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Failure Analysis: Crop production on the Lunar surface

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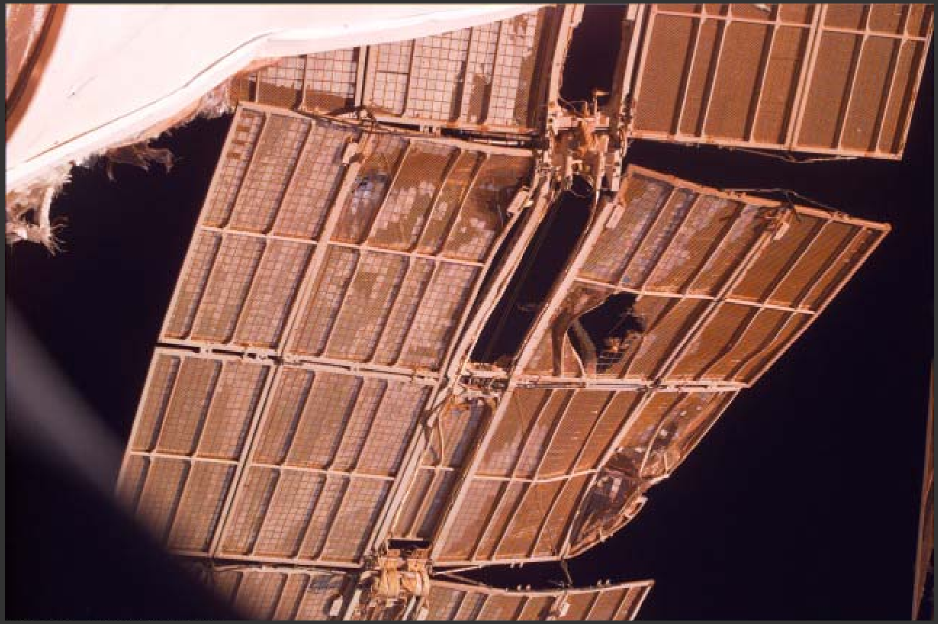


Mitigating the Effects of Prolonged Darkness with Reduced Temperature and Low Light

Julie Chard, Giridhar Akula, & Bruce Bugbee

Background

- We have sought to optimize conditions for crop yield for many years, but optimal conditions will not always be cost effective. More importantly, environmental control systems routinely fail, and we need to learn how to gracefully recover from these failures.
- Failures of the power supply system are among the most common and most detrimental of all system failures. A battery back-up could supply a small amount of power during a power outage, but we need to know how to best utilize the back-up power.
- Early in this project, it became clear that the detrimental effects of a power loss could be mitigated by reducing temperature and adding low light. This was so effective that we began to investigate crop production using natural light on the lunar surface. This requires keeping plants alive and healthy during the 14.7 day-long interval on the dark side of the Moon.

Lunar base agriculture must tolerate 14.7 days on the dark side

Lunar Station

- Bright sunlight for 14.7 days.

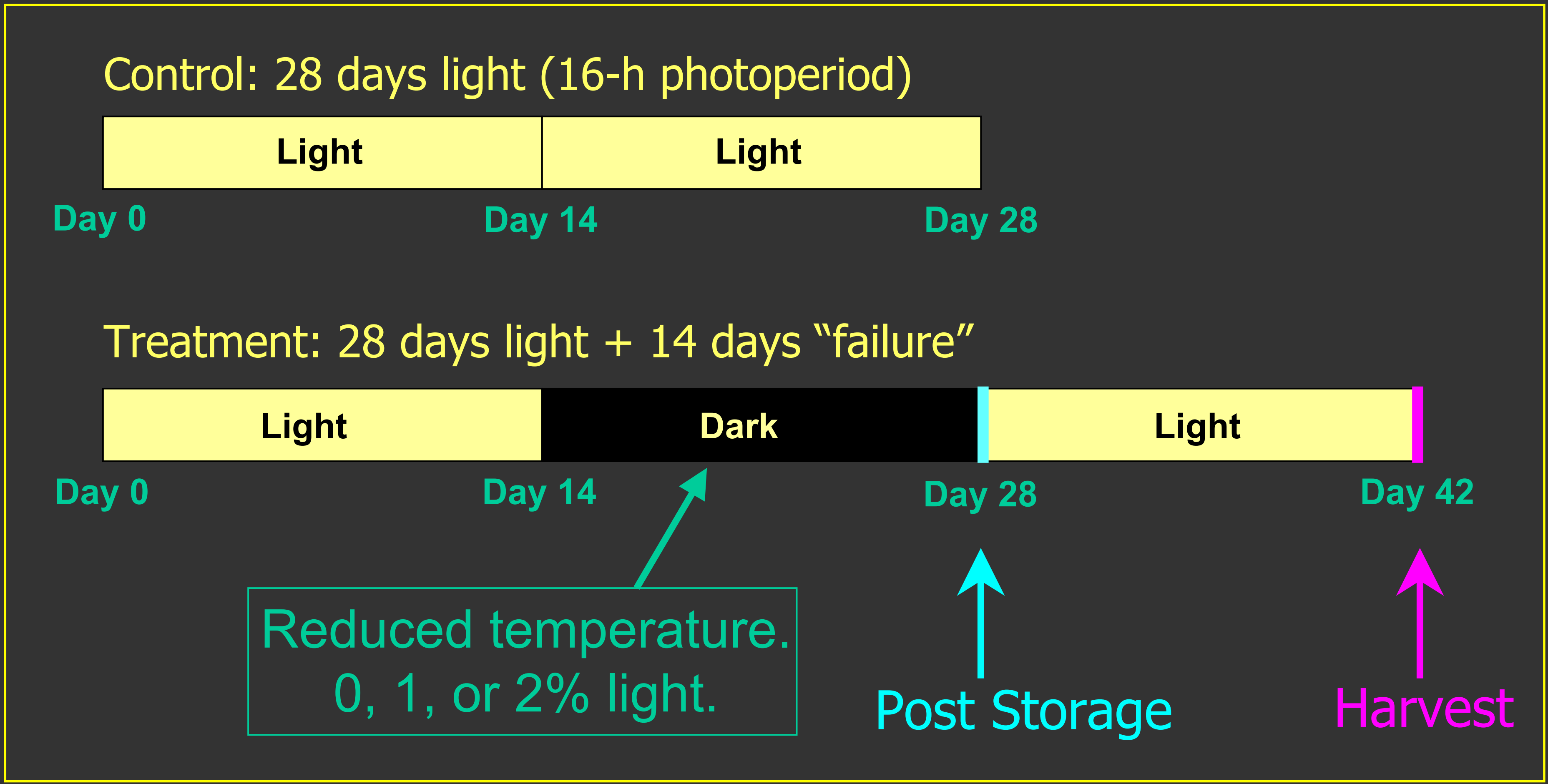
- Small nuclear reactor or batteries to provide some environmental control on the dark side.

Literature Review

Four studies examined a similar approach:

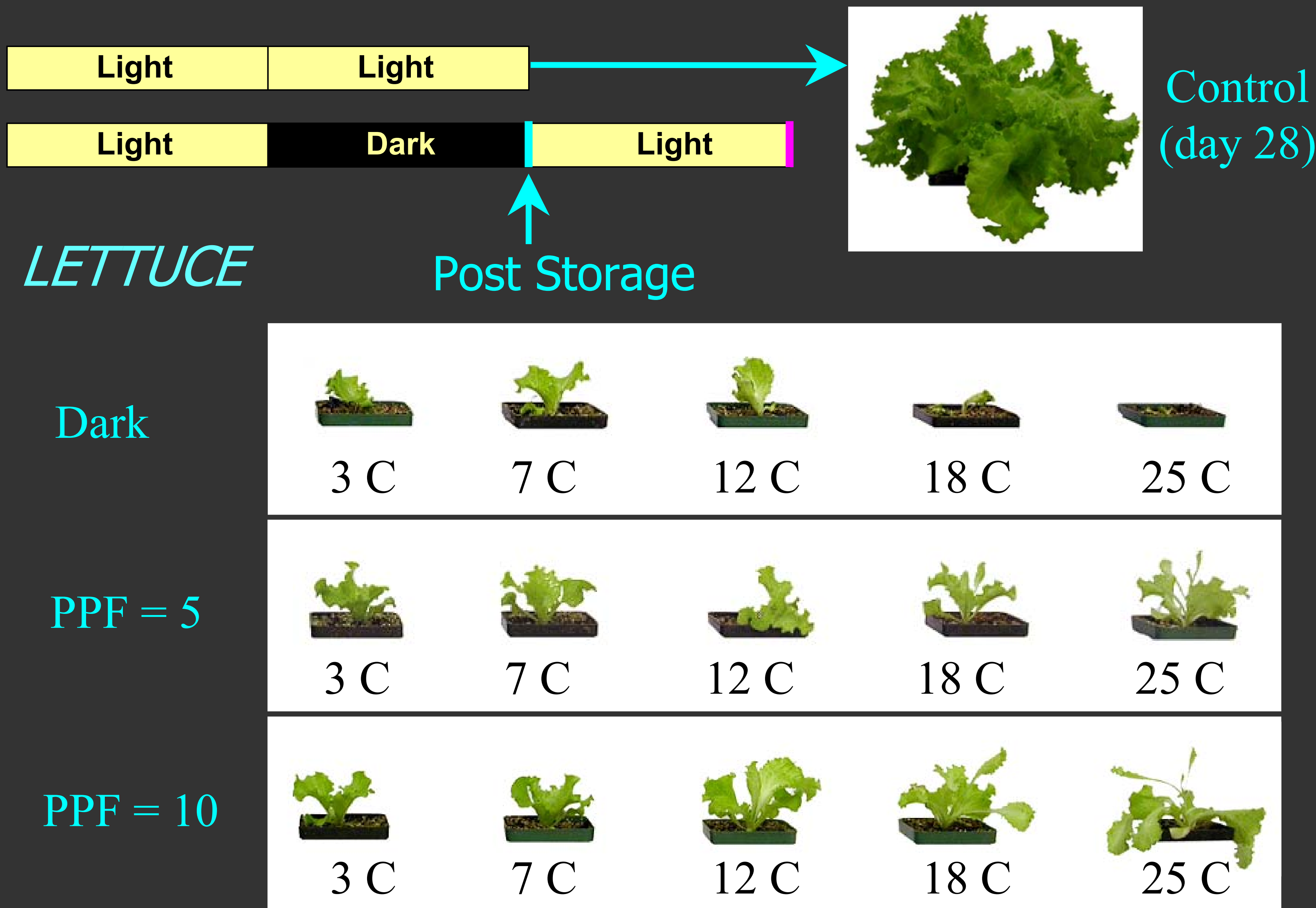
- Terskov, I.A., G.M. Lisovskiy, S.A. Ushakova, O.V. Parshina and L.P. Moiseyenko. 1976. Possibility of using higher plants in Lunar life-support systems. *Space Biology and Aerospace Medicine* 3:63-66.
- Kubota, C. and T. Kozai. 1994. Low-temperature storage for quality preservation and growth suppression of broccoli plantlets cultured in vitro. *HortScience* 29:1191-1194.
- Kubota, C., G. Niu and T. Kozai. 1995. Low temperature storage for production management of in vitro plants: Effects of air temperature and light intensity on preservation of plantlet dry weight and quality during storage. *Acta Horticulturae* 393:103-110.
- Heins, R.D., M.P. Kaczperski, T.F. Wallace Jr., N.E. Lange, W.H. Carlson, and J.A. Flore. 1995. Low-temperature storage of bedding plant plugs. *Acta Horticulturae* 396:285-296.

Materials and Methods

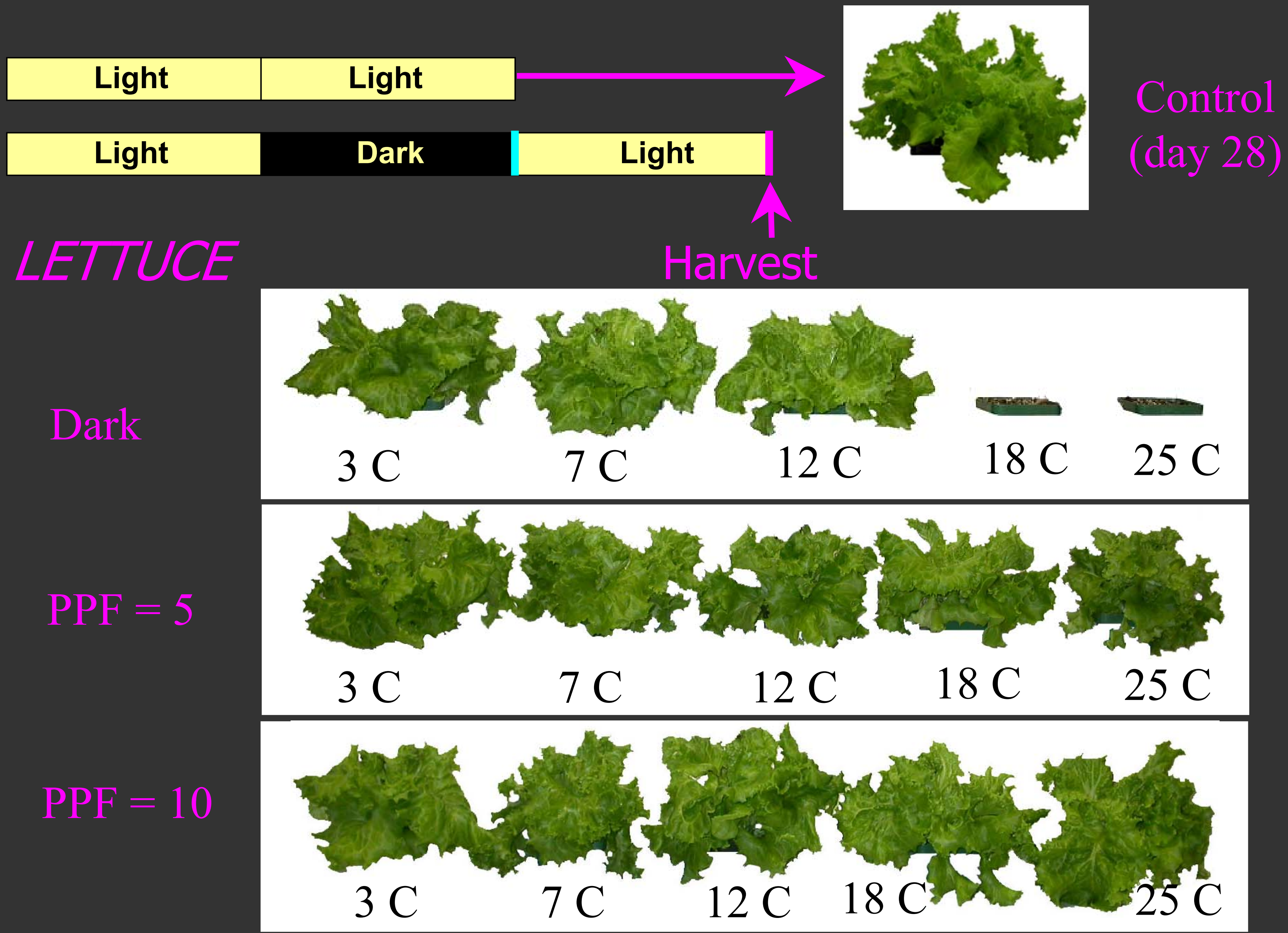


- Treated plants got the same total amount of light over 42 days that control plants got over 28 days.
- This represents a light period, a dark period, and another light period on the Lunar surface.

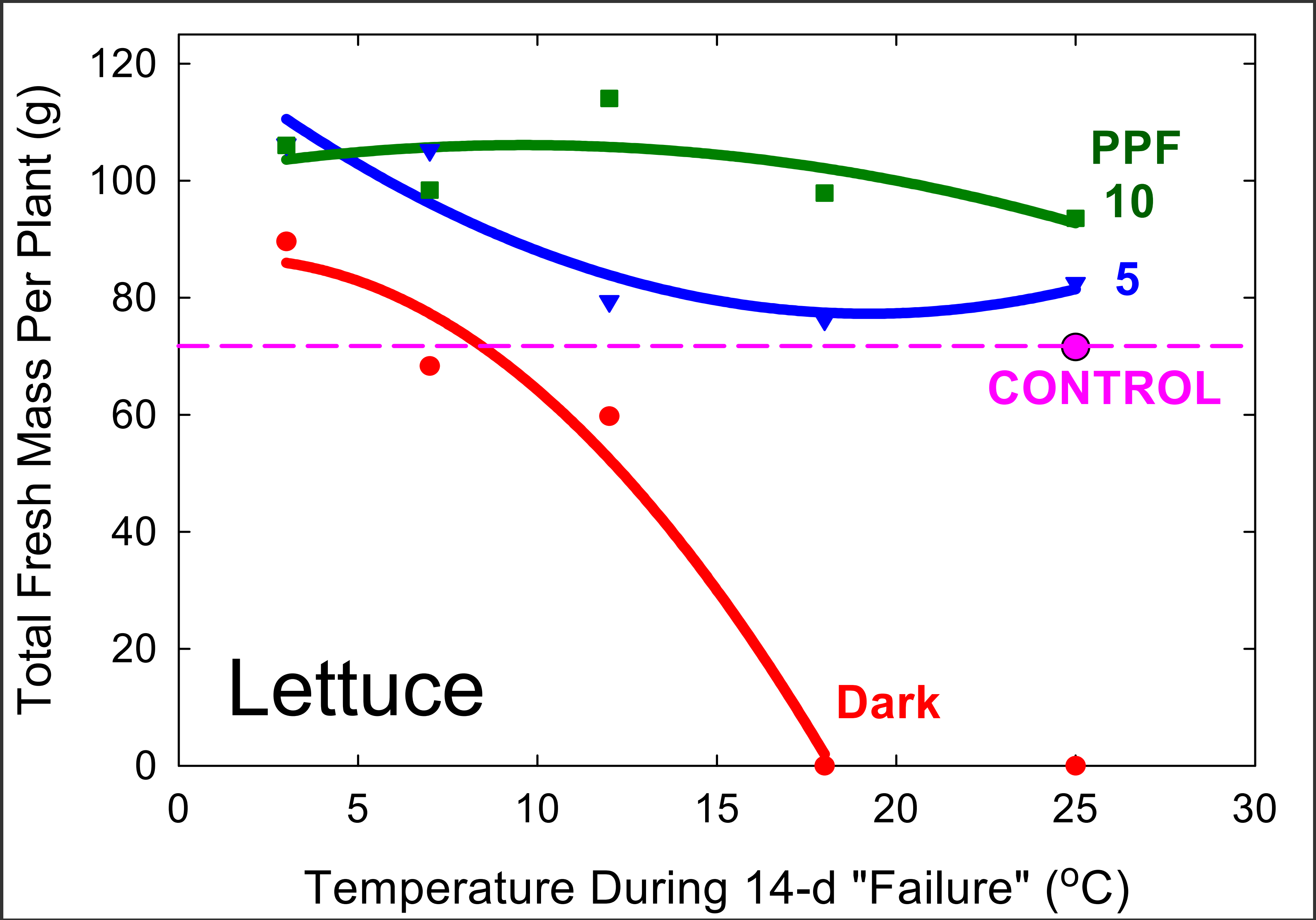
Visual appearance of plants after 14-d of "failure"



Visual appearance of plants at harvest



Effect of light and temperature on lettuce fresh mass at harvest on day 42. Control was harvested on day 28.



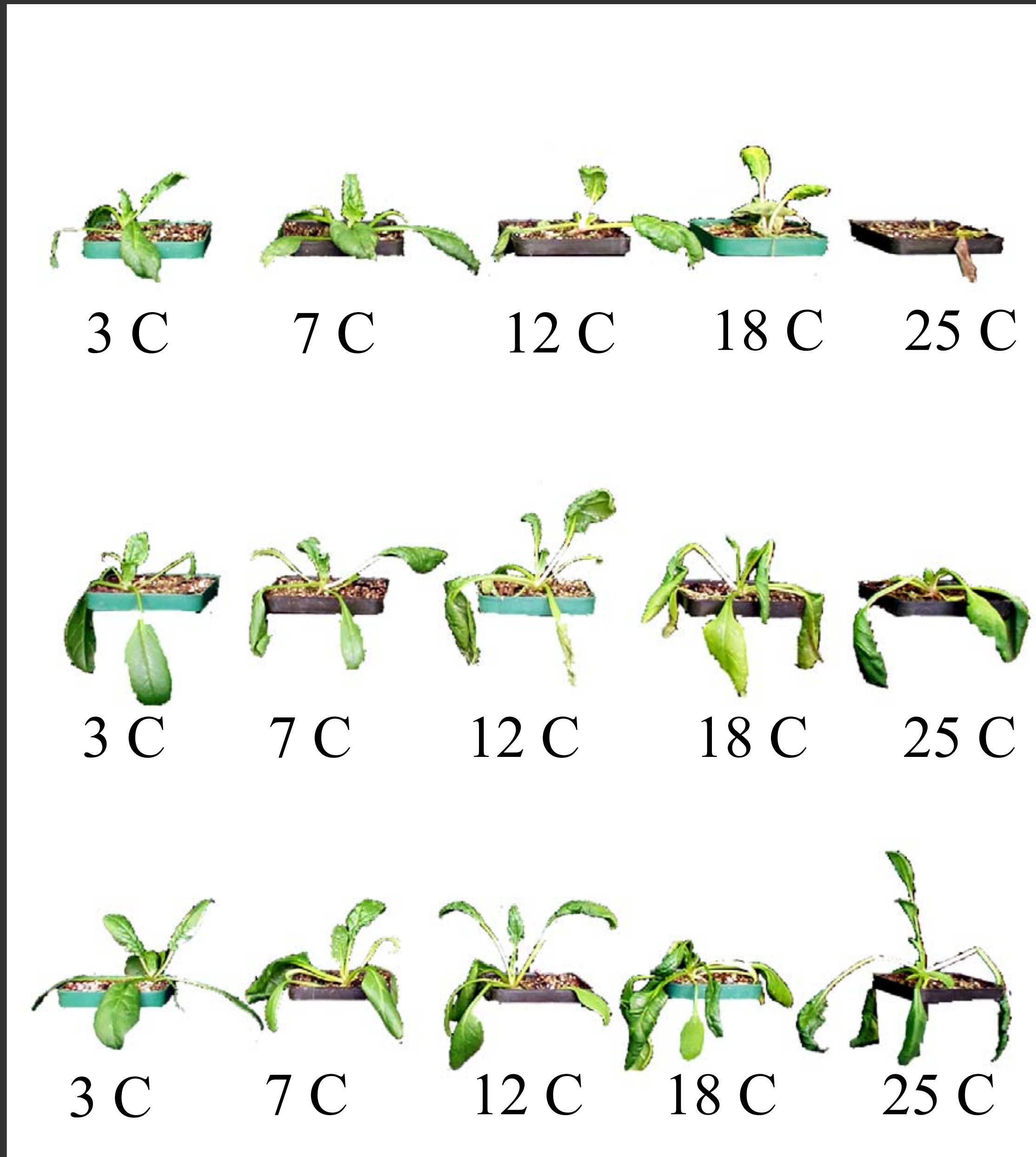
Visual appearance of plants after 14-d of "failure" (Post Storage)

SPINACH

Dark

PPF = 5

PPF = 10



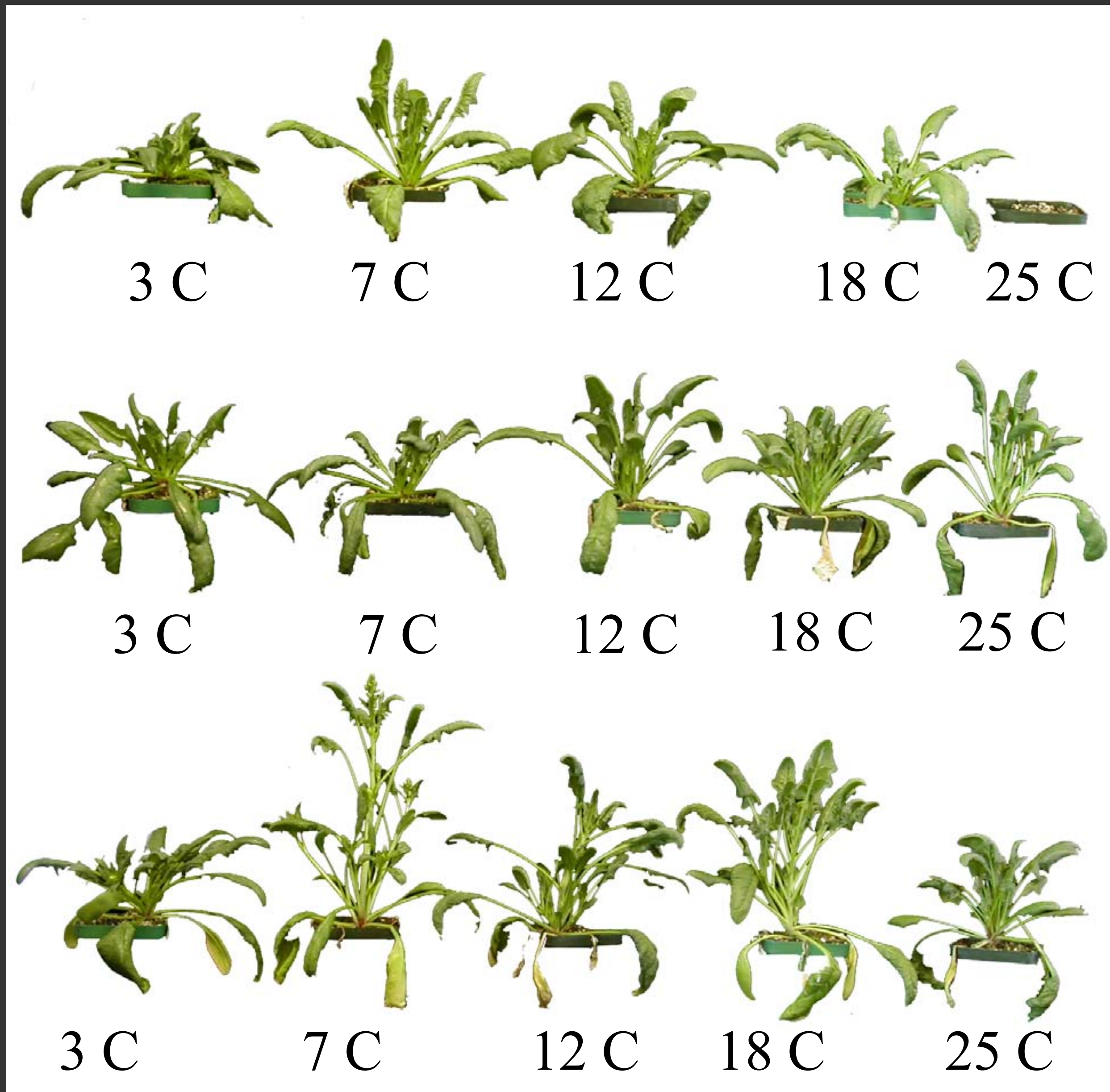
Control
(day 28)

Visual appearance of plants at Harvest

Dark

PPF = 5

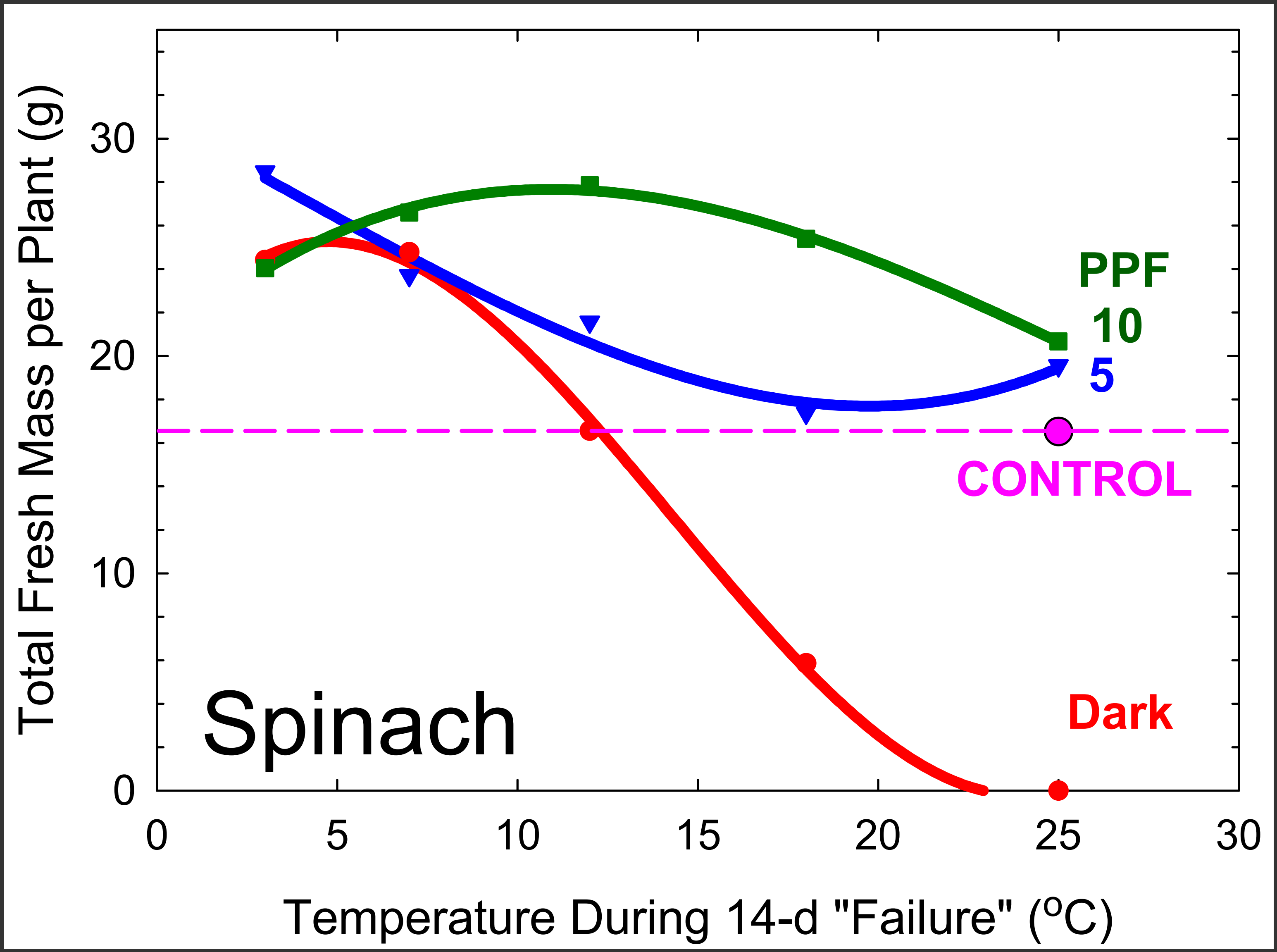
PPF = 10



SPINACH

Control
(day 28)

Effect of light and temperature on spinach fresh mass at harvest on day 42.
Control was harvested on day 28.



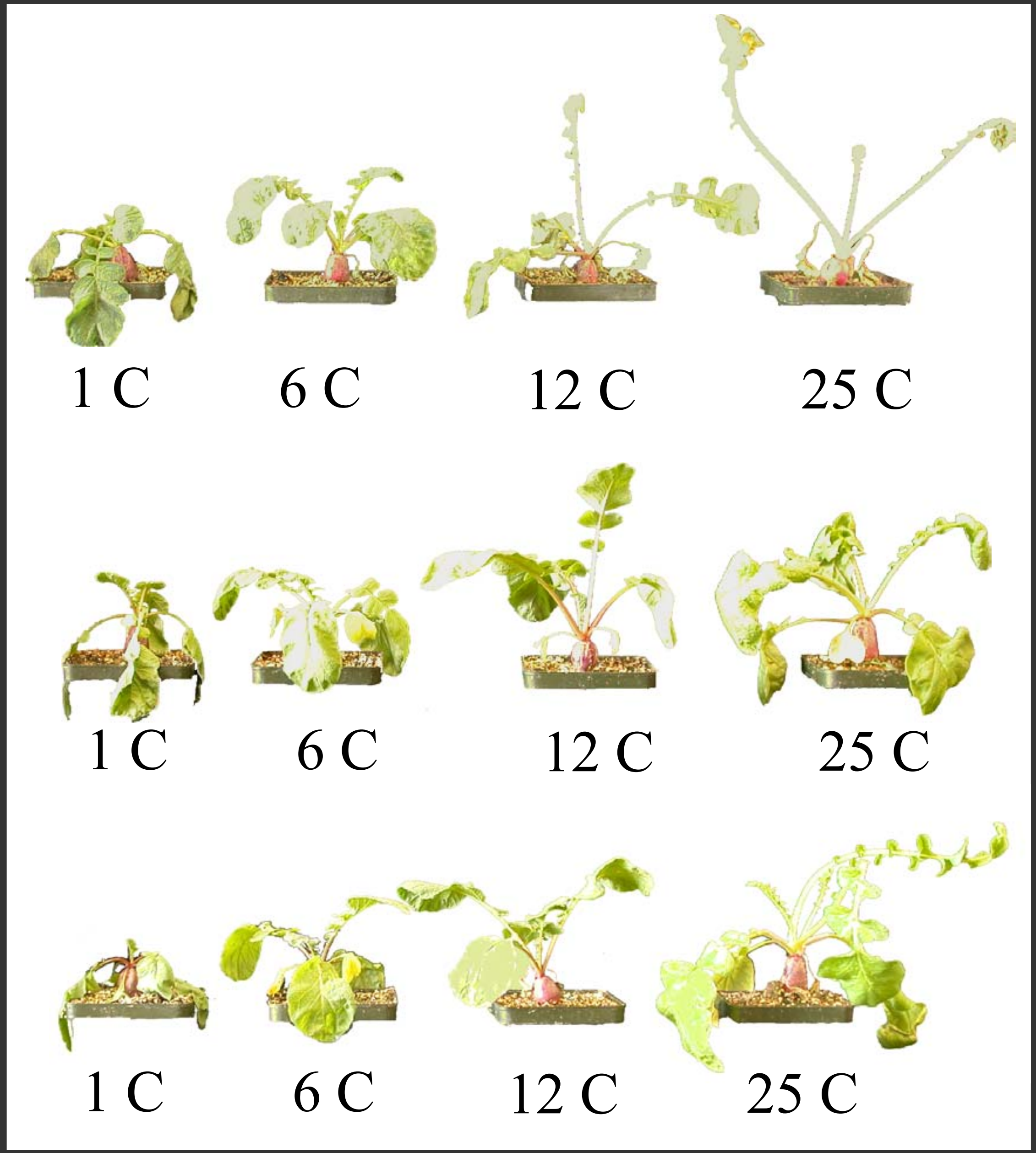
Visual appearance of plants after 14-d of "failure" (Post Storage)

RADISH

Dark

PPF = 5

PPF = 10



Control
(day 28)

Visual appearance of plants at Harvest

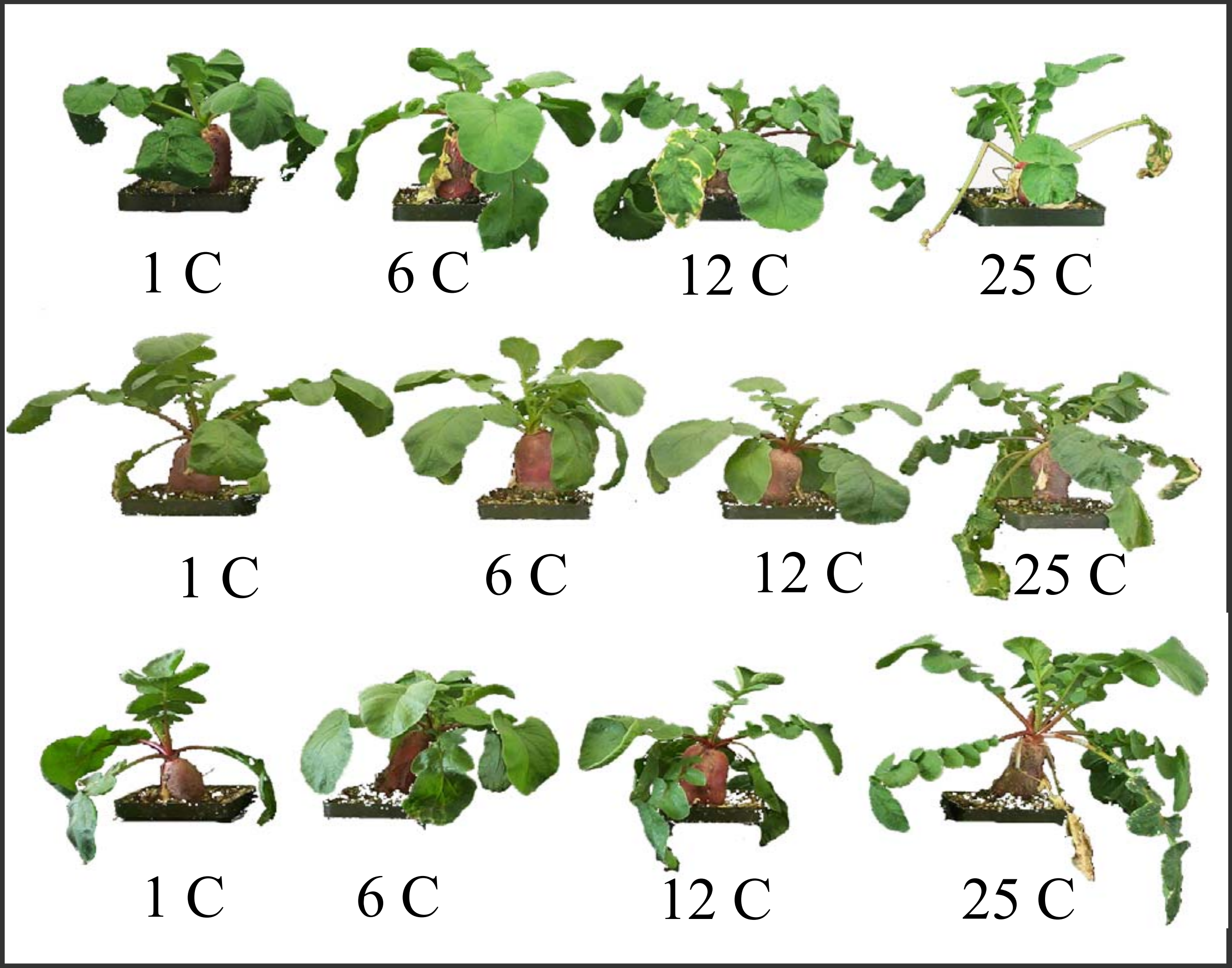
Control (day 28)

RADISH

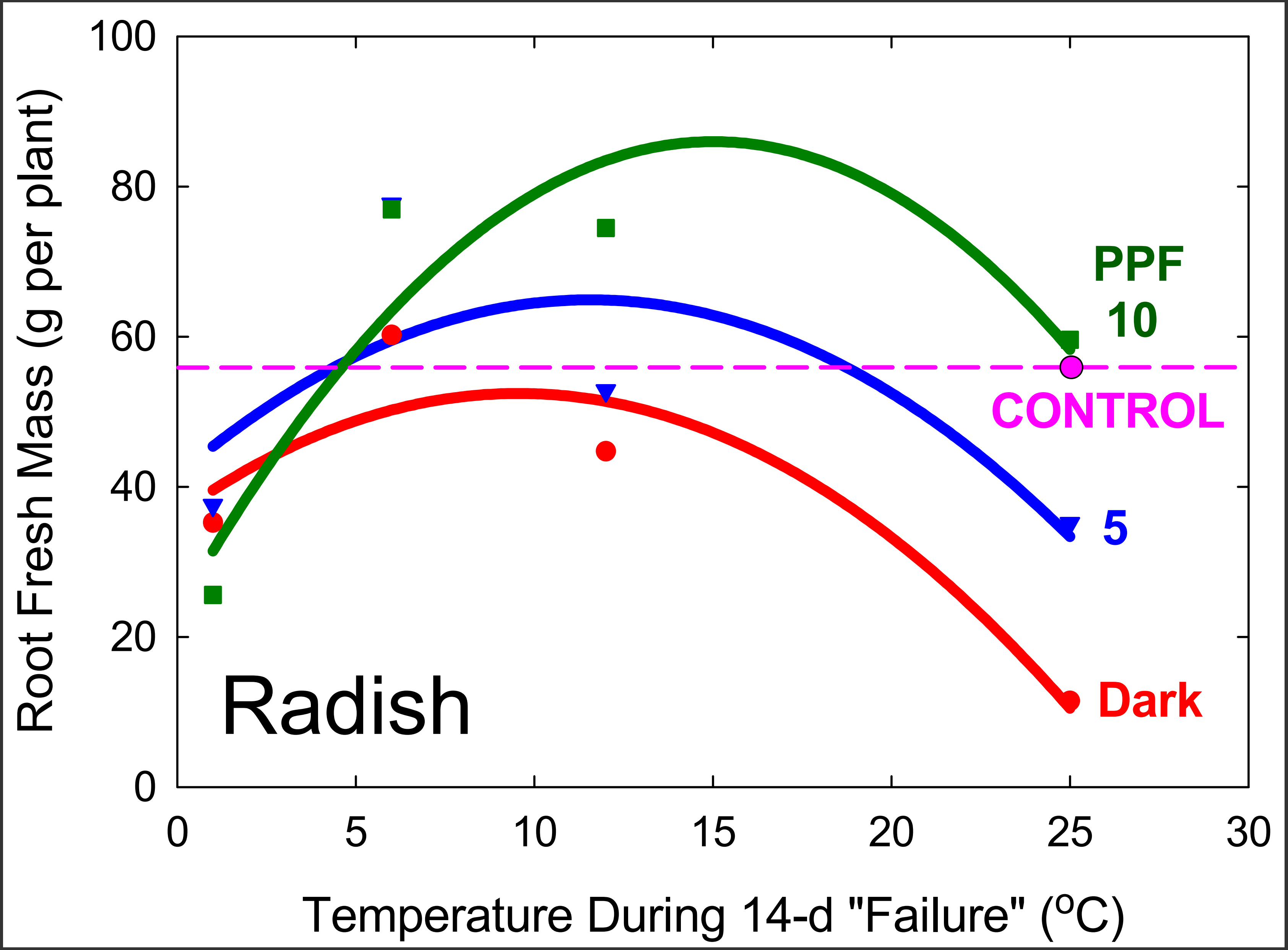
Dark

PPF = 5

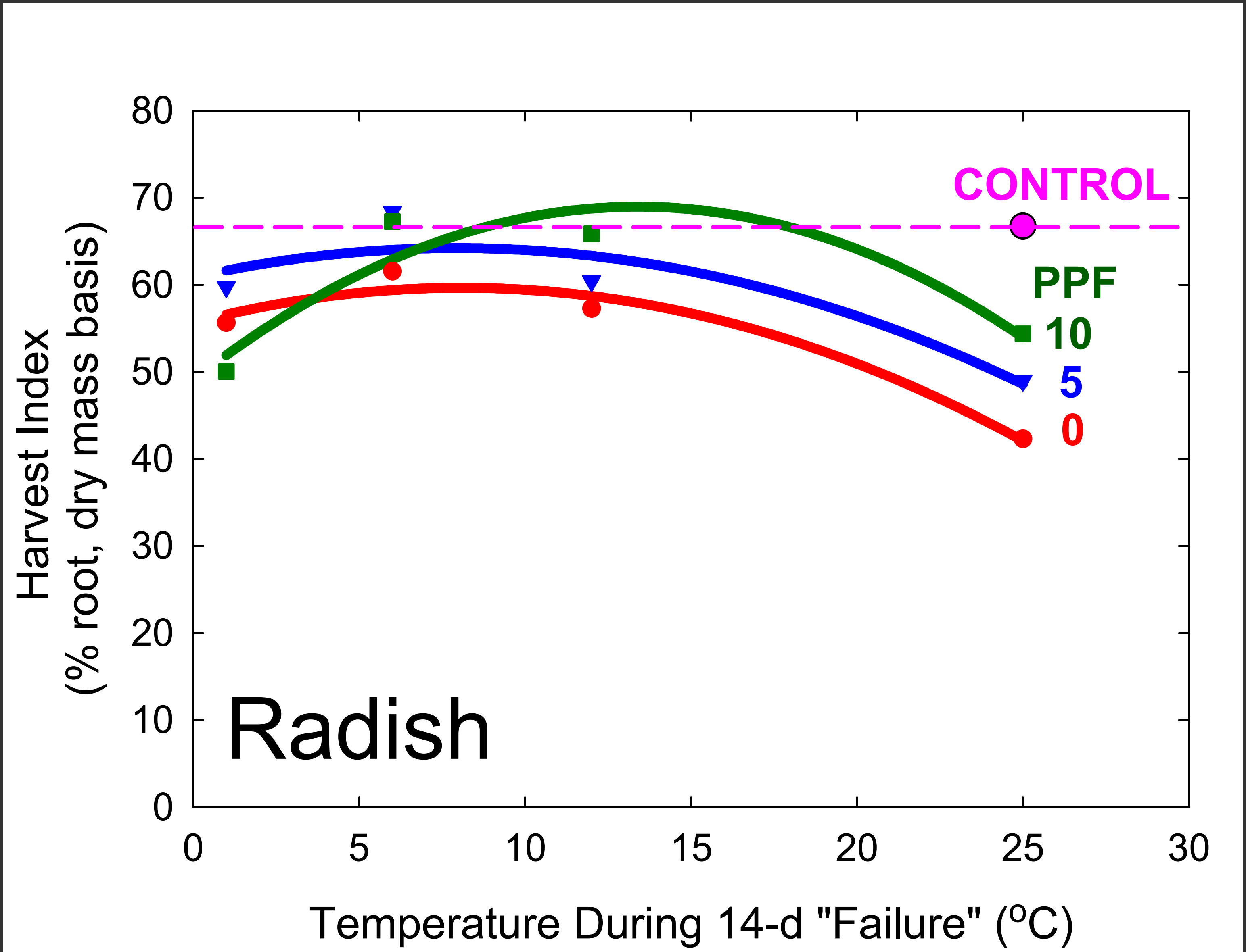
PPF = 10



Effect of light and temperature on radish fresh mass at harvest on day 42. Control was harvested on day 28.

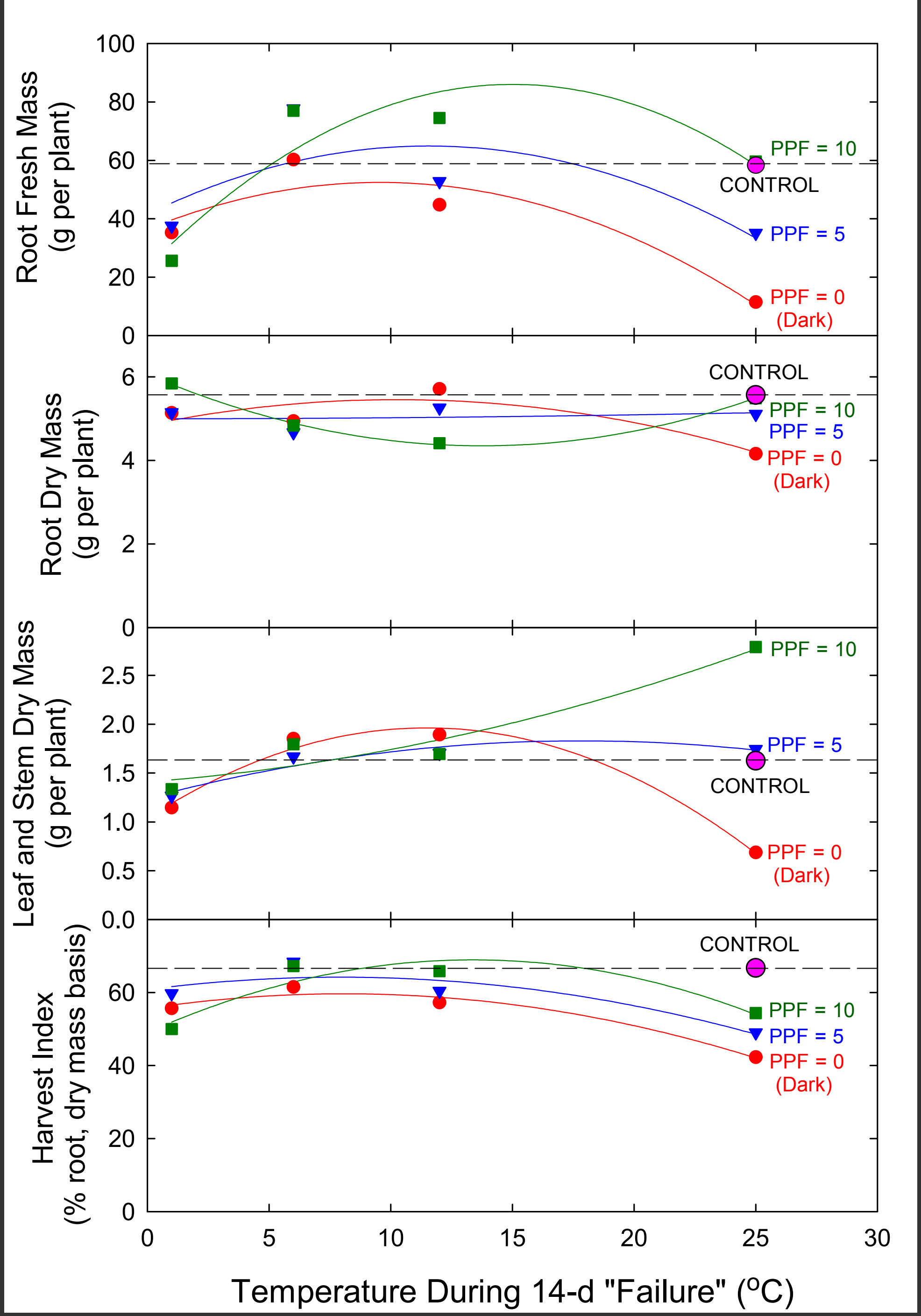


Radish - Harvest Index



Radish

Fresh and Dry Mass at Harvest and Harvest Index



Visual appearance of plants after 14-d of "failure" (Post Storage)

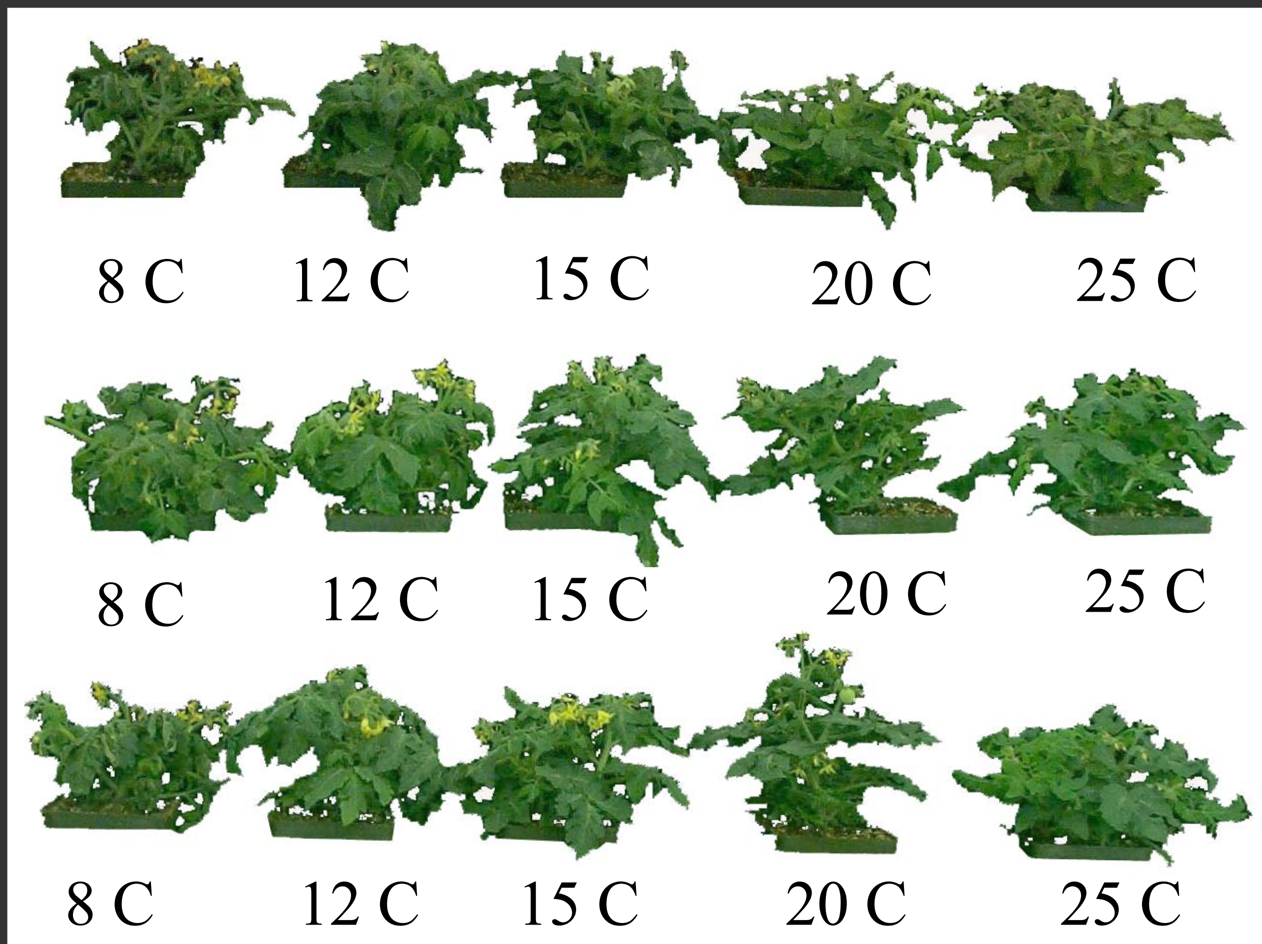
TOMATO

Control (day 42)

Dark

PPF = 5

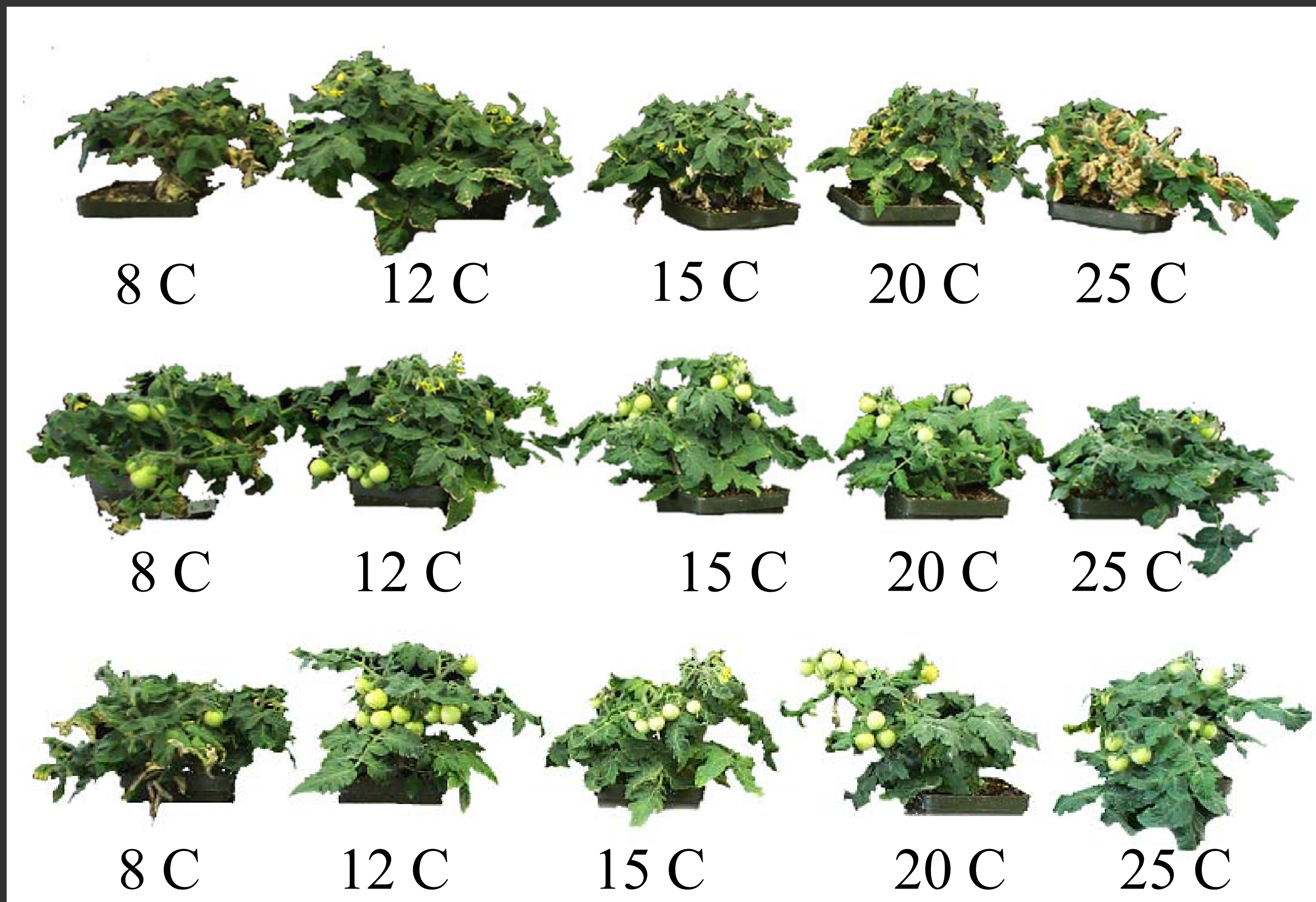
PPF = 10



Visual appearance of plants at Harvest

Control (day 42)

TOMATO

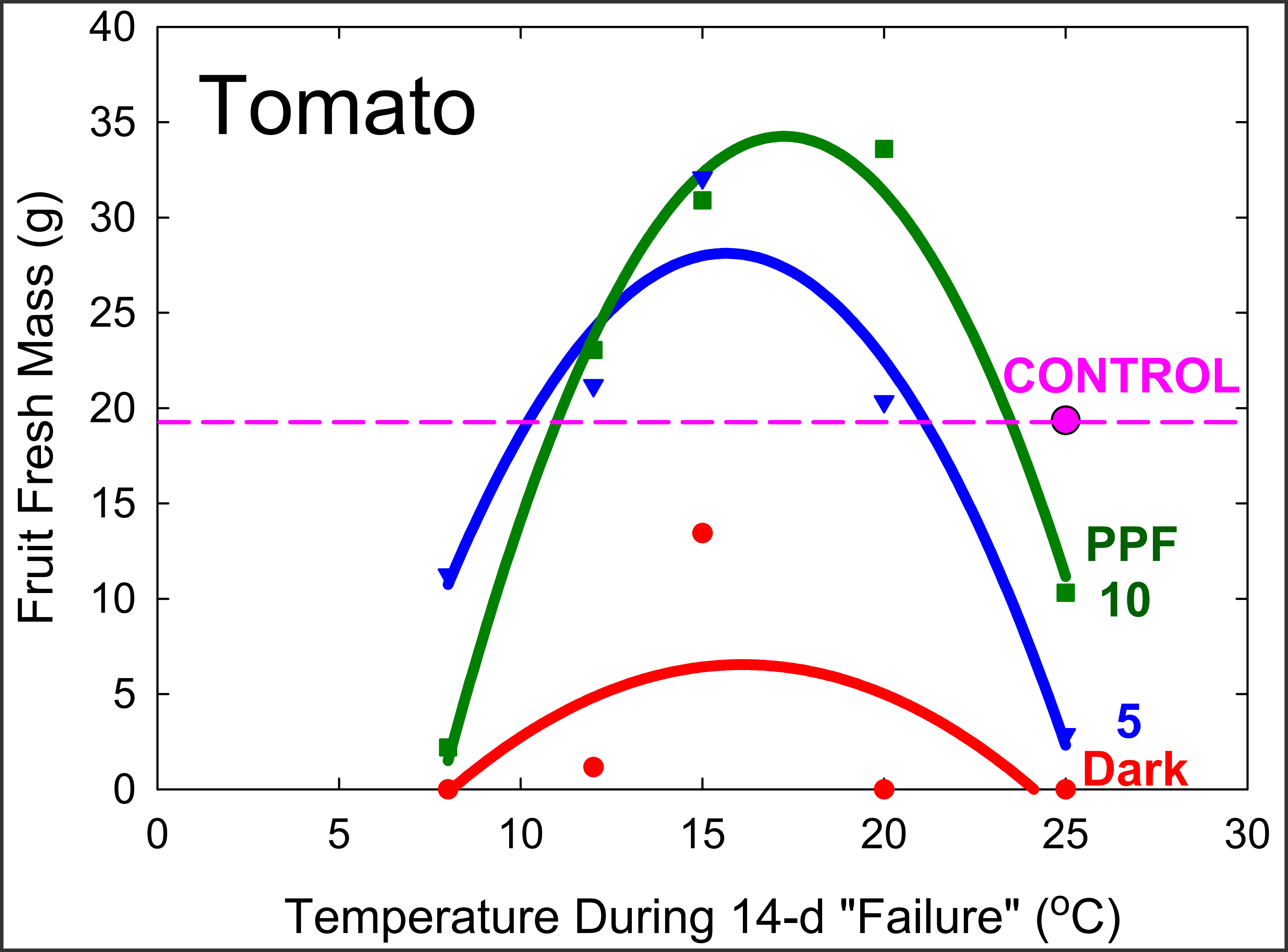


Dark

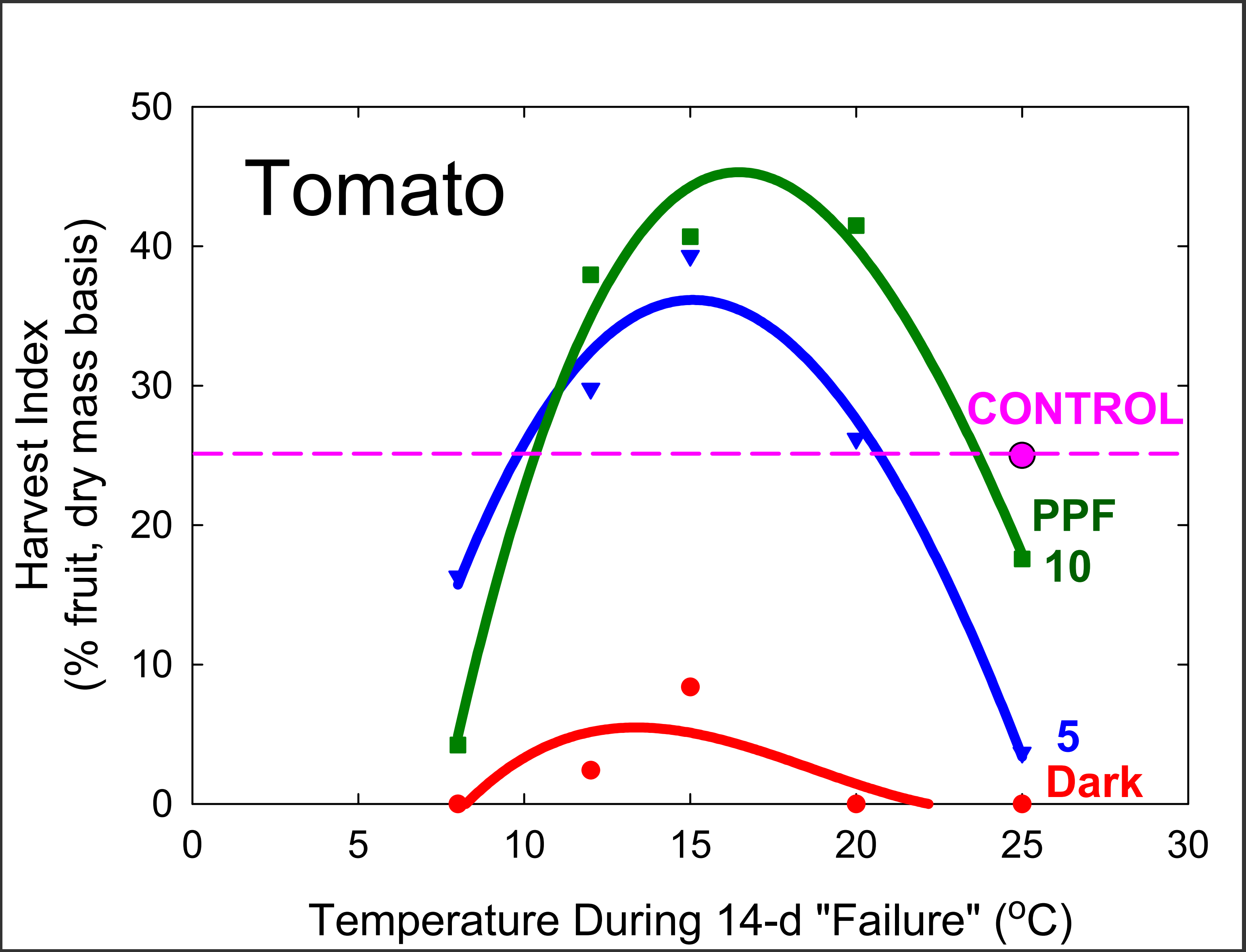
PPF = 5

PPF = 10

Effect of light and temperature on tomato fresh mass at harvest on day 42. Control was harvested on day 28.

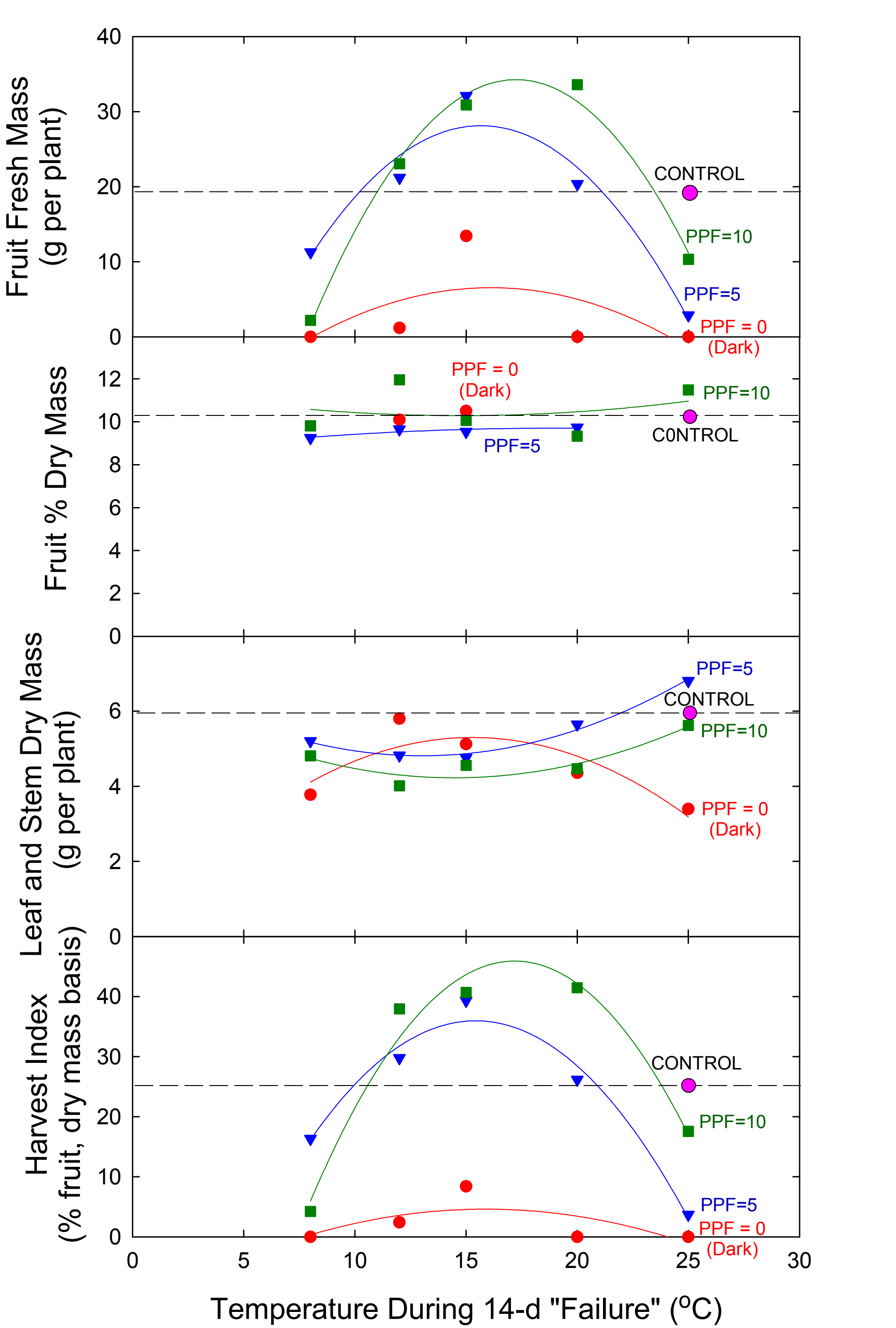


Tomato - Harvest Index



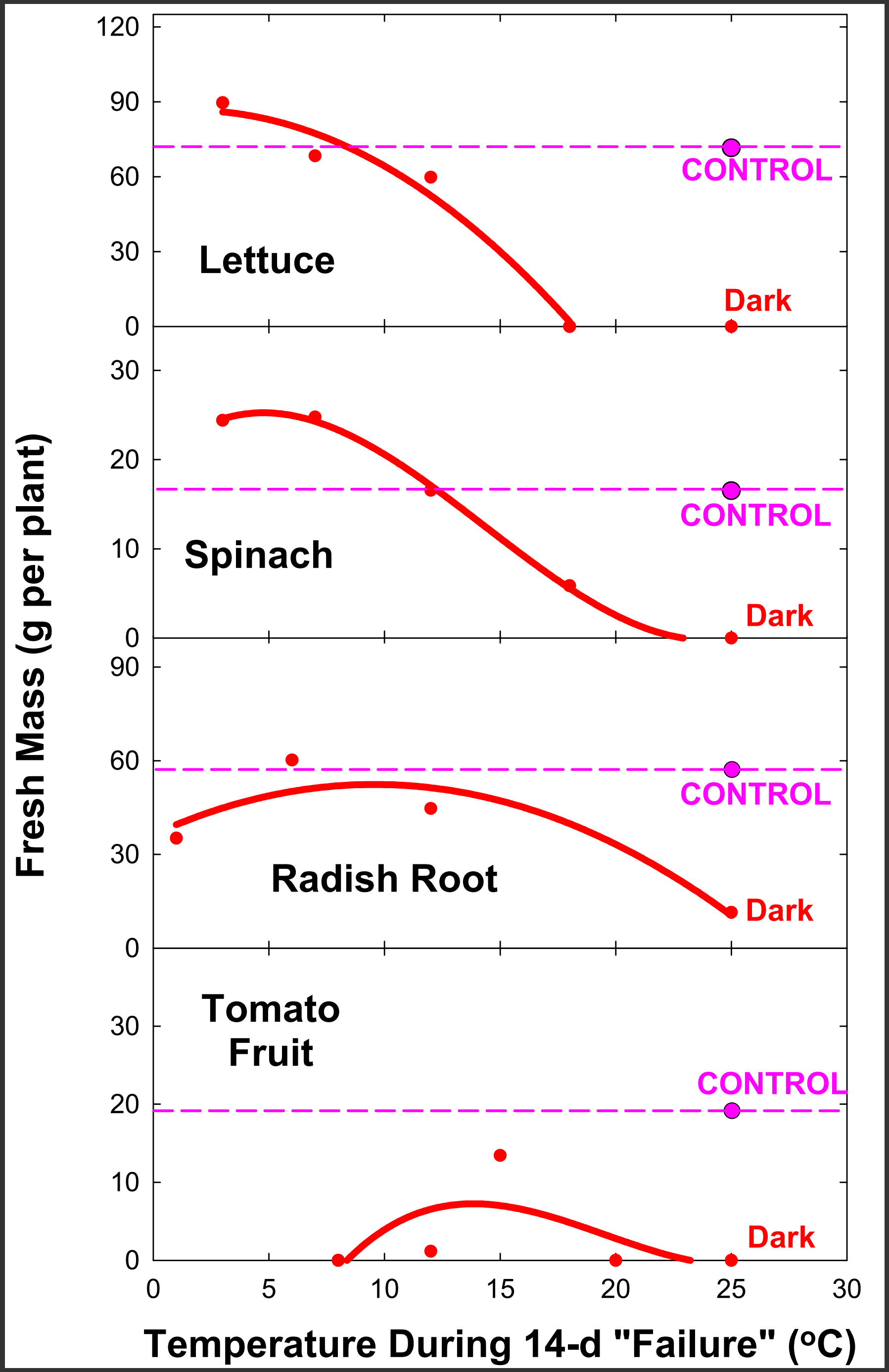
Tomato

Fresh and Dry Mass at Harvest and Harvest Index



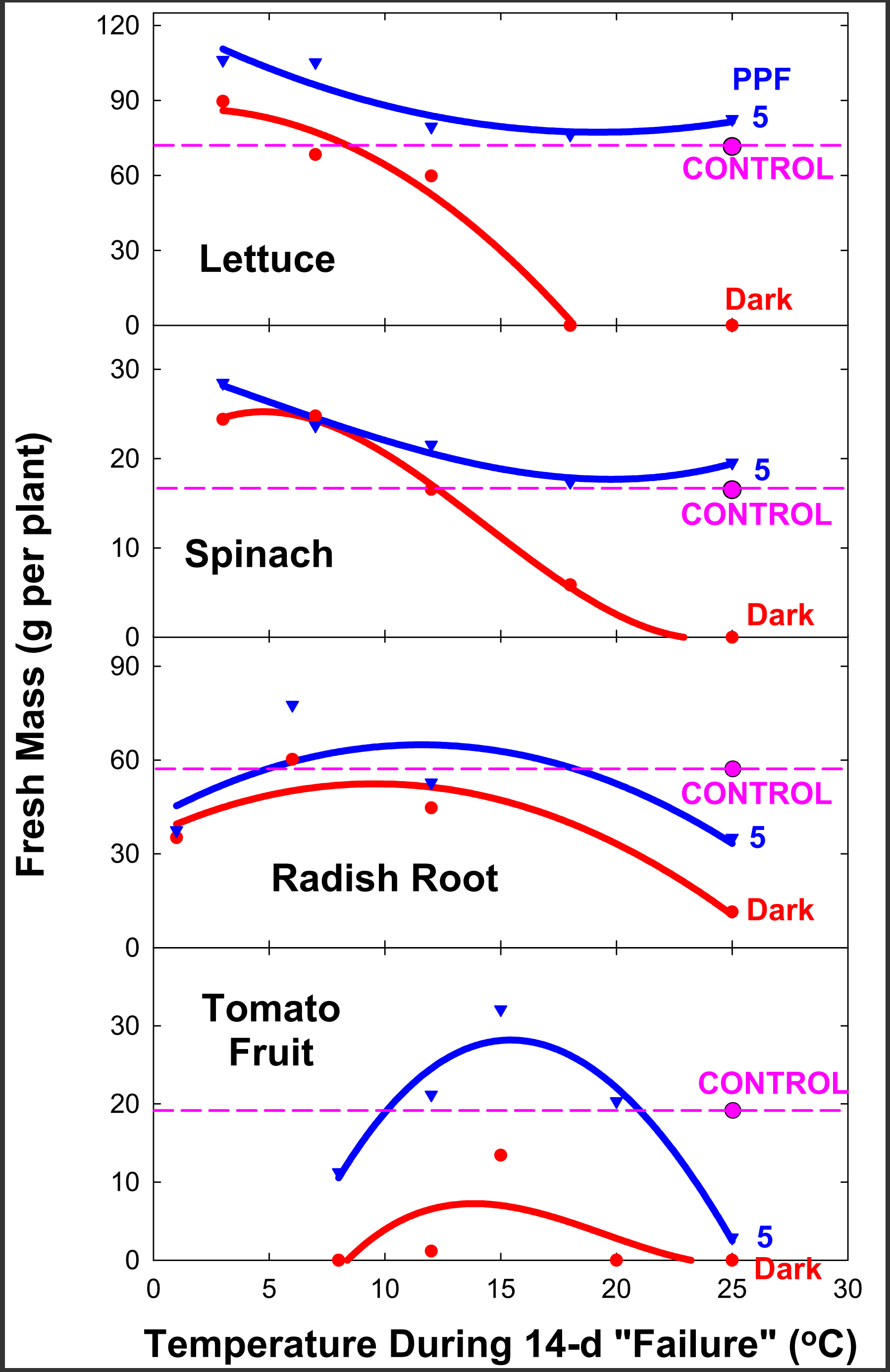
All 4 species

no supplemental light



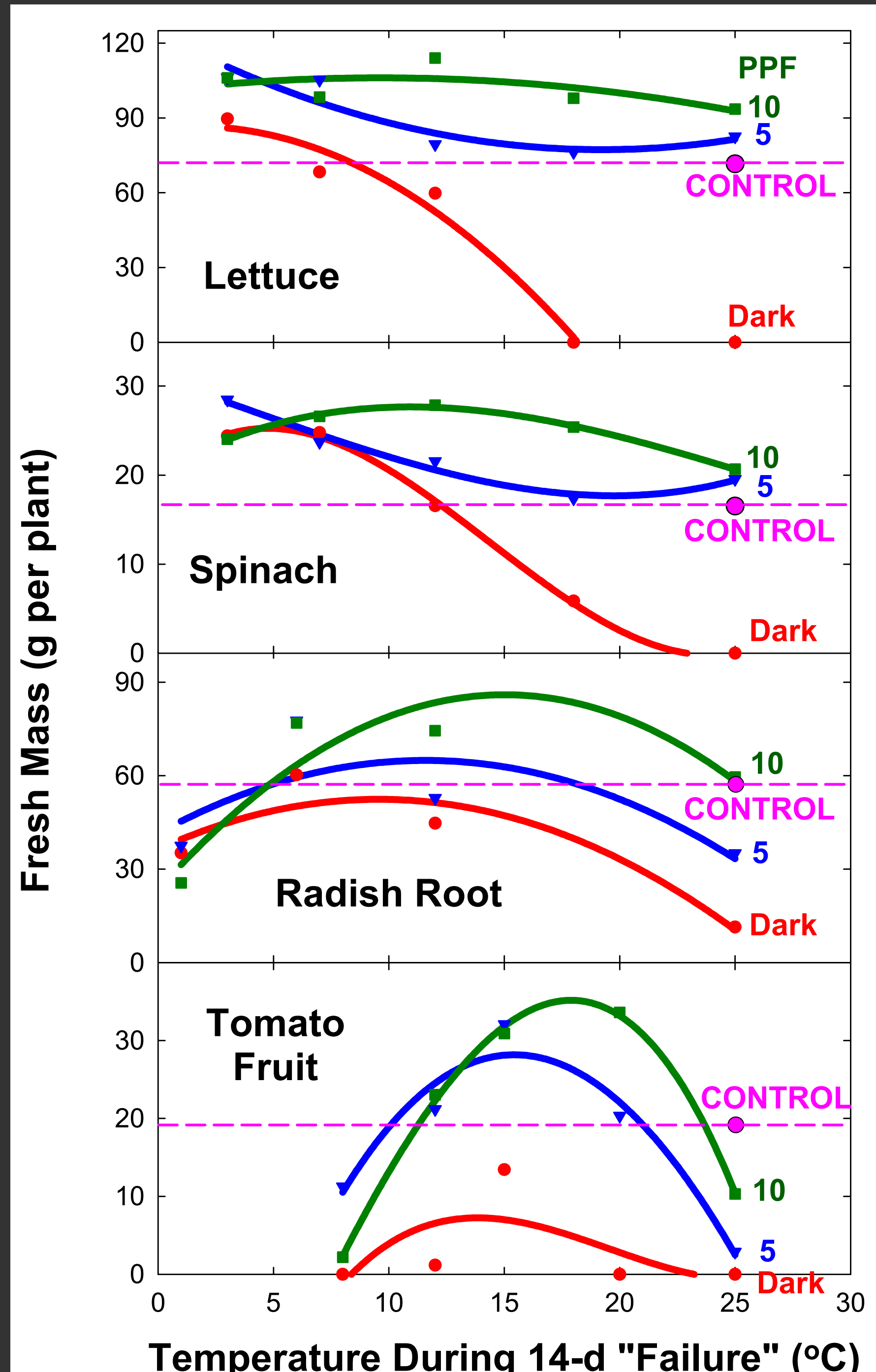
All 4 species

Dark & PPF = 5



All 4 species

Dark, PPF = 5, 10



Crop plants can tolerate 14.7 days on the dark side

Dark

14.7-d

- Add 1 to 2% light
- Lower temperature

Light

14.7-d

Conclusions

- Addition of light during a power outage dramatically improves recovery.
- Lowering temperature preserves plants in the absence of light.
- Plants can grow on the dark side of the moon with a small energy input if temperature/light conditions are optimized


Power outages occurred on MIR and they will occur on the ISS.
We should design our plant growth research chambers so that they can provide low light and low temperature during power outages.
Shanon Lucid with USU-Apogee wheat