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Impact of plant probiotics and *Frankia* on revival of soil and promotion of growth and yield of tomato (*Solanum lycopersicum* L.) in cold regions of Himalayas, India

The soils of arid temperate regions of Leh valley, situated at an elevation of more than 3000m in J&K, India, are poorly developed under influence of climatic factors (where mean monthly temperature varies from of 27.8°C to -14.3°C and sometimes falls to -30°C), geomorphic processes aided by glacial drift and geolithology. Most of the soils of this valley have more than 35% coarse fragments (skeletal), calcareous, neutral to alkaline in reaction, the very low content of organic carbon, available N and P and classified as Sandy-skeletal (calcareous) Typic Eutrocypts. Under such circumstances, microbial activities and nutrients cycling of added organic manure/fertilizers in the soil is very poor and consequently grown vegetable crop give less response to nutrients. By principle, dynamic properties of soils can be improved by application of beneficial microbes. Therefore, efforts were made to revive the soils of Leh valley by isolation, selection and application of quality plant probiotics (plant growth promoting rhizobacteria) with cultivation of vegetables particularly tomato (*Solanum lycopersicum* L.). Selection of effective plant probiotic strains of *Pseudomonas trivialis* (JY-01, JY-05), *Pseudomonas* sp. (JY-02, 03, 04, 07, and JY-11), *Pseudomonas aeruginosa* (BHUPSB-02), *P. fluorescens* (BHUPSB-06) and *Bacillus subtilis* (BHUPSB-13) was done on the basis of biochemical, plant growth promoting properties and molecular characterization of many rhizosphere bacteria isolated from the soils of Leh valley. Further, isolation and selection of *Frankia* strain FL-1 (symbiotic N₂-fixer) was done from the root nodules of non-leguminous Seabuckthorn (*Hippophae* spp.) shrubs wildy grown in Leh valley. This strain of *Frankia* was showing plant growth promoting properties and synergistic relationship with above plant probiotic strains. During the interaction study, *Frankia* isolate (FL-1) and *B. subtilis* (BHUPSB-13) were showing inhibitory effect on both *Ralstonia solanacearum* (causing root wilt) and *Fusarium oxysporum lycopersici* (causing stem wilt) in tomato under *in-vitro* condition. Therefore, based on theory of Koch Postulate, a pot experiment was conducted on tomato Var. *Kashiamrit* with 12 treatments in triplicate under CRBD at Banaras Hindu University, Varanasi during *kharif* 2014-15 to see the effect of *P. fluorescens*, *B. subtilis* and *Frankia*, separately and in combination, to control the infestation of wilt causing pathogen and promotion of growth and yield. Observation after 10 days of infestation showed that the plants without pretreated with PGPR were showing much more infestation and few of plants died completely in separate or combined treatments of bacterial and fungal pathogens. Though, *B. subtilis*, *P. fluorescens* and *Frankia* (FL-1) were effective, separately or in combination, to control the infestation of both pathogens but *B. subtilis* was more effective to control bacterial pathogen while, *Frankia* isolate (FL-1) was effective not only to controlling both pathogens but also for higher plant growth and early flowering in the tomato plant. However, combined effect of *B. subtilis* and *Frankia* had given significantly better performance of disease control, growth and fruit yield of tomato in comparison of individual inoculants. These strains of plant probiotics are now being used by different agricultural laboratories and other stakeholders involved in

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cultivation of tomato and other vegetables in Leh valley. Though, there is need of further study but results of improvement in rhizosphere microflora, soil microbial biomass carbon, hydrogenase and phosphatase enzymic activities high yield of tomato under inoculated conditions conferred that the plant probiotic consortium of *Pseudomonas trivialis* (JY-01, JY-05), *Pseudomonas* sp. (JY-02, 03, 04, 07, and JY-11), *Pseudomonas aeruginosa* (BHUPSB-02), *P. fluorescens* (BHUPSB-06) and *Bacillus subtilis* (BHUPSB-13) would be useful to revive the soils of Leh valley for cultivation of tomato as well as other vegetables.

Biography

For being B.Sc.(Ag) and M.Sc.(Ag) from BHU, he was awarded PhD in Soil Science and Agricultural Chemistry by Banaras Hindu University, Varanasi in 1992. He started his academic career as Sr. Research Assistant followed by UGC- Research Associate at BHU. After that, he joined DRDO as Scientist 'C' in 1996 at IAT, Pune and finally served Defence Agricultural Research Laboratory, now Defence Institute of BioEnergy Research, Pithoragarh, Uttarakhand. There he worked as Officer-in-Charge of DARL Field Stations at Arabachauhan (Barmer) and Auli (Joshimath). He joined as lecturer in 2003, became Reader in 2004 and presently serving as Professor in the Department of Soil Science and Agricultural Chemistry at Banaras Hindu University (BHU), Varanasi, India. The area of his research of interest has been soil microbiology/microbial biotechnology/organic farming/soil fertility with emphasis on development of quality plant growth promoting rhizobacteria using molecular tools and techniques to enhance crop production and maintenance of soil health under organic and integrated nutrient management system in Indo-Gangetic plains of India. During his tenure in DRDO, he, first time, studied the soils of Leh and Ladakh. In addition to propagation of medicinal plants including seabuckthorn, agriculture and environmental warfare, development of technologies for season / off-season (protected) vegetables and their dissemination to the locals and Jawans of army units staying at high altitude were his interest area of research work. However, he is still involved in revival of cold desert soils of Himalayan region by means of bioinoculants. Besides executing 12 research projects, guiding 10 PhD and 27 M.Sc.(Ag) students at BHU he has published more than 100 research papers in journals of national and international repute, 7 book chapters and many popular articles. He is presently acting as reviewer of research papers in many journals of national and international repute. He joined 20th World Soil Science Congress held at Jeju, South Korea during 2014 and he has been a recipient of Fellow of Uttar Pradesh Academy of Agricultural Sciences, BHU-Research Fellowship, UGC-Post Doctoral Fellowship, Award of "Best Research Paper by DRDO". Besides serving as member of different committees of administrative bodies in BHU, he has also been elected as Councilor of Indian Society of Soil Science, New Delhi for the year of 2009 and 2010.

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