How reliable are microbial inoculants in agriculture for improving nutrient use efficiency and yield? – a meta-analysis of field studies from 1981 to 2015

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Introduction

Rhizosphere microorganisms have evolved together with the plants and represent a valuable gene pool for plant growth and health. Potential beneficial effects:

- Nitrogen fixation
- Facilitated nutrient access from fertilizers and soil stocks
- Improved water availability
- Improved plant health

Soils of poor quality are most promising for an application and most studies originate from tropical and subtropical countries. However results have been inconsistent and the question is:

What are the factors determining the success of inoculation?

Literature collection

All studies were collected for arable crops grown in field trials only, with all types of fertilization (70% mineral, 16% no, 9% mixed, 4% organic).

613 studies were identified with the keywords «biofertilizer» and «microbial inoculant» → 458 studies were excluded because eligibility citeria were not met → 172 studies were selected for data extraction

Statistical analysis

Three effect sizes were calculated:

- Yield response
- Nitrogen use efficiency (from fertilizer N
- Phosphorus use efficiency (from fertilized P)

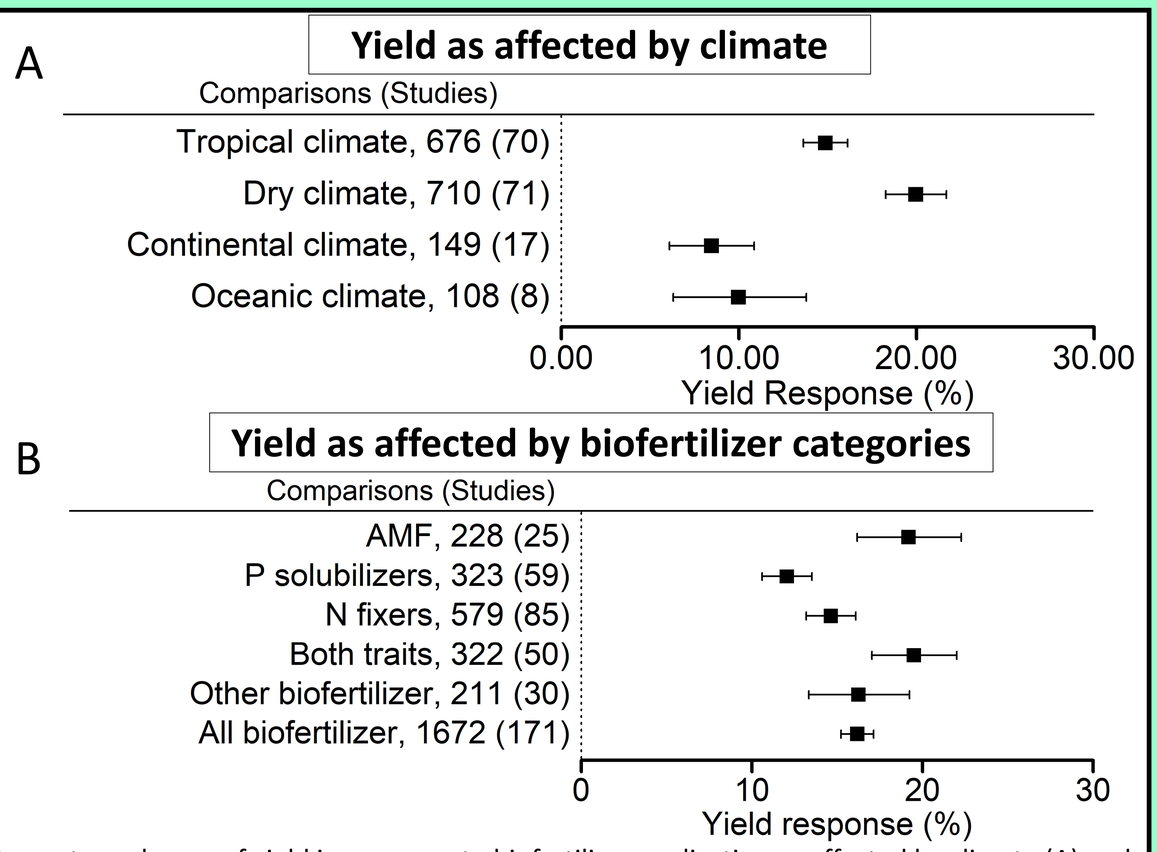
Mean difference between inoculated versus non-inoculated treatments was used to calculate effects. A random effects model was chosen to model effect sizes. If effect sizes in the graphs do not overlap they are considered significantly different as they represent the 95% confidence interval. Outliers were identified in the R package "METAFOR" (Viechtbauer, 2010).

Key findings

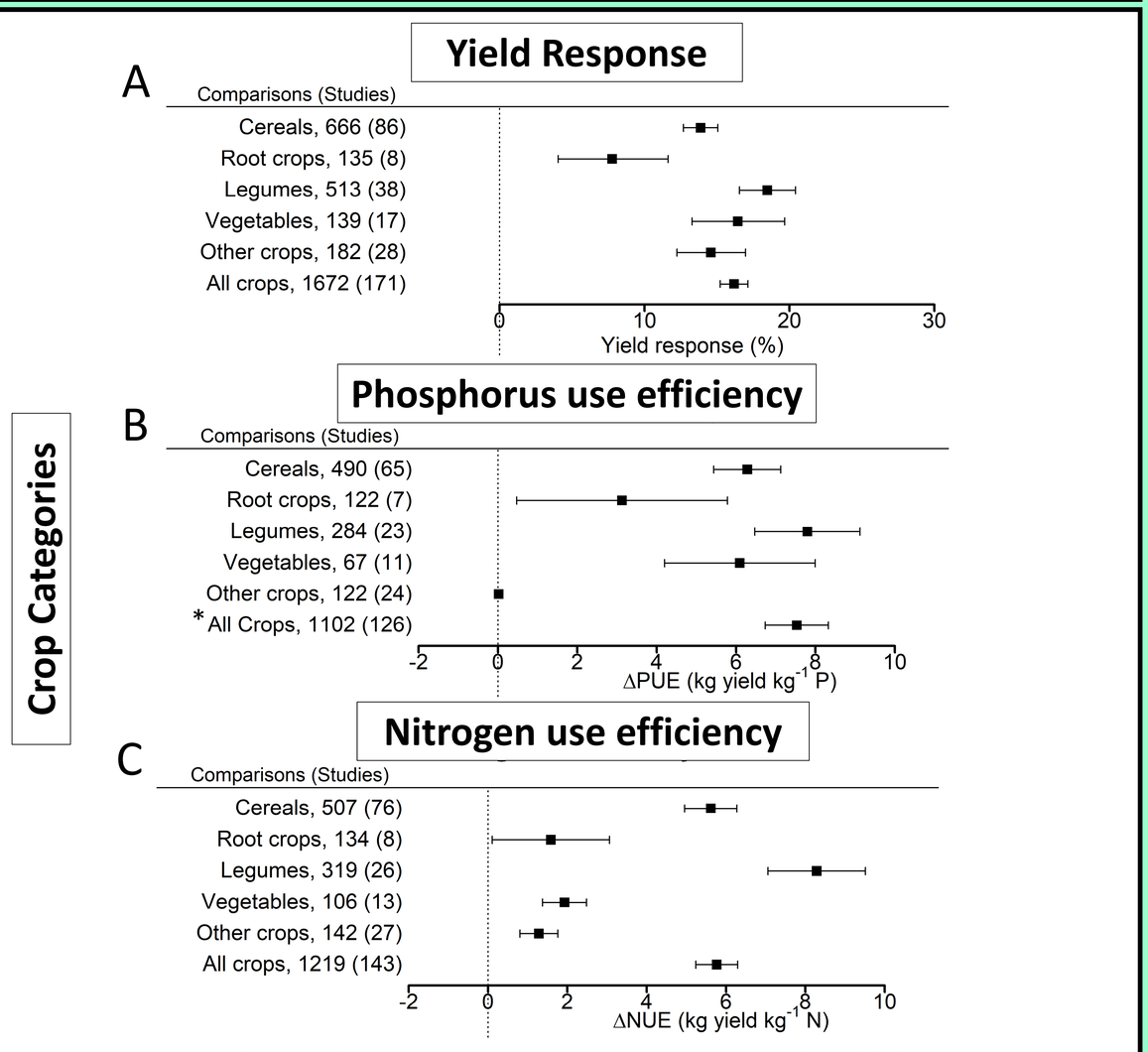
I. The superiority of biofertilizer performance in dry climates over other climatic regions (yield response: dry climate +20.0 ± 1.7%, tropical climate +14.9 ± 1.2%, oceanic climate +10.0 ± 3.7%, continental climate +8.5 ± 2.4 %) (see graph).
II. Soil available P levels determines yield response of functional traits in the order from low to high: arbuscular mycorrhizal fungi< P solubilization< N fixation and P solubilization< N fixation alone (not shown).
III. Success of inoculation with AMF was greater at low organic matter content and at neutral pH (see graph).
IV. Crop type had little effects; tubers had lowest yield promotion (10.29%) (see graph).

Organic agriculture was not assessed specifically, but is expected to perform similarly in respect to the here identified key abiotic factors.

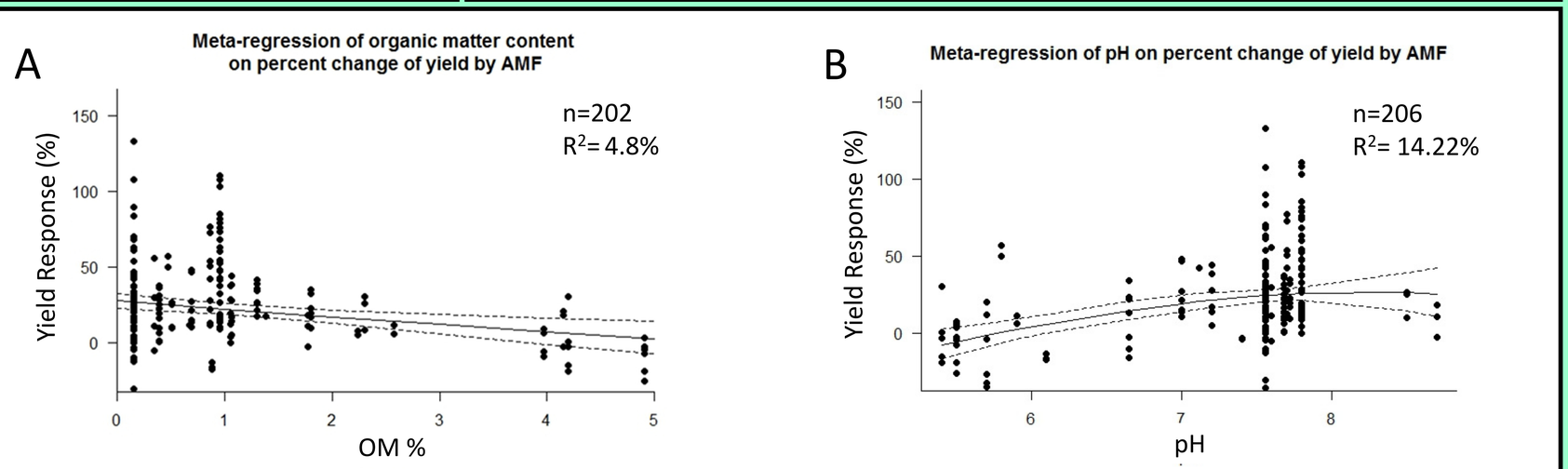
Various biofertilizers (Rhizobia, Pseudomonas, Cyanobacteria and AMF) and biofertilizer being applied in the BIOFI project in India by the Indo-Swiss collaboration in Biotechnology (ISCB) (photo: M. Natarajan).



Percentage change of yield in response to biofertilizer application as affected by climate (A) and in response to the application of various categories of biofertilizers (B). Mean values and 95% confidence intervals are shown. The highest effect was found in dry climates and was actually higher when rainfed.



Percentage change of yield (A), change in phosphorus use efficiency (PUE) (B) and nitrogen use efficiency (NUE) (C) in response to biofertilizer application. Mean values and 95% confidence intervals are shown. * The high value for all crops is caused by the outlier calculation that resulted in different pairs being excluded for the full sample and the sub-samples



Mixed effects model with organic matter (OM) (A) and with pH as moderator (B) as moderator for AMF inoculations.

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References

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