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Effects of Light Limitation on Plant-Rhizobia and Plant-Mycorrhiza Interactions

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Abstract

Plants respond with a sink stimulation of photosynthesis when colonized by bacterial and fungal mutualists, which compensates for costs of carbohydrate allocation to the microbes. Problems may arise when light is limited and plants cannot increase photosynthesis. We hypothesize that under such conditions the costs for maintaining the mutualism outweigh the benefits, which ultimately turns the beneficial microbes into parasites exploiting resources and reducing host fitness. We study these plant-microbe interactions under different light availabilities using lima bean plants, rhizobia (nitrogen-fixing bacteria), and mycorrhizal fungi. In our study, we apply two levels of light (full light and light intensity reduced by 75%) and four levels of microbial inoculation (sterile soil, rhizobia, mycorrhiza, and rhizobia x mycorrhiza). Fitness-relevant plant parameters will be measured including plant vegetative growth as well as flower and seed production. Our study will provide first insights into potential shifts in functional interactions between plants and plant-associated microbes under light limitation.

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Introduction

- Mutualism between plants and microbes are an important component in the determination of plant diversity and ecosystem productivity
- Mycorrhizal fungi: colonize plant roots, contribute nutrients, mainly phosphorus
- Rhizobia: form nodule structures on plant roots, fix atmospheric nitrogen
- Each symbiont may consume up to 16% of photosynthetically fixed carbon from the plant¹



Rhizobium nodules on Soybean roots
© Wally Eberhart/Visuals Unlimited

- Plants compensate for symbiotic costs by increasing photosynthesis, a process known as sink stimulation²
- Sink stimulation increases availability of photosynthates for the plant and its symbionts
- Under light limiting conditions, photosynthesis cannot be increased
- Under light limitation, do symbionts turn into parasites and reduce plant fitness?



Mycorrhizal fungi © Nathan Brandt/
ISU Extension News

Research Questions

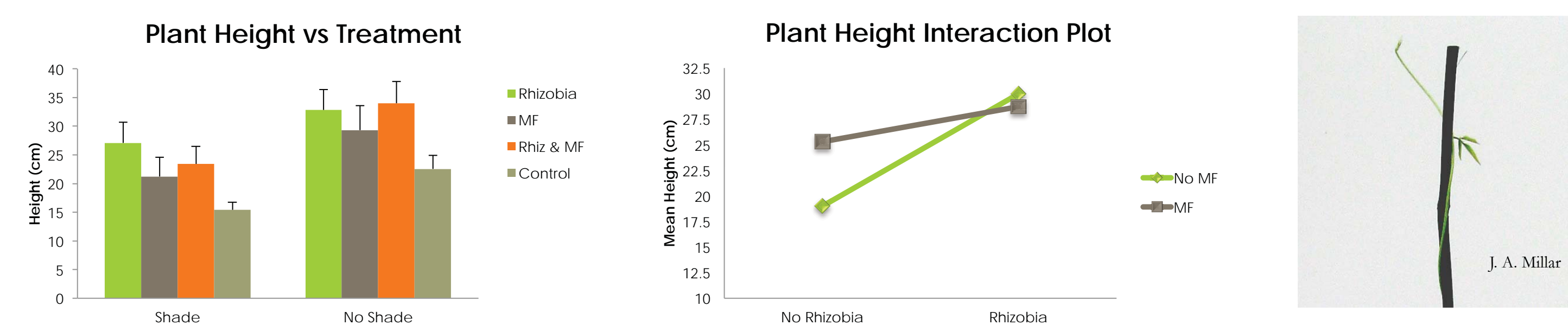
- 1) Do plant associated mutualistic microbes (rhizobia and mycorrhizal fungi) cause constraints in plant growth under low light conditions?
- 2) Does reduced light intensity result in adaptive plant morphological changes such as lower leaf production?
- 3) Do microbe-colonized plants show increased photosynthetic rates under full light conditions?

Methods

- Full factorial randomized block experiment using Lima bean plants (*Phaseolus lunatus*) to be continued through Summer 2012
- Two levels of light: full light & 75% shading
- Four levels of microbial inoculation: Sterile soil, Rhizobia (grown in liquid growth culture medium), Mycorrhiza (powder inoculant, BioOrganics), and Rhizobia x Mycorrhiza
- Measurements taken over the course of the experiment: plant height, leaf number, flowers and seed number, photosynthetic activity using PAM fluorometry
- Measurements to be taken at the end of the experiment: shoot:root ratio, leaf area, chlorophyll content, number and weight of nodules, percentage mycorrhizal colonization

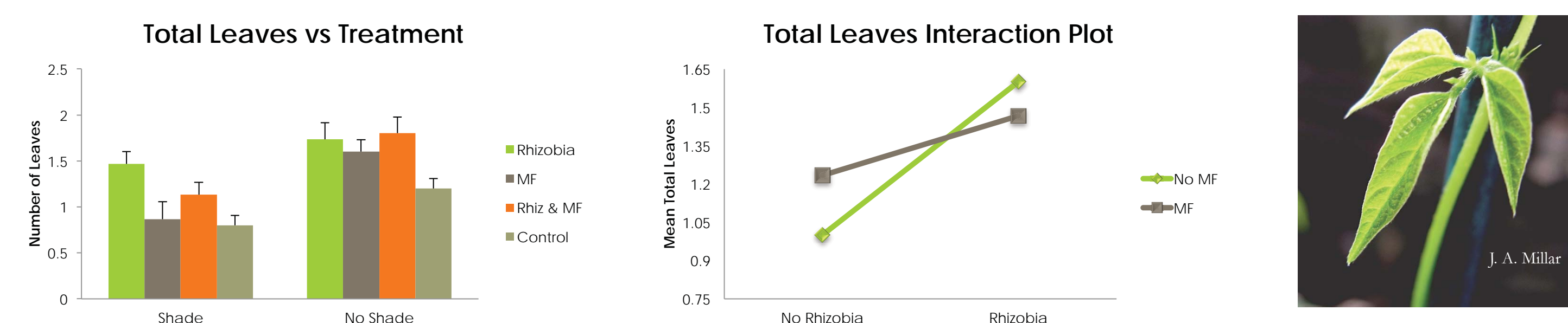
Preliminary Results

Plant Height



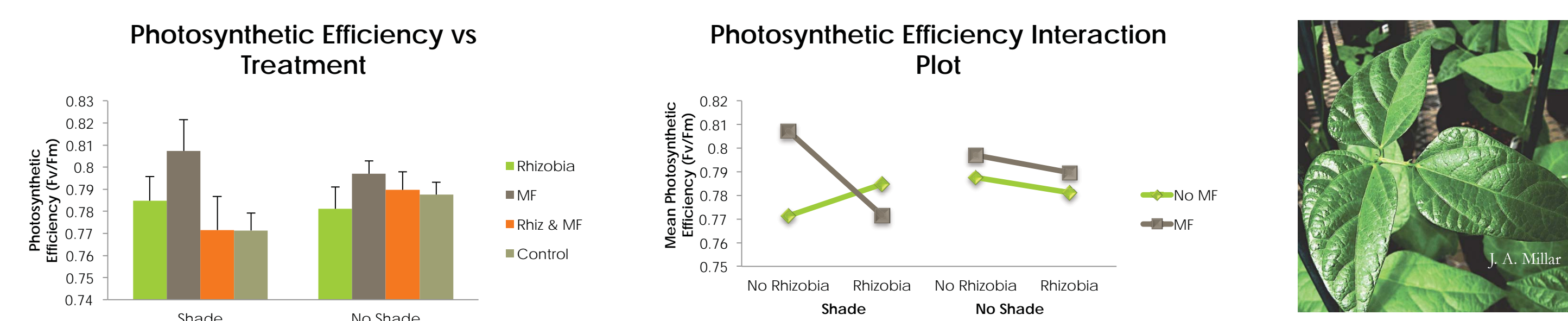
Statistical analysis using general linear model ANOVA of all treatments and pairwise interactions. Plant height for Rhizobia and Shade treatments were both found to be statistically significant (Rhizobia: $F=10.07$, $P=0.002$; Shade: $F=10.46$, $P=0.002$). Rhizobia x Mycorrhiza interactions were found to be nearly significant ($F=3.23$, $P=0.07$).

Total Leaves



Statistical analysis using general linear model ANOVA of all treatments and pairwise interactions. Total plant leaf number for Rhizobia and Shade treatments were both found to be statistically significant (Rhizobia: $F=13.22$, $P<0.001$; Shade: $F=22.29$, $P<0.001$). Rhizobia x Mycorrhiza interactions were found to be nearly significant ($F=3.53$, $P=0.06$).

Photosynthetic Efficiency



Statistical analysis using general linear model ANOVA of all treatments, pairwise and three-way interactions. The photosynthetic efficiency for both Rhizobia x Mycorrhiza and Rhizobia x Mycorrhiza x Shade interactions were found to be nearly significant (RxM: $F=3.00$, $P=0.086$; RxMxS: $F=2.78$, $P=0.098$).

Discussion

- Variation in plant height and total leaves was observed in the different microbe treatments.
- The addition of rhizobia may be affecting plant height and leaf number due to symbiotic effects. It is also possible these effects are influenced by inoculation with rhizobia growth medium.
- Under shaded conditions, photosynthetic efficiency was higher in both individual microbe treatments as compared to the non-shaded control. In contrast, the dual microbe treatment was lower in shaded conditions than the control.
- It is possible that under photosynthetically limiting conditions, supporting more than one mutualist is too costly for the plant.

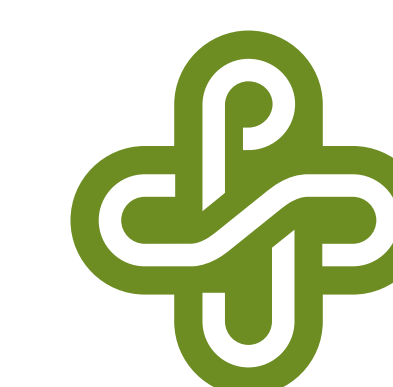
Ongoing Questions

- 1) Does reduced light intensity result in other adaptive plant morphological changes such as increased shoot:root ratio and increased area per leaf?
- 2) Does the maintenance of symbiosis in low light result in reduced fitness in microbe-colonized plants?
- 3) Do these differences in morphological characteristics and photosynthetic rates change over time?

Literature Cited

1. Kaschuk, G., Kuyper, T.W., Leffelaar, P.A., Hungria, M., Giller, K.E. 2009. Are the rates of photosynthesis stimulated by the carbon sink strength of rhizobial and arbuscular mycorrhizal symbioses? *Soil Biology & Biochemistry* 41, 1233–1244.
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