Energy-Efficient Greenhouse Production of *Petunia* and *Tagetes* by Manipulation of Temperature and Photosynthetic Daily Light Integral

The cost of fuels is an increasingly significant production expense for greenhouse growers in temperate climates. There are several strategies that growers can use to improve production efficiency and reduce energy consumption; one of which is to optimize greenhouse temperature and photosynthetic daily light integral (DLI) so that less energy is consumed on a per-crop basis. Mathematical models have been developed to predict the influence of mean daily temperature (MDT) and DLI on time to flower; however, these models need to be integrated with those that estimate greenhouse energy consumption to evaluate energy-efficient production regimes.

The objectives of this study were to (1) quantify the influence of MDT and DLI on flowering during the finish stage for *Petunia* x*hybrida* Vilm.-Andr. and *Tagetes patula* L., (2) to develop crop models that predict the effects of changing MDT and DLI on flowering time and plant quality, and (3) to predict energy costs for greenhouse heating for different crop finish dates and at different locations in the United States. *Petunia* and *Tagetes* seedlings were transplanted to 10-cm pots and grown in glass greenhouses at temperatures of 14, 17, 20, 23, or 26°C under one of two DLI treatments. Flowering data were collected and the MDT and DLI crop models were validated. Crop model data were used as inputs in the Virtual Grower (VG) management software for a standard greenhouse located in seven cities across the USA.

In both species, time to flower decreased as MDT and DLI increased (Figure 1A-B). The number of flower buds or inflorescences at first flowering decreased for both species as temperature increased and DLI decreased (Figure 1E-F). The VG model predicted transplant dates for both species for flowering dates of 1 April and 15 May (Table 1). Calculated energy costs for a 1 April flowering date for a *Petunia* crop were 32-547% lower when grown at an MDT of 14 versus 23°C for locations in San Francisco, California, Tallahassee, Florida, Charlotte, North Carolina, and Fort Worth, Texas. In contrast, energy costs for *Petunia* grown in the same greenhouse in Grand Rapids, Michigan and Cleveland, Ohio were 3-5% greater at an MDT of 14°C compared to 23°C (Table 1). For a finish date of 15 May, a *Petunia* grown at an MDT of 14 or 17°C had the lowest predicted energy costs for heating at all locations. In *Tagetes*, an MDT of 14°C had the lowest predicted energy cost for both finish dates at all locations.

The models developed can be used to evaluate the benefits of increasing the DLI on flowering time and plant quality during different production seasons and can help identify the most energy-efficient production strategy for their location and crop.

For more information, contact: Matt Blanchard, mgblanch@msu.edu, Department of Horticulture, Michigan State University, East Lansing, MI 48824

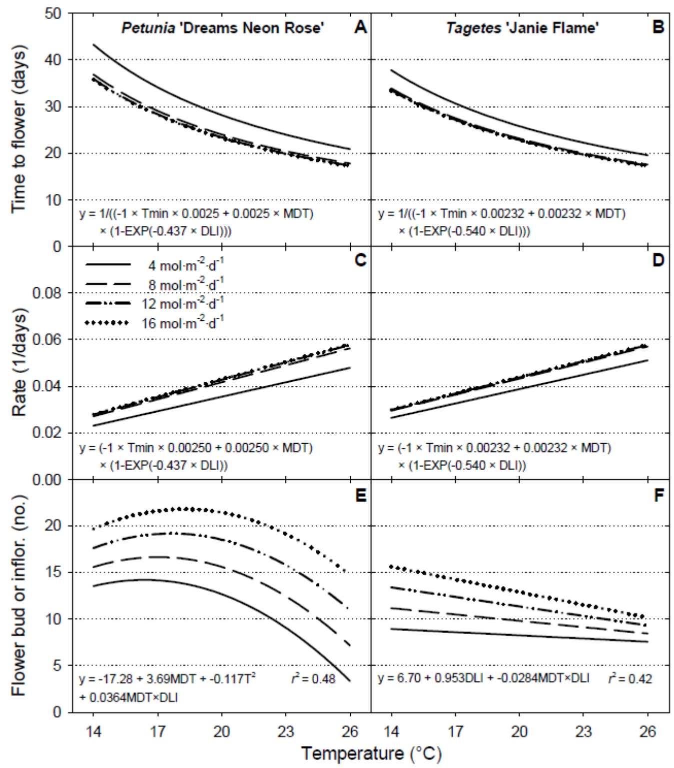

Figure 1. The effect of mean daily temperature (MDT) and photosynthetic daily light integral (DLI) on the predicted time to flower (A and B), rate of progress to flower (C and D), and number of flower buds or inflorescences at first flowering (E and F) in *Petunia* and *Tagetes* grown under a 16-h photoperiod. Legend in panel C applies to all panels. Time to flower is from transplant of 6-leaf (*Petunia*) or 6- or 8-leaf (*Tagetes*) seedlings that had been grown at an MDT of 20.4°C and under a 16-h photoperiod and a DLI of 10 mol m^{-2} d^{-1}.

Table 1. Estimated heating costs using Virtual Grower software (USDA-ARS, 2009) from time of transplant of 6-leaf *Petunia* and 6- or 8-leaf *Tagetes* to first flowering on 1 April or 15 May. Time to flower was calculated using models in Figure 1 and is for plants grown at different constant temperatures in different locations under a 16-h photoperiod and a mean DLI of 10 mol m^{-2} d^{-1}.

	Estimated heating cost (US\$ m^{-2} $crop^{-1}$)									
	1 April					15 May				
	Mean daily temperature (°C)									
Location	14	17	20	23	26	14	17	20	23	26
Petunia 'Dreams Neon Rose'										
San Francisco, CA	0.75	1.07	1.23	1.41	1.57	0.51	0.81	0.97	1.10	1.21
Tallahassee, FL	0.56	0.69	0.78	0.97	1.04	0.09	0.11	0.16	0.30	0.43
Grand Rapids, MI	2.78	2.64	2.56	2.70	2.75	1.12	1.11	1.14	1.22	1.30
New York, NY	1.96	1.92	1.94	2.06	2.03	0.48	0.63	0.70	0.83	0.88
Charlotte, NC	0.95	1.15	1.24	1.40	1.44	0.29	0.40	0.41	0.54	0.72
Cleveland, OH	2.52	2.34	2.31	2.40	2.52	0.96	0.98	1.19	1.26	1.33
Fort Worth, TX	0.55	0.70	0.75	0.93	1.07	0.06	0.12	0.25	0.42	0.60
Tagetes 'Janie Flame'										
San Francisco, CA	0.69	1.03	1.18	1.34	1.57	0.46	0.79	0.92	1.03	1.21
Tallahassee, FL	0.48	0.65	0.76	0.91	1.04	0.07	0.09	0.16	0.28	0.43
Grand Rapids, MI	2.46	2.51	2.50	2.61	2.75	0.98	1.05	1.07	1.15	1.30
New York, NY	1.79	1.85	1.86	1.92	2.03	0.43	0.61	0.65	0.77	0.88
Charlotte, NC	0.84	1.11	1.21	1.29	1.44	0.28	0.35	0.37	0.51	0.72
Cleveland, OH	2.22	2.30	2.18	2.32	2.52	0.80	0.94	1.14	1.17	1.33
Fort Worth, TX	0.48	0.67	0.71	0.88	1.07	0.04	0.12	0.25	0.39	0.60

Blanchard, M.G., E.S. Runkle, and J.M. Frantz. 2011. Energy-efficient greenhouse production of *Petunia* and *Tagetes* by manipulation of temperature and photosynthetic daily light integral. Acta Hort. 893:857-864.