Mikrobiologi Pertanian: Plant Growth Promoting Rhizobacteria (PGPR)
How does it work?
Rhizo -

• Rhizosphere – soil layer bound to the plant’s roots

• Rhizobacteria – soil bacteria
  – Some rhizobacteria are called *plant-growth-promoting rhizobacteria* (PGPR)
  – Wanna guess what they do?
    • They promote plant growth by:
      – Producing chemicals that stimulate growth
      – Produce antibiotics to protect roots from infection
      – Absorb toxic metals or make nutrients available for plants
Plant-Microbes Interaction in The Rhizosphere

Plant Growth-Promoting Rhizobacteria

P tersedia

P tak tersedia

N₂

NH₃

siderofor

antibiotik

Growth Hormone

Rhizosfer
Mechanisms of Plant Growth-Promoting Rhizobacteria

Direct PGPR mechanisms:
- N\textsubscript{2} fixation
- Phytohormones
- ACC deaminase
- Water-soluble B vitamins
- P solubilization
- K solubilization
- Siderophore production

Indirect PGPR mechanisms:
- ISR responses
- Prevention of plant diseases
- Siderophore production
- Competition
- Antibiotics
- HCN
- Lytic enzymes
- Toxins

Fixed N\textsubscript{2} → Photosynthates

(+)

Pathogens
Mechanisms of PGPR-Mediated Enhancement of Plant Growth

- The ability to produce ACC deaminase
  - Reduce ethylene in the roots-----root length & growth
- Ability to produce hormones: Indole acetic acid (IAA); Gibberellic acid; Cytokinins.
- Non-symbiotic nitrogen fixation
- Antagonisms against phytopathogenic microbes by
  - Producing siderophore; B 1,3 glucanase; chitinase; antibiotics; cyanide.
- Solubilisation of mineral phosphates and mineralization of other nutrients.
“Beneficial free-living soil bacteria isolated from rhizosphere, which have been shown to improve plant health or increase yield”

- Azotobacter
- Azospirillum
- Pseudomonads
- Acetobacter
- Burkholderia
- Bacillus

(Glick 1995)
An auxin, Indole-3-acetic acid (IAA), produced by Bacteria

• Indole-3-acetic acid
  - Compounds that stimulate plant growth (coleoptile tissue) in lower concentrations.
  - In contrast, if the concentration becomes higher, the effect reverses and elongation of root and shoot is inhibited.

• Bacteria synthesize IAA (IAA-Producing Bacteria)
  - Inhibit root growth in sugarbeet, blackcurrant, and morning glory.
Atmospheric $\text{N}_2$ is converted into $\text{NH}_3$ (Nitrogen fixing bacteria) $\rightarrow$ $\text{NH}_4 \rightarrow$ $\text{NO}_3$ (nitrifying bacteria) which can be used by plants for incorporation into organic systems.

Ammonifying bacteria can also convert organic material into $\text{NH}_4$ as well.
Rhizobacteria

- Plant benefits were discussed on prior slide
- Bacterial benefits since 20% of photosynthetic products go to the bacteria
- Hence, bacteria benefit from a healthy plant (roots) in the rhizosphere
Rhizobium Bacteria

- Bacteria that fix atmospheric nitrogen and supply it as ammonium
- Legumes have a ready source of nitrogen
- Symbioses with Rhizobium (Root living) bacteria
- Peas, soybeans, peanuts, and alfalfa
- **Nodules** – swellings in the roots infected by rhizobium bacteria
- Bacteroids – bacteria in vesicles in root cells in the nodules
Mutualistic Relationship?

- Rhizobium bacteria provide nitrogen in a usable form
  - Used to make amino acids for plant growth

- Plant provides photosynthetic products to the nodules via the vascular system
Many heterotrophic bacteria and fungi efficiently solubilize insoluble phosphate in the soil as well as the inert phosphorus sources.

Many bacteria belonging to *Bacillus*, *Pseudomonas Flavobacterium Micrococcus*, *Streptomyces* and fungi belonging to *Aspergillus*, *Penicillium* and *Trichoderma* efficiently solubilize insoluble phosphate of rock phosphate groups.

These organisms secrete organic acids that solubilize insoluble phosphorus which becomes then available for plant absorption.
Selection Procedure

- Grow bacteria / fungi in specified media containing insoluble phosphate.
- Incubate and observe the clearing zone around colonies.
- Quantify the phosphorus dissolved by specified organism.
- Select efficient culture based on above criteria.
Siderophore: low-molecular-weight (generally less than 1000 Daltons) of ferric specific ligands that facilitate the solubilization and transport of Fe(III) enter the cell.

Under low iron conditions

Fe (III)  ↓  High-affinity Fe(III) ligand (siderophore)

External (medium)  ↓  Receptor  ↓  Outer cell membrane

Intracellular region

Fe (II) is released siderophore

Fig. Siderophore-mediated iron transport
Pyoverdines are a group of structurally related siderophores produced by fluorescent pseudomonas species (Figure 3)
Production of Bioactive Compound by Rhizobacteria

A rhizobacterium producing Bioactive compound
Produksi senyawa anticendawan oleh Pseudomonas sp

A. Pseudomonas sp. 80 vs Sclerotium rolfsii
B. Pseudomonas sp. 16 vs Fusarium oxysporum
C. Pseudomonas sp. 102 vs Rhizoctonia solani
Penyakit busuk akar

E busuk kecambah, F busuk hipokotil dan kotiledon, G busuk kotiledon, H busuk pangkal batang, I stunted (kerdil)
Penekanan penyakit

Perlakuan benih dengan *Pseudomonas* sp. CRB mengurangi jumlah tanaman dengan gejala penyakit cendawan tular tanah
Tanaman dengan perlakuan *seed coating* dan kontrol yang tidak diberikan perlakuan (tanaman umur 1 minggu)
Take-all Disease of Wheat

One infected root in 10,000 is sufficient to cause an epidemic caused by Gaeumannomyces graminis var. tritici.
No 1 disease of cereals worldwide (up to 50% yield loss).
No varieties of wheat or barley exist with specific resistance to take-all.
No direct method of chemical control is presently available.
Take-all disease of wheat

**Pathogen:**
*Gaeumannomyces graminis* var. *tritici*

Invades root vascular tissues

Physically blocks water & nutrient transport
Take-all Decline- An Example of Natural Suppression

Years of wheat monoculture

Pseudomonas aureofaciens 30-84
**Pseudomonas aureofaciens** Produces Phenazine Antibiotics

Phenazine 1 Carboxylic Acid → 2-OH-PCA → 2-OH-PZ

*Phenazine Phacts*
- **Broad spectrum**
- **Block respiration**
- **Pathogen inhibition**
- **Competitive fitness**

*PCA* → *2-OH-PCA* → *2-OH-PZ* hydroxyphenazine
Pseudomonas (bacteria)

> product with dual benefit on crop as disease controller and growth promoter

> contains active strains of *Pseudomonas fluorescens* wards-off seed-borne pathogen

> actively multiplies in root-zone, enters into the vascular system and protects the plant

> acts by reducing the available iron for harmful bacteria or fungi controls wilt and root-rot diseases

> effective against blast, bacterial leaf streak and tungro virus in paddy rice, and panama disease of banana

> protective against nematode infection
**Azospirillum (for grain crops)**

> contains versatile strains of plant growth promoting bacterium *Azospirillum brasilensela. lipoferum*

> absorbs and fixes atmospheric nitrogen in root-zone, and provides 30-50% of nitrogen requirements

> produces plant growth hormones auxins and cytokinins

> enhances germination efficiency and early seedling vigour, plant immunity and the yield (25%)

> suitable for paddy rice, maize, sorgum, cotton, sunflower, sugarcane and vegetable crops both under rainfed and irrigated soil

> mix with pseudomonas for better plant disease control.
Aplikasi PGPR untuk Biofertilizer
Biofertilizer

• Pupuk hayati (biofertilizer) adalah pupuk yang mengandung mikroorganisme yang dapat mendorong pertumbuhan dengan menyediakan nutrisi bagi tanaman.

• Pupuk mikrobiologis (Biofertilizer)
  Pupuk mikrobiologis atau biofertilizer atau pupuk hayati adalah pupuk yang mengandung mikroorganisme hidup yang ketika diterapkan pada benih, permukaan tanaman, atau tanah, akan mendiami rizosfer atau bagian dalam dari tanaman dan mendorong pertumbuhan dengan meningkatkan pasokan nutrisi utama dari tanaman. [Wikipedia](https://en.wikipedia.org/wiki/Biofertilizer)

Mikroba yang digunakan sebagai pupuk hayati yang mampu memacu pertumbuhan tanaman, menambah nitrogen, melarutkan fosfat dan menghambat pertumbuhan penyakit (patogen) terhadap tanaman (Yuliar, 2006). Biofertilizer berfungsi sebagai penyedia hara dalam tanah, sehingga mudah diserap oleh tanaman dan untuk dapat menciptakan biofertilizer yang bersumber dari mikroorganisme, harus digunakan kelompok mikroorganisme unggul yang dapat berperan baik bagi tumbuhan (Nugraha dkk., 2014).
Effects of biofertilizers on physiological and biochemical properties of soil
Biofertilizers are important for the following reasons:

- Biofertilizers improve soil texture and yield of plants.
- They do not allow pathogens to flourish.
- They are eco-friendly and cost-effective.
- Biofertilizers protect the environment from pollutants since they are natural fertilizers.
- They destroy many harmful substances present in the soil that can cause plant diseases.
- Biofertilizers are proved to be effective even under semi-arid conditions.
contoh formulasi biofertilizer