INTRODUCTION

Microorganisms, as an important driver of biogeochemical cycles, play a key role in soil fertility and nutrient uptake by plants. Biofertilizers include nitrogen fixing, phosphate, potassium and zinc solubilising; nutrient mobilizing microorganisms used for application to seed or soil. The manipulation of rhizosphere of plants leads to increase in numbers of such microorganisms and thereby accelerate the microbial processes which augment the availability of nutrients that can be assimilated by plants. Biofertilizers are economical and ecofriendly alternative of chemical fertilizers. Integrated nutrient management (INM) considers biofertilizers as an important component and advocates judicious application of fertilizers along with organic manures and biofertilizers which is imperative to sustain crop production and maintenance of soil health in the long term.

Rhizosphere bacteria that favourably influence plant growth and yield of crop plants are designated as plant growth promoting rhizobacteria (PGPR). They not only influence plant growth but also help the plants to overcome abiotic and biotic stresses.

In India, biofertilizer industry has developed over years and many significant changes have taken place. The shift from carrier based to liquid formulations, inclusion of microbial consortium in Fertilizer Control Order (FCO), increase in numbers of efficient strains have led to the surge in production of biofertilizers. ICAR is continuously striving to develop quality assured biofertilizers using efficient and competitive strains. This bulletin is a compilation of **41 biofertilizer technologies** developed by ICAR that are at different stages of commercialization.

Abbreviations

AICRP	All India Coordinated Research Project
ATARI	Agricultural Technology Application Research Institute
CAZRI	Central Arid Zone Research Institute
CCARI	Central Coastal Agricultural Research Institute
CCC	Cyanobacterial Culture Collection
CCSRI	C C Shroff Research Institute
cfu	Colony Forming Unit
CIARI	Central Island Agricultural Research Institute
CICR	Central Institute for Cotton Research
CPCRI	Central Plantation Crops Research Institute
CRIDA	Central Research Institute for Dryland Agriculture
DARE	Department of Agricultural Research and Education
DGR	Directorate of Groundnut Research
FFP	Farmers First Program
FLD	Frontline Demonstration
FYM	Farmyard Manure
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
IGFRI	Indian Grassland and Fodder Research Institute
IIHR	Indian Institute of Horticultural Research
IIPR	Indian Institute of Pulses Research
IISR	Indian Institute of Soybean Research
KVK	Krishi Vigyan Kendra
MCC	Microbial Culture Collection (now National Centre for Microbial Resource)
MTCC	Microbial Type Culture Collection
MULLaRP	Mungbean, Urdbean, Lentil, Lathyrus, Rajmash and Pea
NAIMCC	National Agriculturally Important Microbial Culture Collection
NBAIM	National Bureau of Agriculturally Important Microorganisms
NBAIR	National Bureau of Agricultural Insect Resources
NCIM	National Collection of Industrial Microorganisms
NEH	North Eastern Hills
NIASM	National Institute of Abiotic Stress Management
NMSA	National Mission on Sustainable Agriculture
NRRI	National Rice Research Institute
NSP	National Seed Project
OFT	On Farm Trial
PGPR	Plant Growth Promoting Rhizobacteria
PSB	Phosphate Solubilizing Bacteria
RDF	Recommended Dose of Fertilizers
RRS	Regional Research Station
UAS	University of Agricultural Sciences

1. Bio NPK

- **Microbial Constituents:** *Azotobacter chroococcum* W5 (NAIMCC-B-00061/MTCC 25045), *Paenibacillus tylopili* (NAIMCC-B-01548) and *Bacillus decolorationis* (MTCC 25044)
- **Type:** Liquid formulation; 2×10^8 cfu/mL of each
- **Shelf life:** 12 months at 25°C to 35°C
- **Target crops:** Wheat, rice, maize, chickpea, soybean, papaya, fodder oat and berseem
- **Method of application:** Seed treatment (100 mL formulation diluted to one litre with water for seeds to be sown in one acre); root dip for seedlings (500 mL formulation diluted to 2.5 L with water for seedlings to be planted in one acre) and soil application for tree plants (10 mL/tree)
- **Target agroecological zones/states**: Delhi, Punjab, Haryana, Uttar Pradesh, Gujarat, Bihar and Manipur
- **Validation:** AICRPs on Maize and Groundnut for two years; at ICAR-IGFRI, Jhansi on fodder oats and berseem for two years; AICRP on NSP (Crops) for two years; Two years on-farm trials with rice and wheat in Uttar Pradesh and Punjab; One year on papaya in Bihar, on chickpea and soybean in Uttar Pradesh
- **Commercialization:** Commercialized in 2017; Available for licensing through Agrinnovate India Ltd. (www.agrinnovateindia.co.in)
- **Benefits:**
  - Saves chemical fertilizers up to 25-30 kg N, 10-15 kg P and 2-5 kg K/ha
  - 5-10% increase in grain yield in rice, wheat and maize
  - Net saving of ₹ 1000-3000/ha in target crops
- **Cost:** ₹ 50/- per 100 mL

Control Treated

Effect of BioNPK on wheat var. HD2967 at ICAR-NBAIM, Mau during 2016-17

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2. Bio Grow

- **Microbial Constituents:** *Bacillus* sp. BC39 (NAIMCC-B-02720), *B. subtilis* RC25 (NAIMCC-B-02721), *Pseudomonas fluorescens* KC30 (NAIMCC-B-02722) and *Pseudomonas* sp. KC31 (NAIMCC-B-02723)
- **Type:** Liquid formulation; 2×10^7 cfu/mL of each
- **Shelf life:** 12 months at 25°C to 35°C
- **Target crops:** Tomato, chilli, egg plant, marigold and tuberose
- **Method of application:** Seed treatment (100 mL formulation diluted to one litre with water for seeds to be sown in one acre)
- **Target agroecological zones/states**: Uttar Pradesh and Haryana
- **Validation:** On-farm trials at ICAR-NBAIM, Mau on tomato and chilli; farmers' fields on tomato, potato and marigold in Mau and Varanasi; UAS, Shivamogga on chilli for two years
- **Commercialization:** Commercialized in 2017; Available for licensing through Agrinnovate India Ltd. (www.agrinnovateindia.co.in)
- **Benefits:**
  - 25-30% increase in yield of tomato
  - Enhanced content of lycopene and β-carotene
  - Prolonged growth of marigold with two additional pickings of flower
- **Cost:** ₹ 50/- per 100 mL

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Effect of Bio Grow on tomato var. Dev-Daksh at ICAR-NBAIM, Mau during 2015-16

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3. Bio Phos and Bio Phos+

- **Microbial Constituent:** *Kluyvera cryocrescens* (Bio Phos; NAIMCC-B-02041) and *Paenibacillus tylopili* (Bio Phos+; NAIMCC-B-01548)
- **Type:** Liquid formulation; 1×10^9 cfu/mL
- **Shelf life:** 12 months at 25°C to 35°C
- **Target crops:** Wheat, maize, rice, mustard and chickpea
- **Method of application:** Seed treatment (100 mL formulation diluted to one litre with water for seeds to be sown in one acre)
- **Target agroecological zones/states**: Delhi, Punjab, Haryana, Uttar Pradesh, Gujarat, Bihar, Manipur and Karnataka
- **Validation:** AICRP on Maize at 22 locations for two years; OFT at ICAR-NBAIM, Mau on wheat, maize, rice and mustard for two years; farmers' fields in Uttar Pradesh, Bihar and Punjab on wheat and maize; UAS, Shivamogga on chickpea for two years
- **Commercialization:** Commercialized in 2017; Available for licensing through Agrinnovate India Ltd. (www.agrinnovateindia.co.in)
- **Benefits:**
  - Save chemical fertilizers up to 25-30 kg P/ha
  - 7-11% increase in grain yield of maize, wheat, rice and mustard
- **Cost:** ₹ 50/- per 100 mL

Control

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Evaluation of Bio Phos on maize var. Bio 9637 at ICAR-NBAIM, Mau during 2017-18

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4. Bio Zn

- **Microbial constituent:** *Bacillus endophyticus* (NAIMCC-B-01543)
- **Type:** Liquid formulation; 1×10^9 cfu/mL
- **Shelf life:** 12 months at 25°C to 35°C
- **Target crops:** Wheat, maize and soybean
- **Method of application:** Seed treatment (100 mL formulation diluted to one litre with water for seeds to be sown in one acre); root dip for seedlings (500 mL formulation diluted to 2.5 L with water for seedlings to be planted in one acre)
- **Target agroecological zones/states**: Delhi, Punjab and Uttar Pradesh
- **Validation:** ICAR-NBAIM, Mau on wheat and maize; farmers' fields in Mau and Azamgarh on wheat, ICAR-IARI, New Delhi on soybean
- **Commercialization:** Commercialized in 2017; Available for licensing through Agrinnovate India Ltd. (www.agrinnovateindia.co.in)
- **Benefits:**
  - Saves chemical fertilizer up to 2-5 kg Zn/ha
  - 5-10% increase in grain yield
  - Improves uptake of Zn in seeds
- **Cost:** ₹ 50/- per 100 mL

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Effect of Bio Zn inoculation on accummulation of Zn in maize roots visualized through Dithiozone staining

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5. Bio Potash

- **Microbial Constituent:** *Bacillus decolorationis* (MTCC 25044)
- **Type:** Liquid formulation; 1×10^9 cfu/mL
- **Shelf life:** 12 months at 25°C to 35°C
- **Target crops:** Maize, wheat, mustard and potato
- **Method of application:** Seed treatment (100 mL formulation diluted to one litre with water for seeds to be sown in one acre)
- **Target agroecological zones/states**: Delhi, Punjab, Uttar Pradesh and Uttarakhand
- **Validation:** In wheat, mustard and maize at ICAR-NBAIM, Mau; on potato in farmers' fields at Dehradun
- **Commercialization:** Commercialized in 2017; Available for licensing through Agrinnovate India Ltd. (www.agrinnovateindia.co.in)
- **Benefits:**
  - Augments 10-15 kg K/ha
  - 2-5% increase in yield
- **Cost:** ₹ 50/- per 100 mL

Control

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Evaluation of Bio Potash on maize var. Bio 9637 at ICAR-NBAIM, Mau during 2017-18

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6. Bio Bacter

- **Microbial Constituent:** *Azotobacter chroococcum* (NAIMCC-B-00061/MTCC 25045)
- **Type:** Liquid formulation; 1×10^9 cfu/mL
- **Shelf life:** 12 months at 25°C to 35°C
- **Target crops:** Wheat, rice and maize
- **Method of application:** Seed treatment (100 mL formulation diluted to one litre with water for seeds to be sown in one acre); root dip for seedlings (500 mL formulation diluted to 2.5 L with water for seedlings to be planted in one acre)
- **Target agroecological zones/states**: Delhi, Punjab and Uttar Pradesh
- **Validation:** ICAR-NBAIM, Mau on wheat, rice and maize; farmers' fields in Mau and Varanasi on wheat
- **Commercialization:** Commercialized in 2017; Available for licensing through Agrinnovate India Ltd. (www.agrinnovateindia.co.in)
- **Benefits:**
  - Saves 20-25 kg N/ha
  - Increases yield by 5-7%
- **Cost:** ₹ 50/- per 100 mL

Control

Treated

Effect of Bio Bacter on wheat var. HD2967 at ICAR-NBAIM, Mau during 2017-18

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7. RhizoNBAIM

- **Microbial Constituent:** Nitrogen fixing rhizobial strains specific to chickpea, pigeon pea, black gram, pea and lentil
  - Chickpea: *Mesorhizobium ciceri* Ca7 (NAIMCC-B-02476)
  - Pigeon pea: *Bradyrhizobium yuanmingense* APP151 (NAIMCC-B-02407)
  - Green gram: *Bradyrhizobium yuanmingense* MV3 ((NAIMCC-B-02475)
  - Pea: *Rhizobium multihospitium* P15 (NAIMCC-B-02717)
  - Lentil: *Rhizobium lentis* LTL3 (NAIMCC-B-02478)
- **Type:** Liquid formulation; 1×10^9 cfu/mL
- **Shelf life:** 12 months at 25°C to 35°C
- **Target crops:** Specific rhizobia for each of the pulse crops *viz*., chickpea, pigeon pea, green gram, pea and lentil
- **Method of application:** Seed treatment (100 mL formulation diluted to one litre with water for seeds to be sown in one acre)
- **Target agroecological zones/states**: Uttar Pradesh
- **Validation:** ICAR-NBAIM, Mau on chickpea, pigeon pea, green gram and lentil; farmers' fields on chickpea at Mau
- **Commercialization:** Commercialized in 2018; Available for licensing through Agrinnovate India Ltd. (www.agrinnovateindia.co.in)
- **Benefits:**
  - Saves 25-30 kg N/ha
  - Increases yield by 7-10%
- **Cost:** ₹ 50/- per 100 mL

Control

Treated

Effect of RhizoNBAIM on chickpea var. Pusa 362 at ICAR-NBAIM, Mau during 2019-20

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8. PUSA Algal Biofertilizer

- **Microbial Constituents:** *Anabaena variabilis* (CCC 421), *Nostoc muscorum* (CCC 442), *Aulosira fertilissima* (CCC 444) and *Tolypothrix tenuis* (CCC 443)
- **Type:** Multani Mitti based formulation; 10^4 propagules/g
- **Shelf life:** 03 months at 25°C to 35°C
- **Target crop:** Rice
- **Method of application:** Soil application (500 g/acre)
- **Target agroecological zones/states**: Punjab, Delhi, Uttar Pradesh, Haryana and Bihar
- **Validation:** Multilocational trials on rice for 20 years
- **Commercialization:** On sale counters in the Division of Microbiology, ICAR-IARI, New Delhi since 1970s; Commercialized in 2010; Licensed to three entrepreneurs
  - Sai Bio Organics, Moga, Punjab
  - Ecological Products Industries, New Delhi
  - Forex Fastners (P) Ltd., Punjab
- **Benefits:**
  - Saves 20-30 kg N/ha
  - Induces early grain setting
- **Cost:** ₹ 50/- per 500 g

Treated Control

Evaluation of Pusa Algal Biofertilizer on rice var. Pusa Sugandh 5 at ICAR-IARI, New Delhi during 2007

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