## Group Name: Plant Microbe Interactions

**Objectives:**

a. Development of efficient assays to evaluate the root colonization capability of the native microbial population in host plant rhizosphere.
b. Identification of native stress-tolerant plant growth promoting microbes.
c. Development of stress tolerant transgenic microbes and plants, to enhance plant growth in degraded ecosystems.
d. Identification and characterization of stress tolerant gene(s) from plant associated bacteria through expression studies, for engineering transgenic plants and microbes.
e. Exploration and exploitation of microbial wealth of India for biotechnological prospects.
f. Elucidate the role of introduced beneficial microbe on crop productivity and microbial community structure alterations.
g. Pilot scale production of bioinoculant formulations, process scale up using fermentor and conduct multi-locational field trials for assessing the viability of the developed bioinoculants and their applicability on various crops.
h. Training and demonstrations to U.P. State Government employees and farmers for the extension of biofertilizers to field level.

1. **Goals:** We aim to meet the needs of farmers and promote sustainable agricultural production and work to assure food safety and protect environment through our research dedicated to development of economic and efficient bioinoculant formulations both for agricultural lands and stressed soils with problems of alkalinity and drought.
2. **Competencies**: The group has expertise in the study of Plant-Microbe Interactions, Microbial Ecology, Development of screening media, Development of bioinoculants, Impart trainings for production and use of biofertlizers etc.

3. **Highlights of Current Research:**

Working out the complexity of interaction between microbes and plants is one of the most complex scientific challenges. We have initiated work on the importance of root zone the hidden half of plant below ground for plant productivity and stress tolerance at NBRI and established a strong research group. The work conducted is aimed at enhancing our knowledge of the ecological and genetic interactions between plants, their root pathogens and beneficial microbes in the rhizosphere. Understanding the population genetics and functional dynamics of soil-borne bacteria which are anticipated to increase our predictive capacity, providing insights to develop targeted management strategies for soil microbiota to improve the sustainability of plant production systems. By combining genomic and ecological research perspectives significant contributions have been made in this important domain not only from the perspective of basic science to understand the role of plant associated bacteria in determining plant gene function but also from the angle of commercial exploitation of the leads obtained through development of products and associated technologies for enhanced crop yield and crop protection. Current R&D activities of the lab include:

- Physiological and molecular mechanisms involved in plant growth promotion
- Signaling and bio-film formation among plant-microbes
- Screening and identification of bio active molecules from biological control agents
- Using biological control agents for controlling phytopathogenic fungi and invasive weeds
- Application of medicinal plants to make the environment cleaner
- Microbe-induced antioxidant level in vegetables and fruit as a viable substitute of synthetic antioxidants
- Genetic and functional diversity of bacteria using substrate utilization pattern and culture-independent approach
- Molecular ecology of plant-pathogen-plant associated bacteria interactions
- Microbial and plant gene expression during their interaction
- Identification of up and down regulated plant gene(s) as elucidated by DNA micro array analysis
- Root biology and its correlation to sustainable plant development and soil fertility
- Generation of soil metagenomic map of India

4. **List of Ongoing projects**:

| Title of the project | Funding Agency | Duration | PI |
|---|---|---|---|
| Root biology and its correlation to sustainable plant development and soil fertility (RootSF; BSC0204) | CSIR | 2012-17 | Dr. C.S. Nautiyal |
| Plant-Microbe and soil interactions (PMSI; BSC 0117) | CSIR | 2012-17 | Dr. C.S. Nautiyal |
| Plant growth promoting rhizobacteria mediated stress management for increasing crop productivity (OLP0091) | CSIR | 2012-17 | Dr. C.S. Nautiyal |
| Quality production of abiotic stress tolerant microbe based bioinoculants and their popularization for improving soil health and sustained crop production in Uttar Pradesh | RKVY | 2013-17 | Dr. C.S. Nautiyal |

**Outside agencies like DBT / DST / MOEF etc.:**

**Foreign Collaborations:**

**Areas open for collaboration:**

5. **Significant achievements**: (major achievements/outputs of the R&D Groups in bullet points)

**Upto 11th Five year Plan:**

- Novel methods have been developed and patented which enables fast screening of a large number of soil samples to identify and isolate useful rhizosphere competent plant growth ***promoting microbes. (FEMS MICROBIOLOGY LETTERS 170: 265-270, 1999; CURRENT MICROBIOLOGY* 43**: 51-56, 2001; US Patent Number **6638730; *BIORESOURCE TECHNOLOGY*; 102:** 8057-8062, 2012).
- Isolation and characterization of novel rhizosphere competent abiotic stress tolerant *Bacillus Rhizobium* strains and *Trichoderma* isolates from different environment niches for phosphate solubilisation, nitrogen fixation, and bio-control.

  (J MICROBIOL BIOTECH **16**: 184-192, 2006; Trinidad and Tobago Patent Number **TT/T/2009/00056**; Australia Patent **AU2002345299B**; European Patent Number

**EP1423011**; US Patent Number **7097830**; South Africa Patent Number **2003/2288**; Patent Cooperation Treaty (PCT) **WO 03/020038**; **CN1479577**; US Patent Number **6495362).**

- Demonstration of significant plant growth and yield, control of pathogens and availability of nutrients to plants with novel microbial consortium.
- Imparting abiotic (salt and drought) and biotic (pathogens) tolerance to plants mediated by microbes. This approach has provided us a very useful and practical means to understand and exploit environment friendly native microbes and their ecology in the rhizosphere of desired crops for imparting optimal tolerance to stresses.
- Identification of novel abiotic and biotic-stress-related genes in plants responding to challenge by plant-growth-promoting rhizobacteria. Thus providing new knowledge and molecular tools for improved plant production under stress that brings immense value relative to investment and an effective approach to improving food security.
- Demonstration of beneficial role of rhizobacteria in allelopathic interaction in withstanding and flourishing of sensitive native plants (***JOURNAL OF APPLIED MICROBIOLOGY* 112**: 793-808, 2012).
- Elucidation of kinship among plants (***PLANT GROWTH REGULATION 66***: 155-165, 2012).
- Elucidation of changes in soil physico-chemical properties and microbial functional diversity in semiarid agro-ecosystem for increased soil carbon sequestration (***SOIL & TILLAGE RESEARCH*** (109: 55-60, 2010).
- Enhancing the yield of plants through successful transfer of technologies, for commercial exploitation by agri-biotechnology Industries.
- To accomplish CSIR's mission of providing scientific R&D that maximises the economic, environmental and societal benefits to the people of India. Our group has successfully demonstrated it by transferring our bioinoculants technology among farmers in larger perspective through Department of Agriculture, U. P. Government. Since 2004 has already covered over 61 lakh hectares and the area is increasing progressively every year. In terms of societal and environmental benefits the impact of the aforementioned technologies are significant as it leads to reduced dependence on chemical fertilizers and pesticides and thus leading to improved, soil, plant and human health.

## In 12th five-year plan:

**Significant Contributions to Science and Technology Development**

Noteworthy contributions are in the area of microbial biotechnology and relate to elucidation of relationships between microbial populations and environmental stresses,

working out the intricacies of relationship between microbes and plants and utilizing the knowledge base thus developed for enhancing the yield of economic crops through transfer of commercially exploitable technologies.

- Colonization of the plant root system is very important in nearly all interactions between plants and soil borne microbes. Selection and improvement of rhizosphere competent bacteria to encourage preferential colonization of desired bacteria can, therefore, be expected to modify plant health. Techniques of genetic engineering were applied to encourage preferential colonization of the desired bacteria by engineering the plant environment specifically the rhizosphere to confer a superior ability to utilize a novel substrate (mannopine), occurring in the "root" environment [US Patent 5610044].

- A novel throughput method has been developed to identify and isolate high antifungal producing rhizosphere competent bacterial strain for suppressing plant pathogens and the technology for their production. This methodology enables fast screening of a large number of soil samples for detecting beneficial rhizosphere competent bacterial strains [US Patent 6495362; Indian Patent Number 186436].

- A novel method for screening phosphate-solubilizing microorganisms using NBRIPBPB broth was also developed. The methodology developed reduces significantly the screening time for phosphate-solubilizing bacteria. It is envisaged that use of this formulation based upon qualitative analysis will be salutary for the quick screening of phosphate solubilizing bacteria [US Patent 6638730].

- Three novel *Bacillus* strains NRRL B-30486, NRRL B-30487 and NRRL B-30488 from the milk of *Sahiwal* cows. These isolates, when used individually or as a novel blend of consortium provide a unique synergism having the ability to control phytopathogenic fungi and promote plant growth. This is the first report of bacteria isolated from the cows' milk demonstrating the ability to control phytopathogenic fungi and promote plant growth under field conditions [Trinidad and Tobago Patent Number TT/T/2009/00056; Australia patent AU2002345299B; South Africa Patent Number 2003/2288; PCT WO 03/020038; European patent EP1423011; US Patent 7097830; CN1479577]. A process has been developed for commercial manufacturing of these products keeping in view local needs and National/International market potential.

- NBRI along with Go-Vigyan Anusandhan Kendra, Nagpur has invented a synergistic composition useful as plant and soil health enhancer using cow urine and its application for promoting plant growth and controlling plant pathogenic fungi. Composition comprises of urine, neem and garlic. Treatment of the plants with the our fermented product results in stimulation of the accumulation of nutrients in the plant biomass,

proliferation of plant growth promoting, phosphate solubilizing, abiotic stress tolerant and ability to control plant pathogenic fungi in the rhizosphere of plants, and enhances the phenolic contents of the plants enabling them resistant towards plant disease causing organisms [Australia Patent Number 2004226117; Japan Patent Number 4422144; US Patent 7297659; European patent DE602004002293T; PCT WO 2004/087618; European patent EP1608606; Netherlands patent 1608606; Zimbabwe Patent Number 29/05].

- A novel synergistic composition useful as bioinoculant, comprising of *Trichoderma harzianum* isolates of accession Nos. NRRL 30595, NRRL 30596, and NRRL 30597 individually showing phytopathogenic fungi controlling activity, abiotic stress tolerating capability, ability to stimulate plant growth, and induce systemic resistance in plants to diseases caused by phytopathogenic organisms, having highly efficient root colonization capacity and long shelf life was developed. The isolates are useful in a method of imparting to plants protection against plant pathogens and promote plant growth by applying them to plants, plant seeds, or soil surrounding plants under conditions effective to impart disease protection and plant growth of the plants or plants produced from the plant seeds [PCT WO 2007/110686].

**Technology Transfers and Commercialization of Products**

Powerful blend of consortium consisting of novel microbes *(Pseudomonas*, *Rhizobium, Bacillus* and *Trichoderma*) constitute a synergistic, stable blend of inoculants along with synergistic fermented plant growth promoting bio-control composition could be applied to agronomic crops, flowers, vegetables, to digest organic wastes such as press mud and to recover degraded ecosystems. The technologies based on aforesaid developments include:

- ***Pseudomonas*** **based technology:** The technology was successfully transferred to a leading Biotechnology Company MBI International, USA in 2000. They have successfully utilized it for in-house biotechnological applications against fish pathogenic fungi;
- ***Rhizobium*** **and phosphate solubilising bacteria (PSB) based technology:** We were invited by **U. P. Government** to transfer its bioinoculant technologies for its commercial production in Department of Agriculture, U. P. Government's biofertilizer manufacturing units and provide technical know-how, R & D support and quality control during its $X^{th}$ five year plan (2002-2007). Based on our technology, 17 biofertlizer producing laboratories of U. P. are producing quality biofertilizer and biopesticide.

***Commercial production*** based on the ***Rhizobium*** and **phosphate solubilising bacteria (PSB) based technology** transferred has begun and since 2004 it has already covered

over 61 lakh hectares of land**.** Due to the successful implementation of the joint venture our collaboration has been extended to XII$^{th}$ five year plan.

- ***Bacillus*** **based technology:** It has been transferred to Biotech International Ltd. (BIL), New Delhi and Balaji Crop Care Pvt. Ltd., Hyderabad.
- ***Trichoderma*** **based technology:** It has been transferred to GAPC, a company jointly promoted by Gujarat State Fertilizer and Chemicals Ltd. (GSFC), Gujarat Agro Industries Corporation (GAIC) and Gujarat National Fertilizers Company Limited (GNFC) and by Balaji Crop Care Pvt. Ltd.

  In terms of environmental benefits the impact of the aforementioned technologies will be innumerable, as these will lead to reduced dependence on chemical fertilizers and pesticides of the economic crops. The deterioration in soil and water quality will be checked if the use of technologies and products move on the anticipated path.

6. **Recent Publications**: (Give latest/best 10 publications)

1. V. Chaudhry and C. S. Nautiyal. 2011. A high throughput method and culture medium for rapid screening of phosphate accumulating microorganisms. *Bioresource Technology.* 102: 8057-8062.

2. H. B. Singh, B. N. Singh, S. P. Singh and C. S. Nautiyal. 2010. Solid-state cultivation of *Trichoderma harzianum* NBRI-1055 for modulating natural antioxidants in soybean seed matrix. *Bioresource Technology.* 101: 6444–6453.

3. C. S. Nautiyal, A. Rehman and P. S. Chauhan. 2010. Environmental *Escherichia coli* occur as natural plant growth-promoting soil bacterium. *Archieves of Microbiology.* 192:185-193.

4. C. S. Nautiyal, R. Govindarajan, M. Lavania and P. Pushpangadan. 2008. Novel mechanism of modulating natural antioxidants in functional foods: Involvement of plant growth promoting rhizobacteria NRRL B-30488. *Journal of Agricultural and Food Chemistry.* 56: 4474-4481.

5. S. Mehta and C. S. Nautiyal. 2001. An efficient method for qualitative screening of phosphate solubilizing bacteria. *Current Microbiology.* 43: 51-56.

6. C. S. Nautiyal, Shipra Bhadauria, Pradeep Kumar, Hind Lal, Rajesh Mondal and Dinesh Verma. 2000. Stress induced phosphate solubilisation in bacteria isolated from alkaline soils. *FEMS Microbiology Letters.* 182: 291-296.

7. C. S. Nautiyal. 1999. An efficient microbiological growth medium for screening phosphate solubilizing microorganisms. *FEMS Microbiology Letters.* 170: 265-270.

8. C. S. Nautiyal. 1997. Rhizosphere competence of *Pseudomonas* sp. NBRI9926 and *Rhizobium* sp. NBRI9513 involved in the suppression of chickpea (*Cicer arietinum* L.) pathogenic fungi. *FEMS Microbiol Ecology.* 23: 145-158.

9. C. S. Nautiyal. 1997. A method for selection and characterisation of rhizosphere competent bacteria of chickpea. *Current Microbiology.* 34: 12-17.

10. C. S. Nautiyal, and P. Dion, 1990. Characterization of the opine-utilizing microflora associated with samples of soil and plants. *Applied and Environmental Microbiology.* 56: 2576-2579.

7. **Scientists**: (Name and Designation of Scientists working in the Research Area/R& D Groups)

- Dr. C.S.Nautiyal,

  Director CSIR-NBRI;

  Area Coordinator (Division of Plant Microbe Interactions)
- Dr. Aradhana Mishra (Sr. Scientist)
- Dr. Puneet Singh Chauhan (Sr. Scientist)
- Dr. Suchi Srivastava (Scientist)
- Dr. Poonam C. Singh (Scientist)

8. **Technical Staff**: (Name and Designation of Technical / Lab Astts./TOs in the Research Area/R& D Groups)

- Mr. Sumit Yadav (TA)

9. **Research Fellows/ Project Assistants**: (Name and Designation of JRF/SRF/RA/PAs working in the Research Area/R& D Groups)

| | |
|---|---|
| Dr. Lalit Agrawal | Scientist Fellow |
| Dr. Archana Yadav | CSIR-RA |
| Dr. Kusum Verma | RA |
| Madhuri Kumari | CSIR-SRF |
| Ashmita Tandon | JRF |
| Shashank Kumar Mishra | PA II |
| Richa Shukla | PA-II |
| Ritu Dixit | PA-II |
| Shipra Pandey | PA-II |
| Rajani Verma | PA-II |
| Gyanendra | PA-II |
| Sonal Srivastava | PA-II |
| Isha Singh | PA-II |
| Manish Kumar | SPF |
| Satyendra Pratap Singh | PA II |
| Vidisha Bist | PA II |
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