TEMPERATURE CONTROLLED LEAF UNFOLDING RATE IN HIBISCUS

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Abstract

Leaf unfolding rate of *Hibiscus rosa-sinensis* 'Brilliant Red' and 'Pink Versicolor' was determined in the temperature range of 5° to 35°C. Plants grown at 5° and 11°C developed chilling injury. At 5°C, plants did not survive and at 11°C, plants grew very slowly. The two cultivars unfolded leaves at similar rates over the 11° to 35° temperature range. Daily leaf unfolding rate was described as a cubic polynomial function of temperature (T) where leaves day^{-1} = 0.0628876 - 0.0202625 * T + 0.0017497 * T^2 - 0.00002983 * T^3. Based on this function, predicted leaf unfolding varied from 0.012 leaves day^{-1} at 11° to a maximum of 0.229 leaves day^{-1} at 32°C. A linear function (leaves day^{-1} = -0.113 + 0.01148 * temperature) could approximate the curvilinear leaf unfolding relationship in the range from 11° to 29°C. Using the linear function, a degree-day relationship was calculated to 0.0115 leaves day^{-1} using a base of 9.8°C. Alternatively, 87 degree-days were required to unfold one leaf. Both the linear model and the cubic model predicted leaf unfolding within 0.5 leaves in a commercial Florida greenhouse over a seven week period.

1. Introduction

Scheduling and timing of crops are important procedures in the floriculture industry. Developmental progress on plants producing a known number of leaves prior to flower initiation can be tracked by the rate of leaf appearance. A leaf unfolding function is a tool useful in predicting and maintaining plant production on a desired schedule.

Leaf unfolding rate in many plant species is determined by average daily temperature (Friend et al., 1962; Tollenaar et al., 1979; Rawson and Hindmarch, 1982; Kiniry et al., 1983; Karlsson et al., 1988). In the range of 22° to 29°C day temperatures and 12° to 22°C night temperatures, leaf appearance in sunflower was linearly related to mean temperature (Rawson and Hindmarch, 1982). Leaf emergence in maize was 'nearly linear' in the range from 12° to 26°C (Tollenaar et al., 1979) and Easter lily leaf unfolding was linear in the range from 14° to 30°C (Karlsson et al., 1988). A positive linear relationship was also found for wheat as the temperature increased to 25°C (Friend et al., 1962). Further temperature increases beyond 25°C, however, resulted in decreased wheat leaf unfolding rates.

Many plant responses over a wide range of temperatures are curvilinear. Curvilinear plant responses can often be approximated by linear relationships due to the range of temperatures commonly encountered in greenhouses (Karlsson et al., 1988). Linearization facilitates the use of thermal unit systems, such as degree-days, to time the crop. Degree-days are calculated by accumulating average daily temperatures above a base temperature in the linear region of the temperature response curve. No development is expected to occur below the base temperature.

Hibiscus are produced in heated greenhouses in temperate climates and in unheated greenhouses in subtropical climates. Under unheated conditions, abnormally cold temperatures slow plant development and adversely affect plant timing and schedules. A model allowing prediction of accumulated crop development would be useful under these situations.

The purpose of this study was to quantify the temperature controlled leaf unfolding rate of Hibiscus rosa-sinensis. Functional relationships were developed to describe and summarize the effects of temperature on hibiscus leaf appearance.

2. Materials and Methods

Leaf unfolding rate was determined in the hibiscus cultivars 'Brilliant Red' and 'Pink Versicolor'. Hibiscus plants growing in 15 cm pots were received from Alva, Florida, and acclimatized in a 50% shaded greenhouse for three weeks upon delivery. After the three weeks, 42 pots of each cultivar with comparable development were selected for experimentation. All the selected pots had plants with at least six developing lateral shoots. The chosen pots were distributed among six growth rooms maintained at 5°, 11°, 17°, 23°, 29° or 35°C to maintain apical leaf and stem tissue at the night temperature setpoint. Irradiance at canopy level was 200 μmol $s^{-1}m^{-2}$ from cool-white fluorescent lamps for 10 hr day^{-1}. Plants were subirrigated as necessary with a nutrient solution consisting of 7.1 mM N and 2.5 mM K.

The most recently unfolded leaf (greater than 1 cm in length) on six shoots of each plant was marked by a hanging paper tag. Number of unfolded leaves above the marked leaf was recorded daily for each individual shoot. Linear regression functions were developed for each individual shoot relating leaf number to time (hours). Time in hours was used as data were not always collected at the same time during the day. The first derivative of these functions gave the rate of leaf unfolding (leaves $hour^{-1}$). The resulting leaf unfolding rates from shoots within a temperature were converted from an hourly to a daily basis and then pooled for further regression analyses to determine temperature driven leaf unfolding rate.

Separate regression functions were developed for the two cultivars. These multiple linear regressions were performed to describe the rate of leaf unfolding (leaves day^{-1} versus temperature) using first, second, third and fourth order terms of temperature as independent variables. Selection of final regression functions was based on significance of included independent variables, F and R^2 values of the equations, and the adequacy of prediction. All independent variables included in the selected functions were significant at the 0.01% level. Both the linear and cubic models were validated by comparing actual leaf unfolding for five hibiscus cultivars ('Brilliant Red', 'Pink Versicolor', 'Florida Sunset', 'Painted Lady', and 'Euterpe') with predicted leaf unfolding. Temperatures were recorded hourly in unheated Florida greenhouse structures (Yoder Brothers, Inc., Alva, Florida). Hourly temperatures were used for all calculations. When temperatures exceeded 30°C, calculations were made using 30°C for the linear model.

3. Results

Hibiscus plants grown at the low experimental temperatures of 5° and 11°C experienced chilling injury. The 5° plants were severely damaged and did not survive, while the 11° plants supported limited growth.

The two examined cultivars had similar rates of leaf unfolding. As the temperature increased, leaf unfolding increased to a maximum rate and then decreased for both cultivars (Figure 1). Based on the test by Williams and Kloot (Williams, 1959), the two selected cultivar functions were equal in predicting rate of 'Brilliant Red' and 'Pink Versicolor' leaf unfolding. The following function using the data from both cultivars was therefore developed to describe the temperature controlled leaf unfolding rate in hibiscus:

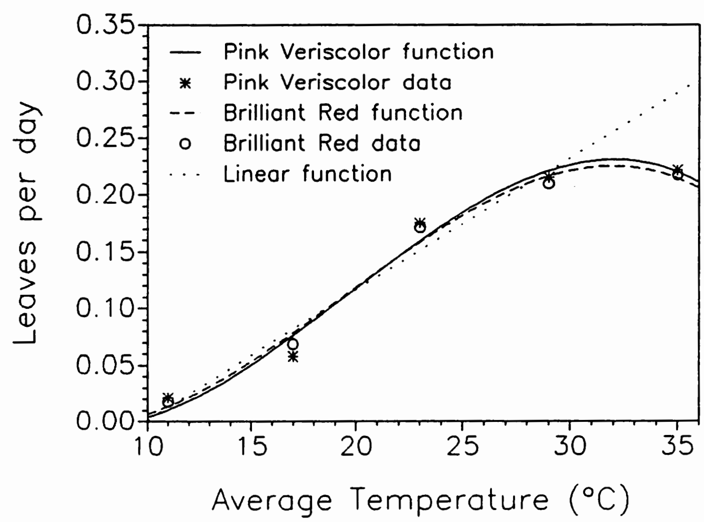

Figure 1 - Leaf unfolding rate of Hibiscus rosa-sinensis in response to average daily temperature.

$$\text{Leaves day}^{-1} = 0.0628876 - 0.0202625 * T + 0.0017497 * T2 - 0.000029\,83 * T3 \quad (r^2 = 0.96)$$

(where T is the temperature in °C).

Maximum rate of leaf unfolding (0.2251 leaves day^{-1}) was predicted at 32°C (Figure 1). A hibiscus plant unfolding leaves at the fastest predicted rate required about 4 days to unfold one leaf. The rate of leaf unfolding in the 11° to 29°C range could be described by a linear function of temperature in the form:

$$\text{Leaves day}^{-1} = - 0.113 + 0.01148 * T \quad (r^2 = 0.93)$$

The largest difference in prediction between the cubic and the linear equations in the 11 to 29°C range was 0.008 leaves day^{-1} at 14.5°C. The base temperature below which no leaf unfolding is expected was estimated at 9.8°C using the linear leaf unfolding function.

Both linear and cubic models accurately predicted leaf unfolding over time (Figure 2). The linear and cubic models overpredicted leaf unfolding by a average of 0.22 and 0.20 leaves, respectively, out of 5.2 leaves through 6.5 weeks from pinching (Table 1). The maximum error was

0.59 and 0.43 leaves for the linear and cubic model, respectively.

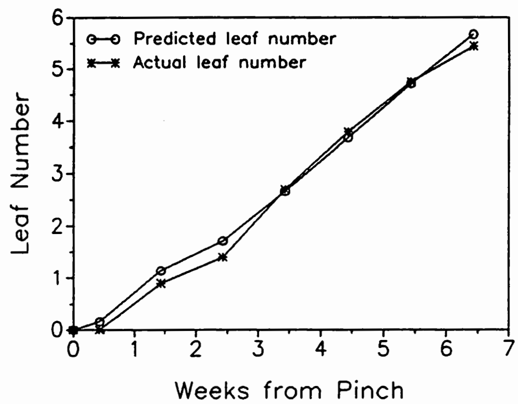

Figure 2 Comparison of actual versus predicted leaf unfolding for Hibiscus rosa-sinensis 'Pink Versicolor' grown in an unheated greenhouse in Florida. Plants were pinched on 24 February, 1989.

4. Discussion and Conclusions

No difference was detected in leaf unfolding rate for the two studied cultivars (Figure 1). Similar leaf unfolding rates among hibiscus cultivars is also suggested by the ability of both models to accurately predict leaf unfolding over five cultivars. Although many hibiscus cultivars may have similar rates of leaf appearance, time to flower will vary depending on number of leaves formed prior to first flower initiation. A longer time period is required for flowering in cultivars with a high leaf number. In this study, the average number of leaves below the first flower on a lateral shoot was 7.4 + 1.1 leaves for 'Brilliant Red' and 6.1 + 0.8 leaves for 'Pink Versicolor'. Leaf number did not vary among plants grown at different experimental temperatures. 'Pink Versicolor', which forms fewer leaves than 'Brilliant Red' before forming flower buds, has been observed to flower earlier than 'Brilliant Red' under the same environmental conditions (Mike Hackmann, personal observation). Flowering of cultivars with a high leaf number will be delayed more significantly at low temperatures than high temperatures compared with cultivars with a low leaf number. For example, flowering would be delayed 35 days on a cultivar with one extra leaf at 12°C. In contrast, the delay is much less at warmer temperatures; a five day delay would be expected at 30°C.

Part of a curve describing temperature driven leaf unfolding can often be approximated by a linear function. Hibiscus leaf unfolding could be described linearly in the 10° to 30°C range. In the linear portion of the response, leaf unfolding rate increased 0.012 leaves day^{-1} for each 1°C temperature increase. As a comparison, the increased rate per 1°C for a chrysanthemum is 0.018 additional leaves day^{-1} in the 10° to 30°C range (Karlsson et al., 1989), and 0.094 additional leaves day^{-1} for Lilium longiflorum in the 14° to 30°C range (Karlsson et al., 1988).

Both the linear and cubic model overpredicted leaf unfolding by a small amount (Table 1). This overprediction is probably due to the models not accounting for a lag phase immediately after pinching. Both models were developed from data collected on leaves developing after the first leaf unfolded from the pinch. Incorporation of a delay model associated with the number of degree-days necessary for release of a lateral shoot from apical dominance would likely improve prediction accuracy.

Approximation by a linear function allows the use of degree-days to schedule a crop. The slope of the linear function is leaves per (degree-day) and the inverse of the slope is degree-days leaf^{-1}. The number of leaves per degree-day is predicted at 0.0115 and the number of degree-day per leaf at 87 with a base temperature of 9.8°C. The number of leaves initiated below the flower will determine the total number of degree-days required from pinching to flowering. This linear model accurately predicts development as long as temperatures do not exceed 30°C (Table 1, Figure 2).

Table 1 - Comparison of actual and predicted number of unfolded leaves after pinch on Hibiscus rosa-sinensis.

		LEAF NUMBER		
			Predicted by model	
Cultivar	Days of growth	Actual	Linear	Cubic
Pink Versicolor	45	5.45	5.67	5.69
Brilliant Red	38	4.75	4.84	4.83
Florida Sunset	39	4.55	5.01	4.98
Painted Lady	45	6.00	5.67	5.69
Euterpe	45	5.15	5.67	5.69

Linear model: leaves/day = - 0.11401 + .01154 * T
Cubic model: leaves/day = 0.06 28876 - 0.02026 25 * T
+ 0.0017497 * T 0.00002983 *T

The rate of leaf unfolding in hibiscus was a function of average temperature. Maximum predicted rate of leaf unfolding occurred at 32°C and a linear function approximated the leaf unfolding response in the 11° to 30°C temperature range. Zero leaf unfolding rate was estimated to occur at 9.8°C.

5. Acknowledgements

This project was funded in part by Yoder Brothers, Inc., Barberton, Ohio.

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