The Effects of Endophytic Bacteria on Photosynthetic Capacity and Carbon Metabolism in Developing and Mature Poplar Leaves

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ABSTRACT

In response to the rise in demand for Earth's energy reserves, the role of endophytes in plant-bacteria symbiotic relationships is being studied to improve the productivity of biofuel feedstocks, and thereby reduce dependence on oil for fuel. Endophytes have the ability to enhance plant health in a variety of species, and have also been shown to increase biomass in poplar. We grew *Populus deltoides x Populus nigra* (OP-367) in a green house to investigate the response of photosynthesis and carbon metabolism to inoculation with *Enterobacter 638.* Fluorescence and gas exchange were measured in developing and mature leaves using a LI-6400 Portable Photosynthesis System. Carbohydrate content was determined in the leaves using continuous enzymatic substrate assays. Plants inoculated with *Enterobacter* showed no difference in photosynthetic capacity early in the study, but by the end of the study a significant 3% lower maximum quantum efficiency of photosystem II was observed in the leaves of plants inoculated with endophytes ($F_{1,44}=11.1$, $P=0.005$). This indicates the possible onset of photoinhibition. Despite similar photosynthetic capacity, the plants inoculated with endophytes accumulated less sucrose, indicating that they may have a larger sink for photosynthate ($F_{1,44}=24.4$, $P<0.01$). Future studies are needed to examine the impact of nutrient availability on the response of poplar to inoculation with endophytic bacteria.

INTRODUCTION

The use of plants for biofuel is a well explored option for alternative energy sources. However, the growth of plants for fuel is in competition with the growth of food crops and is therefore often not profitable. If plants can produce substantial biomass on marginal soils, their use as a biofuel could become more widespread. Endophytic bacteria have been shown to increase the productivity of their host plants but the mechanism underlying this response is not well understood. We grew *Populus deltoides x Populus nigra* (OP-367) inoculated with *Enterobacter 638 in order to investigate* the effect of endophytes on photosynthetic capacity and carbon metabolism.

METHODS

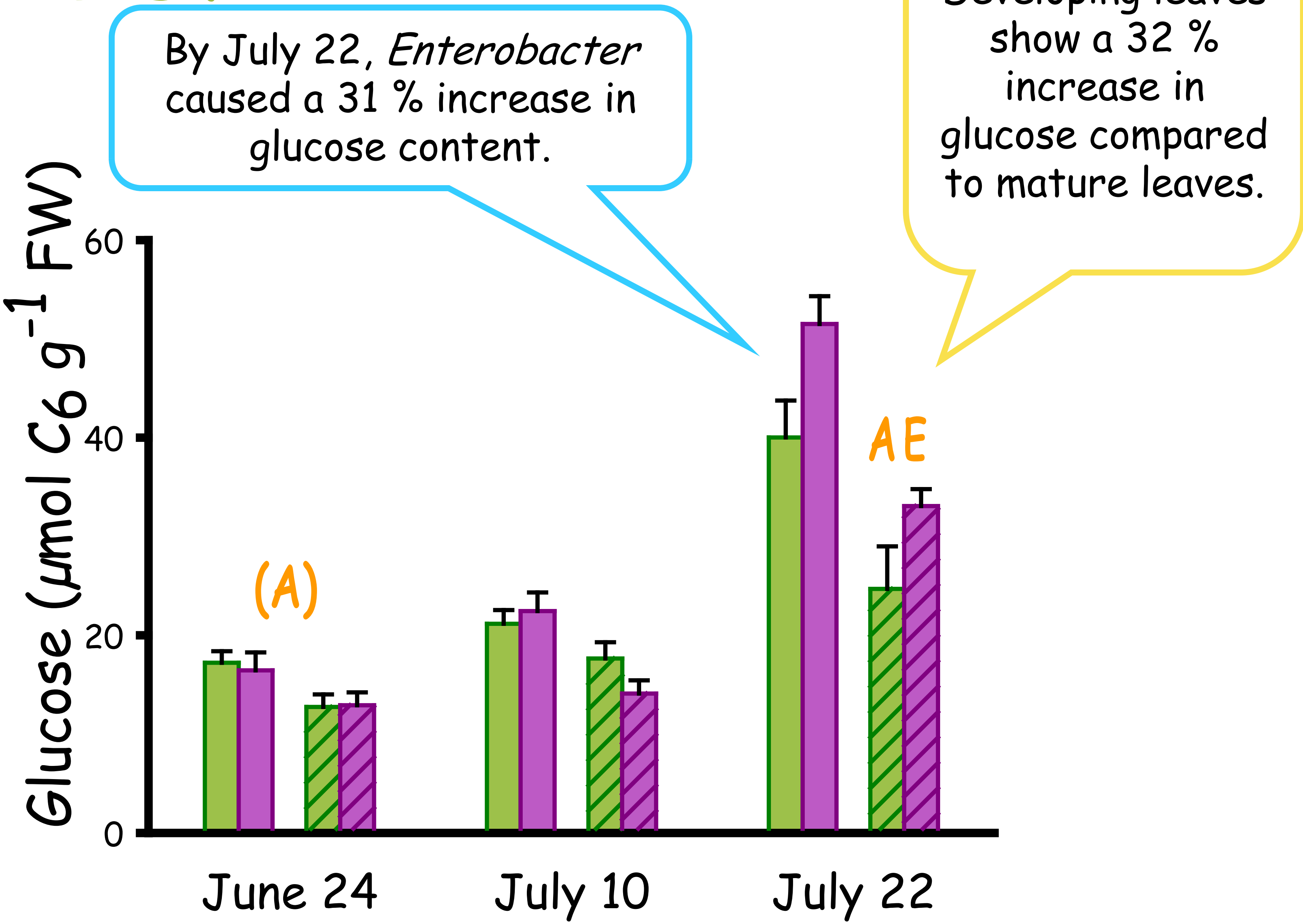
A Li-6400 Portable Photosynthesis System was used to sample physiologically identical leaves (identified by leaf plastochron index) from poplars growing in a greenhouse. Fluorescence and gas exchange measurements were made on developing and mature leaves. Leaf samples were harvested and carbohydrate content was determined using continuous enzymatic substrate assays. Data show mean ± SE, n=12.

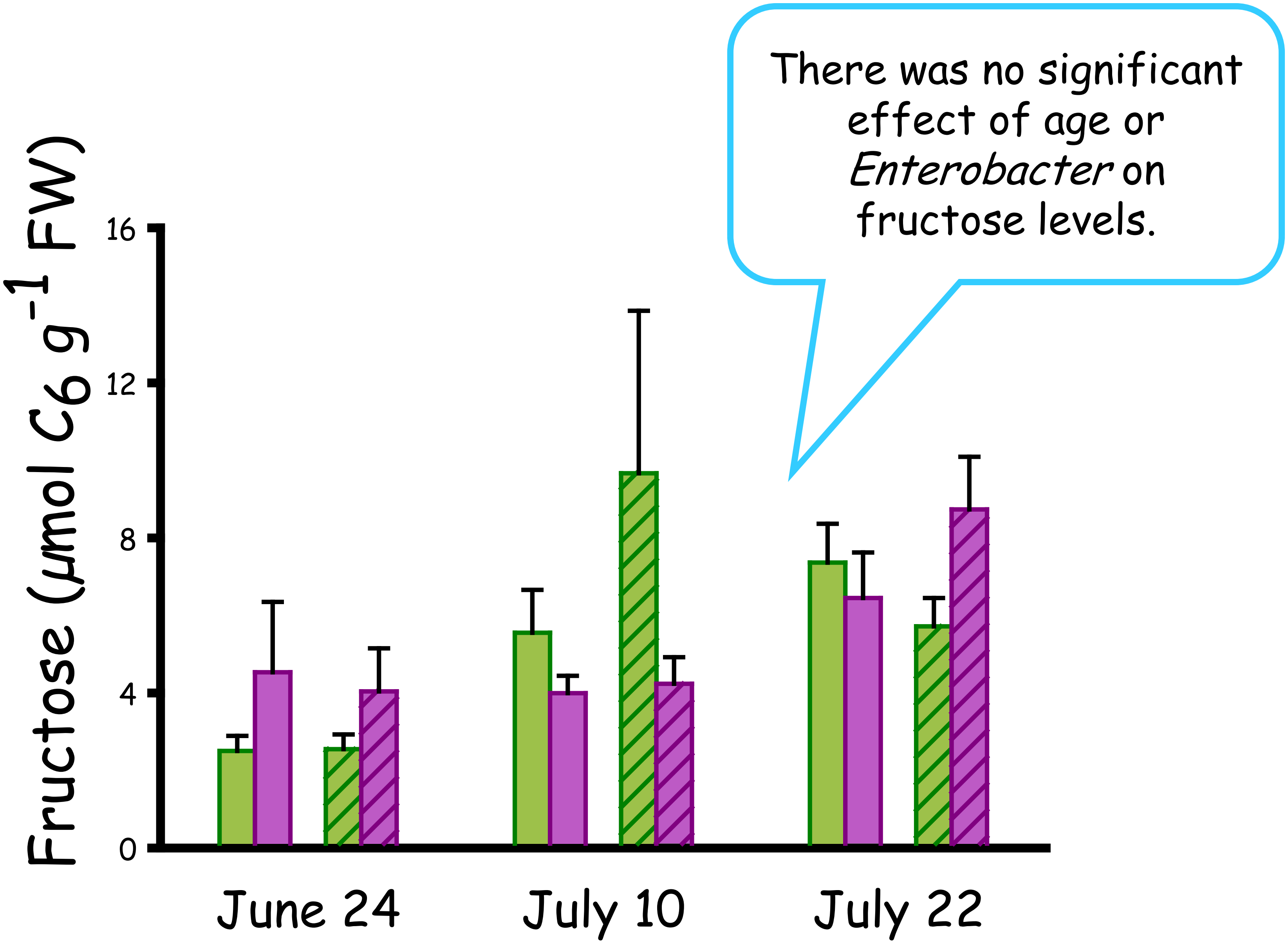
RESULTS

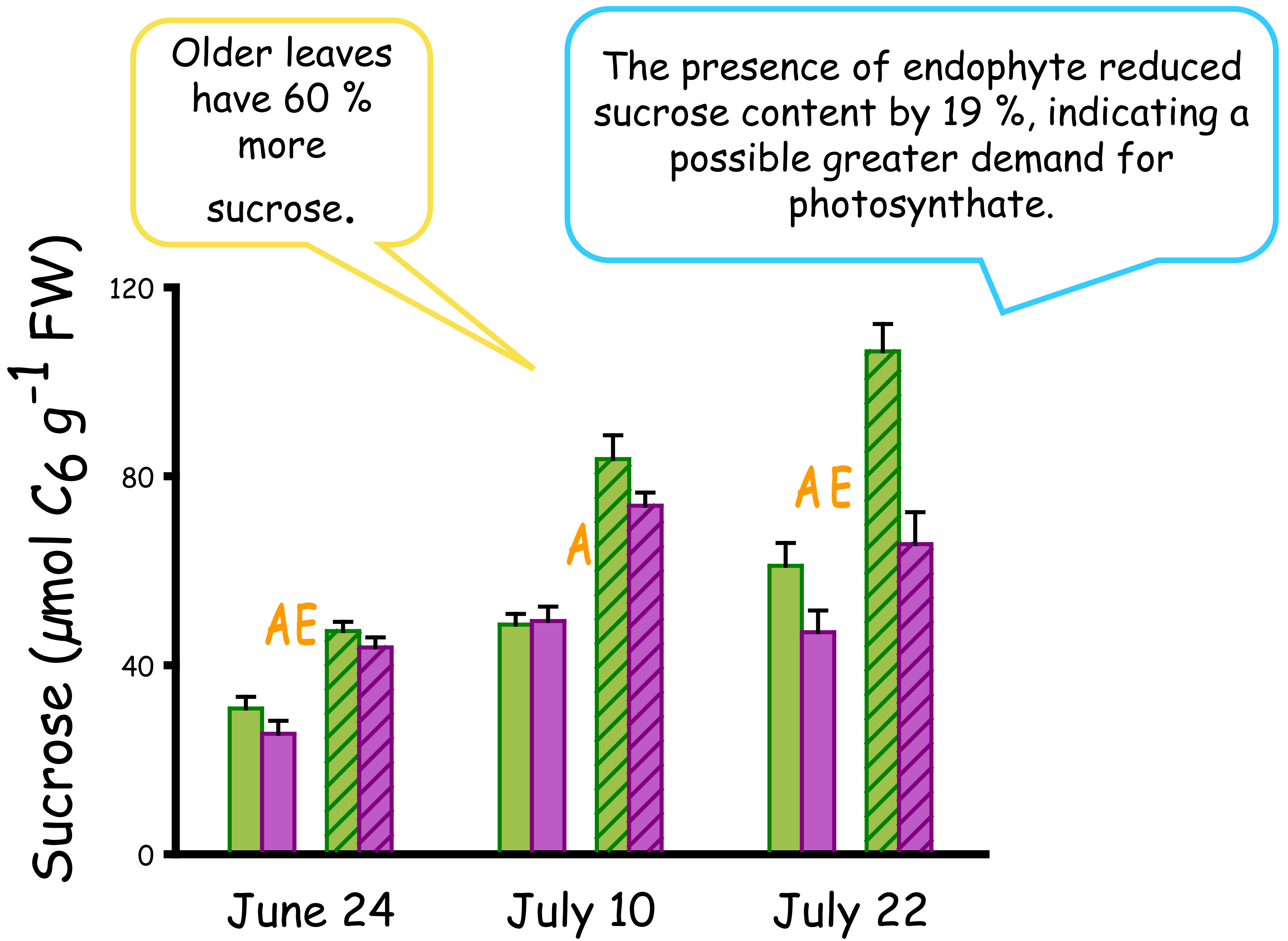
- CONTROL DEVELOPING
- ENTEROBACTER DEVELOPING
- CONTROL MATURE
- ENTEROBACTER MATURE

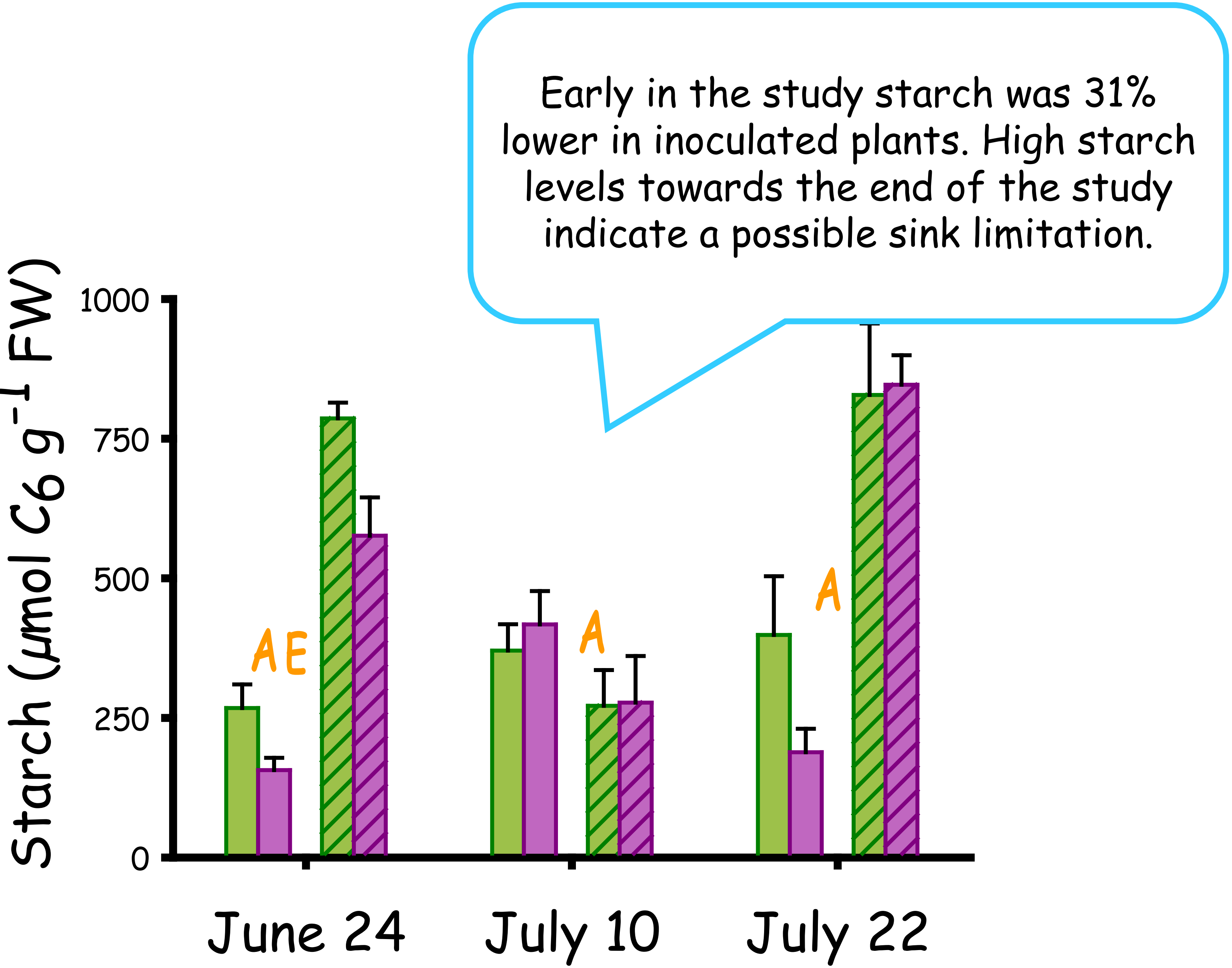
(A) Significant age effect ($p<0.05$)
(A) Significant age effect ($p<0.1$)
E Significant Enterobacter effect ($p<0.05$)
(E) Significant Enterobacter effect ($p<0.1$)

CARBON

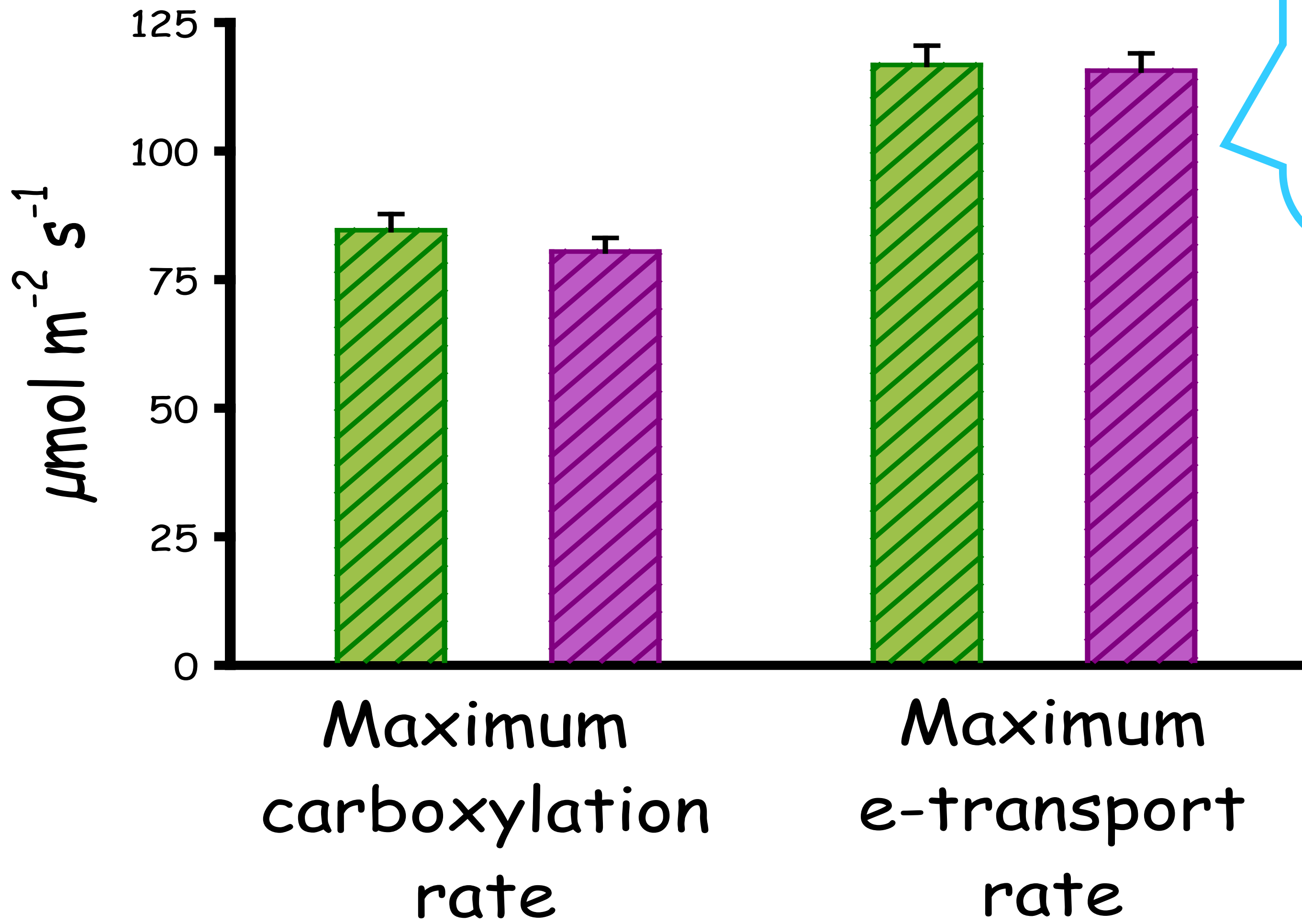

By July 22, *Enterobacter* caused a 31 % increase in glucose content.
Developing leaves show a 32 % increase in glucose compared to mature leaves.
Glucose (μmol C6 g-1 FW)
60
40
20
0
(A)
AE
June 24
July 10
July 22


There was no significant effect of age or *Enterobacter* on fructose levels.
Fructose (µmol C6 g-1 FW)
16
12
8
4
0
June 24
July 10
July 22


Older leaves have 60 % more sucrose.
The presence of endophyte reduced sucrose content by 19 %, indicating a possible greater demand for photosynthate.
Sucrose (µmol C6 g-1 FW)
120
80
40
0
AE
A
AE
June 24
July 10
July 22

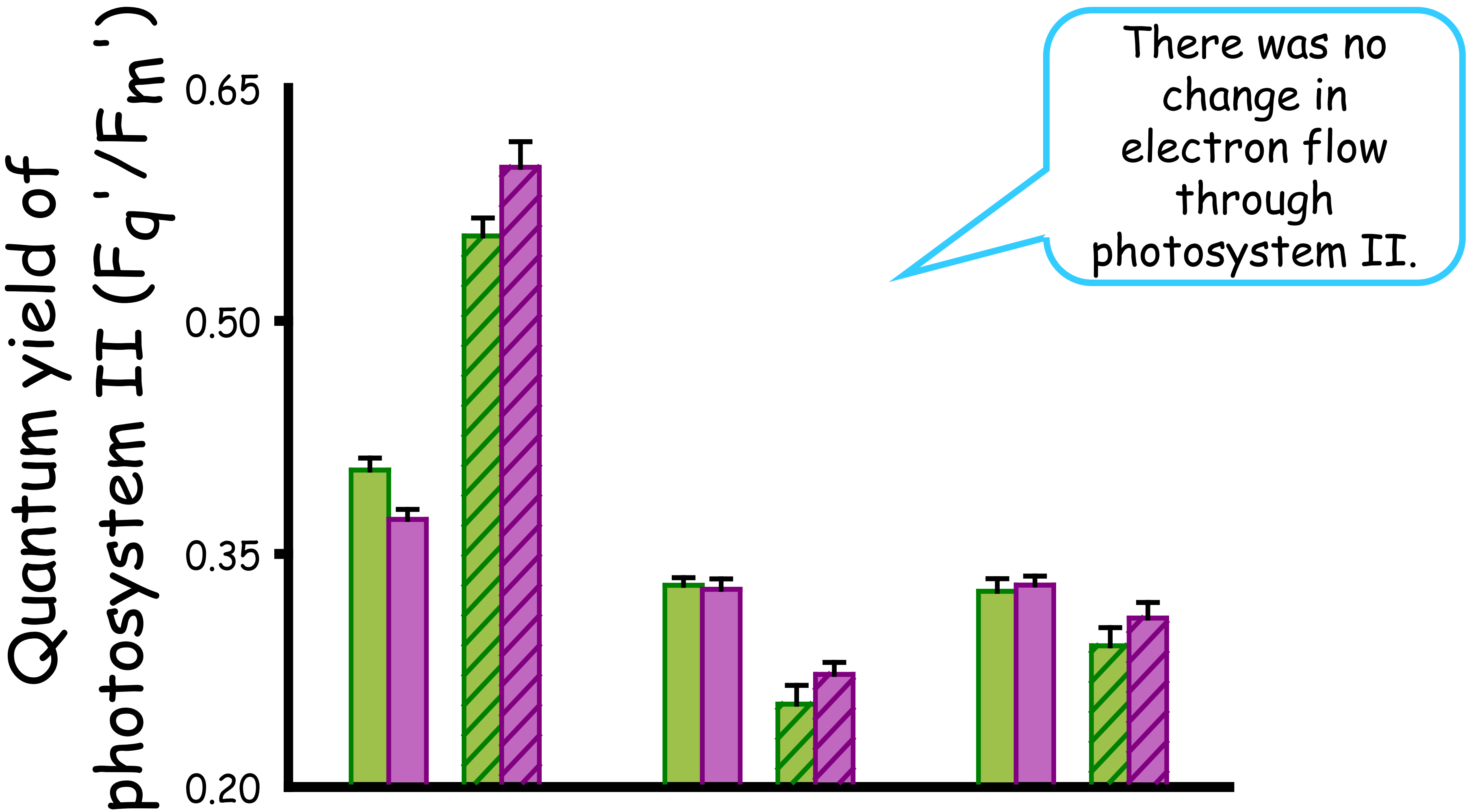

Early in the study starch was 31% lower in inoculated plants. High starch levels towards the end of the study indicate a possible sink limitation.
Starch (μmol C6 g-1 FW)
1000
750
500
250
0
AE
A
A
June 24
July 10
July 22

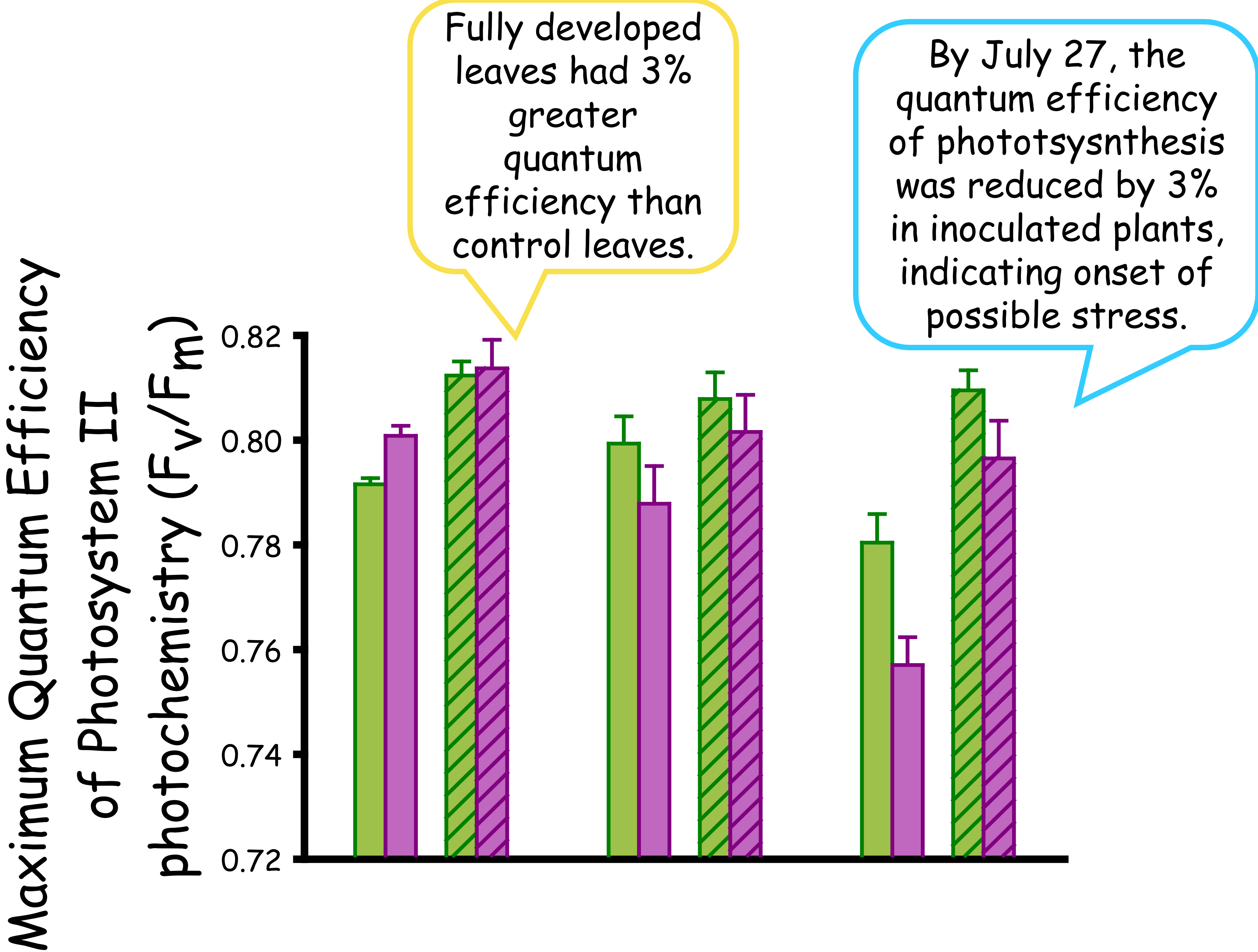
PHOTOSYNTHETIC CAPACITY

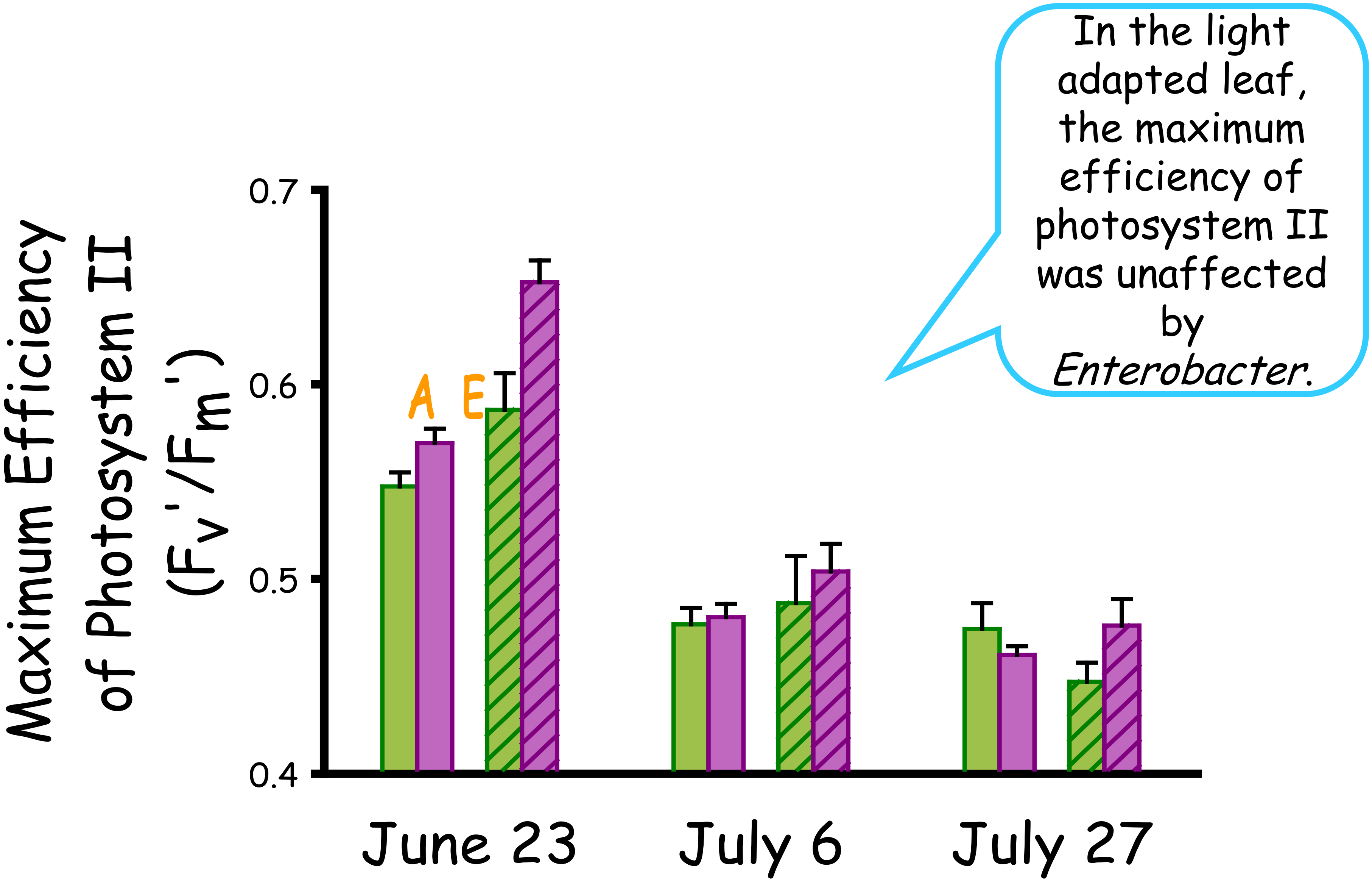


The presence of the endophyte had no effect on photosynthetic capacity in mature leaves.

FLUORESCENCE




Fully developed leaves had 3% greater quantum efficiency than control leaves.
By July 27, the quantum efficiency of phototsysnthesis was reduced by 3% in inoculated plants, indicating onset of possible stress.
Maximum Quantum Efficiency of Photosystem II photochemistry (F_v/F_m)
0.82
0.80
0.78
0.76
0.74
0.72



Maximum Efficiency of Photosystem II (F_v'/F_m')
0.7
0.6
0.5
0.4
A
E
June 23
July 6
July 27
In the light adapted leaf, the maximum efficiency of photosystem II was unaffected by *Enterobacter*.

CONCLUSION

Despite similar photosynthetic capacity, plants inoculated with endophytic bacteria had a lower sucrose content, suggesting that there was a greater demand for photosynthate in the inoculated plants. A reduction in the maximum quantum efficiency of photosystem II photochemistry at the end of the study suggests the onset of photoinhibition in inoculated plants.

ACKNOWLEDGMENTS

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