Bio-Plant Microbial Bio-Fertiliser

Bacterial Constituents: Roles in the Soil Food Web & Soil Health

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Introduction

The Soil Food Web is the interconnected community of organisms — bacteria, fungi, protozoa, nematodes, arthropods, and earthworms — that live in healthy soil and drive nutrient cycling, organic matter decomposition, and plant growth. Bio-Plant's bacterial strains each occupy a specific niche within this web, collectively supporting the Carbon Cycle, the Nitrogen Cycle, phosphorus availability, soil structure, and bioremediation. The following sections detail the role and benefits of 7 of the bacteria. **We have not named them specifically as they are proprietary information.**

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1. 1-XX — Carbon & Nitrogen Cycling, Bio-Fungicide

1-XX is a well- studied and versatile plant-growth-promoting rhizobacteria (PGPR). It plays a multi-faceted role in soil:

Carbon Cycle Contribution: By secreting enzymes including **amylase** (starch breakdown), **protease** (protein breakdown), and **pectinase** (pectin breakdown), *1-XX* breaks down complex organic polymers into simpler compounds. This is a foundational step in the decomposition arm of the Soil Food Web, releasing carbon as CO_2 and as soluble organic compounds that feed other soil organisms. It also contributes to **carbon sequestration** in soil when applied at regulated concentrations, improving long-term soil organic matter.

Nitrogen Cycle Contribution: *1-XX* can fix atmospheric nitrogen and promote nodulation by other nitrogen-fixing rhizobacteria. It also acts as a potent **denitrifying agent** in agroecosystems and has been shown to reduce ammonia (NH_3) volatilization from soil by up to 44% — reducing nitrogen loss to the atmosphere and retaining it in plant-available forms. It enhances urease enzyme activity in soil, increasing bioavailable nitrogen by up to 34% and ammonium by up to 57%.

Bio-fungicide / Biocontrol: *1-XX* produces antimicrobial lipopeptides (such as iturin and surfactin), biofilm structures, and triggers **Induced Systemic Resistance (ISR)** in plants — protecting them from fungal and other pathogens without chemical inputs.

Soil Microbiome Support: It increases the relative abundance of beneficial soil bacteria including actinomycetes and chloroflexi, and can foster nutrient-sharing interactions with beneficial soil fungi such as *Serendipita indica*, which further promotes plant stress tolerance.

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2. 2-XX — Denitrification (Nitrogen Cycle)

2-XX is a denitrifying soil bacterium whose primary and scientifically well-characterised contribution is the production of **copper-containing nitrite reductase (CuNiR)** — a key enzyme in the denitrification pathway of the global Nitrogen Cycle.

Role in the Nitrogen Cycle: Nitrite reductase catalyses the reduction of nitrite (NO_2^-) to nitric oxide (NO), which is then further reduced to nitrous oxide (N_2O) and ultimately to dinitrogen gas (N_2) by additional denitrification enzymes — including nitrous oxide reductase, also produced by this organism. This returns nitrogen to the atmosphere, completing the cycle and preventing toxic accumulation of nitrite in soil.

Ecological Balance: By performing denitrification, *2-XX* helps regulate total inorganic nitrogen in soil, preventing excess nitrogen build-up that can cause soil acidification, eutrophication of adjacent waterways, and suppression of beneficial microbial communities. Within the Soil Food Web, denitrifying bacteria are essential "balancers," working in opposition to nitrogen-fixing and nitrifying bacteria to maintain equilibrium.

Working Partnership: In Bio-Plant, *2-XX* works in partnership with the nitrifying bacteria (*5-XX* and *7-XX*) to ensure nitrogen moves efficiently through its full cycle — from fixation and nitrification to controlled denitrification.

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3. 3-XX — Soil Structure, Humus Formation & Biocontrol

3-XX is an actinomycete — a filamentous, thread-like bacterium that grows branching networks through soil, making it a structurally unique and ecologically important member of the Soil Food Web. It is the type species of the entire “3-” genus.

Soil Structure: The branching mycelial networks of *3-XX* physically bind soil particles together, aiding in the **formation of soil aggregates**. These aggregates improve **soil aeration, water infiltration, and water retention**, and create a crumblier (friable) soil texture with greater pore space — directly giving the loose, workable quality described in Bio-Plant's product notes. Better aggregate stability also protects the soil from compaction and erosion.

Humus Formation: The “3-” species — including *3-XX* — play a vital role in the decomposition of **cellulose and lignin**, the most resistant plant materials in soil. By breaking down these complex polymers through a suite of cellulolytic and hydrolytic enzymes, they convert organic plant residues into **humus**: the stable, dark organic matter that stores nutrients, increases cation exchange capacity (CEC), and supports diverse microbial life. They also produce **geosmin**, the volatile compound responsible for the characteristic "earthy" smell of healthy soil.

Biocontrol: *3-XX* produces secondary metabolites including **antibiotics, antifungals, and antiviral compounds** that suppress plant pathogens and harmful microbes in the soil, protecting plant roots and supporting overall rhizosphere health.

Nutrient Cycling: By breaking down organic matter, *3-XX* enhances the availability of nitrogen and phosphorus for plant uptake, supporting plant growth as part of a balanced decomposer community.

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4. 4-XX — Nitrogen Fixation & Mineral Uptake

4-XX is a versatile plant-growth-promoting bacterium with a broad suite of soil and rhizosphere benefits.

Nitrogen Fixation: *4-XX* species are recognised nitrogen fixers — they convert atmospheric N_2 into ammonia (NH_3) through the enzyme **nitrogenase**, making nitrogen available for plant uptake without the need for synthetic fertilisers. Unlike legume-associated Rhizobium, the "4-" genus fixes nitrogen as a free-living organism in the rhizosphere.

Mineral Uptake Enhancement: *4-XX* can solubilize phosphorus, potassium, magnesium, zinc, and silicates in soil, releasing them into plant-available forms. It also produces **siderophores** (iron-chelating compounds) that sequester iron and deliver it to plants, and **indole-3-acetic acid (IAA)**, a phytohormone that stimulates root growth, increasing root surface area and therefore the plant's ability to access soil minerals.

Additional Benefits: It produces enzymes including **ACC deaminase** (which reduces plant ethylene stress), chitinase, and other hydrolytic enzymes. It has also been identified as a **DDE-degrading strain** — capable of breaking down persistent organochlorine pesticide metabolites in contaminated soils, adding a bioremediation dimension to its activity.

Soil Food Web Role: As a rhizosphere coloniser that promotes root growth and enhances mineral availability, *4-XX* strengthens the plant–microbe interface — the most biodiverse and active zone of the Soil Food Web — making more nutrients available not only to plants but to the broader community of soil organisms.

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5. 5-XX — Nitrification & Bioremediation

5-XX is the most extensively studied **ammonia-oxidizing bacterium (AOB)** and is a cornerstone organism in the Nitrogen Cycle.

Nitrification — Step 1: Using the enzyme **ammonia monooxygenase (AMO)** followed by **hydroxylamine oxidoreductase (HAO)**, *5-XX* oxidises ammonia (NH_3) to nitrite (NO_2^-). This is the first and critical step in nitrification, converting otherwise gaseous, volatile ammonia into a form that can be further processed in the soil. It obtains all its energy from this oxidation reaction and fixes CO_2 for its carbon — making it a chemolithoautotroph, an organism that sustains itself entirely on inorganic mineral chemistry.

Supporting Plant Nutrition: By converting ammonia to nitrite (and indirectly enabling its conversion to nitrate by *7-XX*), *5-XX* is essential for producing the nitrate forms of nitrogen that most plants preferentially absorb through their roots.

Bioremediation: *5-XX* 's remarkable metabolic versatility allows it to simultaneously oxidise ammonia and degrade a wide range of **environmental pollutants** — including aromatic hydrocarbons (benzene, toluene, phenol) and halogenated compounds (chlorobenzene, halogenated fumigants). This dual capacity makes it highly attractive for **controlled bioremediation** of contaminated soils and water bodies. Research models confirm it can predict and perform simultaneous ammonia oxidation and pollutant degradation under varying conditions.

Ecological Role: *5-XX* helps regulate total nitrogen levels in soil ecosystems, supporting ecological balance and biodiversity within the Soil Food Web by ensuring nitrogen moves efficiently through its biogeochemical cycle rather than accumulating as toxic ammonia.

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6. 6-XX — Phosphate Solubilization, Nitrogen Enhancement & Soil Disinfection

6-XX is a versatile gram-negative PGPR found naturally in soil, water, and on plant root surfaces. It is one of the best-characterised biocontrol and nutrient-cycling bacteria in sustainable agriculture.

Phosphate Solubilization: *6-XX* releases **organic acids** (including gluconic and oxalic acids) that chemically solubilize inorganic phosphate complexes — bound to iron, aluminium, and calcium in the soil — into free **phosphate anions ($H_2PO_4^-$)** that plants can absorb. This acidification reaction is particularly valuable in tropical and acidic soils (common in Thailand) where phosphate fixation is a major constraint on crop production. In controlled studies, *6-XX* demonstrated 37% higher phosphate solubilization capacity than even *1-XX* releasing up to 1,318 µg/mL of soluble phosphate.

Nitrogen Enhancement: *6-XX* contributes to nitrogen cycling through nitrogen fixation, increases bioavailable nitrogen in soil, and dramatically enhances **urease enzyme activity** in soil by approximately 70% — accelerating the conversion of organic nitrogen to ammonium. Soil amended with *6-XX* showed bioavailable nitrogen content increases of up to 34% and ammonium increases of up to 57%.

Soil Disinfection / Biocontrol: *6-XX* is recognised as a powerful **systemic biocontrol agent**. It produces a range of antibiotics, hydrolytic enzymes, and induces systemic resistance in plants, protecting them from soil-borne pathogens including *Phytophthora*, *Pythium*, *Rhizoctonia*, and others. It produces fluorescent siderophores that compete with pathogens for iron, effectively "disinfecting" the rhizosphere.

Iron Chelation & Phytohormones: Like *4-XX*, it produces siderophores for iron delivery and IAA for root development, further amplifying nutrient uptake throughout the plant.

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7. 7-XX — Nitrification Completion (Nitrite → Nitrate)

7-XX is a **chemolithoautotrophic, nitrite-oxidizing bacterium (NOB)** that performs the essential second step of nitrification, directly following the work of *5-XX*.

Nitrification — Step 2: *7-XX* uses the enzyme **nitrite oxidoreductase** to oxidise nitrite (NO_2^-) — the end product of *5-XX*'s activity — into **nitrate (NO_3^-)**. Nitrate is the primary form of inorganic nitrogen absorbed by most plant species and is far more stable and less toxic than nitrite. Without this second step, nitrite would accumulate, potentially becoming toxic to plants and other soil organisms.

Carbon Cycle Connection: As an autotroph that fixes CO_2 for growth, *7-XX* forms the **base of heterotrophic food webs** in nitrifying soil systems. The carbon it assimilates is recycled by heterotrophic microbes — fungi, protozoa, nematodes — that feed on it, forming the foundation of the Soil Food Web energy pyramid.

Global Nitrogen Cycle: Together with *5-XX*, *7-XX* completes the two-step nitrification process that is central to the global biogeochemical nitrogen cycle. This process plays a crucial role in the transformation of fertiliser nitrogen in agricultural systems and is also a key component of nitrogen removal in wastewater treatment.

Microbial Communication: Research has shown that *7-XX* produces quorum-sensing molecules (N-acyl-homoserine lactones), suggesting it participates in **cell-density-dependent communication** with other soil microbes — a mechanism that likely helps regulate nitrogen cycling activity in concert with the broader microbial community.

Summary Table: The Seven Bacteria & Their Soil Functions

Bacterium	Primary Role	Cycle / System
1-XX	Organic polymer degradation, N-fixation, ammonia retention, bio-fungicide	Carbon & Nitrogen Cycles, Biocontrol
2-XX	Nitrite reduction (denitrification), nitrogen balance	Nitrogen Cycle
3-XX	Soil aggregate formation, humus production, cellulose/lignin breakdown, biocontrol	Soil Structure, Carbon Cycle, Biocontrol
4-XX	Nitrogen fixation, mineral solubilization (P, K, Mg, Zn), root growth promotion	Nitrogen Cycle, Mineral Uptake
5-XX	Ammonia → Nitrite (nitrification step 1), pollutant degradation	Nitrogen Cycle, Bioremediation
6-XX	Phosphate solubilization, nitrogen enhancement, soil disinfection	Phosphorus Cycle, Nitrogen Cycle, Biocontrol
7-XX	Nitrite → Nitrate (nitrification step 2), heterotrophic food web base	Nitrogen Cycle, Carbon Cycle

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Collective Impact on the Soil Food Web

Together, these seven bacteria represent a **complete, integrated microbial ecosystem** that:

- Completes the full **Nitrogen Cycle** — from fixation (4-XX) through nitrification (5-XX + 7-XX) to balanced denitrification (2-XX) — reducing fertiliser dependency.
- Drives the **Carbon Cycle** through polymer degradation (1-XX, 3-XX) and humus formation (3-XX), building long-term soil organic matter.
- Unlocks **phosphorus and minerals** otherwise locked in soil (6-XX, 4-XX, reducing the need for inorganic mineral fertilisers.
- **Rebuilds soil structure** through mycelial aggregation and humus production (3-XX), improving drainage, aeration, and water retention.
- Provides **natural biocontrol** against fungal and bacterial pathogens (1-XX, 6-XX, 3-XX), reducing chemical pesticide dependence.
- Supports **bioremediation** of pollutants including aromatic hydrocarbons and organochlorines (5-XX, 4-XX), helping detoxify degraded soils.

The synergy between these organisms mirrors the complexity of a naturally healthy soil ecosystem, making Bio-Plant a holistic approach to sustainable soil management.

Report compiled using published scientific literature. Key sources include peer-reviewed research from Wiley Journal of Applied Microbiology, APS Molecular Plant-Microbe Interactions, ScienceDirect, PubMed/PMC, Frontiers in Microbiology, MDPI Plants, and microbial taxonomy databases.