Functionally complementary bacterial inoculant coordinates arbuscular mycorrhizal fungi to improve *Angelica sinensis* root yield and quality

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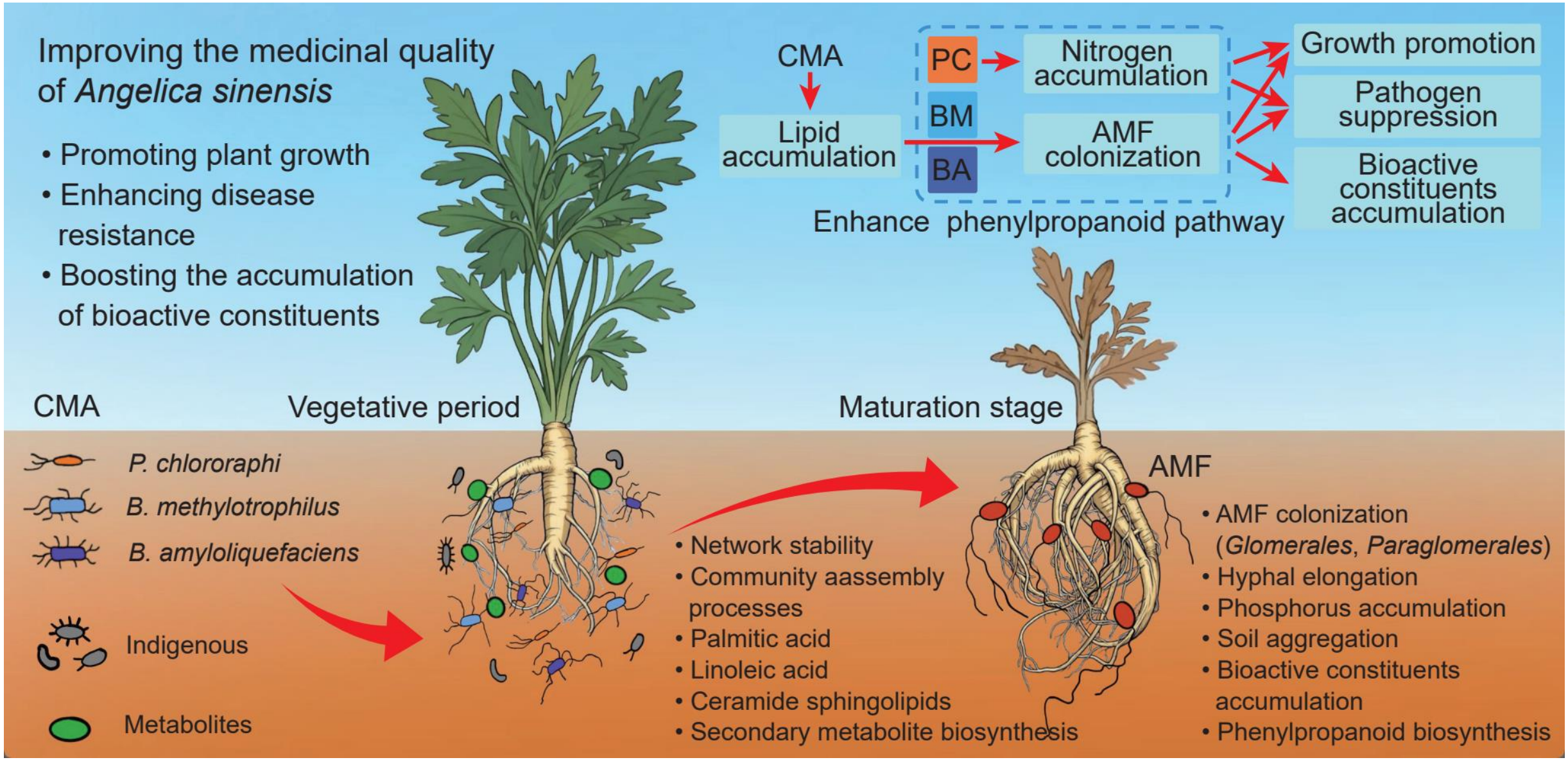
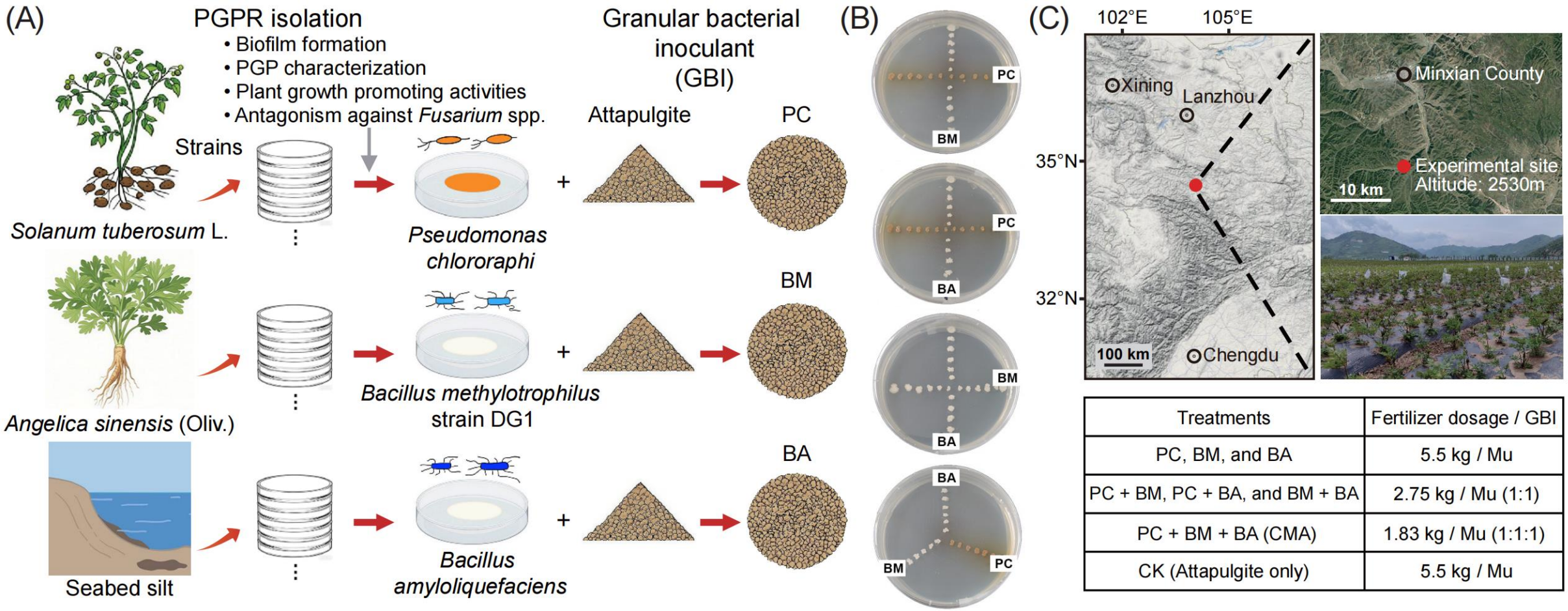
Highlights


Improving the medicinal quality of *Angelica sinensis*
• Promoting plant growth
• Enhancing disease resistance
• Boosting the accumulation of bioactive constituents
CMA
Lipid accumulation
PC
BM
BA
Nitrogen accumulation
AMF colonization
Enhance phenylpropanoid pathway
Growth promotion
Pathogen suppression
Bioactive constituents accumulation
CMA
Vegetative period
Maturation stage
P. chlororaphi
B. methylotrophilus
B. amyloliquefaciens
Indigenous
Metabolites
• Network stability
• Community aassembly processes
• Palmitic acid
• Linoleic acid
• Ceramide sphingolipids
• Secondary metabolite biosynthesis
AMF
• AMF colonization (*Glomerales*, *Paraglomerales*)
• Hyphal elongation
• Phosphorus accumulation
• Soil aggregation
• Bioactive constituents accumulation
• Phenylpropanoid biosynthesis

Field applications of GBI enhance *A. sinensis* growth



Treatments	Fertilizer dosage / GBI
PC, BM, and BA	5.5 kg / Mu
PC + BM, PC + BA, and BM + BA	2.75 kg / Mu (1:1)
PC + BM + BA (CMA)	1.83 kg / Mu (1:1:1)
CK (Attapulgite only)	5.5 kg / Mu

Figure 1. Formulation of bioinoculants and assessment of single and multiple consortia effects on the growth and morphology of *A. sinensis*.

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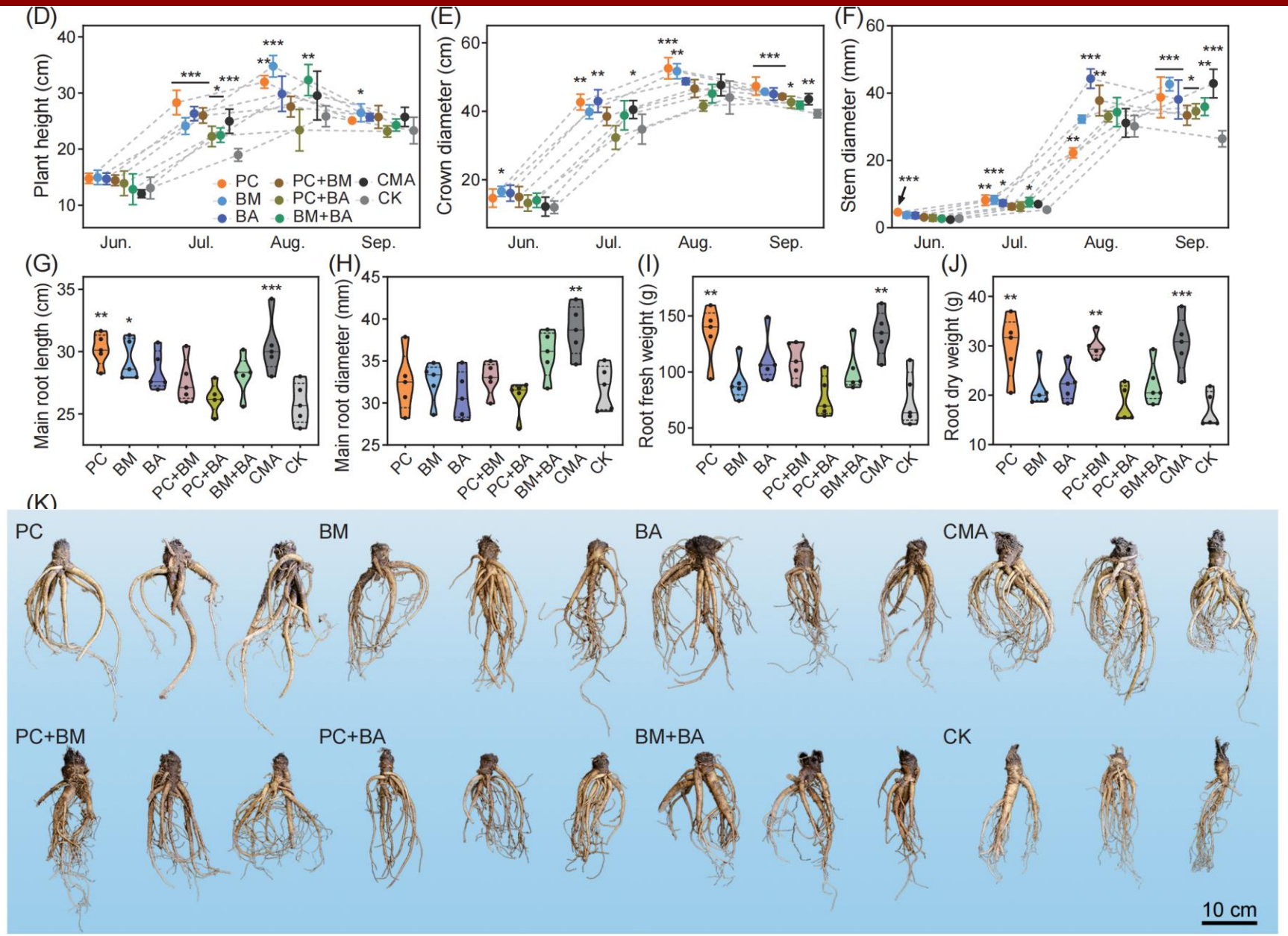

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Probiotic agents drive the alteration of microbial communities in *A. sinensis* rhizosphere

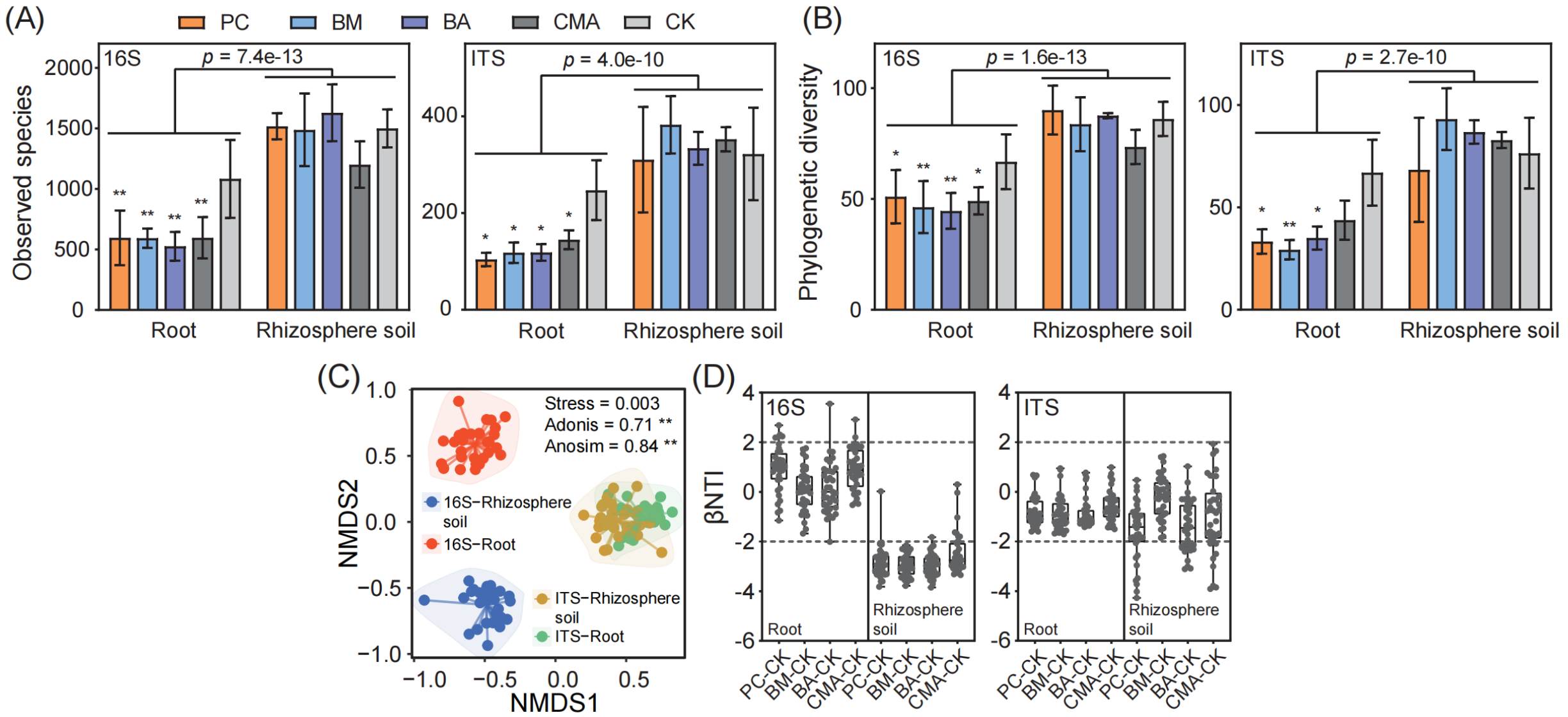
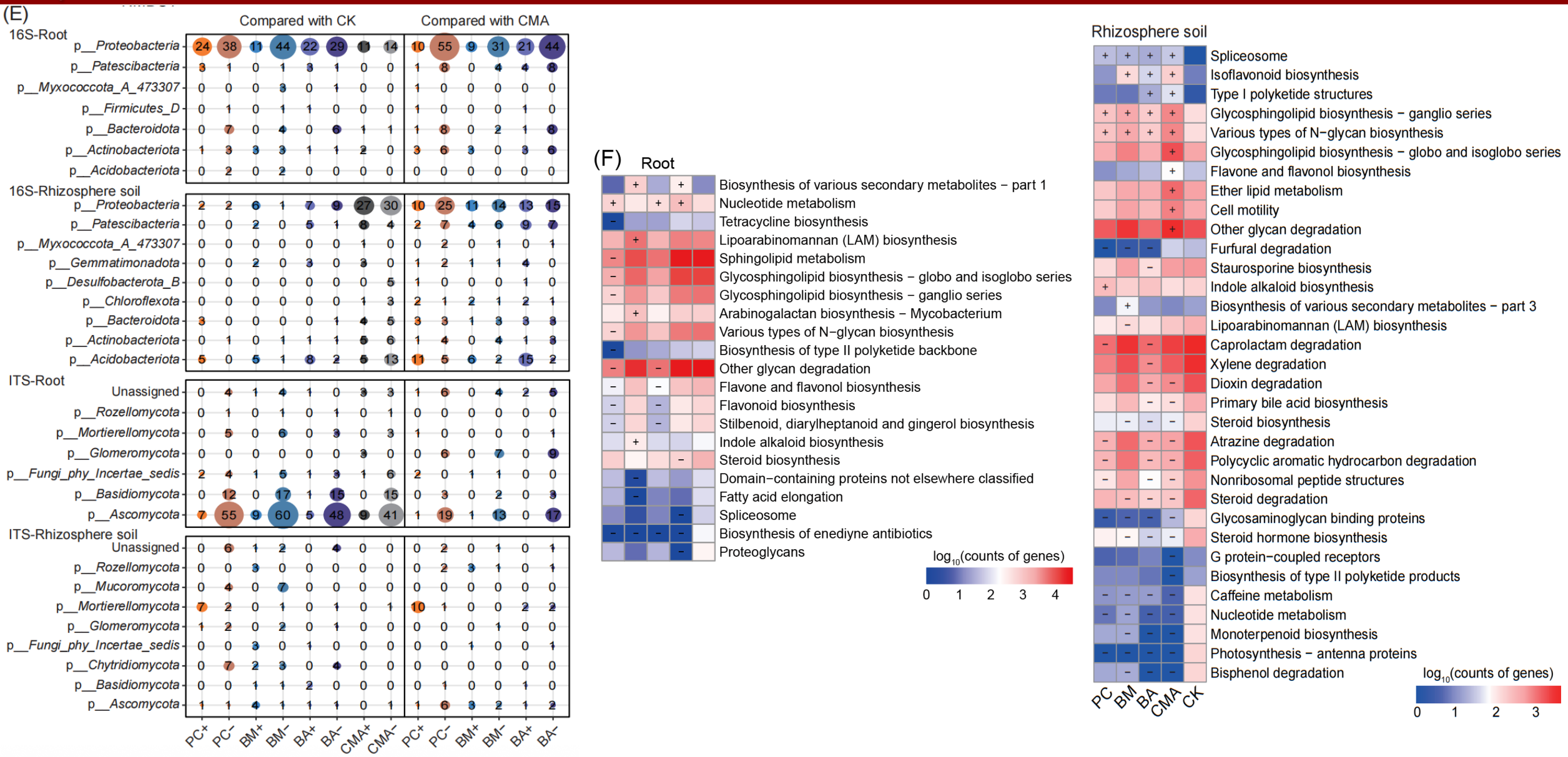


Figure 2. Bacterial and fungal diversity and functional potential under different inoculant treatments.

Probiotic agents drive the alteration of microbial communities in *A. sinensis* rhizosphere



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Network-based co-occurrence patterns reveal root and soil microbial interactions

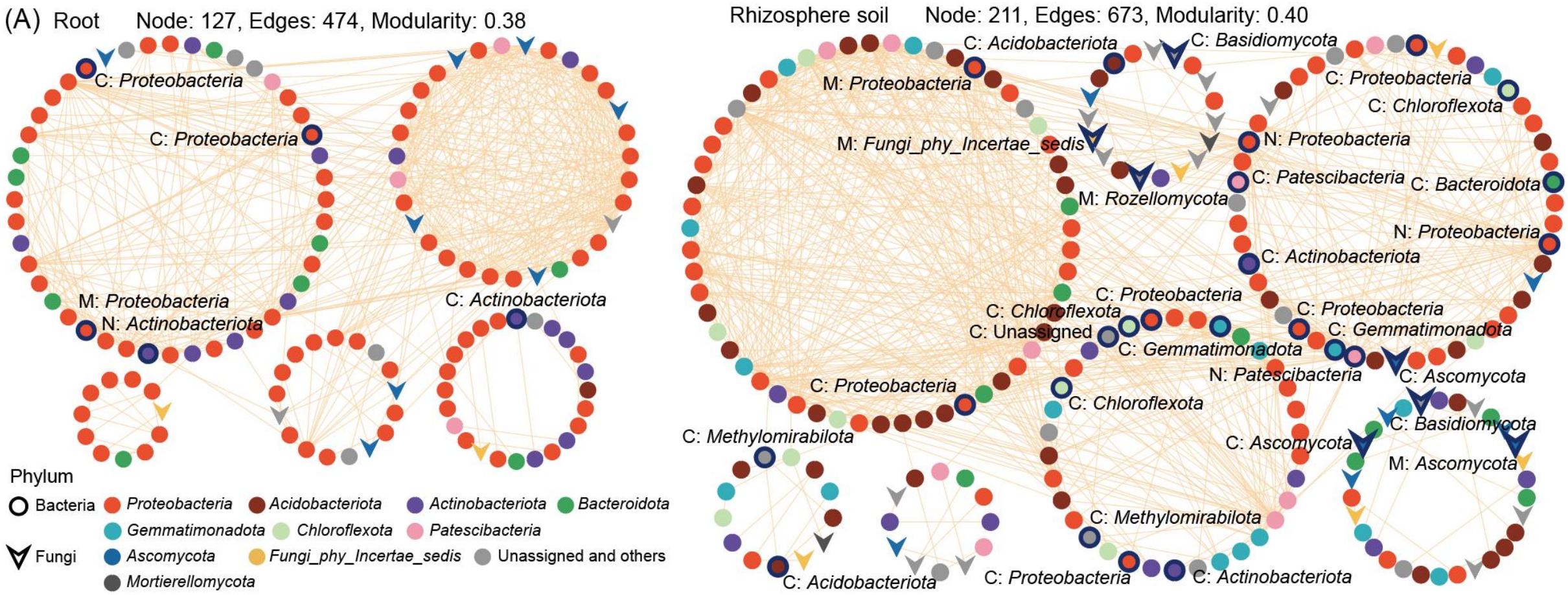

Figure 3. Co-occurrence network of 16S and ITS amplicon sequence variants in the root and rhizosphere soil.

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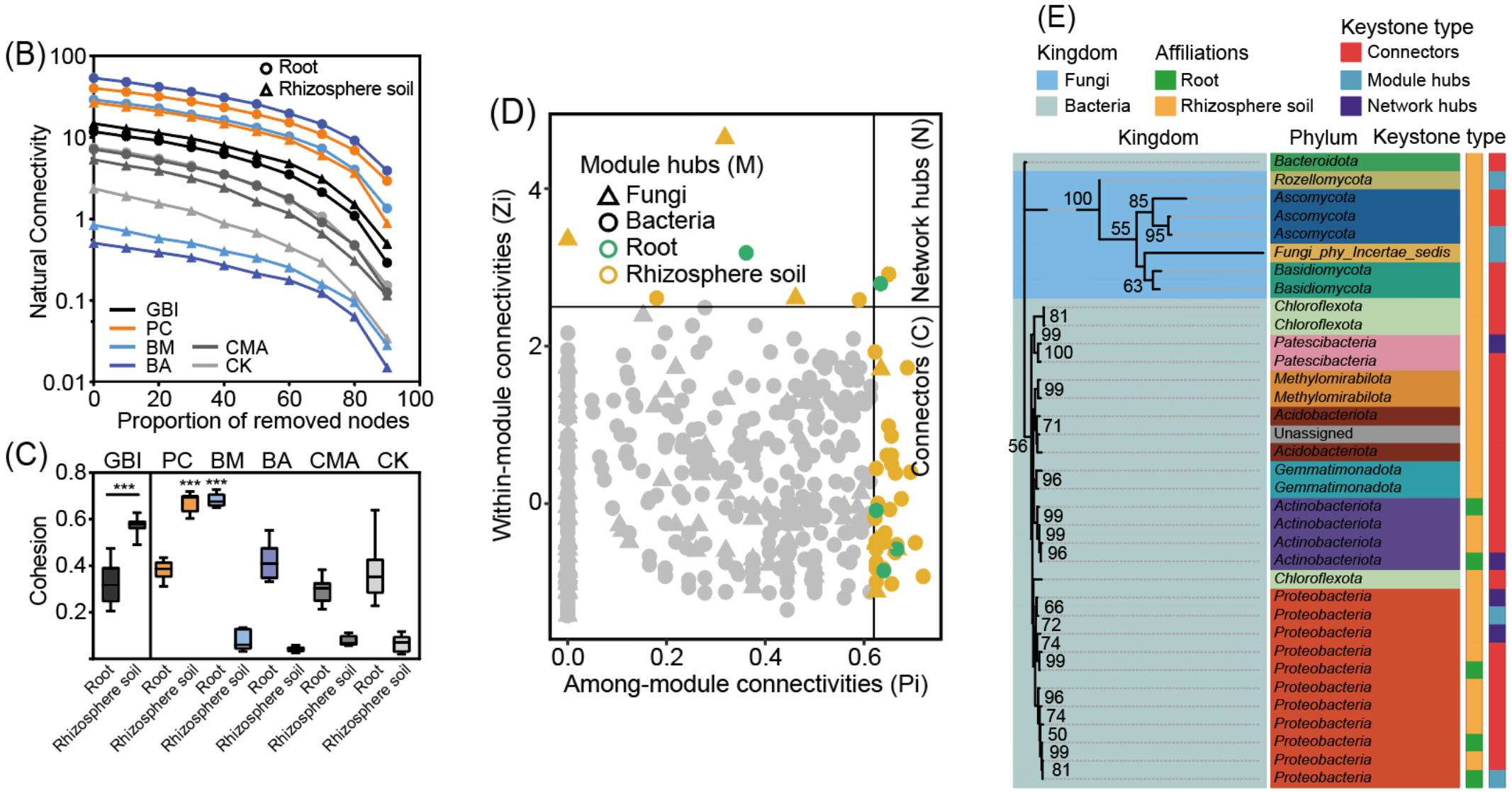

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CMA treatment promotes marked enrichment of lipid metabolites in RAS

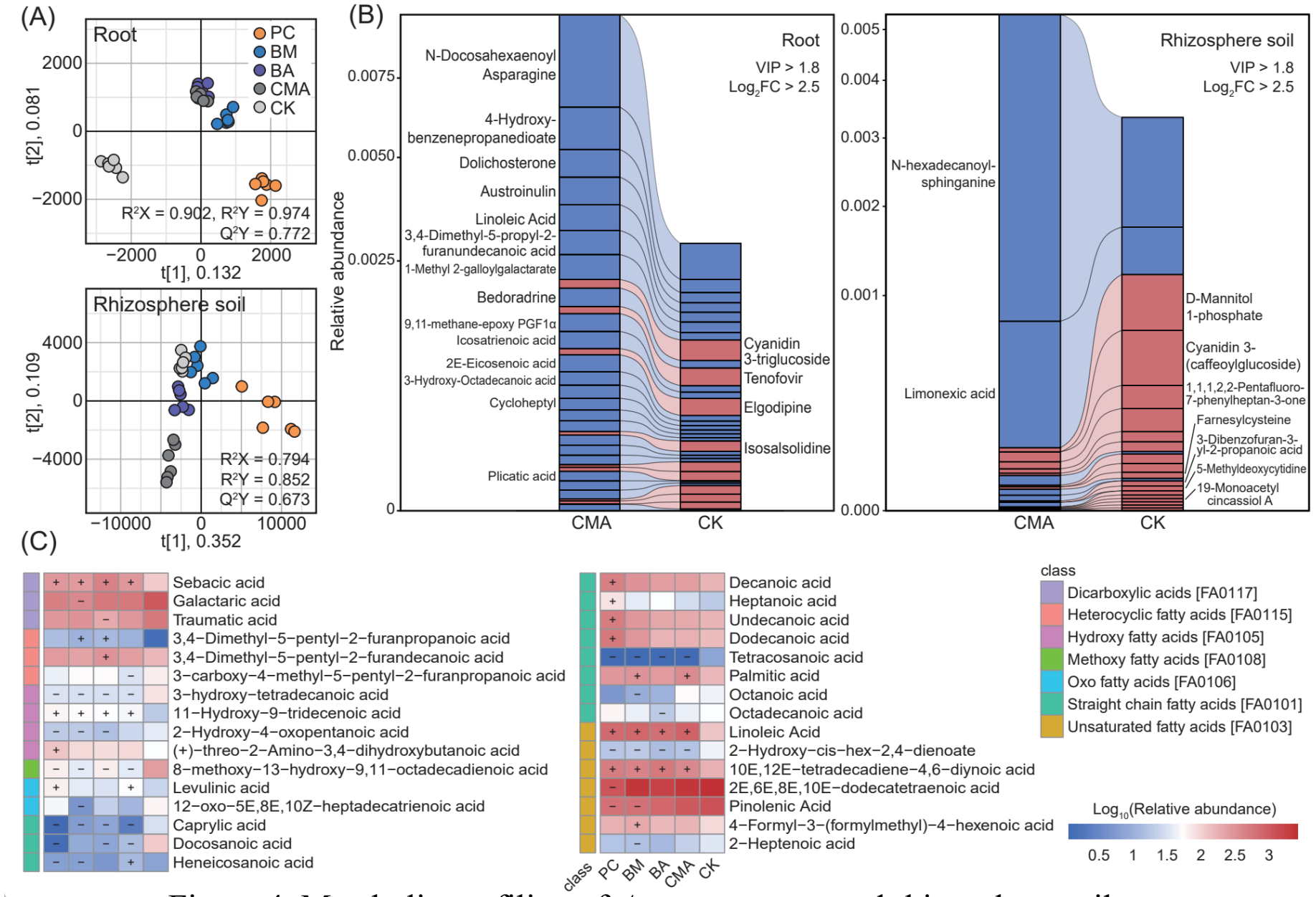

Figure 4. Metabolic profiling of *A. sinensis* root and rhizosphere soil.

Bacillus-like PGPR promotes the colonization of AMF in host roots

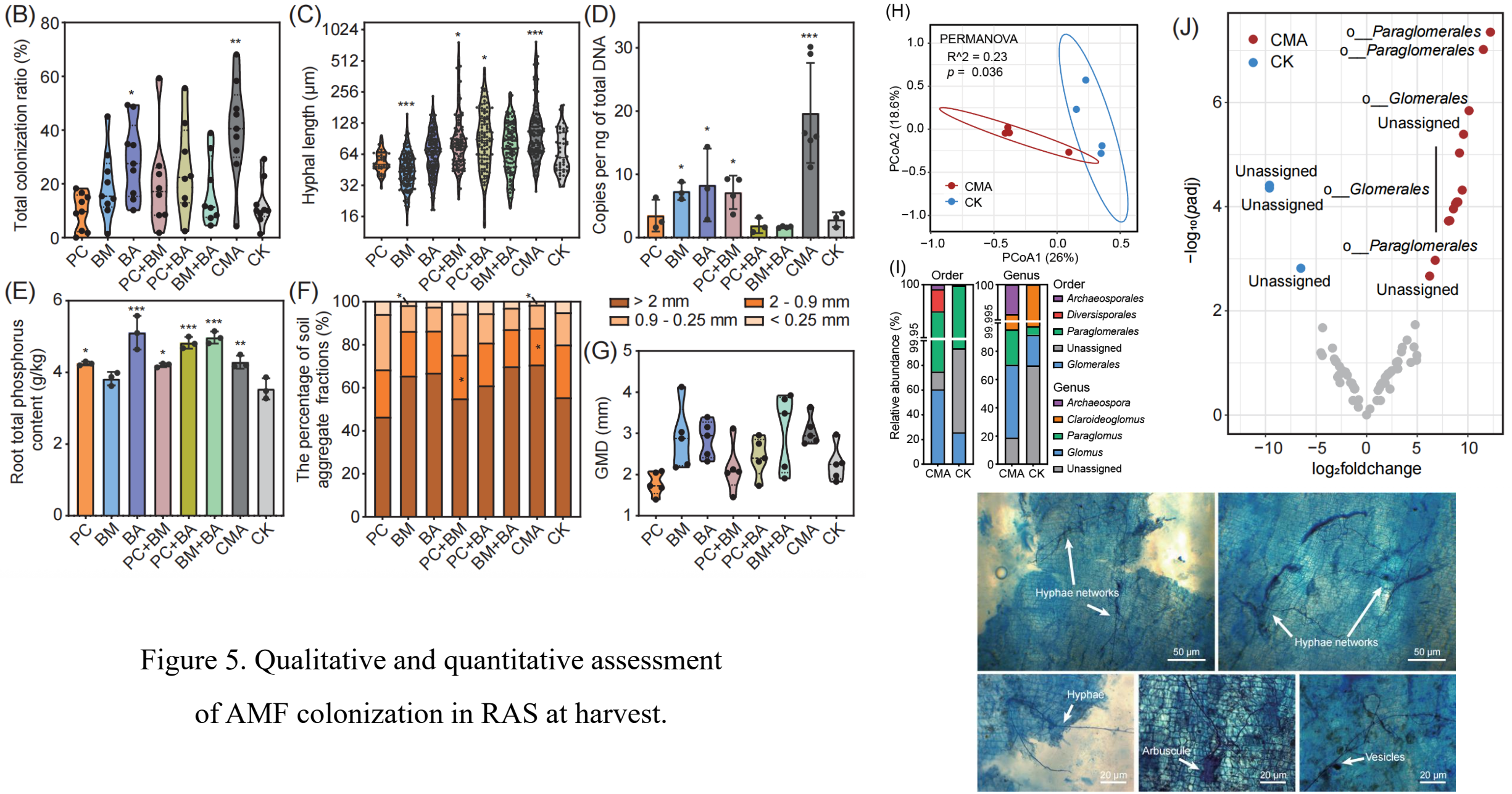

Figure 5. Qualitative and quantitative assessment of AMF colonization in RAS at harvest.

CMA treatment activates phenylpropanoid biosynthesis in RAS at harvest

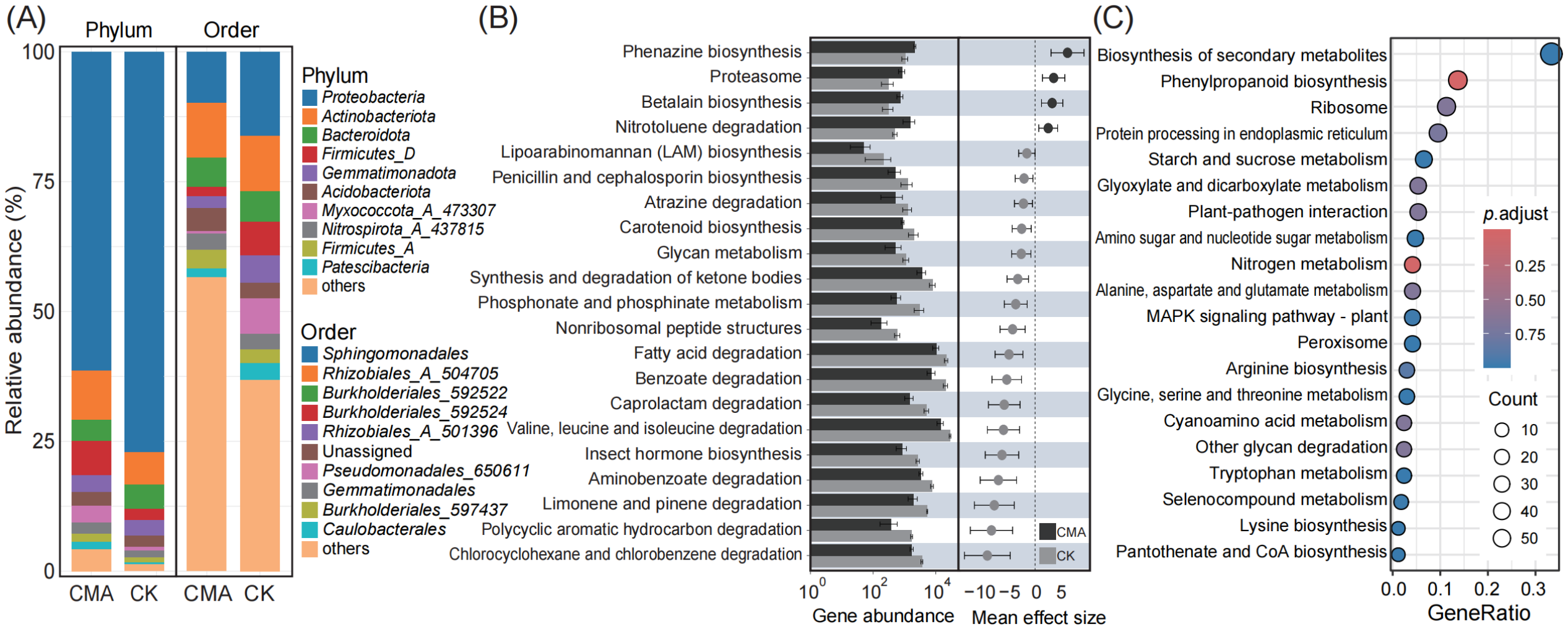

Figure 6. Modulation of microbiota-host interactions on critical biological pathways in the RAS of CMA at harvest.

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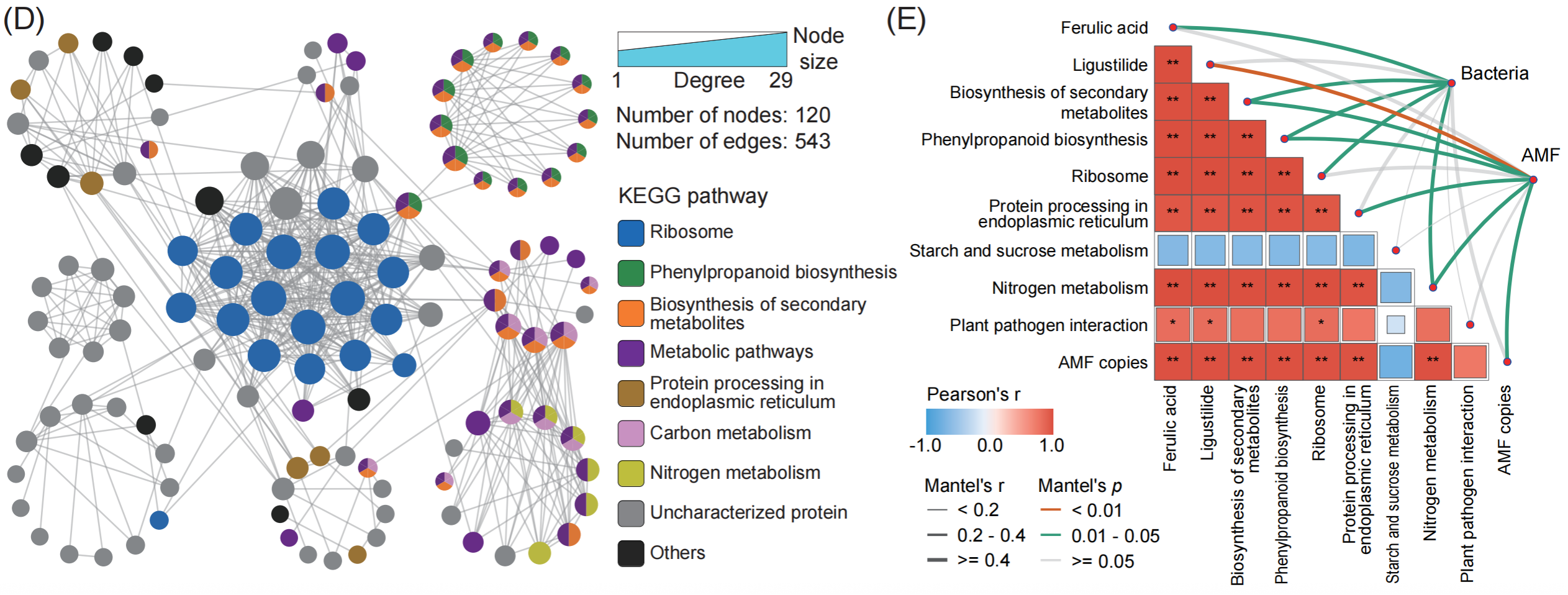

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The integrated profile of microbial inoculant effects on RAS quality

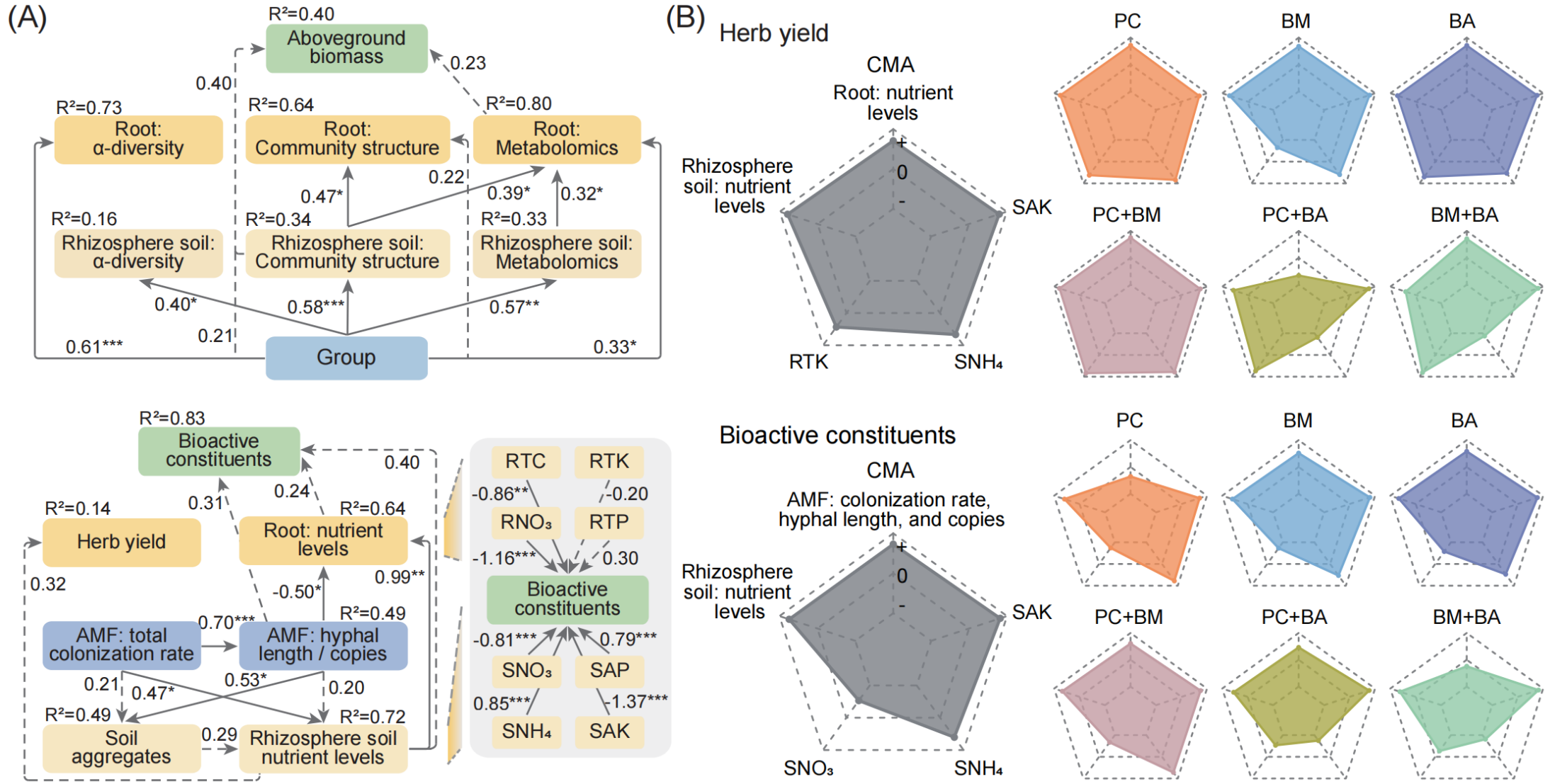

Figure 7. Overview of contribution analysis evaluating the effects of bio-inoculant application, microbial community profiles, and changes in soil attributes on *A. sinensis* biomass production and product quality.

The integrated profile of microbial inoculant effects on RAS quality

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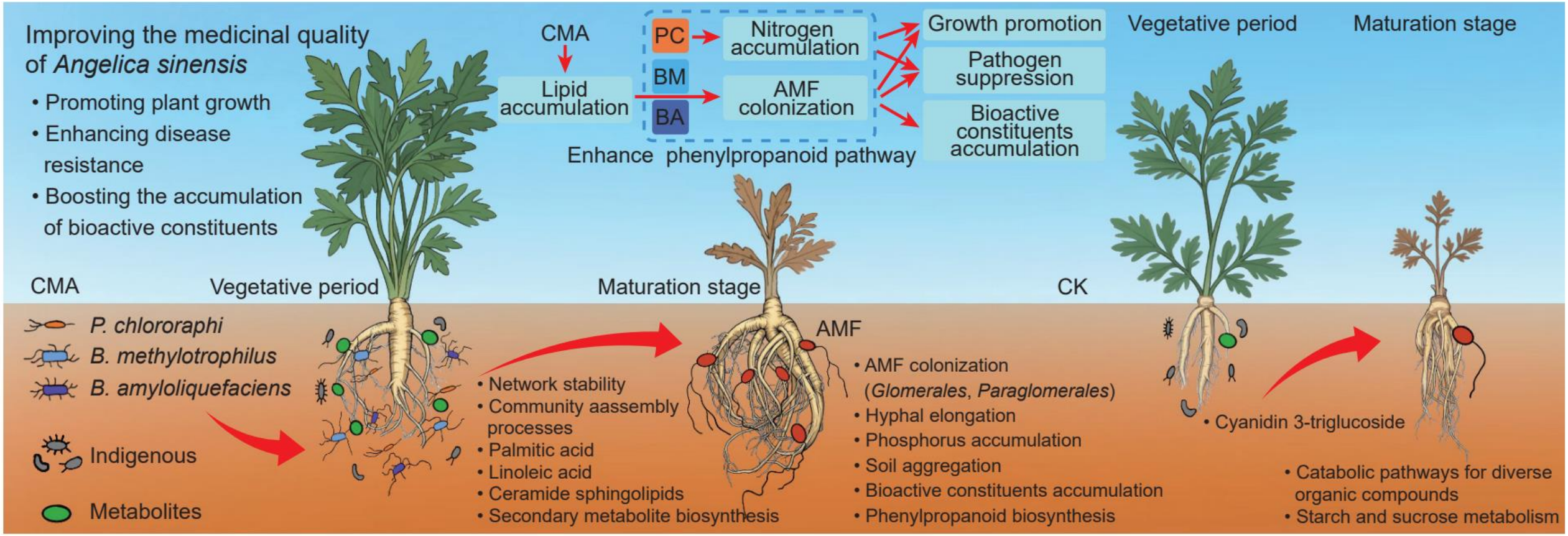

Figure 7. Overview of contribution analysis evaluating the effects of bio-inoculant application, microbial community profiles, and changes in soil attributes on *A. sinensis* biomass production and product quality.

Summary

- In this study, we present an efficient composite microbial inoculant that markedly enhances the production and quality of Radix *Angelica sinensis*.
- The *Bacillus* members facilitated AMF colonization in plant roots, thereby establishing a cross-kingdom consortium that exerts synergistic benefits to the host.
- *Pseudomonas* enhances disease suppression and plant growth via nitrogen enrichment and rhizosphere network stabilization, but barely increases RAS bioactive metabolites.
- This functionally complementary bioinoculants shows strong potential for broad application in diverse root- and rhizome-based medicinal plants.

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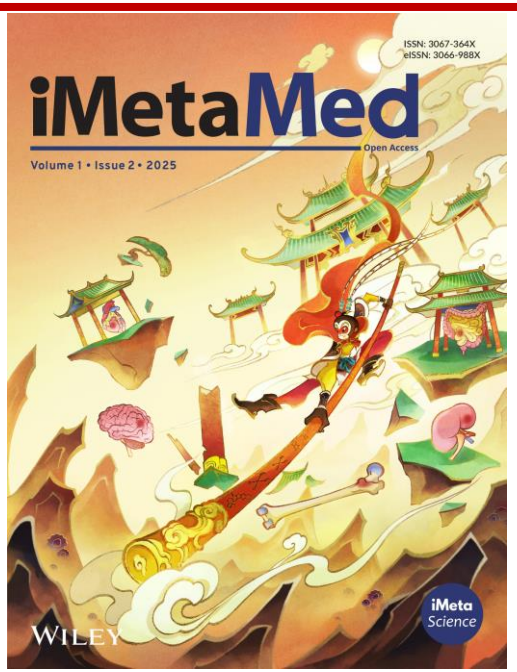

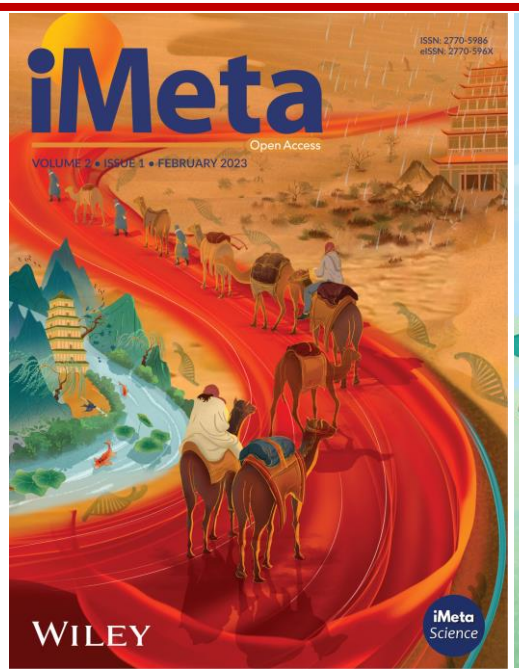

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