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Crop Production on the Lunar Surface Using Solar Fiber Optics: Mitigating the effects of prolonged darkness with low temperature and low light

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Mitigating the effects of prolonged darkness with low temperature and low light

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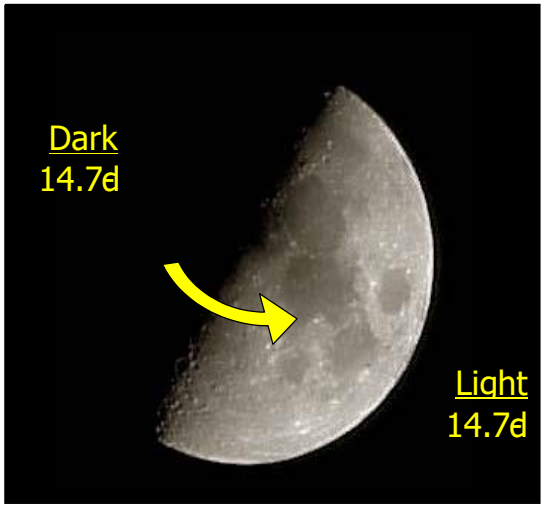
INTRODUCTION

Plant metabolism and growth are reduced in low temperature. As metabolism slows, energy requirements are reduced and less light is needed. The temperature should be maintained above the chilling temperature for the plant, which is species dependent. The addition of light will allow the plant to continue to expend energy on maintenance and some growth. Here we show that low light and cool temperatures can be used to maintain plants through the 14.7 days on the dark side of the Moon. Growth resumes immediately after the light is restored.



LITERATURE REVIEW

Studies that have addressed long term storage of plants in darkness include Terskov et al. (1978); Kubota and Kozai (1994); Kubota, Niu and Kozai (1995); and Heins et al. (1995).

OBJECTIVE

We sought to quantify the response of salad crops to 14 days of lunar darkness. We assumed that 1 to 2% of full power would be available as back-up power to provide cool temperatures and low light.

MATERIALS AND METHODS

Experimental Design

We have studied the following four salad crop species:

1. lettuce (*Lactuca sativa,* cv. Grand Rapids)
2. spinach (*Spinacia oleracea* L., cv. Melody)
3. radish (*Raphanus sativus,* cv. Cherry Belle)

4. tomato (*Lycopersicon esculentum*, cv. Micro Tina)

Individual experiments were conducted for each species. The length of the pre- and post-treatment periods varied according to the length of the life cycle for each crop (Table 2). The treatment period was designed to reflect the 14.7-day light period followed by a 14.7-day dark period for a Lunar colony.

Table 2. Each experiment had three replicate plants per treatment.

Plant Species	Days Pre-Treatment	Days of Treatment	Days of Post-Treatment	PPF Levels During Storage (μmol m^{-2} s^{-1})	Treatment Temperatures During Storage (°C)
Lettuce	14	14	14	Dark, 5, 10	3, 7, 12, 18, 25
Spinach	14	14	14	Dark, 5, 10	3, 7, 12, 18, 25
Radish	14	14	14	Dark, 5, 10	3, 6, 12, 25
Tomato	28	14	14	Dark, 5, 10	8, 12, 15, 20, 25

Plant Propagation

Plants were direct seeded into peat-perlite mix in individual 4-inch pots and the seeds were covered with a thin layer of fine vermiculite. The pots were gently watered daily with nutrient solution.

Treatments

Each experiment was initiated when seedlings had uniformly emerged. This was day zero. On day zero, seedlings were thinned to one seedling per pot. Seedlings were grown for two weeks (four weeks for tomatoes) under optimal conditions, either in the greenhouse or in a growth chamber, prior to the start of the cold and dark treatments.

At the start of the treatment period (the 14-day dark period) plants were visually sorted into small, medium and large sizes and one plant of each size was included in each treatment. Six to nine plants of each size were continuously maintained in optimal conditions as controls (Table 3). Controls were grown for time equal to the pre-treatment plus the post-treatment periods so that all pants had the same amount of light at the end of the study (Figure 1).

Table 3. Experimental growth conditions for control plants.

Plant Type	Control Plants (#)	Photoperiod (h)	Day Temp. (°C)	Night Temp. (°C)	Days of Plant Growth
Lettuce	6	16	25	20	28
Spinach	9	16	25	20	28

Radish	6	16	25	20	28
Tomato	9	16	25	20	42

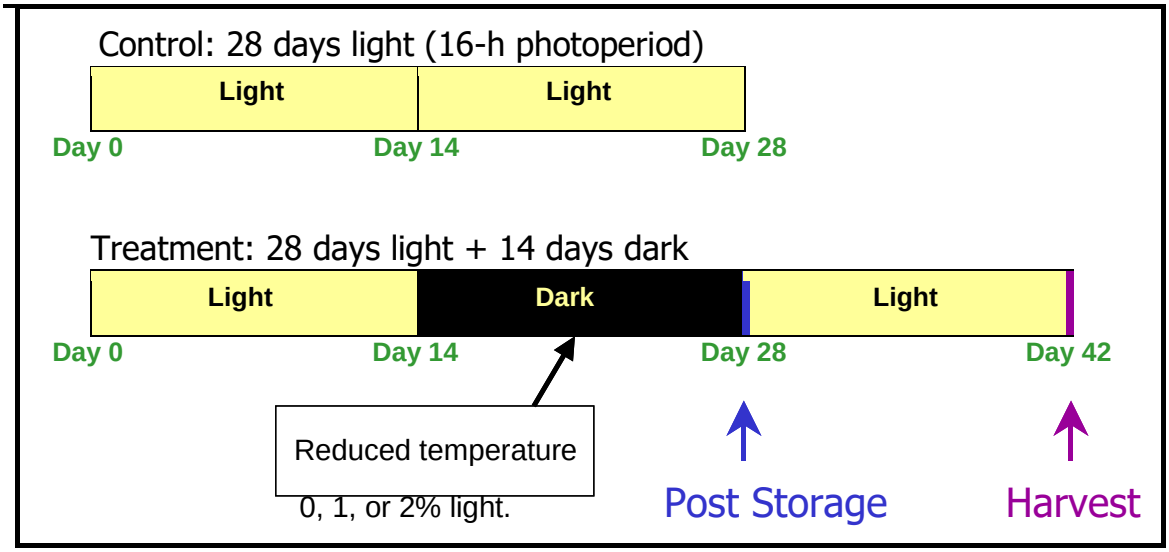


Figure 1. Treated plants received the same total amount of light over 42 days (66 days for tomato) that control plants got over 28 days (42 days for tomato). This represents a light period, a dark period, and another light period on the Lunar surface.

Data Collection

Percent Ground Cover: A digital camera was used to quantify the percent ground cover of all treatment and control plants once at the end of the cold/dark treatment period ('Post Storage') and again at the end of the experiment ('Harvest') (Figure 2). Plant Dry Mass: At Harvest, the plants were separated into their component parts (Table 4). In some cases, leaf area measurements were taken prior to drying. Dry weight was measured after drying at 80ºC for 48 hours.

Relative Plant Size: Plants were photographed to show the effects of each temperature and light level. Photographs were taken of plants grown at each temperature for a given light level, and at each light level for a given temperature.

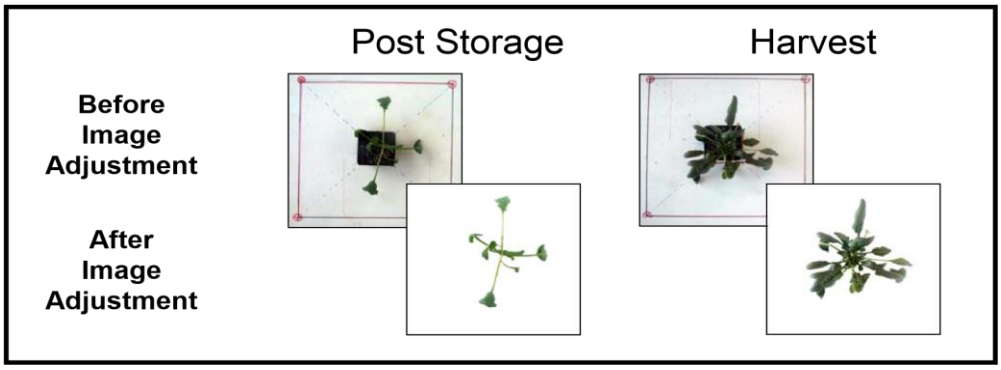


Figure 2. Spinach plant in the 25 ºC, PPF=10 treatment. A digital camera was used to generate an electronic top-view image of the plant. Each image was "adjusted" in software so that only the plant remained. Percent ground cover was calculated by

dividing the number of pixels in the plant by the total number of pixels in a fixed area.

Results

Figure 3 shows the effect of light and temperature during the treatment period on the fresh mass of each species. Additional photographs and graphs for each species are available on request.

Lettuce photos and graphs
Spinach photos and graphs
Radish photos and graphs
Tomato photos and graphs

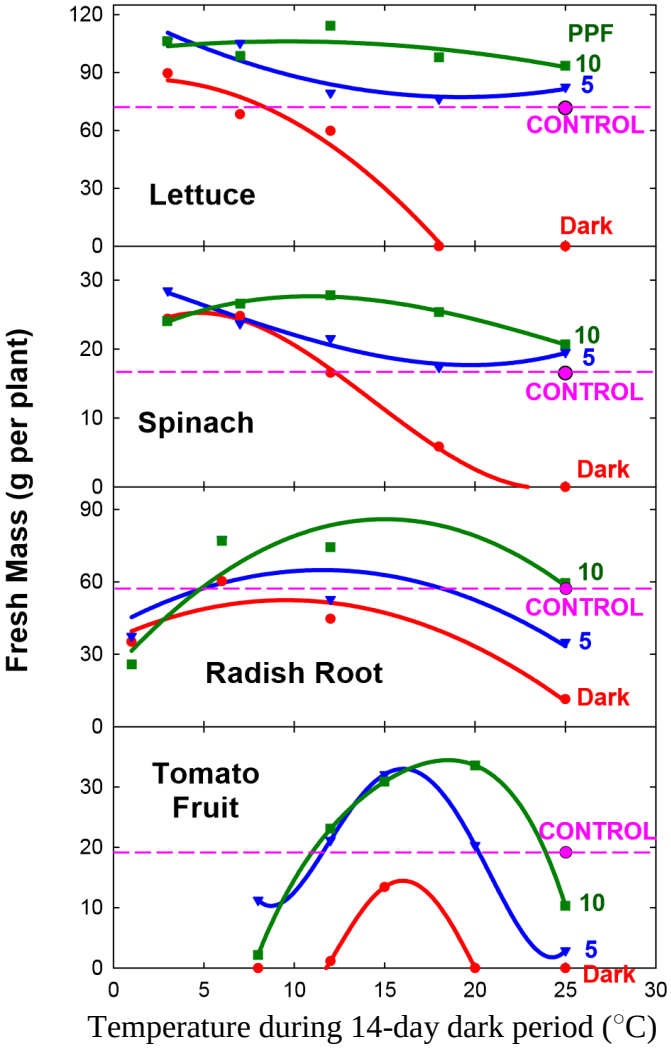


Figure 3. Average fresh mass of plants of each species in each treatment.

Discussion

All crops benefited from both reduced air temperature and increased light. Radish and spinach grew as well as the control plants if a PPF of 10 was provided – even without reducing the air temperature. They also could grow as well as the controls if the temperature was reduced to 7 ºC. Providing both reduced air temperature and increased PPF was only slightly beneficial.

Tomatoes went into storage just as the plants were flowering and a PPF of 10 was tremendously beneficial. Slightly reducing air temperature, along with a PPF of 10, increased yield by a surprising 80% above the control plants. The tomato plants effectively set fruit during the cold, dark period, and these fruits rapidly grew after full light was restored.

The reduction of plant metabolism from low temperature reduced the light needed to maintain plant health. The temperature should be maintained above the chilling

temperature for the plant, which is species dependent. The light compensation point appears to be reduced to a PPF of less than 10 after plants adapt to the reduced light level.

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