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HOW CAN TEMPERATURES BE USED TO CONTROL PLANT STEM ELONGATION?

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I. Introduction

After proper timing, the cultural procedure requiring the most attention in producing a greenhouse crop is often height control. The market value of almost all plants sold as containerized plants decreases rapidly when they are excessively short or tall. Considering how important height control is to the floriculture industry, it is interesting to note how little is known about how the environment influences stem elongation!

During the past 3 years we have realized the importance of day and night temperature on stem elongation. This research initially showed that plant height increased as day temperature increased and also as night temperature decreased. Later a new exciting concept developed when further research determined that the difference between day and night temperature (DIF = day temperature - night temperature) determined plant stem elongation and not absolute day or night temperature.

We took the concept of DIF one step further and suggested that high quality crops can be produced when plants are grown with a warmer night temperature than day temperature! While it seems "unnatural" to grow plants with warmer night temperatures day temperatures - there are at least 3 reasons why this method makes sense. First, final plant height is reduced when compared to traditional temperature regimes, i.e. higher day than night temperature. Second, reverse day/night temperature regimes can save money by reducing or eliminating the need for growth retardants and by reducing heating costs provided that thermal blanket systems are used. Third, reverse day/night temperature regimes allow more precise control of stem elongation on a daily basis.

To understand the benefits of reversing day and night temperatures, let's review the way temperature affects stem elongation in more detail.

II. How Temperature Affects Plant Height

Basic Concepts

Day temperature influences plant height in a different way than night temperature. Plant height increases as day temperature increases. Conversely, plant height decreases as night temperature increases, as seen with the Easter lilies in Figure 1.

As mentioned previously, when these 2 concepts are combined something became obvious; it is the relationship between the day and night temperature that controls plant stem elongation. The warmer the day compared to the night, the taller the plant at flower. **In other words, it is the difference (DIF) between the day and night temperature (day**

The format of the bulletin has been changed to make it easier to read and reproduce. Further modifications may be made in later issues. Any comments or suggestions concerning these changes would be greatly appreciated. Please contact John Dole, Department of Horticultural Science & Landscape Architecture, University of Minnesota, St. Paul, MN 55108, (612) 624-5300.

temperature - night temperature) which determines stem elongation. As DIF between day and night temperature becomes more positive (day temperature warmer than the night temperature), final plant height increases. In contrast, as DIF becomes more negative (day temperature cooler than the night temperature), final plant height decreases (Figure 3). For example, a crop grown with 70°F day and 60°F night temperature (+10°F DIF) will be taller at flower than the same crop grown with 60°F day and 70°F night temperature (-10°F DIF). If day and night temperature are constant (0°F DIF), internode lengths will be similar among plants grown at different absolute day and night temperatures. It is important to realize that the difference between day and night temperature determines internode length regardless of the absolute day and night temperature. Although each of the Easter lilies in Figure 4 were grown with different average daily temperatures, the difference between their day and night temperatures was the same - therefore, plant height at flower was the same.

It is important to realize that the DIF concept has worked on every crop which we have studied with the exception of spring bulb crops. The success of the DIF concept on bedding plant crops is particularly exciting. Even impatiens stem elongation was successfully reduced by DIF (Figure 2)!

An exception to the DIF concept occurs on certain short-day plants such as chrysanthemum, and poinsettia. Very warm nights or days (usually over 72°F) can cause 'heat delay'. This is a condition where plants form a greater number of nodes (leaves) prior to flower initiation. The difference concept still holds with respect to internode length, but the number of internodes is greater so plant height is greater. With regards to poinsettias and chrysanthemums it is best to keep both day and particularly night temperature below 70°F to avoid heat delay.

Cool Temperature Pulse

Some growers observed a greater response of their crops to a negative DIF than did others. Growers who observed a large response to a negative DIF had thermal blankets and opened their blankets quickly in the morning. Temperatures plunged rapidly from the warm night to the cooler day temperature. Those who observed a smaller response to a negative DIF opened their blankets gradually in the morning over a 1-2 hour period.

We suspected the first 2 hours of the morning (light) were especially important in influencing a plant's response to DIF. To test this, Easter lilies were grown with a 1) 68°F day and 68°F night temperature, 2) 54°F day temperature and 68°F night temperature, 3) 54°F for only the first 2 hours of the day and 68°F the rest of the day with a 68°F night temperature and 4) 68°F for the first 2 hours of the day and 54°F for the remaining 7 hours of the day with a 68°F night temperature.

The 54°F day/68°F night temperature regime lilies were significantly shorter than the 68°F day/54°F night temperature plants due to negative DIF, as expected. **Interestingly, stem elongation was reduced almost as much by cooling only the first 2 hours of the day as by cooling all day.** Preliminary experiments have also shown that a cool temperature pulse the first 2 hours of the morning works great with bedding plants as well. Plants seem to be more sensitive to cool day temperatures at the beginning of the day than at the end of the day.

Height control using a cool temperature pulse during the first 2 hours of the morning allows some height control where day temperatures cannot be maintained below night temperatures all day. This has tremendous application for greenhouses which are unable to cool effectively during warmer times of the year and for southern growers!

While a benefit in height reduction is expected from a drop in temperature at sunrise, it is also important to control day temperature as much as possible throughout the day to get the maximum response to the morning cool temperature dip. Previous research shows that high temperatures during the afternoon can stimulate stem elongation.

III. Optimal Time In Plant Development To Apply the DIF Concept

Plants with a terminal flower do not have a constant rate of stem elongation throughout development. Growth starts slowly, increases to a maximum, and then slows. Pinched poinsettias and chrysanthemums elongate in this manner. In both crops, lateral shoot elongation is slow immediately after pinching, increases to a maximum rate of elongation, and then slows as flowers develop. Elongation essentially stops at flower.

Since stem elongation varies during development, the response to DIF also varies during plant development. A large positive DIF or negative DIF during periods of slow stem elongation will have little effect on final plant height. For instance, a negative DIF given to a poinsettia crop immediately after pinching for about 0-14 days will have little effect on final plant height since the lateral shoots are elongating slowly at this time. In contrast, exposure of a plant to a large positive DIF during a period of rapid elongation will have a major impact on final plant height. Rapid growth in the poinsettia begins about 21 days after pinching and ends about 2-3 weeks after visible bud. The influence of DIF on final plant height at this time is great. It is during this time that growers often say "the plants just seem to jump" after several bright sunny days. The "jump" is real and is caused by 2 factors:

1) bright sunny weather increases the average daily plant temperature compared to cloudy days, therefore, plants develop rapidly, i.e. warmer temperatures hasten plant growth and maturation.

2) warm day temperatures increase DIF. A high DIF during rapid periods of elongation will stimulate elongation.

Therefore, a grower must be aware of when DIF is most effective in stimulating and/or inhibiting stem elongation for a crop. **A very significant reduction in final plant height can be accomplished if a negative DIF is applied only during the period of most rapid stem elongation.**

IV. <u>How Increasing Night Temperature Can Save Money</u>

It may seem as if increasing night temperatures during the winter months would be just another added expense. In reality heating costs are only greater if a greenhouse is not equipped with a thermal blanket system. In addition, the savings from a reduction in growth retardant applications may be greater than the additional cost of heating in greenhouses without heating blankets.

A practical example was tested by simulating Easter lily production during January, February, and March. The heating cost for growing Easter lilies with a 68°F day/65°F night temperature regime was compared to that of a 65°F day/68°F night temperature regime. The simulation was done for single pane glass greenhouses with and without thermal blanket systems and was based on the average weather conditions during the past 5 years for East Lansing, Michigan.

When a thermal blanket was not used, heating costs with the reversed day/night temperature regime were 5% greater than those of the traditional temperature regime. When a thermal blanket was used, heating costs were actually 2.5% lower using the reversed temperature regime!

Climate is a significant factor. Michigan winters are cold and cloudy. As a result heating costs are greater during the day than the night if a thermal blanket is used. The opposite is true for sunny climates where the majority of the heating during the day comes from the sun. In a sunny climate, reversed day/night temperature regimes would probably not reduce heating costs.

The possible increase in heating costs associated with using a reverse day/night temperature regimes should be weighed against the savings from reduced growth retardant costs. In addition, the increased control of plant height and development that can be achieved using this method should be considered.

Let us compare the costs associated with increased heating with decreased growth retardant applications on an Easter lily crop. A-Rest is the growth regulator typically applied to Easter lilies. Recommended A-Rest application rates for the Easter lily are 0.25 milligrams of active ingredient per plant if drenched and 0.5 mg active ingredient per plant if sprayed. A-Rest costs approximately $48 per quart. One quart of A-Rest will treat about 1,000 plants as a drench and 500 plants as a spray. The chemical cost would therefore be 4.8 cents per plant as a drench and 9.6 cents per plant as a spray. Completely eliminating A-Rest applications on an Easter lily crop using temperature could save a grower 12 to 24 cents per square foot depending on the plant spacing. This savings is substantially higher than the 5% additional cost of heating associated with the reverse day/night temperature environment.

Controlling height by using the DIF concept on chrysanthemum and poinsettias is not as economical since the cost of growth retardants per square foot is much less. However, using DIF can be very beneficial if 1) reverse temperatures are used only when the plant is in its rapid elongation phase, and/or 2) reverse temperatures are used at the time of the day when the plant is most sensitive, i.e. in the morning. Furthermore, DIF provides an attractive alternative late in a crop's development when application of growth retardants would reduce flower and/or bract size.

V. Disadvantages of Using DIF

Most plants grown with a large negative DIF become somewhat chlorotic. The degree of the chlorosis increases as DIF becomes more negative. In our experience little or no chlorosis occurs when a small negative DIF is used, i.e. 1-5°F. Regardless of the DIF, the chlorosis often disappears as the crop matures so we do not consider it a major problem. However, we have observed very strong responses to a large negative DIF by small (10 day old) bedding plant seedlings. The chlorosis was so great that plant development was markedly slowed.

One advantage in using DIF for height control can also become a disadvantage. The advantage is the great flexibility to increase or decrease elongation on a daily basis depending on the DIF you use. This advantage can quickly become a disadvantage if you wish to control height with a negative DIF but lost temperature control due to weather conditions. Under this circumstance, rapid elongation can occur in a very short period of time.

We do not believe temperature should totally substitute for growth regulators. Instead, we believe it is a tool which can be used to reduce the need for growth regulators and increase the degree of control which growers have over their crops.

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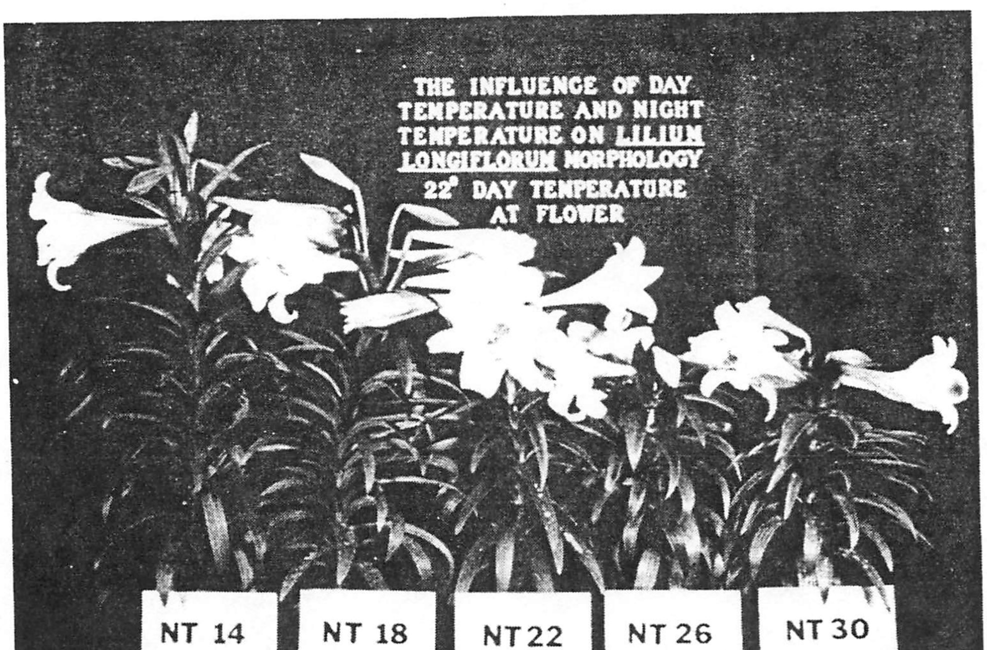

Figure 1. The effect of increasing night temperature from 57°F (14°C) to 86°F (30°C) on Easter lily plant height at flower when grown with a 57°F night temperature.

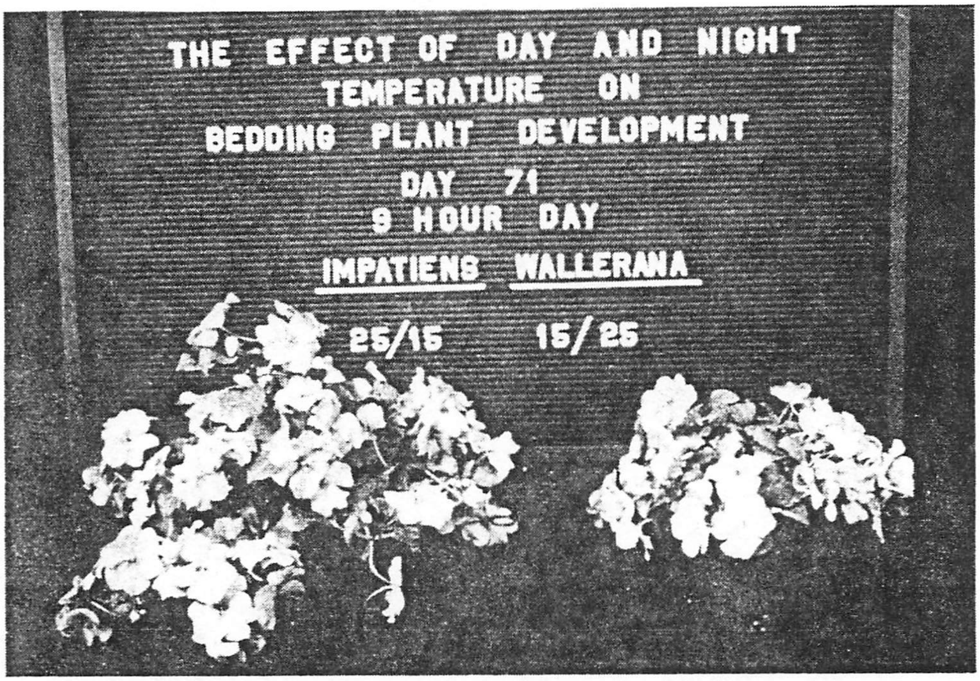

Figure 2. The effect of growing impatiens with a positive DIF (77°F (25°C) day temperature/59°F (15°C) night temperature) or a negative DIF (59°F day temperature/77°F night temperature) on plant height.

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CHEMIGATION STATUTES IN MINNESOTA

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The Minnesota Department of Agriculture (MDA) has recently adopted new regulations concerning chemigation--the process of applying pesticides to land or crops, in or with irrigation water. These directives are part of a public and political movement to prevent the contamination of water supplies. All growers should be aware of the regulations, even if they are not currently using chemigation, because similar statutes concerning the application of fertilizers through irrigation water may be enacted as early as next year.

Irrigation systems are classified as either stand alone pesticide application or chemigation systems. A stand alone pesticide application system utilizes a supply tank containing a mixture of pesticides and water, separate pump, and separate pesticide delivery devices **without any connection to a source of ground or surface water,** or to an irrigation system which is directly connected to ground or surface water. A chemigation system is a device or combination of devices having a hose, pipe, or other conduit **connected directly to a source of ground or surface water** through which a mixture of water and pesticides are drawn and applied to land, crop, or plants.

A "hose on" that contains a direct connection (hose, pipe, or other conduit) to a source of ground or surface water is a chemigation system and is