$$

where L is length of the house, 3.1416 is pi and W is the house width. Using our numbers,

$$\text{Vol} = \frac{0.5 \times 110' \times (3.1416 \times 30' \times 30')}{4}$$

therefore, Vol = 38,882 ft^3.

Air flow for this greenhouse, then, should be somewhere between 39,000 and 59,000 cfm, depending upon whether we choose 1 air change per minute or 1.5 air changes per minute. The primary deciding factor should be the expected outside temperatures and the potential damage to the crop if inside temperatures rise too high. For this area of the country, 1.5 air changes per minute should be used if you plan to grow throughout the summer, especially if the crop will be in the flowering stage (the most temperature sensitive stage for flowering crops) during the warmest weather or if a temperature sensitive crop (subject to heat delay) is to be grown.

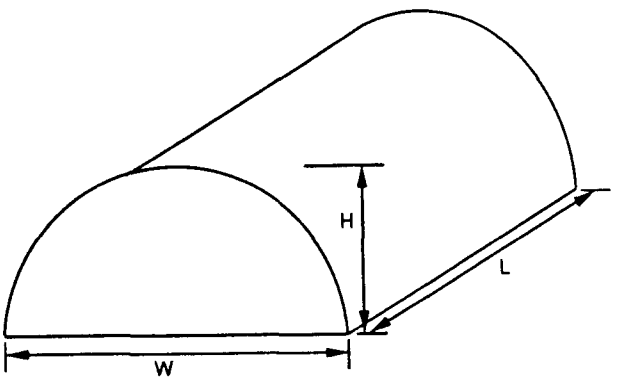


Figure 3. *A typical Quonset-style greenhouse.*

From the fan charts supplied by the exhaust fan manufacturer, a 48", 1 hp fan should supply 19,600 cfm at 0.1" of water static pressure (use the 0.1" rating if you will be using evaporative pads, 0.05" rating if not). Two such fans will provide the lower airflow while three will be required if the higher airflow is desired.

Using the recommended pad velocities from Table 1, a 4" thick pad would require:

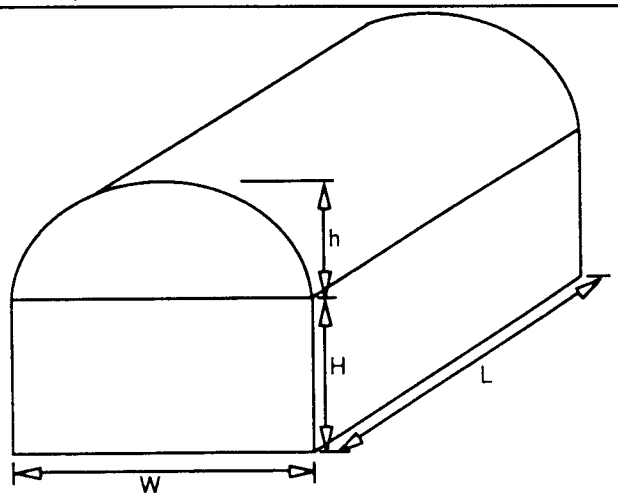


Figure 4. *A typical section of gutter-connected raised Quonset greenhouse.*

$$\text{Area} = \frac{(39{,}200 \text{ cfm})}{(250 \text{ fpm})} = 157 \text{ ft}^2$$

if two fans are selected and:

$$\text{Area} = \frac{(58{,}800 \text{ cfm})}{(250 \text{ fpm})} = 235 \text{ ft}^2$$

if three fans are selected. As a rule, 235 ft^2 would not be available is a 30 ft wide Quonset house. An alternative, if we were to use three fans, would be to use a 6" pad, which would require only 168 ft^2:

$$\text{Area} = \frac{(58{,}800 \text{ cfm})}{(350 \text{ fpm})} = 168 \text{ ft}^2$$

For the remainder of this example, calculations will be based on using only two fans totaling 39,200 cfm and a 4"-sized pad totaling 157 ft^2 of pad area. A 4" pad sided for two exhaust fans would require about 28 ft of pad:

$$\frac{157 \text{ ft}^2}{5.6'} = \text{about 28 ft}$$

A 4" pad requires 0.50 gpm/ft of pad run, so the water flow rate delivered to the pad should be:

(0.5 gpm/ft) x (28 ft) = 14 gpm

The bleedrate (water drained off from the pipe delivering water to the pad to remove excess salts) needs to be added in prior to pump selection:

(0.05 gpm/1000 cfm) x (39,200 cfm) = 2 gpm

This gives us a required water flowrate by the sump pump of:

Water Flow = 14 gpm + 2 gpm =16 gpm

The sump pump should then be sized to provide 16 gpm at a head of about 10 ft.

Calculating the sump capacity required for the 4" pad gives:

Sump Capacity = (0.75 gal/ft^2 pad) x (157 ft^2) = 118 gallon capacity required

In the above calculations we approximated the volume of a quonset house as that of ½ of a cylinder of width W and length L. The volume of gutter connected raised Quonset houses (Figure 4), must be approximated differently.

For each section of width W, gutter height H, gutter-to-peak distance h and Length L, we can calculate the volume of the lower section as a rectangular box (a hexahedron):

Lower Volume = H x W x L

We can approximate the volume of the upper section by assuming the circular arc can be represented by a triangle with base W and height h, giving the volume of the triangular box (a pentahedron) section as:

Upper Volume = 0.5 x h x W x L

The volume of the entire bay can then be approximated by adding the upper volume to the lower volume. For multiple bays, just multiply volume of one by the number of bays.

The bleedrate (water drained off from the pipe delivering water to the pad to remove excess salts) needs to be added in prior to pump selection.

POINSETTIA HEIGHT CONTROL

John Erwin
University of Minnesota

Height control is critical for the production of a high quality poinsettia crop.

Height control is critical for the production of a high quality poinsettia crop. Breeding programs have been active in producing cultivars which are naturally shorter growing. However, management of height artificially is still critical to produce a saleable crop. Traditionally, height control has been achieved through the use of chemical growth retardants. Increasing social concerns over the use of chemicals has lead to a renewed interest in non-chemical methods of height control. One non-chemical method which has proven to be economical and easily applied in the floriculture industry is to manipulate temperatures daily to limit stem elongation.

This chapter will concentrate on how to control poinsettia stem elongation and growth through crop management and the use of daily temperature manipulations within a greenhouse to produce a saleable plant at a desired height. Scheduling mother cutting management, pinching technique and specific effects of temperature manipulation will be discussed.

The ability of a plant to reach its potential height is modified by the environment in which it grows.

What Determines Plant Height?

Every plant has a potential for growth. There are both short and tall growing plants and/or cultivars. The ability of a plant to reach its potential height is modified by the environment in which it grows. Management of plant structure also affects plant height. Poinsettia plant height is composed of 1) the height of the 'mother' stem on pinched plants, 2) the number on internodes on a lateral shoot and 3) the length of each of the internodes on a lateral shoot.

Basic Concepts Of Plant Growth:

Node Number: The rate at which leaves or nodes unfold on a poinsettia is determined by the average daily temperature which plants are grown under. Poinsettia node unfolding rate, as with all plants, responds to temperature in a similar fashion. There is a base temperature where little or no leaf unfolding occurs. There is a linear range where leaf unfolding increases proportionally to an increase in temperature. There is an optimal temperature where leaf unfolding is at its most rapid rate possible. As temperature increases above the optimal temperature, leaf unfolding rate decreases. The base temperature for poinsettia leaf unfolding is approximately 45°F. Leaf unfolding increases as average daily temperatures increase from 45°F to 76-80°F. Leaf unfolding does not increase as temperatures increase greatly above 76°F and will, in fact, decrease if temperatures exceed 90°F. Death occurs when poinsettias are grown at constant 100°F.

Table 1. *The number of days needed from planting until pinching to produce plants with various break numbers at various average daily temperatures. To generate this table it was assumed that cuttings had 4 leaves when planted, that pinching resulted in the removal of 2 leaves, that 80% of the axillary buds developed into breaks and that flower initiation occurs on September 20. Times are based on leaf unfolding rate functions published in the following reference: Berghage, R., R.D. Heins and J.E. Erwin, Quantifying leaf unfolding in the poinsettia. Acta. Hort., 272:243-247.*

The rate at which leaves or nodes unfold on a poinsettia is determined by the average daily temperature which plants are grown under.

Final Estimated Inflorescence Number	Average Daily Temperature (°F)				
	60	63	65	68	71
4 Inflor.	21	18	16	15	14
5 Inflor.	28	24	22	20	19
6 Inflor.	35	30	27	25	23
7 Inflor.	42	35	33	30	28
8 Inflor.	49	41	38	35	33

Internode Length: Poinsettia internode length or elongation is affected by the way in which temperature is delivered to a plant during a day/night cycle and the actual temperatures plants are grown under.

Internode length increases as day temperature increases relative to night temperature (Figure 1). The greater the difference between day and night temperature, the greater the stem elongation. One way to describe this relationship is to simply say that poinsettia stem elongation increases as the difference (DIF) between day and night temperature increases when day and night temperatures range from 50 to 86°F.

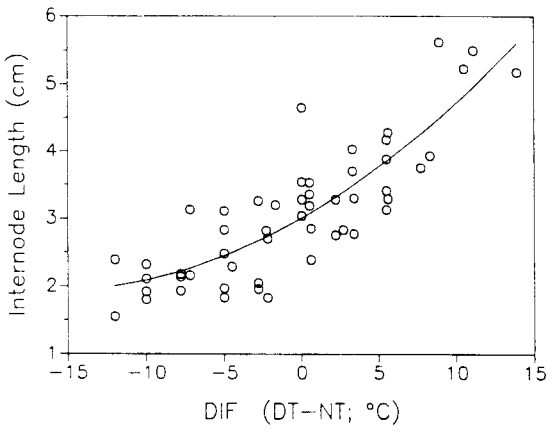


Figure 1. *Relationship between DIF and length of internodes on the second lateral shoot of poinsettia 'Annette Hegg Dark Red' grown with 36 DT/NT combinations. Data shown are for all nodes after the first with a VBI of 0 for each of the temperature treatments. From: Berghage, R.D. and R.D. Heins. 1991. Quantification of temperature effects on stem elongation in poinsettia. J. Amer. Soc. Hort. Sci. 116(1):14-18.*

Internode length increases as day temperature increases relative to night temperature.

Poinsettia stem elongation is most sensitive to cool and/or warm temperatures at the beginning of the morning. Dropping temperatures during the last hour of the night and the first 4-5 hours of the morning will dramatically reduce internode elongation. In contrast, allowing temperatures to increase rapidly in the morning will stimulate elongation.

Poinsettia stem elongation is most sensitive to cool and/or warm temperatures at the beginning of the morning.

Poinsettias have an optimal temperature for stem elongation. The optimal temperature for poinsettia stem elongation is 76°F. Elongation is reduced if either day/night temperature deviates from 76°F.

Height Management:

The importance of leaf number and/or internode elongation varies at different times during the development of a poinsettia. For instance, leaf number and internode length may be of primary concern prior to flower initiation, whereas internode elongation only is usually of concern after initiation, since leaf number is set. Bract expansion and color may be more important than internode elongation late in development. It is critical that you, as a grower, understand how you can manage temperature effectively to promote what type of growth you desire at different times in the development of the poinsettia.

The importance of leaf number and/or internode elongation varies at different times during the development of a poinsettia.

An effective way to break down environmental management of a 'pinched' poinsettia crop is to simply discuss each stage of poinsettia development and what factors are critical during each stage to produce a quality poinsettia. Factors which determine mother shoot height and leaf number will be discussed first. Second, timing of pinching and how pinching technique affect plant height will be discussed. Lastly, management of the environment following flower initiation to control stem elongation and promote bract expansion will be discussed.

Cutting and Mother Shoot Management:

The mother shoot is of importance because it determines the potential break number following a pinch and establishes the plant height from which the lateral shoots develop. Few leaves on the mother shoot will result in few breaks. In contrast, high leaf numbers on a mother shoot often result in higher break or lateral shoot numbers. Therefore, it is important to manage the cutting after potting but prior to pinching to promote leaf unfolding to achieve the desired leaf number.

It is also important to control internode elongation on the mother shoot to result in a short compact plant. This is often difficult to do since

It is also important to control internode elongation on the mother shoot to result in a short compact plant.

Table 2. *Days required to produce a 3 leaf shoot after pinching when 'Dark Red Annette Hegg' plants are grown in a variety of average daily temperature environments. Times are based on published in the following reference: Berghage, R., R.D. Heins and J.E. Erwin, Quantifying leaf unfolding in the poinsettia. Acta. Hort., 272:243-247.*

	Average Daily Temperature				
	60	**63**	**65**	**68**	**71**
Number of Days	20	18	17	15	14

Remember, the higher the day temperature relative to the night temperature, the greater the internode elongation.

mother shoot or cutting growth often occurs in August (one of the warmest months of the year). Because temperature manipulation is difficult during the summer, growers frequently depend on growth retardant applications to control mother shoot height. Experience has shown that frequent lower concentration applications of growth retardants result in better height control than infrequent higher concentration applications.

Frequently, mother shoot height control is ignored and, as a result, cutting height is too tall. When this occurs you will find yourself in the difficult situation of deciding whether you will accept a taller final plant, or reducing potential break number by 'hard' pinching the cutting.

If temperature manipulation is possible, attempt to reduce the day temperature as much as possible the remainder of the day. Remember, the higher the day temperature relative to the night temperature, the greater the internode elongation. If you cannot control day temperatures all day, drop morning temperatures to below the night temperature, if possible, starting 1 hour prior to dawn until 3 hours after sunrise to get some reduction of stem elongation using temperature. Temperature control of stem elongation is preferable to chemical control of stem elongation since repeated growth retardant applications may affect subsequent lateral shoot breaking after pinching.

Planting and pinching dates should be managed to result in the desired leaf number on a cutting at the desired pinch date.

Planting and pinching dates should be managed to result in the desired leaf number on a cutting at the desired pinch date. In addition, enough time needs to be allocated to allow lateral breaks to develop after pinching but prior to flower initiation to produce strong growth, large leaves and high bract quality. Table 1 shows the predicted pinch and planting dates for poinsettia crops grown at different average daily temperatures prior to pinching and which vary in the final desired break number. This data was calculated from information collected on the cultivar 'Dark Red Annette Hegg'. Leaf unfolding rates may vary between cultivars (personal communication, Royal Heins).

Table 2 shows the length of time required for plants, after pinching, when grown under a variety of different average daily temperatures to produce lateral breaks with 3 leaves. A shoot should have at least 3 leaves on it at the time of flower initiation if it is to be sold as a 5 inch or greater pinched plant.

To figure out your schedule simply back up from September 20th. For instance, if you would like to grow a 5 break crop at 68°F average daily temperature prior to flower initiation, you will need to pinch your crop on September 5 and plant a cutting on August 17th. Remember, failure to maintain the desired average daily temperatures in the tables means that your schedule will need to be altered.

Remember that newer cultivars such as 'Freedom' will initiate flowers earlier than the older cultivars. Anticipate that 'Freedom' plants will probably initiate flowers one week earlier on September 13.

Break Joint Strength

Breakage of lateral shoots during sleeving and/ or shipping is a common problem.

Breakage of lateral shoots during sleeving and/ or shipping is a common problem. The problem seems to arise from two situations:

1) weak joints - the union of the mother and lateral shoot
2) breaks which are perpendicular to he mother shoot

Weak joints can occur when breaks form rapidly and/or breaking occurs under low light. Weak break joints can also occur when piants are crowded. Crowding results in higher amounts of far red colored light hitting the axillary buds. High far red light inhibits breaking and stimulates rapid elongation of the first internode. Solutions to the weak joint problem include:

1) Maintain temperatures at constant 68-70°F. Do not 'heat up' the crop to stimulate rapid development!

2) Space plants to allow adequate light.

3) Do not allow leaves to shade axillary buds on adjacent plants.

4) Do not grow plants with a high +DIF as this will stimulate rapid elongation.

Weak joints can occur when breaks form rapidly and/or breaking occurs under low light.

Horizontal branching occurs when plants are grown with too much space. Lots of space is fine if the plants are not going to be sleeved. However, horizontal branching resulting from lots of space (light) frequently results in breakage during sleeving. The solution is to simply delay spacing to encourage an upright branch orientation early in shoot development. Early spacing can often result in problems.

Horizontal branching occurs when plants are grown with too much space.

Pinching Techniques:

Pinching technique can influence total plant height. The way in which you pinch influences the number of lateral shoots which develop, the way the axillary buds develop and the final plant architecture and height (Table 3).

We pinch a poinsettia to release the plant from apical dominance. Apical dominance is defined as the inhibition of the lateral bud growth by the growing apex. Traditionally, growers pinch plants based on the size and leaf number on a cutting at the time of pinching. Pinches are either hard (>1" removed), medium (1/2-1" removed) or soft (<1/2" removed).

We pinch a poinsettia to release the plant from apical dominance.

The objective when pinching a poinsettia is to promote rapid uniform lateral shoot development. In order to do this we need to remove all tissues which cause apical dominance. Recent research has shown that the young, immature expanding leaves also contribute to apical dominance in poinsettias. Therefore, the

The objective when pinching a poinsettia is to promote rapid uniform lateral shoot development.

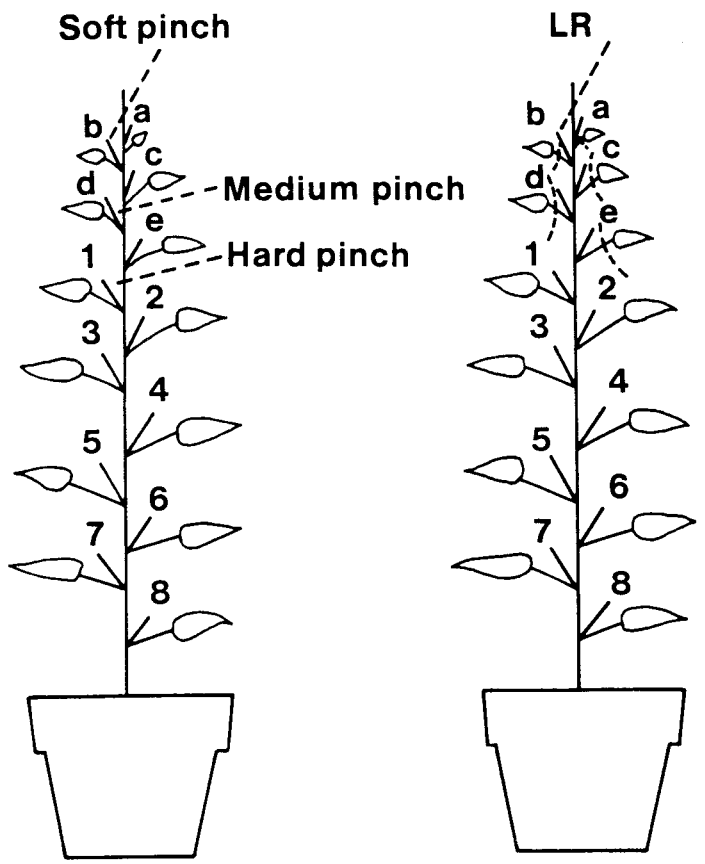


Figure 2. *Effect of pinching technique on average lateral shoot growth rate of shoots 1 to 8 and analysis of variance for 'Annette Hegg Dark Red' in 1987, from pinching to anthesis. Lateral shoot 1 is one subtended by the uppermost fully expanded leaf at pinching. Shoots 2 through 8 were the lateral shoots subtended by the 2nd through the 8th fully expanded leaf at pinching. Pinching treatments were: soft (removal of the apical meristem plus stem and leaf tissue associated with leaves ≤2 cm long); hard (removal of the apical meristem plus stem and leaf tissue associated with all immature leaves); and leaf removal (LR) (soft pinch as defined above plus removal of all immature leaves but not the associated stem tissue). From: Berghage, R.D., R.D. Heins, M. Karlsson, J. Erwin and W. Carlson. 1989. Pinching technique influences lateral shoot development in poinsettia. J. Amer. Soc. Hort. Sci. 114(6):909-914.*

Table 3. *The influence of pinching technique on days to flower (DTF), height to width ratio, primary stem length and inflorescences in the bract canopy. Primary stem length is the length of the uppermost lateral shoot on the mother shoot. A high height to width ratio denotes an upright plant whereas a low height to width ratio denotes a broad plant. Data contained in this table was extracted from a table from: Berghage, R., R.D. Heins, M. Karlsson, J. Erwin and W. Carlson. 1989. Pinching technique influences lateral shoot development in poinsettia. J. Amer. Soc. Hort. Sci., 114(6):909-914.*

Cultivar	Pinch Type	DTF	Height:Width	StemLength (cm)	Inflorescence # in flow. canopy
Annette Hegg Dark Red	soft	48	.85	19.9	6.3
	hard	51	.85	10.9	5.5
	soft + leaf removal	56	.74	16.7	8.2
Annette Hegg Brilliant	soft	48	.79	17.3	6.3
	hard	53	.68	10.4	5.7
	soft + leaf removal	54	.67	14.3	8.7
V-14 Glory	soft	66	.74	15.4	7.6
	hard	78	.59	9.9	6.3
	soft + leaf removal	80	.55	11.3	8.9

Removal of the immature leaves results in uniform breaking, maximizes total break number, greater plant width, reduction in total plant height and more inflorescences contributing to the overall flowering canopy.

presence of immature leaves on a 'soft-pinched' plant will influence subsequent lateral shoot development on a mother cutting. A new technique has been proposed by R. Berghage and R. Heins where young leaves are removed following a soft pinch. Removal of the immature leaves results in uniform breaking, maximizes total break number, greater plant width, reduction in total plant height and more inflorescences contributing to the overall flowering canopy (Table 3). The benefits and disadvantages of each pinching technique are shown below (Figure 2).

Hard Pinch

Advantages: Easy, fast, and generally results in uniform axillary bud breaking.

Disadvantages: Can only be used on plants which have attained a desired leaf number. Occasionally one of the upper 2 shoots will be excessively tall resulting in an uneven flowering canopy.

Medium Pinch

Advantages: More nodes are left on the plant than on a hard pinch which can ultimately result in more breaks.

Disadvantages: Immature leaves left on the mother shoot inhibit the growth of lateral shoots below. This results in the tendency for the uppermost lateral shoots to be longer, sticking out above the plant flower canopy giving the plant an uneven appearance.

Soft Pinch

Advantages: More nodes are left on the mother shoot. Plants which receive a soft pinch will often grow tall and narrow which may be an advantage with limited bench space.

Disadvantages: Plants are tall and narrow with more lateral shoots appearing below the flower canopy. A smaller percentage of the lateral shoots develop into flowering shoots.

Soft Pinch + Leaf Removal

Advantages: Release of lateral shoots occurs quickly and uniformly. Number of potential lateral breaks is maximized. More of the lateral shoots contribute to the flower canopy compared to medium or soft pinched plants. A more uniform flower canopy with respect to height.

Disadvantages: Labor intensive. Flowering is delayed on plants on which leaf removal has been used compared to plants which are soft, medium, or hard pinched. The delay is usually no longer than 2-3 days.

Clearly one way to help manage total plant height is to pinch using a hard or soft pinch plus leaf removal. From the data presented above, we can see that a hard pinch reduces final plant height 40-45% and soft pinch plus leaf removal reduces plant height 12-27% relative to the soft pinch with no leaf removal.

Flower Initiation:

The poinsettia is a short day plant. In other words, poinsettias will flower when the night length exceeds some critical length. Flower initiation occurs under natural photoperiodic conditions throughout the United States for most cultivars between September 10 and 25th. Each cultivar varies with respect to its critical photoperiod.

The optimal temperature for flower initiation of poinsettia is 68°F. It is critical that you, as a grower, maintain night temperatures during the flower initiation period below 74°F. Failure to do this will delay flowering, increase node number and will increase overall plant height in most cases.

Lateral Shoot Height Management:

After flower initiation, the primary concern for most growers is control of stem elongation of the lateral shoots. This is the period where plant height can get 'out of control'. This period typically occurs between September It is critical to control stem elongation during this period as growth regulators cannot be used after October 15 because they reduce bract size. In addition, use of temperature late in development (after October 15), when the plants are not elongating as rapidly, will not have as great an impact on total plant height.

Graphical Tracking: The elongation pattern of the lateral shoots of all determinant crops is similar. First, there is a lag period. Second, there is a period of rapid elongation. Lastly, elongation slows and finally stops as the inflorescence develops. A 'model' curve can be developed which can help you follow the elongation of your crop graphically to determine whether your crop is elongating more rapidly than may be desired, or not enough. This technique was developed by Royal Heins at Michigan State University and is referred to as 'graphical tracking'. The procedure for developing a graphical track for your poinsettia crop is shown in the following article, 'Making a graphical track'.

A more in depth article on graphical tracking of a variety of poinsettias will appear in the next issue of the MCFGA bulletin.

Plants are entering the rapid elongation phase in the beginning of October if they are pinched prior to flower initiation and are initiated under natural photoperiodic conditions. With older cultivars both temperature manipulation and growth retardant application will be necessary to control stem elongation during the rapid elongation phase. However, in northern climates many growers are finding that height control can be achieved solely with temperature manipulation when newer-shorter growing cultivars such as 'Freedom' are grown.

DIF: Control of day and night temperature during the rapid elongation phase is critical. Traditional temperature regimes suggested that day temperatures should be maintained 7°F higher than night temperatures. The estimated internode length on 'Annette Hegg Dark Red' plants grown with this regime is 3.75 cm. In contrast, if you drop your day temperature so that day and night temperature are equal, the estimated internode length is reduced to 3.0 cm. This translates into a 20% reduction in height! The reduction in internode length is greater when day/night temperatures are changed from a higher day than night temperature to equal day/night temperatures than when the temperature regime is changed from equal day/night temperatures to cooler day than night temperatures.

The poinsettia is a short day plant.

The optimal temperature for flower initiation of poinsettia is 68°F.

After flower initiation, the primary concern for most growers is control of stem elongation of the lateral shoots.

Plants are entering the rapid elongation phase in the beginning of October if they are pinched prior to flower initiation and are initiated under natural photoperiodic conditions.

Control of day and night temperature during the rapid elongation phase is critical.

Table 4. *The influence of dropping the temperature during the first 2 hours of the morning on total plant height at flower of poinsettia cvs 'Starlight'(SL) and 'Lilo'(L). Data presented was extracted from a table presented in: Moe, R., N. Glomsrud, I. Bratberg and S. Valso. 1992. Control of plant height in poinsettia by temperature drop and graphical tracking. Acta Hort., 327:41-48.*

Temperature Treatment	Plant Height (cm)		Plant Diameter (cm)	
	SL	L	SL	L
Constant 66°F	20.3	16.5	28.5	29.1
Drop to 55°F for first 2 hours of morning	15.7	12.7	27.4	27.1
Increase to 77°F for first 2 hours of morning	21.1	18.9	28.3	30.5

Monitor effectiveness of growth retardant applications using graphical tracking.

To limit stem elongation, it is critical that temperatures are cool when light first hits the plants.

The response to day and night temperature and/or the morning drop in temperature is greatest when light intensity during the day is high.

It is important to realize, however, that bract and inflorescence size have an optimal temperature for development.

Chemical Control: Control of internode elongation can be achieved by applying cycocel. Recommended rates for cycocel application range from 750-2500 ppm.

B-Nine application alone is not effective in controlling stem elongation. However, when B-Nine is combined with cycocel, they are together more effective in controlling elongation than either chemical separately. Combining B-Nine and cycocel together is referred to as 'tank mixing'. If you 'tank mix' B-Nine and cycocel together, do not mix more than 750 ppm of each as a single application.

Monitor effectiveness of growth retardant applications using graphical tracking. Plants will 'grow out' of a growth regulator application more quickly when grown under a +DIF temperature regime compared to a 0DIF temperature regime. Do not apply growth regulators after October 15.

Cool Mornings: As stated before, stem elongation responses to temperature are greatest in the morning. Cool morning drops in temperature can greatly reduce plant stem elongation. Conversely, increases in temperature during the early hours of the morning can greatly increase stem elongation.

To limit stem elongation, it is critical that temperatures are cool when light first hits the plants. Do not wait until the sun has already risen. The rapidity of the change in temperature also seems to influence the stem elongation response to the temperature shift. The more rapid the change in temperature, the greater the response.

Table 4 clearly shows that final plant height can be reduced markedly by dropping the temperature for only 2 hours in the beginning of the morning. It is important to realize that the reduction in height is due to a reduction in stem elongation and that node number, plant width and bract size are not greatly affected (Table 4). If you cannot cool plants using air, cool plants by watering plants overhead using cool water.

Interaction Between DIF And Other Environmental Factors:

The response to day and night temperature and/or the morning drop in temperature is greatest when light intensity during the day is high. Under cloudy conditions, temperature control of stem elongation is not as great, and growth retardant applications may be necessary.

The response of stem elongation to day/night temperature is also affected by photoperiod. Stem elongation response to DIF increases as photoperiod length decreases. Therefore, you will probably get a greater response to DIF during October than you would in September.

Bract Expansion and Development:

When many cultivars are initiated using natural photoperiodic conditions, bract expansion usually occurs during the last 1-2 weeks of October. Growth retardants should not be applied during the bract expansion period, i.e. after October 15. Application of growth retardants during bract expansion will, in general, reduce bract size and inflorescence width. Temperature manipulation to control stem elongation will, in general, not reduce bract or inflorescence size, and can be used after October 15.

It is important to realize, however, that bract and inflorescence size have an optimal temperature for development. In general, the warmer day and night temperatures (up to 76°F) are during the bract expansion period, the greater individual bract and inflorescence size is. For this reason you should try to grow a crop at constant 68-72°F when bracts are expanding. After bract expansion is complete, temperatures can be dropped to 55-60°F to intensify the color of the bracts.

References

Berghage, R., R.D. Heins and J.E. Erwin. Quantifying leaf unfolding in the poinsettia. Acta Hort. 272:243-247.

Berghage, R., R.D. Heins, M. Karlsson, J. Erwin and W. Carlson. 1989. Pinching technique influences lateral shoot development in poinsettia. J. Amer. Soc. Hort. Sci. 114(6):909-914.

Berghage, R.D. and R.D. Heins. 1991. Quantification of temperature effects on stem elongation in poinsettia. J. Amer. Soc. Hort. Sci. 116(1):14-18.

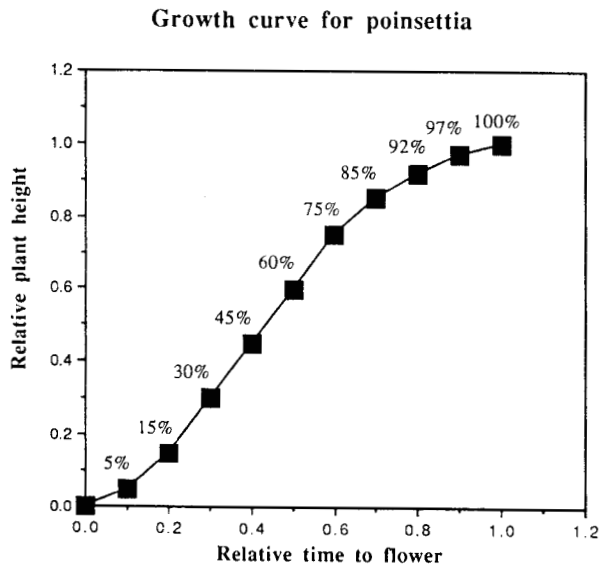
Moe, R., N. Glomsrud, I. Bratberg and S. Valso. 1992. Control of plant height in poinsettia by temperature drop and graphical tracking. Acta Hort. 327:41-48.

MAKING A GRAPHICAL TRACK FOR A POINSETTIA CROP

John Erwin
University of Minnesota

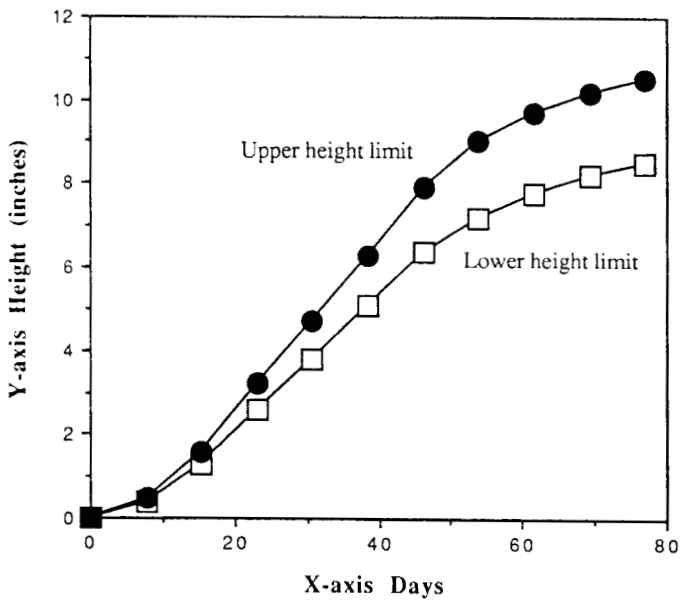
To make a graphical track, all you need to know is your crop time (from pinch to flower), cutting and pot height, growth percentages at specific points during crop development (taken from growth curve, Figure 1) and final desired crop height.

Figure 1.



To make a graphical track for a poinsettia crop, start with the growth curve in Figure 1. This is a typical growth curve for a poinsettia crop -- it's called a sigmoid curve. Along the points on this curve you can see stages of growth for a typical poinsettia. You initially see a lag phase, or a period when the plant is getting established in the pot. Zero to about 15% of the elongation occurs during this phase. Then the rapid elongation phase, when the plant is putting on most of its height (15 to 85% of growth on our graph). The plateau phase represents that period in plant growth when the flower buds are developing and the rate of height increase is slowing down (in our graph from 85 to 97%). And finally flowering, where the plant is in flower and ready for sale (100% of the desired height). From the curve and the percentages shown you can make your own growth curve for any poinsettia crop and understand where your plants are in their growth phases.

Figure 2.



For the purpose of example, let's use the poinsettia crop we grew at the university, which has an 11-week (77 days) production time from pinch to finish. The pot height is 5.5 inches; cutting height is 4 inches. Final desired height is between 18 and 20 inches, determined by customer specifications.

The growth we're really concerned with is the lateral shoot growth after pinching.

To make a graphical track, all you need to know is your crop time (from pinch to flower), cutting and pot height, growth percentages at specific points during crop development and final desired crop height.

From the curve and the percentages shown you can make your own growth curve for any poinsettia crop and understand where your plants are in their growth phases.

In order to get the desired lateral shoot length for our crop, we need to subtract the fixed or constant factors, such as pot height and cutting height, that contribute to total plant height.

In order to get the desired lateral shoot length for our crop, we need to subtract the fixed or constant factors, such as pot height and cutting height, that contribute to total plant height.

Lateral shoot length = 18 to 20 inches final plant height - 4 inch cutting height - 5.5 inch pot height = 8.5 inches to 10.5 inches needed growth.

Give yourself a window on your final lateral shoot length of 1 or 2 inches.

In this case, over the 77-day crop time, we want the lateral shoots to elongate at least 8.5 inches but no more than 10.5 inches. The lateral shoot lengths are numbers you'll use to calculate the upper and lower limits of your tracking window.

Table 1. X-axis

1	2	3
Time (%)	**Calculation (time % as a decimal x days from pinch to flower**	**Days (x-value)**
0	0 x 77	0
10	0.1 x 77	7.7
20	0.2 x 77	15.4
30	0.3 x 77	23.1
40	0.4 x 77	30.8
50	0.5 x 77	38.5
60	0.6 x 77	46.2
70	0.7 x 77	53.9
80	0.8 x 77	61.6
90	0.9 x 77	69.3
100	1.0 x 77	77.0

Now, to make the graphical tracking window, you'll need to make two tables, x-axis and y-axis like the ones on this page. In both tables, the relative time (Table 1, column 1) and relative height columns (Table 2, column 1) stay the same for every poinsettia graph. The numbers you need to fill in are the number of days from pinch to flower on the x-axis table (in our example 77 days) (Table 1, column 2) and the lower and upper height limits on the y-axis table (8.5 and 10.5 inches) (Table 2, columns 2 and 4).

The numbers in the third column in Table 1 and the third and fifth columns in Table 2 are the ones we calculate, these are the numbers we'll use to create your tracking window. In the x-axis table (Table 1), multiply the time in crop development (expressed as a decimal not a percentage) by the number of days from pinch to flower to get your x values. In the y-axis table (Table 2), multiply the crop height (taken from the growth curve and expressed as a decimal,

Table 2. Y-axis

1	2	3	4	5
Height (% taken from growth curve)	**Calculation (height % as a decimal x final height lower limit)**	**Lower height limit (inches) (y-value)**	**Calculation (___ x final height upper limit)**	**Upper height limit (inches) (y-value)**
0	0 x 8.5	0	0 x 10.5	0
5	0.05 x 8.5	0.4	0.05 x 10.5	0.5
15	0.15 x 8.5	1.3	0.15 x 10.5	1.6
30	0.30 x 8.5	2.6	0.30 x 10.5	3.2
45	0.45 x 8.5	3.8	0.45 x 10.5	4.7
60	0.60 x 8.5	5.1	0.60 x 10.5	6.3
75	0.75 x 8.5	6.4	0.75 x 10.5	7.9
85	0.85 x 8.5	7.2	0.85 x 10.5	9.0
92	0.92 x 8.5	7.8	0.92 x 10.5	9.7
97	0.97 x 8.5	8.2	0.97 x 10.5	10.2
100	1.00 x 8.5	8.5	1.00 x 10.5	10.5

The lateral shoot lengths are numbers you'll use to calculate the upper and lower limits of your tracking window.

not a percentage) by the lower final height limit to get y values for the lower line of your tracking window. Follow the same procedure with the upper final height limit to get y-values for the upper line of your tracking window.

Use the numbers you've calculated (Table 1, column 3; Table 2, columns 3 and 5) to create a graphical tracking window. Measure sample plants regularly (use different plants over time) and plot average lateral shoot length (y-value) against the day in crop development (x-value). Remember lateral shoot length = total height - mother shoot height - pot height. Points should fall within the tracking window. If the plants are getting too tall you may need to apply growth regulators, or use -DIF; if the plants are too short, you may need to increase the day temperature relative to the night temperature to increase the elongation of the plants.

The tables and corresponding graphical tracks are easiest to make if you have a spreadsheet computer software program.

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POINSETTIA PROBLEM AVOIDER

John Erwin
University of Minnesota

The 5 most common problems which I have seen in producing a high quality poinsettia crop are 1) scheduling to insure proper size and break number at flower initiation, 2) shoot breakage during shipping, 3) bract edge necrosis, 4) excessively small bracts and 5) root rot in the postharvest environment or late in the production cycle. The basis for each of these problems and the solutions for each are shown below.

The 5 most common problems which I have seen in producing a high quality poinsettia crop are 1) scheduling to insure proper size and break number at flower initiation, 2) shoot breakage during shipping, 3) bract edge necrosis, 4) excessively small bracts and 5) root rot in the postharvest environment or late in the production cycle.

Scheduling To Insure Proper Size and Break Number:

Plants which are pinched late or after flower initiation often have small bracts and leaves and are excessively short due to a reduced node number. In addition, shoot strength is usually weak. Last year this was a common problem because September was unusually cloudy in many areas of the United States. As a result, plant temperatures were somewhat cooler than usual and plants were smaller at the time of flower initiation than what is typical.

Solution: How fast poinsettias unfold leaves depends on the average daily temperature which they are grown. Table 1 shows the predicted pinch and planting dates for poinsettia crops grown at different average daily temperatures prior to pinching and which vary in the final desired break number.

Table 2 shows the length of time required for plants, after pinching, when grown under a variety of different average daily temperatures to produce lateral breaks with 3 leaves. A shoot should have at least 3 leaves on it at the time of flower initiation if it is to be sold as a 5 inch or greater pinched plant.

To figure out your schedule simply back up from September 20th. For instance, if you would like to grow a 5 break crop at 68°F average daily temperature prior to flower initiation you will need to pinch your crop on September 5th and plant a cutting on August 11th. Remember that newer cultivars such as 'Freedom' will initiate flowers earlier than the older cultivars. Anticipate that 'Freedom' plants will probably initiate flowers on 1 week earlier on September 13.

Shoot Breakage During Shipping:

Shoot breakage during shipping is probably related to the temperature and light quality environment that plants are exposed to immediately after pinching. High temperatures will result in rapid axillary bud and shoot development immediately after pinching. Rapid development after pinching seems to result in weak 'stem joints' and long, weak first internodes.

Table 1. *The number of days needed from planting until pinching to produce plants with various break numbers at various average daily temperatures. To generate this table it was assumed that cuttings had 4 leaves when planted, that pinching resulted in the removal of 2 leaves, that 80% of the axillary buds developed into breaks and that flower initiation occurs on September 20. Times are based on leaf unfolding rate functions published in the following reference: Berghage, R., R.D. Heins and J.E. Erwin, Quantifying leaf unfolding in the poinsettia. Acta. Hort., 272:243-247.*

Final Estimated Break Number	Average Daily Temperature (°F)				
	60	63	65	68	71
4 Breaks	21	18	16	15	14
5 Breaks	28	24	22	20	19
6 Breaks	35	30	27	25	23
7 Breaks	42	35	33	30	28
8 Breaks	49	41	38	35	33

Crowding of plants results in low light which is high in far-red light in the canopy. Low light conditions and light high in far-red light results in a thinner more elongated first internode. In addition, axillary shoot development is inhibited so break number will typically be reduced.

Solution: Make sure that plants are not grown at an excessively high temperature environment or are crowded immediately after pinching. Maintain plants at constant 65-70°F if possible after pinching. In addition, space plants if you can. The strongest joint and internode should be the first one! Later, do not give too much space, as horizontal branches will develop which also break when sleeved.

Table 2. *The number of days required to produce a shoot with 3 leaves after pinching when plants are grown in a variety of average daily temperature environments. Times are based on published in the following reference: Berghage, R., R.D. Heins, and J.E. Erwin, Quantifying leaf unfolding in the poinsettia. Acta. Hort., 272:243-247.*

	Average Daily Temperature				
	60	**63**	**65**	**68**	**71**
Number of days	20	18	17	15	14

Bract Edge Necrosis:

Bract edge necrosis is due to calcium deficiency on the edge of the bract leaves late in crop development. Calcium is not taken up readily when sufficient levels of calcium are not in the medium, when plants are grown in an environment which does not result in transportation (evaporation of water out of the leaves) and/or when excessively high levels of magnesium are in the medium. Calcium is taken up more readily when the plant is actively transpiring, or using water. Low light and/or high humidity environments result in reduced transpiration levels. Low levels of calcium or competition with magnesium for entry into the plant can also result in calcium deficiency.

Solution: Fertilize plants adequately to insure recommended calcium levels are attained. Do tissue tests to insure that your calcium levels in the tissue are also in the recommended range. When you do a tissue test, send in the outer edge of the leaf and not the whole leaf. Do not apply excessive amounts of magnesium to the medium. Grow plants in a low humidity environment especially if light levels are low. Select cultivars which are not prone to get bract edge necrosis.

Small Bracts:

Small bracts are due to pinching the plant near or after flower initiation or from growing a crop at cool temperatures when the bracts are expanding. Late applications of growth retardants will also reduce bract size.

Solution: Do not apply growth retardants after October 15. Control stem elongation with temperature if possible. DIF will affect stem elongation more than bract expansion in most cases.

Bract size increases as temperature increases up to 76°F. The warmer you grow a crop when the bract leaves are expanding, the larger the final bract size will be. Therefore, pay attention to temperatures at the end of October to insure good bract size. Grow you crop at constant 68-70°F the last 2 weeks of October, if possible. After bracts have expanded, temperatures can be dropped to 'color' bracts.

Late Root Rot:

Often poinsettia crops develop root rot late in the production cycle, in the store or in the consumers home. The problem is often aggravated when plants are foiled and, therefore, do not have good drainage. As a result, plants appear wilted and loose the lower leaves. Such root rot is usually due to *Pythium* and/or *Rhizoctonia* infestation.

Solution: Apply a preventative fungicide application for both *Pythium* and *Rhizoctonia* as late in the crop production cycle as possible while still following the label. Late root rot is often a result of *Pythium* infestation due to growing crops cool late in development to enhance bract color. The most effective material for *Pythium* control, based on tests on a seed geranium crops, is Subdue.

Bract edge necrosis is due to calcium deficiency on the edge of the bract leaves late in crop development.

Small bracts are due to pinching the plant near or after flower initiation or from growing a crop at cool temperatures when the bracts are expanding.

Often poinsettia crops develop root rot late in the production cycle, in the store or in the consumers home.

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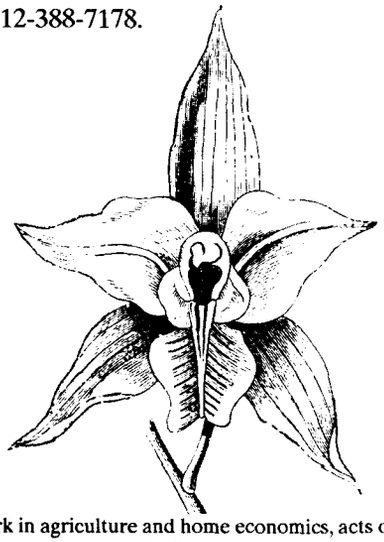

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