Study on Exploration of Novel Multifunctional Plant Growth-Promoting Bacteria and Analysis of Microbiome in Oil Palm Rhizosphere

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(新規多機能性植物成長促進細菌の探索およびオイルパーム根圏における微生物叢の解析に関する研究)

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Thesis Summary

With the increase in global population, the agricultural sector has become essential for humanity, playing a crucial role in achieving several Sustainable Development Goals (SDGs), including food security, climate action, sustainability, and life on land. Among vital agricultural commodities, oil palm plantation has significantly contributed to the world's vegetable oil supply. However, intensive use of chemical fertilizers, herbicides, and pesticides has been detrimental to the soil microorganism ecosystem, resulting in declining soil health and quality. Thus, an urgent need is to adopt eco-friendly and sustainable materials, such as organic matter and plant growth-promoting bacteria (PGPB), to maintain soil health. This study aimed at elucidating the microbial community structure in the oil palm rhizosphere under the long-term organic matter application and obtaining plant growth-promoting bacteria (PGPB) from the oil palm rhizosphere. In addition, isolated PGPB strains were evaluatied for the growth of various crops.

Chapter 1 highlights the negative impacts of conventional agricultural practices on soil fertility, nutrient availability, and plant nutrient absorption. It emphasizes the need for eco-friendly solutions like application of organic matters, which would improve soil's physical, chemical, and biological properties. Moreover, organic matters provide a carbon source essential for soil microbial proliferation including beneficial PGPB, and highlights the importance of microbiome data in predicting beneficial bacteria for future researches.

Chapter 2 examined the microbial community analysis and detection of PGPB abundances PGPB in the oil palm rhizosphere with analyzing functional enzymes from microbiome data. The study shows that good soil management practices and widespread organic matter application improved soil chemical properties and increased the presence of beneficial microbes while suppressing pathogenic fungi. Long-term organic matter application created a favorable environment for beneficial bacteria, supported by higher bacterial copy numbers and PGPB functional enzymes, as predicted by Picrust2. In addition, this study is the first report to utilize metabolic functionalities from the microbiome to predict potential PGPB abundance in oil palm plantations, highlighting the importance of selecting appropriate sources for isolating PGPB.

Chapter 3 focused on isolating, characterizing, and evaluating novel multifunctional PGPB strains from the oil palm rhizosphere. The PGP traits examined include nitrogen fixation, phosphate solubilization, potassium solubilization, silicate solubilization, and indole acetic acid production. Six

strains (*Klebsiella huaxiensis* AJNA23, *Kosakonia oryzendophytica* AJLB38, *Azotobacter beijerinckii* AJLB47, *Pseudomonas duriflava* AJTS72, *Enterobacter quasimori* AJTS77, and *Lelliottia jeotgali* AJTS83) demonstrated strong multifunctional PGP capabilities and effectively inhibited the growth of *Ganoderma boninense* in vitro. These strains, distinct from reported type strains, proliferated under various environmental conditions and significantly enhanced the growth and biomass of *Brassica rapa* (Komatsuna) while improving fertilizer efficiency, allowing a 50% decrease in inorganic fertilizer usage. The PGP activities observed in quantitative screening tests positively correlated with *B. rapa* growth, suggesting a rapid, cost-effective strategy for evaluating PGPB without extensive plant cultivation experiments.

Chapter 4 evaluates the effectiveness of the multifunctional PGPB strains in an oil palm nursery. This study found that these indigenous PGPB strains significantly improved soil chemical properties, creating a favorable environment for oil palm growth, as indicated by higher growth rates and biomass than the uninoculated treatments. The strains effectively substituted the 100% chemical fertilizer treatment in combination with 50% and 75% chemical fertilizers, indicating strong proliferation and association with native plants. Moreover, this study suggests that these PGPB strains can decrease chemical fertilizer usage by up to 50% in oil palm nurseries. Additionally, inoculating PGPB strains in consortium showed similar effects to single inoculation, underscoring their potential for broader application.

The future perspective in Chapter 5 underscores the importance of reintroducing eco-friendly materials like organic matter and incorporating PGPB to enhance soil health and fertility. These eco-friendly materials can be combined as biofertilizers, offering additional benefits such as soil amendments, soil conditioners, and nutrient enhancers. These findings suggest a promising future for evaluating these strains across various climates and geographical areas, as well as their potential as biocontrol traits. Our study can significantly improve environmental health and contribute to the achievement of sustainable agriculture system.