Plant Growth Promoting Rhizobacteria (PGPR) are More Effective Under Water Stress: A Meta-Analysis

Rachel L. Rubin[1,2], Kees Jan van Groenigen[1,2] Bruce A. Hungate[1,2]
Department of Biology, Northern Arizona University[1]; Center for Ecosystem Science and Society, Northern Arizona University[2]
Contact: rlr276@nau.edu

Introduction

Fig. 1 Drought stricken soybeans near Navasota, TX.

- Drought and salinization threaten more than 50% of earth's arable lands, and irrigation demand is expected to increase 10% by 2050 due to climate change alone[2].
- PGPR represent a diverse group of bacteria that produce a wide range of enzymes and metabolites, influence nutrient acquisition, modulate hormone levels, and ameliorate the negative impacts of biotic and abiotic stressors[1]. However, there is no general consensus of their effectiveness under the influence of drought.
- We conducted a global synthesis on the effects of PGPR inoculation on plant performance under drought and well-watered conditions, and explored moderators that influence variation to these effects.

Methods

- Using the search terms "*PGPR and drought*" and "*rhizobacteria and drought*", we conducted a comprehensive search on Google Scholar and Web of Science. We screened papers based on having a full factorial drought*PGPR design. Our final analysis included 52 papers with 448 total observations.
- We calculated effect sizes using the response ratio, $RR=\ln(\bar{x}_t/\bar{x}_c)$, where $\bar{x}_t$ is the mean for inoculated plants and $\bar{x}_c$ is the mean for control (not inoculated) plants.
- We performed multivariate meta-regressions on subsets of data, weighting studies by the inverse of the pooled variance. We extracted parameter estimates and 95% CI's for graphing purposes.
- For ease of interpretation, effect sizes and CI's were back-transformed from response ratios to percentages.

Results

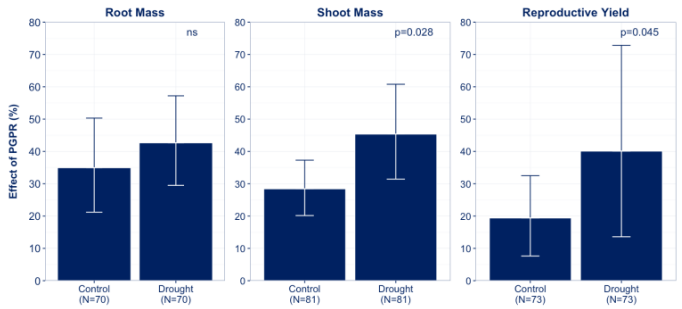

Fig. 2 PGPR improved root mass by 43%, shoot mass by 45% and reproductive yield by 40% under drought conditions. The effects of PGPR were significantly greater under drought compared to watered conditions for shoot mass and reproductive yield. Graph reflects parameter estimates and 95% CI's for mixed effects meta-regressions on subsets of data, controlling for observations and citations by coding them as random effects. Significance tests reflect mixed effects meta-regressions with drought as the sole moderator (α = 0.05), controlling for variation due to individual observations and citations by coding them as random effects.

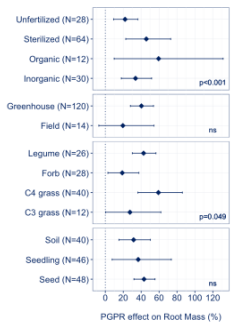

Fig. 3 The effects of PGPR on root mass were mediated by fertilization treatments and plant functional group. Graph reflects parameter estimates and 95% CI's for mixed effects meta-regressions on subsets of data, controlling for observations and citations as random effects.

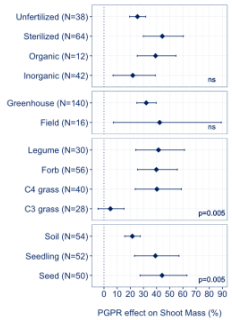

Fig. 4 The effects of PGPR on shoot mass were mediated by plant functional group and inoculation method. Graph reflects parameter estimates and 95% CI's for mixed effects meta-regressions on subsets of data, controlling for observations and citations as random effects.

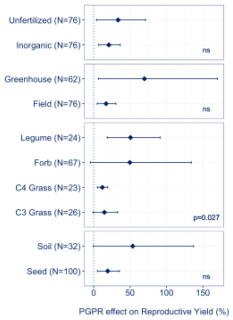

Fig. 5 The effects of PGPR on reproductive yield were mediated by plant functional group. Graph reflects parameter estimates and 95% CI's for mixed effects meta-regressions on subsets of data, controlling for observations and citations as random effects.

Conclusions/Discussion

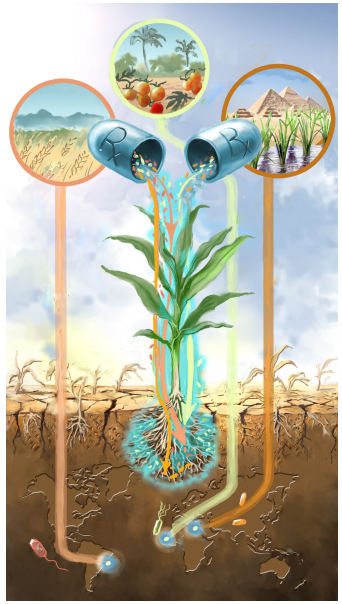

Fig. 6 PGPR as a metaphorical "prescription for drought", using a consortium of bacteria sourced from stressed locations around the world. Illustration by Victor Leshyk, 2016.

- PGPR were highly effective at improving root mass, shoot mass and reproductive yield, with greater effects seen under drought conditions for shoot mass and reproductive yield.
- PGPR improved plant growth on a similar order of magnitude as mycorrhizal fungi[3,4]
- By 2050, the world's population will exceed 9.1 billion, and food demand is expected to double[5].
- Arid regions in the developing world may benefit the most from PGPR application because these regions are characterized by rapid population growth and are among the most vulnerable to climate change.

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