Minnesota Commercial Flower Growers Association Bulletin

Serving the Floriculture Industry in the Upper Midwest

IN THIS ISSUE

November, 1991 Volume 40, Number 6

THE HISTORY OF DIF AND THE USE OF A MORNING TEMPERATURE DIP TO CONTROL PLANT HEIGHT

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Using DIF (difference between day and night temperature) all day and dropping the day temperature for 2 hours immediately at sunrise has become a common practice by growers attempting to control plant height. This article presents the history behind the discovery of DIF and the temperature dip procedure.

The concept of using cooler day temperatures than night temperatures for height control originated with research by Meriam Karlsson, now a faculty member at the University of Alaska. Meriam made the first of several key observations that led to the DIF and temperature dip concepts. Her observation in 1984 was that chrysanthemum height at flower became progressively shorter as the plants were grown with progressively cooler day temperatures. Royal Heins was discussing this observation with Andy Mast, a grower in Grand Rapids, MI, and Andy asked if day temperature also affected Easter lilies in the same way. Since we did not know, Andy donated some Easter lily plants in 1985 and we grew the lilies under 6 different day and night temperature treatment combinations. Final height of the plants became progressively shorter as day temperature decreases, the second key observation on the way to understanding the effects of day and night temperature on plant stem elongation.

We placed plants from each treatment in a cooler as they flowered so photographs could be taken after all plants had flowered. Placing the plants in the cooler was the key to the discovery of DIF.

The third key observation, and probably the most important, was that of John Erwin. Royal had originally decided to grow another lily crop under 6 different day and night temperature combinations during the 1986 lily season. John, after reading a paper where plants were moved among several greenhouses to expose plants to a factorial combination of day and night temperature combinations, decided to conduct a similar experiment. Andy again donated bulbs. The lily plants were moved twice a day among 5 greenhouse sections sect a 14, 18, 22, 26 and 30°C at 8:00 a.m. and again at 5 p.m. This experimental procedure allowed us to increase the number of day and night temperature treatments from 6 to 25.

It was obvious throughout the experiment that plants were shorter as day temperature decreased. We placed plants from each treatment in a cooler as they flowered so photographs could be taken after all plants had flowered. Placing the plants in the cooler was the key to the discovery of DIF. John started to take pictures when plants in treatments had flowered. To his amazement, plants which were grown with a similar relationship between day and night temperature were the same height. DIF as a concept, had just been discovered.

Implementation of the DIF concept was trialed by several growers the following year, 1987. One day, Royal was visiting a grower who was not seeing a significant effect of the negative DIF treatment on his Easter lilies even though he said he was growing his crop with cooler days than nights. When asked when and how he was lowering his temperatures, he said he opened his thermal blanket slowly in the morning so the temperature did not drop too abruptly.

Because the MSU experiments had been conducted with abrupt temperature changes, Royal suggested the grower completely open his thermal blanket at sunrise so the temperature dropped abruptly. The grower was very hesitant to abruptly open the blanket and let all the cold air drop on the crop as the current thinking at the time among growers was that such a procedure was somehow "bad" for the plants.

However, he did open the blankets abruptly the next morning and within 2 days, he could see a significant change in plant appearance and elongation. The fourth key observation was now in place, i.e., a negative DIF was more effective in reducing stem elongation when the temperature was abruptly dropped at first light than when the temperature was dropped slowly or later in the morning.

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Table 1. Environmental treatments designed to determine the importance of cool temperatures during the first 2 hours of the morning on Easter lily stem elongation. Night temperatures were maintained at 68°F.

	Temperature Treatments	
Treatment Group	During the first 2 hours of the day	During the last 7 hours of the day
1	68	68
2	61	61
3	54	54
4	54	68
5	54	61
6	68	54
7	61	54

The next step in the development of the temperature dip technique came from a problem that Andy Mast faced that same year (1987) with his lily crop. He wanted to control height with DIF but yet needed to maintain a high average daily temperature to achieve

an adequate development rate on the lily crop. Maintaining a lower day temperature than night temperature controls height but reduces the average daily temperature and therefore slows plant development. Night temperature could be raised to offset the cool day temperature but night temperatures above 70°F are not recommended on the Easter lily to avoid flower bud abortion, root rot and lower leaf yellowing.

Maintaining a lower day temperature than night temperature controls height but reduces the average daily temperature and therefore slows plant development.

Table 2. The effect of cool temperatures during the first 2 hours of the morning on Easter lily cvs 'Ace' and 'Nellie White' stem elongation. Night temperatures were maintained at 68°F.

Temperature	Treatment	Cultivar	Mean Change in Height
1	(68/68)	Ace	28.0 + 3.7
		Nellie White	23.0 + 2.7
2	(61/61)	Ace	20.8 + 2.8
		Nellie White	14.8 + 2.2
3	(54/54)	Ace	9.6 + 1.7
		Nellie White	10.6 + 2.1
4	(54/68)	Ace	21.2 + 2.3
		Nellie White	13.8 + 0.8
5	(54/61)	Ace	16.0 + 2.0
		Nellie White	13.2 + 2.6
6	(68/54)	Ace	19.2 + 1.1
		Nellie White	20.0 + 3.0
7	(61/54)	Ace	19.2 + 2.2
		Nellie White	18.2 + 0.5

Andy was already maintaining a 70°F night temperature. So out of this problem, the idea of the temperature dip was born in the mind of Andy Mast. Andy called Royal and asked if he could drop the temperature abruptly at sunrise, maintain the low temperature for a couple of hours, then raise the temperature the rest of the day to 70°F to achieve an average daily temperature of near 70°F. The concept seemed logical so the joint decision was for Andy to go ahead and try it while MSU conducted a controlled experiment testing the idea. Andy tried the technique and was very satisfied with the results. Our experimental results are described below.

We received reproductive 'Ace' and 'Nellie White' Easter lilies from Andy Mast the first week of February, 1987. The height of each plant was measured and the uppermost leaf was dotted with a permanent ink black magic marker to indicate the developmental stage each plant was in at the start of the experiment. Plants were placed into one of seven treatments (Table 1).

Plants were moved among greenhouses during the day to deliver the treatment combinations. Black cloth was pulled over the plants during the night (1700-0800 hour) to insure a constant night length.

The average change in plant height in each of the treatment groups is shown in Table 2. The experiment confirmed earlier observations which showed plant shoot elongation was progressively reduced as DIF became more negative (Figure 1). Shoot elongation was reduced 18.4 and 12.4 cm as DIF decreased from 0 to -14 for 'Ace' and 'Nellie White', respectively (Treatments 1 to 3).

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A dip in temperature in the first 2 hours of the day had a greater effect on stem elongation per hour of cool temperature than dropping the temperature later in the day.

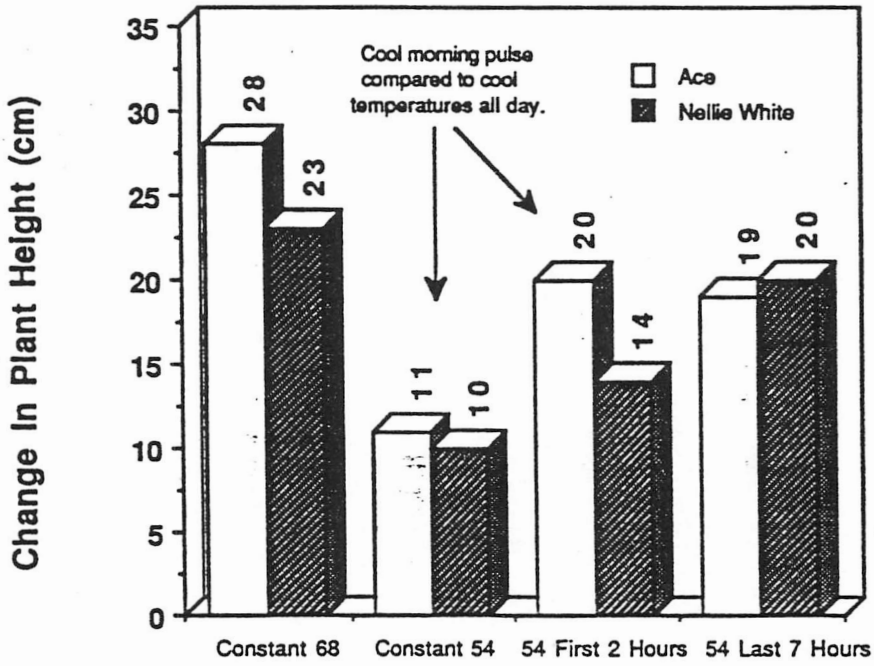

Figure 1. The effect of delivering temperatures at different times of the day on *Lilium longiflorum* cvs 'Ace' and 'Nellie White' stem elongation. The uppermost leaf was marked after flower initiation upon placement in the temperature environments. Plant height was then measured at anthesis. The change in plant height is presented in the figure. Differences in leaf number among treatments was not significant.

The use of lower day temperatures is now common in the greenhouse industry, even though it was once considered heresy.

The dip in temperature at first light also reduce stem elongation. Dropping the temperature to 12°C for the first 2 hours of the day reduced elongation 8 cm on 'Ace' plants and 9 cm on 'Nellie White' plants (Treatment 4). Surprisingly, dropping the temperature a full 7 hours to the same 12°C temperature by starting 2 hours into the day (Treatment 6) only reduced elongation 9 cm on 'Ace' plants and 3 cm on 'Nellie White' plants. Clearly, Andy's idea worked. A dip in temperature in the first 2 hours of the day had a greater effect on stem elongation per hour of cool temperature than dropping the temperature later in the day. A dip in temperature at sunrise followed by a warmer temperature the rest of the day could be used on the Easter lily to reduce stem elongation while maintaining adequate plant development rate.

The temperature dip at sunrise for only the first 2 to 3 hours has especially gained wide acceptance.

It is important to note that while the first 2 hours of the daylight were more important than the remaining hours, the shortest plants were the plants which were exposed to a negative DIF condition all day, not just the first 2 hours of the day (Compare Treatment 3 with 4 and 5).

The use of lower day temperatures is now common in the greenhouse industry, even though it was once considered heresy. The temperature dip at sunrise for only the first 2 to 3 hours has especially gained wide acceptance. Reasons include:

1) Significant height reduction can occur while the rate of plant development to flower is not greatly impacted.

2) The temperature dip can be used for height control in most climates since the coolest time of the day is normally at sunrise. Some reduction in height can be achieved even if temperatures later in the day are greater than the night temperature.

This article has attempted to describe the historical development of the DIF concept and to present data to support the temperature dip concept. Neither has been published before.