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Controlling undesirable *Bradyrhizobium japonicum* with phages to enhance soybean nodulation, Biological nitrogen fixation, and plant growth

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The effective interaction between soybean genotypes and Bradyrhizobium japonicum  $\mathbf{I}$  inoculants are limited by the ability of these strains to compete with the relatively mediocre indigenous soybean bradyrhizobia strains. Soybean inoculation with phageresistant bradyrhizobia strains and selected rhizobiophages can be used as biocontrol system for controlling undesirable strains of *B. japonicum*. Five rhizobiophages lytic to *B. japonicum* strains, USDA 138, USDA 110, USDA I-110ARS, USDA 126, USDA 141, USDA 147 and Sinorhizobium fredii strains USDA 194, USDA 201, USDA 214, and USDA 217 were isolated from soybean rhizosphere soils. Phages were characterized by direct observation of plaque formation and by transmission electron microscopy. Rhizobiophages differed in their host specificity. Phages namely PA14, PA10, FW15, PD20, and PA18 lyzed 60, 40, 33, 20, and 13% of bradyrhizobia strains, respectively. Phage PA14 which had the widest host range was used to examine the potential of using lytic rhizobiophages (Phage PA14) along with phage-sensitive (USDA 110) and phage-resistant (USDA TA11NOD<sup>+</sup>) bradyrhizobia strains to limit soybean nodulation by undesirable indigenous bradyrhizobia and enhance the nodulation by the effective inoculant strains. The inoculant containing phage PA14 and USDA 110 suppressed nitrogenase activity by 49%, while no significant difference was found when the inoculant containing USDA TA11NOD+ either with or without phage PA14. Further, nodule occupancy by the superior inoculant strain, USDA TA11NOD+, was increased by 59% when soybean seeds were coated with USDA TA11NOD+ and Phage PA14. When soybean seeds were coated with PA14 and USDA 110, nodule occupancy by USDA 110 was decreased by 78%. This study indicates that phage PA14 in the presence of a compatible phage-resistant bradyrhizobia inoculant has the ability to significantly decrease the occupancy of mediocre bradyrhizobia strains. Therefore, phage PA14 can be used as a potential biocontrol agent to partially eliminate mediocre yet competitive B. japonicum strains and, thus, enhance nodulation, biological nitrogen fixation and growth of soybean by the desirable strain.