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 origin in 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.

613 studies were identified with the keywords «biofertilizer» and «microbial inoculant» → 451 studies were excluded because eligibility criteria were not met → 179 studies were selected for data extraction

Statistical analysis

Three effect sizes were calculated:

- Yield response
- Nitrogen use efficiency (from fertilizer N and modelled mineralised 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).

Modelling of mineral nitrogen to calculate nitrogen use efficiency

Mineralized soil N that was needed to meet the plants' nitrogen requirements was estimated using the nitrogen emission model by Meier et al. (Meier et al. 2012; Meier et al. 2014). Modeled values of mineralized soil N depend on nitrogen utilization rates, which are different for fertilizer type, management and region. Values were only modelled for main crops and NUE only calculated for those.

Key findings

I. Superiority of biofertilizers in arid over humid regions (Yield response +18.97% vs +14.45%; NUE: +1.97 vs +0.81 Kg yield/Kg N; PUE: +12.66 Kg Yield/Kg P vs 5.45 Kg Yield/Kg P) (see graph).

II. Arbuscular mycorrhizal fungi showed often highest and most consistent result across climates and effect sizes (see graph).

III. 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).

IV. Greater effects in developing countries than in developed countries which correlates to soil fertility and climate (not shown).

V. Crop type (cereals, legumes, tubers, vegetables) had little effects; tubers had lowest yield promotion (10.29%) (not shown).

Figure 1: Biofertilizer being applied in the BIOFI project in India by the Indo-Swiss collaboration in Biotechnology (ISCB) (photo: M. Natarajan).

Biofertilizer performance depending on climate

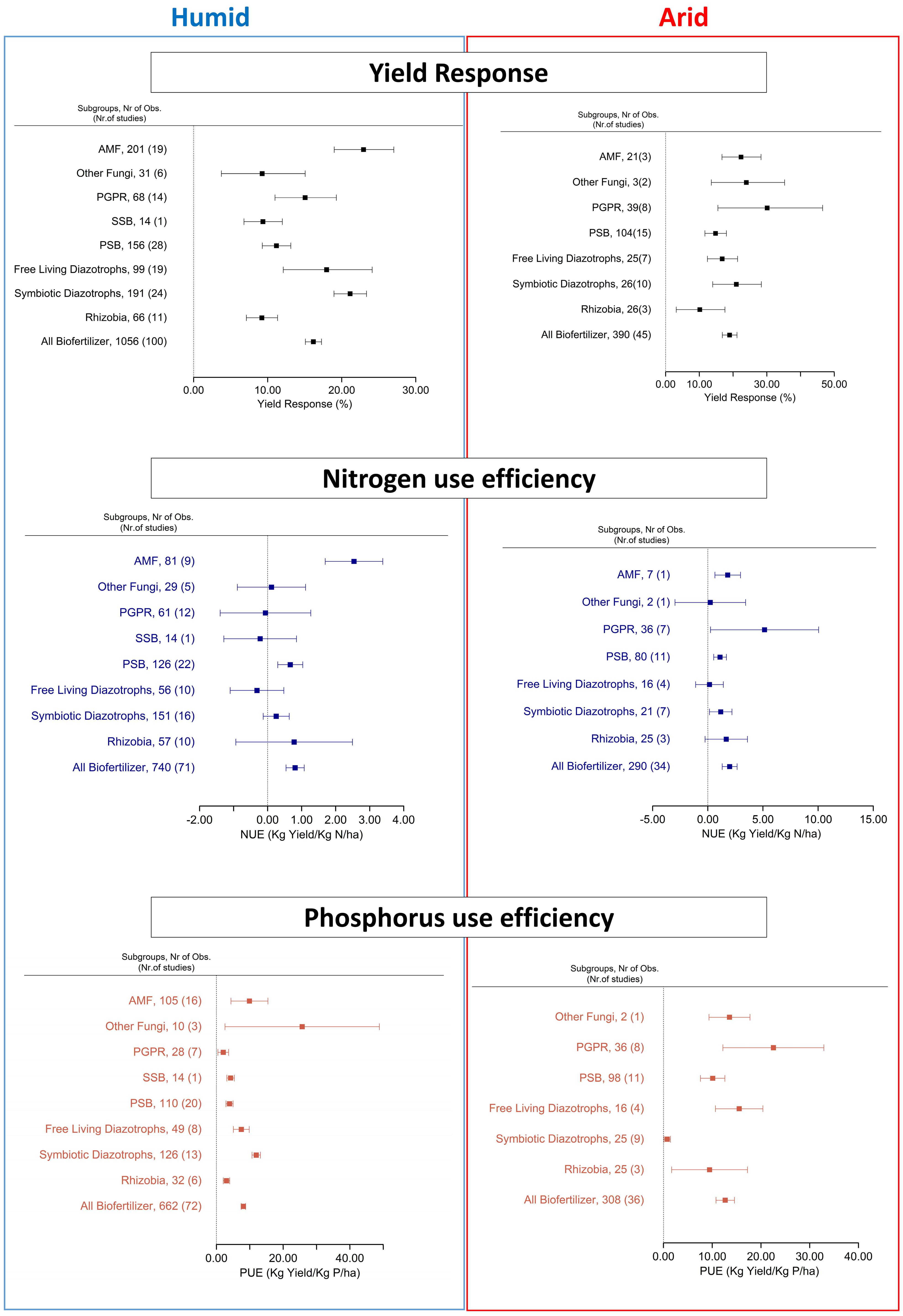

Figure 2: Performance of biofertilizers in humid and arid climate for the three effects sizes yield response, nitrogen use efficiency and phosphorus use efficiency. PGPR is a general group of plant growth promoting rhizobacteria, SSB are Sulphur solubilizing bacteria, PSB are phosphorus solubilizing bacteria, AMF are arbuscular mycorrhizal fungi and diazotrophs are nitrogen fixers.

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