Day and night temperature effects on kale morphology and photosynthesis

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Introduction

Growers in the upper Midwest are increasingly producing vegetable crops during the late fall, winter and early spring in greenhouses. The greenhouses they use vary from conventional mechanically heated and cooled greenhouses to passive solar greenhouses. Kale (*Brassica napus* var. *pabularia*) is a leafy vegetable that grocery store produce managers in the upper Midwest have identified as a crop where supply is not meeting local demand. Kale can be produced under cool temperatures that allow for winter production with lower heating inputs than other vegetables crops such as tomatoes, peppers and eggplant. Red Russian kale is a popular variety, known for smooth, dark green leaves and purple veins and stems.

A limiting factor in kale production is information of growth responses to temperature and light. In particular, information on how temperature and light affect development rate and photosynthesis would be very helpful to maximize yield while minimizing inputs. This poster summarizes some of the information we gained from an experiment aimed at determining the effects of day-night temperature regime and irradiance on several yield and quality attributes of Red Russian kale.

Objectives

1. Determine how day-night temperature regime affects morphological traits associated with kale yield (leaf fresh weight, leaf dimensions, and leaf unfolding rate).

2. Determine how day-night temperature regime affects photosynthetic responses of kale to carbon dioxide concentration and irradiance.

Materials and Methods

Red Russian kale seed was sown, germinated, and grown in a greenhouse under a 24°C day-13°C night temperature regime under an 18 hour photoperiod in Sunshine LC8 media (SunGro Horticulture, Bellvue, WA). Plants were moved to five environmental growth chambers maintained at 10°C, 15°C, 20°C, 25°C, and 30°C (8 hour photoperiod; 300 µmol m^{-2} s^{-1}) when seedlings had unfolded four true leaves. Plants were moved among chambers at 0800 and 1600HR daily to result in 25 unique day-night temperature regimes. The experiment was replicated four times in time. Plants were fertilized twice weekly with 400 ppm N (Peter's Cal-Mag 15-5-15; Scott's Company, Marysville, OH) and watered as needed with care taken to not leach pots.

After 48-56 days, photosynthetic responses to irradiance, carbon dioxide and temperature was measured on the youngest fully expanded leaf (three replicates) using a LI-COR LI-6400XT Portable Photosynthesis System (LI-COR Inc., Lincoln, NE). Irradiance response curves (0, 100, 200, 400, 600, 800, 1000, and 1200 µmol m^{-2} s^{-1}) were determined while holding leaf temperature at 20°C and CO_2 concentrations at 400 ppm. CO_2 response curves (50, 200, 400, 600, 800, 1000, and 1200 ppm) were determined while holding temperature at 20°C and irradiance at 300 µmol m^{-2} s^{-1}. After 58 days in the chambers, plants were photographed (Figure 2), leaf number was counted, and leaf fresh weight and leaf length and width were measured.

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Morphology results

- Leaf unfolding rate was significantly affected by average temperature where leaf unfolding rate increased from 0.76 to 1.54 leaves/week as average daily temperature increased from 10°C to 25°C ($p<.001$; Figure 1).
- Fresh leaf weight, leaf length, and leaf width were affected by day-night temperature regime ($p<.001$; Figure 2 and 3).
- Highest fresh leaf weight (8.17 g) occurred when plants were grown with a 20°C day-10°C night temperature regime and lowest (1.15 g) when grown with a 10°C day-30 °C night temperature regime (Figure 2).
- Leaf length was longest (19.01 cm) and shortest (6.92 cm) when plants were grown with a 20°C day-20 °C night temperature regime and 10°C day-30 °C night temperature regime, respectively. Leaf width was widest (11.85 cm) and narrowest (5.45 cm) when plants were grown with a 30°C day-25 °C night temperature regime and 10°C day-30°C night temperature regime, respectively (Figure 3).

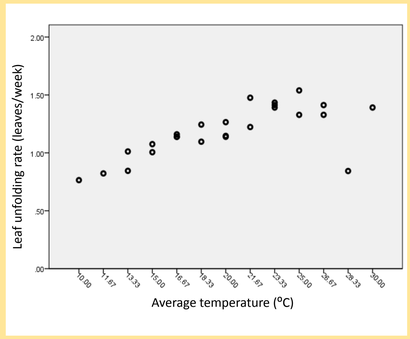

Figure 1. Leaf unfolding rate (leaves/week) by average 24 hr temperature of a regime.

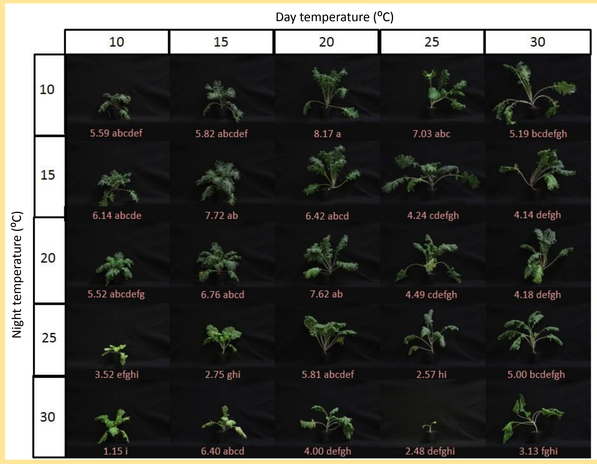

Figure 2. Effect of day-night temperature regime on morphological appearance and fresh weight per leaf (g). Letters denote mean separation using Tukey's HSD (p = 0.05)

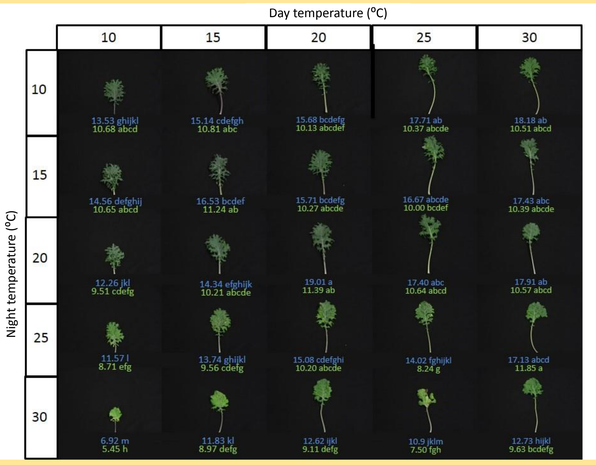

Figure 3. Effect of day-night temperature regime on leaf morphology. Leaf length (cm, above) and width (cm, below) are shown with letters denoting mean separation using Tukey's HSD (p = 0.05)

Photosynthesis results:

- Maximum photosynthetic rate in response to increasing irradiance for day-night temperature regimes with the highest, median, and lowest fresh leaf weight were 19.99, 14.56, and 11.92 µmol CO_2 m^{-2} s^{-1}, respectively (Figure 4).
- Maximum photosynthetic rate in response to increasing CO_2 for day-night temperature regimes with the highest, median, and lowest fresh leaf weight were 19.87, 16.92, and 11.78 µmol CO_2 m^{-2} s^{-1}, respectively (Figure 5).

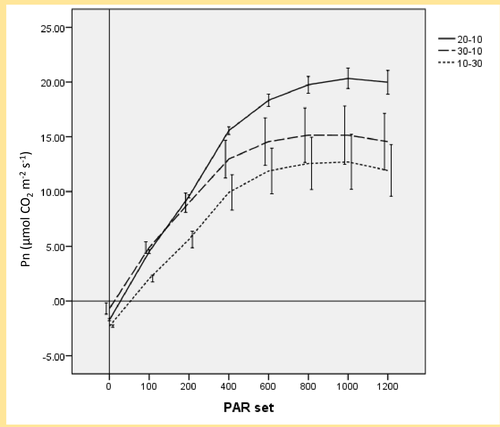

Figure 4. Photosynthetic responses to increasing irradiance for 20°C day-10°C night, 30°C day-10°C night, and 10°C day-30°C regimes. Letters denote mean separation using Tukey's HSD (p = 0.10)

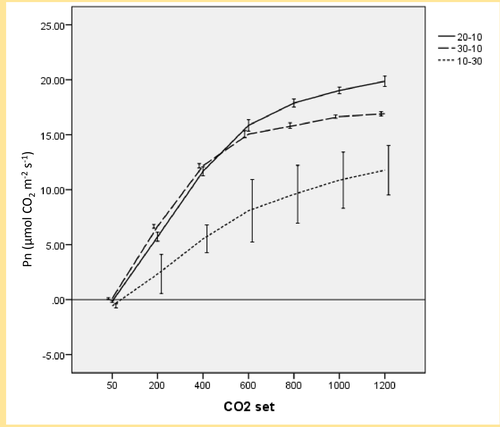

Figure 5. Photosynthetic responses to increasing CO_2 concentration for plants growth with 20°C day-10°C night, 30°C day-10°C night, and 10°C day-30°C night regimes. Letters denote mean separation using Tukey's HSD (p = 0.05)

Conclusions

- Leaf traits associated with higher yield (leaf dimensions and fresh weight) were observed on plants grown with 15°C-25°C day, and 10°C-20°C night temperatures.
- Plants grown with a 10°C day-30°C night temperature regime had the smallest leaf dimensions and lowest fresh weight, likely due to low photosynthesis during the day and high respiration rates during the night (Figure 4).
- Leaf unfolding rate increased with average day temperature up to 25°C, and decreased as temperature was further increased above 25°C (20°C day-30°C night, 25°C day-30°C night, 30°C day-25°C night, and 30°C day-30°C night temperature regimes).
- Day-night temperature regime resulted in a 68% difference in photosynthetic capacity at saturating irradiance level and a 69% difference at saturating CO_2 level.