National Symposium

ON

Sustainable Disease Management Approaches and Applications

&

IPS- MEZ Annual Meeting

21-23 Dec, 2017

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&

Indian Phytopathological Society, New Delhi

Department of Plant Pathology

College of Agriculture, G B Pant University of Agriculture & Technology,
Pantnagar-263145, Uttarakhand

National Symposium

on

Sustainable Disease Management: Approaches and Applications

&

IPS-MEZ Annual Meeting

December 21-23, 2017

Souvenir & Abstracts

Jointly Organized by

G. B. Pant University of Agriculture & Technology, Pantnagar
&
Indian Phytopathological Society (Mid-Eastern Zone)

Department of Plant Pathology
College of Agriculture,
G. B. Pant University of Agriculture & Technology,
Pantnagar-263145, Uttarakhand

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FOREWORD

Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, established in 1960 on land grand pattern is a centre of excellence in generating and disseminating technologies in agriculture, mountain agriculture, animal science, technology, agro forestry and allied fields for the sustainable development of the plain and Himalayan region of Uttarakhand. Since its inception, the university has been carrying out programmes of human resource development, multidisciplinary researches and technology transfer suitable to hill and plain agro-climatic conditions, promoting all round agricultural development leading to social integration and ecological regeneration. With fifty seven years of glorious past, the university encompasses eight colleges, nine ***Krishi Vigyan Kendras*** and eight research sub-stations covering virtually every field of hill and plain agriculture, animal science and technology. Ever since its establishment the University is committed to its mandatory role of imparting teaching, research and extension education in agriculture and allied areas. Plant Pathology Department of the College of Agriculture, a Centre of Excellence of Plant Pathology has numerous achievements to its credit. One of such deliverable, the invention of Khaira disease of rice and its management not only rejuvenated rice cultivation in the tarai region of Uttarakhand but also necessitated application of Zn in various other cereals for harnessing potential yield. It is praiseworthy that the initiative has been taken up by the department to address sustainable disease management by way of organizing a National Symposium.

The scientific community is relentlessly engaged in evolving novel eco-friendly strategies for plant disease management with application of modern molecular and biotechnological tools, to tackle ever increasing plant disease problems. It is my firm belief that the deliberations during the National Symposium on **"Sustainable disease management: Approaches and Applications"** will be of immense value to the plant pathologists, students, teachers and policy makers for sustainable crop production.

I extend my warm greetings and felicitations to the organizers and the participants, and wish a grand success for the forthcoming symposium.

(A. K. Misra)
Vice-Chancellor

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Dr. K. K. Paul
Governor, Uttarakhand

RAJ BHAWAN
Dehradun-248 003

6th December, 2017

MESSAGE

It is a matter of immense pleasure for me to know that the harbinger of Green Revolution, the G.B. Pant University of Agriculture and Technology, Pantnagar is organizing a National Symposium on **"Sustainable disease management: Approaches and applications"** from December 21-23, 2017.

Diseases cause substantial losses to the productivity of agricultural food crops. The incidence of a particular disease may largely depend on the crop genotypes, prevailing climate and nutritional status, cropping system and cultivation techniques. The intensive agriculture with high fertilizer responsive crop varieties attracted newer problems, which were not serious in earlier days. At the same time, emergence of new virulent races or biotypes are common features in places grown with crop varieties that are highly resistance to a given pathogens. Nevertheless, the impact of global climate change on disease scenario of agricultural crop plants is well evident.

I understand that these issues will be discussed in different Sessions during the Symposium and, I hope, resultant deliberations will be of immense use in formulating the strategy for managing the plant diseases.

My best wishes for the organizers and participants of this Symposium.

(Dr. K.K. Paul)

Y.L. Nene
Ex-Director - ICRISAT
Chairman of Asian Agri-History Foundation (AAHF),
Secunderabad, Telangana

MESSAGE

I am delighted to know that the Department of Plant Pathology, College of Agriculture, Gobind Ballabh Pant University of Agriculture and Technology, Pantnagar along with Indian Phytopathological Society (Mid-East Zone), is organizing a National Symposium on **"Sustainable disease management: Approaches and applications"** during **December 21-23, 2017**.

For centuries, Indian farmers and scholars have generated the knowledge of "Vrikshayurveda" in preventive and curative measures for plant disease and pest management, using indigenously available inputs. The symposium should provide solutions in achieving our goal of sustaining agricultural growth, maintaining sound health of crop plants, enhancing input use efficiencies, and applying environmentally sound agricultural practices. I hope that the participants in the National Symposium will deliberate upon most sustainable methods of disease management with least adverse impact on the environment.

I would like to congratulate and wish all success to the organizers and I am confident that the discussions during the symposium would be fruitful.

(Y.L. Nene)

National Academy of Agricultural Sciences

Prof. Panjab Singh
Former Secretary, DARE & DG, ICAR and
President, National Academy of
Agricultural Sciences

MESSAGE

I am pleased to know that the National Symposium on **"Sustainable disease management: Approaches and applications"** is being organized by Department of Plant Pathology, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar along with Indian Phytopathological Society (MEZ), during **Dec. 21-23, 2017.**

Although, Green Revolution has given us self-sufficiency in food production but it has given rise to second generation problem in farm of several biotic and a biotic stresses. The new agricultural production scenario calls for another revolution to achieve for sustainable crop production without having any adverse impact on the environment.

I hope that the delegates in the National symposium will deliberate upon the important issues relating to Plant pathological problems of the country and will come out with suitable recommendations.

I congratulate and wish all success to the organizers and participants of the national symposium.

(Panjab Singh)

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CIMMYT
International Maize and Wheat Improvement Center

Dr. Ravi P. Singh,
CIMMYT

MESSAGE

It is a pleasure to know that *Department of Plant Pathology, College of Agriculture,* Govind Ballabh Pant University of Agriculture and Technology, Pantnagar along with Indian Phytopathological Society (Mid East Zone), is organizing a National Symposium on **"Sustainable Disease Management: Approaches and Applications"** during **December 21-23, 2017**.

India has a long history of knowledge in preventive and curative measures to manage plant diseases using indigenously available inputs. This knowledge, combined with genetic control, require extensive deliberations at the symposium to develop more sustainable, ecofriendly and cost effective methods to reduce crop losses. The need of the day is to produce food not only free from diseases and pests but also pesticides.

I would like to congratulate and wish a great success to the organizers and hope that the discussions during the symposium would be fruitful and lead to a better and sustainable management of diseases.

Dr. Ravi Prakash Singh

Uma Shankar Singh
Director, IRRI South Asia Regional Centre (Varanasi)
Principal Scientist, Division of Plant Breeding
South Asia Regional Project Coordinator,
Stress Tolerant Rice Program
International Rice Research Institute (IRRI)

MESSAGE

It gives me immense pleasure to know that Department of Plant Pathology, G B Pant University of Agriculture and Technology, Pantnagar has taken up a timely venture of organizing a National Symposium on **"Sustainable disease management: Approaches and applications"** from **December 21- 23, 2017** as a major event during the zonal meeting of the Indian Phytopathological Society of the Mid-Eastern Zone. For long, I have been associated with Pantnagar in various capacities and hence am conscious of the important role played by the Department of Plant Pathology in the advancement of pathological research and also dissemination of the new knowledge and technologies to the farmers of the country. The ever increasing demand for producing more from less for more necessitates enhancing production and productivity per unit area. Unfortunately, however, today an estimated 40% of crops are lost each year to pests and diseases. The new emerging diseases have adversely affected agricultural productivity, profitability, and finally livelihood of the farmers. Reducing this crop loss by just one percent could feed millions more people, as also would add more produce to the agriculture basket. This symposium would undoubtedly provide opportunities to the scientific community to share their research findings and understand emerging views in the improvement of crop health in particular and in enhancing crop productivity in general.

I wish to record my appreciation to the Organizing Committee for its efforts in organizing this important conference and I like to wish great success to this symposium.

(U S Singh)

UTTARAKHAND STATE COUNCIL FOR SCIENCE & TECHNOLOGY

उत्तराखण्ड राज्य विज्ञान एवं प्रौद्योगिकी परिषद

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Rajendra Dobhal
PhD; FAFESc; FNASc
Director General
Secretary
NASI, UK Chapter

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MESSAGE

Global agriculture has been considerably threatened by diseases of fungal, bacterial and viral nature. The disease scenario has also taken a shift under the impact of climate change. The new emerging diseases have adversely affected agricultural productivity, profitability, and finally livelihood of the farmers. Keeping those issues in mind, Plant Pathology department of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar along with Indian Phytopathological Society (MEZ), is organizing a National Symposium on **"Sustainable disease management: Approaches and applications"** during **December 21- 23, 2017**. I hope that the participants including scientists, research scholars, and policy makers will discuss various aspects of microbial diversity and sustainable plant disease management.

I extend my good wishes for the grand success of the symposium.

Rajendra Dobhal
Director General

Asia-Pacific Association of Agricultural Research Institutions

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Dr Ravi Khetarpal
Excecutive Secretary

MESSAGE

I am happy to know that *Department of Plant Pathology, College of Agriculture,* Gobind Ballabh Pant University of Agriculture and Technology, Pantnagar along with Indian Phytopathological Society (MEZ), is organizing a National Symposium on **"Sustainable disease management: Approaches and applications"** during **December 21-23, 2017**.

The topic of the Symposium is very apt keeping in view the national and global focus on working towards Sustainable Development Goals of the United Nations. The Symposium will indeed provide a platform to all the relevant stakeholders to take a stock of the plant disease management scenario and will facilitate development of best practices for the primary producers, the farmers, apart from giving insight to the way forward for addressing the relevant research agendas.

I extend my warm greetings and good wishes for the success of the symposium and congratulate both IPS and the University for conceiving such a meeting.

Dr Ravi Khetarpal
Executive Secretary, APAARI

भाकृअनुप
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Dated: 16-12-2017

Dr. P.K. Chakrabarty,
Ph. D., FNAAS
Adjunct Professor, UF
Assistant Director General (Plant Protection)

MESSAGE

It is a matter of great pleasure for me to know that the harbinger of Green Revolution, the G B Pant University of Agriculture and Technology, Pantnagar is organizing a National Symposium on **"Sustainable disease management: Approaches and applications"** from December 21- 23, 2017.

Global agriculture is threatened considerably by diseases caused by pathogens of fungal, bacterial, viral origin besides, that due to non-conventional pathogens. The disease scenario has also taken a shift under the impact of climate change. The spurt is also facilitated by trade liberalization and movement of two billion people flying through the airports and 18 million containers through the seaports every year. All these activities serve to bring the biosecurity threat closer to our International borders. Nearly 15-20% losses are caused in plants due to diseases, the loss if averted could save additional 40-55 million metric tons of food grains and 60 million metric tons of horticultural produces, even without any increase in productivity. Crop Biosecurity is thus paramount to farmer's profitability, sustainable livelihood and food security of the nation.

Keeping these issues in mind, I appreciate the need of this conference on the above theme. I am sure that the conference will provide opportunities to the scientific communities to discuss, share and understand their views in the improvement of crop health in particular and in enhancing crop productivity in general.

I congratulate the organizers for planning this symposium and wish this event a grand success.

(P.K. Chakrabarty)

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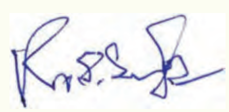
Dr. Rama S. Singh
Ex-Professor and Head,
Department of Plant Pathology,
GBPUAT, Pantnagar

MESSAGE

A majority of Indian population still gets its livelihood from agriculture. It is of high priority that the crop be protected from threatening pest and diseases. I am pleased to learn that Department of Plant Pathology, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar along with Indian Phytopathological Society (MEZ), is organizing a National Symposium on **"Sustainable disease management: Approaches and applications"** during **December 21- 23, 2017.** The organization of National Symposium is very timely and noteworthy. I hope that the participants will ponder upon the key plant disease challenges faced by the nation today, and bring out specific recommendations for plant disease management for sustainable crop production, particularly for small and marginal farmers.



(Rama S Singh)

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निदेशक,
डा. एस.एन. तिवारी
DIRECTOR

MESSAGE

It is a matter of great pleasure to know that the G.B. Pant University of Agriculture and Technology, Pantnagar, along with Indian Phytopathological Society (Mid East Zone) is organizing a National Symposium on "Sustainable disease management: Approaches and applications" at Department of Plant Pathology, College of Agriculture, in the backdrop of Uttarakhand from Dec. 21-23, 2017.

The University since its inception has come a long way in addressing the research, teaching and extension needs of the State, Uttarakhand in the areas of agriculture, animal science and allied areas. Conservation and protection of agricultural crops and Agro forestry species is undoubtedly is of paramount importance to achieve the goal of sustainability. With the modernization of agriculture and increasing urbanization, it is necessary to review and update the advances made in research through deliberations among the researchers. Uttarakhand state being is a vast reservoir of biodiversity in the flora and fauna, organization of a National Symposium at Department of Plant Pathology, College of Agriculture, Pantnagar, is expected to accelerate efforts on R&D programmers for sustainable disease management in the region. I hope that this symposium will provide an opportunity to the researchers, policy makers, extension specialists, and students to share their ideas for mutual benefit.

I am sure that the outcome of the symposium will not only serve a greater purpose in the interest of farming community of state but also that of entire nation. My best wishes for the successful conduct of this national symposium.

(S.N. Tiwari)
Director
Experiment Station

G.B. Pant University
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Dr. J. Kumar
Dean

MESSAGE

The College of Agriculture came into existence in 1960 simultaneously with the G.B. Pant University of Agriculture & Technology, Pantnagar, which holds the credibility of being the first landmark rural university of the nation and over the period, has ushered in India's renaissance in agriculture education, research and extension. The College has played a pivotal role in earning such authority for the University. Through the important contributions of its various faculties, the College has also contributed significantly towards the pronounced credibility of the university in ushering green revolution in the country. The college with its 11 departments continues to address emerging challenges that confront sustainable agriculture production and food and nutritional security. It has been widely agreed that agriculture production must increase in foreseeable future to meet the food and feed demand of growing human population and increased livestock production. Plant protection has an important role to play in sustaining the productivity of agriculture crops that drive an increasing proportion of small and marginal farmers. There has been a continuous change in pest and disease dynamics due to change in their host preferences and climate change. Newer virulent strains of the pathogens threaten the efforts to enhance the crop production. With increasing awareness about the environmental pollution and degradation, there has been more emphasis on integrated disease management for sustainable crop production. Disease management in organic mode of cultivation is yet another challenge. Organization of the National Symposium on "Sustainable disease management: Approaches and applications" by Department of Plant Pathology of the college is timely and is expected to promote debate on some of the above issues. I hope that the symposium would bring together scientific community, which is inexorably engaged in evolving future strategies to combat the threatening plant disease problems to attain the ultimate goal of agriculture sustainability. I wish the symposium a great success.

(J. Kumar)
Dean

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Dr. K. Vishunavat
Professor & Head

MESSAGE

It is indeed a movement of great pleasure that Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, in collaboration with Indian Phytopathological Society (MEZ) is organising National Symposium on sustainable disease management: "Approaches and applications" in the Department of Plant Pathology , College of Agriculture, w.e.f. 21st -23rd December 2107.

The topic of the symposium has aptly been chosen in context of plant disease management, in present agriculture scenario, to underpin the sustainable agricultural growth.

One-third of food produced for human consumption is lost or wasted globally, annually. This amounts to around, 1.3 billion tons. In many developing countries, due to inappropriate and inadequate agriculture practices, attack of pests and diseases, and post harvest handling and storage, many farmers lose up to 40 percent of their harvest. The only annual post harvest grain losses in India are sufficient to feed about 100 million people. In present scenario of crop cultivation where there are many direct or indirect factors due to frequent global or regional changes affecting plant disease scenario , the sustainable plant disease management needs contemplation on the areas of integration and alignment of efforts and supports for effective disease management in the fast changing climatic context, environmentally sustainable techniques for pest and disease management, exploration of allelopathy, bio-control agents, natural plant products, organic amendments and other non chemical cultural measures for integration in plant disease management, promotion of IPM through support for public awareness, research, extension and training with emphasis on decentralized yet integrated and harmonised farmer-centric initiatives and right from varietal development to on farm translation including post harvest management.

I am sure that this symposium would come up with fruitful deliberations that would recapitulate with useful recommendations.

I congratulate and wish all the success to the organisers of the symposium.

(K. Vishunavat)

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INDIAN PHYTOPATHOLOGICAL SOCIETY

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MESSAGE

It is a pleasure to know that *Department of Plant Pathology, College of Agriculture,* Gobind Ballabh Pant University of Agriculture and Technology, Pantnagar along with Indian Phytopathological Society (Mid East Zone), is organizing a National Symposium on "Sustainable disease management: Approaches and applications" during December 21-23, 2017.

India has long history of knowledge in preventive and curative measures for plant disease management using indigenously available inputs. I hope that the participants in the National Symposium will deliberate upon more sustainable methods of disease management with least impact on the environment.

I would like to congratulate and wish all success to the organizers and hope that the discussions during the symposium would be fruitful.

Date: November 27th 2017

(B.N. Chakraborty)

INDIAN PHYTOPATHOLOGICAL SOCIETY

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No. IPS/Sec/2017/00375
Dated: November 30, 2017

Dr. Dinesh Singh
Secretary

MESSAGE

I am extremely delighted to note that College of Agriculture, GBPUAT, Pantnagar, Uttarakhand is organizing Annual Meeting of MEZ and National Symposium on "**Sustainable disease management: Approaches and applications**" in collaboration with Mid-Eastern Zone (MEZ) of Indian Phytopathological Society (New Delhi) during Dec. 21-23, 2017.

Plant protection is a major component in the endeavor for sustainable and increased production of cereals, pulses, oilseeds, fruits and vegetables. Managing diseases to attain a healthy and productive crop is one of the major functional components in successful crop production. The present symposium is aimed to provide a forum to the scientists, students and policy makers from various fields of agriculture, forestry, horticulture and information technology to discuss the problem of plants caused by various pathogens and their management. The symposium is an attempt to showcase advances made by researchers in the field of disease management to reduce yield losses due to diseases.

I am hoping that the symposium will lead to some fruitful and actionable recommendations for research, policy and extension areas all of which need to be looked at holistically.

(Dinesh Singh)

(A. K. Tewari)
Councillor -IPS (MEZ)

PREFACE

(K. P. Singh)
President-IPS(MEZ)

The success of green revolution was based solely on cultivation of high yielding varieties supported with high input agriculture. Though it has made country self sufficient in food grain production but indiscriminate use of chemical inputs lead to deterioration of soil health, increase in hazardous outbreaks of pests, diseases and weeds, adverse effect on soil micro flora and fauna, deterioration in the quality of produce and loss of biodiversity. Today the demand of safe food is increasing world over where farmers will get fair price of quality produce that can be achieved by a holistic production system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles and soil biological activities.

Plant protection is a major component in the endeavour for sustained and increased production of cereals, pulses, oilseeds, fruit and vegetables. In modern India, disease spectrum and intensity are changing continuously because of dynamic nature of agriculture and climatic change. A logical disease management program has to be normally based on the knowledge of the current disease profile in a given ecosystem, and management strategies need to consider.

The symposium attempts to showcase advances made by researchers in the areas of: Host plant resistance; Microbial diversity/biodiversity for crop improvement; Sustainable utilization and conservation of natural resources; PGPR, bio-inoculants, nano-technology and biotechnological approaches in the management of plant diseases; Disease management in medicinal and horticultural crops as well as post-harvest diseases; Biotic and abiotic stress management strategies under changing climate scenario, disease dynamics, epidemiology and disease forecasting; Integrated management of Phytopathogens; Role of plant clinics and extension workers in the sustainable plant disease management

To address these emerging issues, the Department of Plant Pathology, College of Agriculture, GBPUAT, Pantnagar is organizing a National Symposium on **"Sustainable Disease Management: Approaches and Applications & IPS-MEZ Meeting** from **December 21-23, 2017.** To make occasion memorable, this souvenir has been brought out the papers from lead speakers, invited lectures, M J Narasimhan award, APS student travel award and abstracts of research papers. We sincerely hope that this symposium will certainly provide a platform to prepare a roadmap for "Sustainable Plant Disease Management" to enhance the production as well doubling the farmer's income. We are grateful to the members of the publication committee for their concerted efforts in compilation of this Souvenir and also to all the contributors of papers and abstracts; members of all the committees involved in organization and sponsors.

(A. K. Tewari)
Councillor -IPS (MEZ)

(K. P. Singh)
President-IPS(MEZ)

ABOUT THE UNIVERSITY

The Govind Ballabh Pant University of Agriculture & Technology was established in 1960 by an Act of the State Legislature of Uttar Pradesh, enacted in 1958. It was established on landgrant pattern of USA, has the inherited distinction of leadership in agricultural education, research and extension as the first Agricultural University of India. The mandate of this foremost institution was pronounced during the initial phase of its evolution when the then Prime Minister, Pt. Jawahar Lal Nehru, and President, Dr. S. Radhakrishnan, emphasized that this university will play a pivotal role in transforming agriculture and rural development of the country through scientific and technological innovations. The University emerged to the expectations of the visionaries to provide a leadership role by providing a template for the development of other agricultural universities of the country. Besides, it has also emerged as epitome of quality education and breakthrough researches with unparalleled excellence. Noble Laureate Dr. N. E. Borlaug echoed endeavours of Pantnagar University as Harbinger of Green Revolution.

The University took seminal role in development of high-yielding varieties, producing nucleus, breeder and foundation seeds to suffice the requirement of the nation. The University has twice been adjudged as the Best State Agricultural University, in the years 1997 and 2006, by the Indian Council of Agricultural Research (ICAR). The University continues to retain its leadership role by innovations in teaching, research and extension and also through their integration. The education system of the University provides a unique opportunity to the students for a hands-on learning experience in all diverse field of agriculture encompassing new concepts resulting in achieving new milestone by getting a mention in QS BRICS universities ranking-2015, the only agricultural university in the country and one of the two agricultural universities of top 200 institutions BRICS ranking.

Pantnagar University witnessed the remarkable rising of India to acquire its food security and to be part of the club of food exporting countries. Prominently, its role in promulgating zinc revolution and revolution in rice and other crops, soybean revolution, seed revolution and revolution in farm implements gave directions to achieve food security in the nation. The university is endeavouring to reach new heights of research for development in agriculture, including crop sciences, horticulture, home science, basic sciences, animal husbandry, fisheries, engineering, and agribusiness management. With a leading role in research and extension the university is operating 302 research projects with a budget of Rs. 3934 lakhs. The university is operating 43 All India Coordinated Research programs most of which have been declared as Best AICRP centres in the country this year. The scientists have developed 280 varieties of different crops for cultivation in different states and 13 varieties developed by university have been declared as Landmark varieties of India. The university produces nucleus and breeder seeds of various crops and also raised saplings of horticultural crops, agro-forestry trees, flowers and medicinal and aromatic plants and also fingerlings of different carp fish in millions. During 2016-17, the university produced 5533 Quintal high quality Breeder Seeds of different crops along with more than 5 lakh planting materials. Moreover, the university has filed 66 applications for national and international patents on different technologies developed by scientists and students.

Adding to the milestones, the Pantvarsity has been declared as the best university of Uttarakhand state in a row for two consecutive years 2015-16 and 2016-17. ICAR-IRRI Golden Jubilee Best Centre Award in Rice Research has been received by the university. The university has been honoured with the best centre award of Network Project on Organic Farming for 2015 by ICAR. It has been awarded with National Kamdhenu Award given under National Gokul Mission programme, for the conservation of Sahiwal breed at its Instructional Dairy Farm. 3 teachers of the university are honoured with Bharat Ratna Dr. C Subhramaniyam Best Teacher Award, Hari Om Ashram Trust Award and Governor's Best Research Paper Award for the year 2016-17. Students of the university topped and strived selections in various examinations like CAT, GATE, PCS and Toppers Conclave and besides academic excellence proved their all-round mettle and captured overall winner's trophy in 21st All India Inter University Youth Festival held at NDRI Karnal in April 2017.

Extension education is a very strong dimension of the university's on-going programmes. Transfer of technologies developed by the university to framers' fields and continuous communication with farmers through various means of communication are on top priority in university's agenda. Farmer's fairs are organized twice in a year in the university for four days in March and October. By October 2017, the university has organised 102 farmers cum agro-industrial exhibitions popularly known as Kisan Mela. These fair are visited by a large number of farmers from Uttarakhand and other states of India and also from Nepal. Besides, farmers' fairs agro-exhibitions were also organized at various Krishi Vigyan Kendras in 9 districts of Uttarakhand. The university is also disseminating agricultural knowledge and latest technologies hrough Jan Vani, which has bagged National Community Radio Award. The Directorate of Extension Education conducted total 752 training programmes, through T&V unit, KVKs and SAMETI-Uttarakhand. In these training programmes, about 17,000 farmers and extension functionaries were trained. The ATIC has facilitated the farmers through a helpline/Kisan Call Centre, computer kiosk visits and sale of seed, literature, etc.

University has formulated a village adoption programme for the whole of Uttarakhand and has submitted it to the Government. It has on its own started the programme and adopted 5 villages of Udham Singh Nagar and Nainital districts where paddy, urdbean and finger millet seed are produced. The planting material of litchi, guava, mango and other citrus fruits has also been provided from the university. The farmers are being trained in seed production technology and grafting methods by the scientists to enhance their skill in these areas.

The university has been entrusted with a new responsibility to prepare the strategy for doubling the farmers' income in Uttarakhand and the university is enacting with its indomitable vigour and prepared extensive action plans for increasing the farmers' income. In a globalizing economy, there are challenges to make continuous strides to emerge as a leading economy of the world. If agriculture flourishes, rest of the sectors of national economy will go on flourishing.

ABOUT THE DEPARTMENT

G.B. Pant University of Agriculture & Technology (the erstwhile U. P. Agriculture University) was established in 1960 and the Department of Plant Pathology was created and accredited by the ICAR in 1961. Department stupendously progressed under the able guidance of Dr. Y.L. Nene, first Head of the Department and stalwarts like Dr. R.S. Singh, Dr. A.N. Mukhopadhyay, Dr. R.K. Tripathi, Dr. S. J. Kolte etc. and further expanded by many dedicated faculty members who lead the department as recognized leader in the country.

In view of the outstanding contribution made in the area of teaching, research and extension by the department, ICAR upgraded the department in the year 1995 to the status of Centre of Advanced Studies in Plant Pathology and subsequently as Centre of Advanced Faculty Training (CAFT) in the year 2009-10. Major mandate of the CAFT is to train scientific faculty from all over the country in important and innovative areas of Plant Pathology. So far 35 trainings, with 724 participants from 25 states, have been conducted, the recent being successfully accomplished from November 22 to December 12, 2017 under the title "Technological Advances to Minimize Pre-and Post-Harvest Losses in Agricultural and Horticultural Crops to Enhance Farmer's Income". The CAS was awarded a certificate of appreciation in commemoration of Golden Jubilee year of independence (1998) by the Education Division, ICAR on August 14, 1998 for organizing the excellent programmes for human resource development and developing useful instructional material**.** Out of the 11 departments of the College of Agriculture at the university, the department received an **"Excellence award for the year 2016"** for its contributions towards research, teaching and extension services rendered to the farmers.

Vision

Attain excellence in teaching and research in Plant Pathology and the services rendered to the farming community.

Mandate

To enhance the competence of the faculty to undertake advanced education, research and extension activities in the field of Plant Pathology.

To update the curriculum and courses of Plant Pathology and to strengthen teaching at UG and PG level.

To impart trainings to the faculty members/scientists in Plant Pathology of various SAU's and Research Institutes/Centers' in the country.

To uplift the agricultural status of farmers of different districts of Uttarakhand state through "Help Line Service".

Priority areas of research

Varietal screening for disease resistance in different crops

Eco-friendly approaches in plant disease management

Biological control

Mushroom Research and Training

Seed Health Testing
Integrated Disease management
Population biology in plant pathogens
Biology and ecology of soil borne plant pathogens
Epidemiology and disease forecasting.

Ongoing extension activities

The scientists participate in the farmers contact program impart trainings for different communities. The Scientists of the department organize/participate in trainings for the benefit of farmers at State level and also for Agricultural Officers and also through technology demonstration. “Help Line Services” are rendered by the specialists of the department through Agriculture Technology Information Centre (ATIC) at the University. Information for farmers and other beneficiaries on disease management measures is either delivered through radio talks, TV programme, Krashak Samwad, published literature as popular articles and disease circulars by the faculty members time to time.

Facilities

All laboratories are equipped well and address crop based viz. wheat Pathology, Maize Pathology, Rice Pathology, Oil Seed Pathology, Pulse Pathology, Seed Pathology and incubation chamber, Soil borne plant pathogens and fungicide, Epidemiology and forecasting, Bio-control, IPM, Mushroom Research & Training Centre, Glass houses, Polyhouses, UG Practical, PG, Training Hall, Conference Hall and basic plant pathological research Lab viz. including Bacteriology, Virology, Nematology, Ecology of soil borne plant pathogens & population biology, Host-pathogen interaction, Molecular plant pathology and a biocontrol lab notified by central insecticide board as referral lab for Quality evaluation of biocontrol agents.

Publications

20 Manuals, 13 Technical Bulletins, 08 Extension Bulletins, >1500 Research papers, >175 Chapters in book and 2 Articles in Annual Review of Phytopathology.

Recognition and Awards:

▪ UNO (Rome) – Dr. Y. L. Nene	
▪ Prof. M. J. Narisimhan Academic Award (IPS)	5
▪ Jawahar Lal Nehru Award (ICAR)	3
▪ Pesticide India Award (ISMPP)	7
▪ P. R. Verma Award for best Ph. D. Thesis (ISMPP)	2
▪ Other (Hexamar, MS Pavgi, Rajendra Prasad etc.)	>21
▪ Uttaranchal Ratana	2
▪ Education Award 2004-05” for book “फलों के रोग” by the Ministry of Human Resource Development, GOI	01

Professional Societies and our Share:

Indian Phytopathological Societies

Presidents – 3

Zonal Presidents – 3

Indian Society of Mycology & Plant Pathology –

Presidents – 3

Vice Presidents – 1

Indian Society Seed Technology

Vice Presidents - 3

Science Congress

President (Agriculture Chapter) - 1

National Academy of Agricultural Sciences

Fellows - 3

Ongoing Research Projects

Projects–24 and AICRP- 14 with Total Budget Outlay of **> 10 Crores** on the on-going projects.

Funding Agencies–IRRI, DBT, DFID, RF, ICAR, French Government, Planning Commission, Uttarakhand Gov., (RKVY, HTM)

CONTENT

MJN : M J Narasimhan, LP : Lead Presentation, IL : Invited Lecture, OP : Oral Presentation, PP : Poster Presentation

APS Student Travel Award

Session 01:
Host Plant Resistance, Microbial Diversity/Biodiversity for Crop Improvement, Sustainable Utilization and Conservation of Natural Resources

MJN : M J Narasimhan, LP : Lead Presentation, IL : Invited Lecture, OP : Oral Presentation, PP : Poster Presentation

Session 02:
PGPR, Bio-inoculants, Nano-technology and Biotechnological Approaches for the Management of Plant Diseases

MJN : M J Narasimhan, LP : Lead Presentation, IL : Invited Lecture, OP : Oral Presentation, PP : Poster Presentation

Session 03
Disease Management in Medicinal and Horticultural Crops and Post-Harvest Diseases

Session 04: Biotic and Abiotic Stress Management Strategies under Changing Climatic Scenario, Disease Dynamics, Epidemiology and Disease Forecasting

MJN : M J Narasimhan, LP : Lead Presentation, IL : Invited Lecture, OP : Oral Presentation, PP : Poster Presentation

Session 05: Integrated Management of Phytopathogens, Plant Clinics and Extension Plant Pathology

Mid-Eastern Zone Presidential Address

Apple Diseases and their Management

K P Singh

Department of Plant Pathology, College of Agriculture,
G. B. Pant University of Agriculture & Technology, Pantnagar, U S Nagar, Uttarakhand

Apple (*Malus domestica* Borkh) cultivation in this temperate region is the most important fruit grown in India and has taken an important position in fruit production. It ranks 5th, first being mango followed by banana, citrus and guava. Its cultivation, therefore, has been receiving special attention in the region. More than 1, 75,000 small and marginal farmers are actively engaged in production of apple fruit in the area and depend for their livelihood on this fruit crop. The total area of commercial fruit production in hilly area of India is approximately 141856 hectares. In fact, the economy of the entire temperate hill region of the country is overwhelmingly dependent upon apple alone than any other fruit crop so far. Apple is cultivated on a large area in hills of Uttarakhand. The trees are planted little more than a meter apart and supported by a two-or three – wire trellis induces precocious fruiting and increased yield per hectare. The main apple varieties are ‗Royal Delicious, Golden Delicious, Red Gold, Tydeman‘s-Early-Worcester, Red Delicious, Rich-a-Red, Starkrimson Delicious, Top Red, Red Chief, William Favourite, Summer Queen, Mcintosh, Red Fuji, Oregon spur, Crab apples, and Jonathan. The production, quality and usage of the fruit is greatly influenced by the insect, pests and diseases. The diseases inflicting injury partly or wholly to an apple tree are several.

Apple suffers from a number of diseases caused by fungi, bacteria, viruses and nematodes. According to Thakur and Xu (2004), there are over 50 pathogens parasitizing apple plants in different parts of the world. However, only a few of them are responsible for causing serious damage to the apple crop. Key pests can be determined using several factors (i) the potential for economic damage (ii) the relative amount of management needed (particularly chemicals), and (iii) the availability of some form of alternative management technique (use forecasting and monitoring systems to increase lead time for control decision and actions). For apple, we established a list of major pests and control recommendations using a strict, calendar-based schedule might make from eight to 10 fungicide applications for a number of diseases, four to six insecticide-miticide applications for several arthropod pests. The most prominent among these are Powdery mildew, Apple scab, Phytophthora root, crown, and collar rot, Apple blotch, Canker, White root rot, Fly speck, Sooty blotch, and Replant problem. In India, there are several research and educational institutions that provide research-based plant disease information and advice to the apple industry. Perhaps the most prominent and best known of these is GBPUAT (Singh and Kumar, 2008).

Powdery Mildew

Powdery mildew is the most important disease of apples worldwide and occurs in every country where the cultivated apple (*Malus domestica* Borkh) is grown. The disease is usually sporadic but occasionally assumes a destructive form under favorable environmental conditions leading to an unimaginable loss in apple production. Loss from apple powdery mildew over a period of years is greater than that from any other diseases of apple. Economic damage from powdery mildew in bearing orchards results from reduction in tree vigor and blossom bud production, aborted blossoms, and fruit russetting (which results in a loss of grade and value). Severe infection can reduce trunk growth, amount of bloom, fruit size, crop weight, value and almost eliminate the crop in the following season. In Uttaranchal Himalayas, apple mildew was an endemic problem in certain cultivars of apple but its incidence has increased in other cultivars also. The disease appears on apple every year and causes stunted trees with reduced vigor, apple production, fruit quality and weakening of the terminal shoot/ trees by attacking the twigs, flower, young leaves, fruit and growing tips of the trees.

The powdery mildew was observed in all the areas of Garhwal and Kumouan Himalayas. The incidence was varied from 10 to 80 per cent in grown up trees. The incidence of the disease even on the same cultivar varied from place to place. In nurseries at Hort. Block, Ranichauri, the disease incidence was maximum and ranged from 30 to 100 per cent. The incidence was more severe in apple seedlings and was less in young grafted plants.

Symptomatology: Powdery mildew pathogen was appeared on mainly apple leaves, shoots and blossom buds. The disease damages both the nursery and the mature trees, reduces the vegetative growth, destroys flower buds and produces die-back symptoms under severe conditions. On the leaves, it first became noticeable in the form of small, irregular white or grayish cobwebby patches. These patches appeared first on the under surface of the leaf and gradually spread until both surfaces were entirely covered. Leaf infection was evident as soon as these emerged from the bud and the fungus spread progressively to newly produced leaves. At first small blisters appeared and then the edges gradually curled inwards until these were markedly distorted. Later these became brittle and had scorched appearance. Finally the colour changed to bronze. As the flower buds are destroyed, the crop is reduced in successive years. Infection spread from the leaves to the petioles and to young shoots. The fungus continued to develop on the shoots until these became silvery white. Fruit size is reduced and russeting symptoms are produced.

The Pathogen: Powdery mildew, caused by *Podosphaera leucotricha* (Ell. And Ev.) Salmon., is a serious foliage disease of apple trees and ranks next to scab. This disease was first noticed in 1871 on apple seedlings by Bessey in the United States. In India, powdery mildew disease was first reported by Butler from Kashmir in 1919 and its outbreak was noted by Koul (1957). Now, it is known to occur in the entire apple growing areas of the country. Powdery mildew pathogen overwinters as fungal mycelium in the buds infected the previous year. In the beginning the mycelium colour was white on all plant parts, but later in the season the colour changed to grayish-white in older pustules. Airborne conidia produced during the spring by overwintered infected buds initiate infection. Secondary infection occurs through the summer until vegetative growth stops.

Life Cycle: Powdery mildew fungi require living plant tissue to grow. It survives from one season to the next as fungal strands in buds infected the previous year. The fungus overwinters as mycelium in infected buds or as cleistothecia on the surface of infected twigs. The infected buds and terminals are more susceptible to cold injury, and it may be silvery-gray in color, stunted, and misshapen. When the buds open in the spring, the mycelium grows on emerging leaves, shoots blossoms, young leaves, and fruit. The mycelial growth produced on infected tissue consists of thousands of tiny spores, called ―conidia". The optimum temperature for infection is between 20 to 36°C and relative humidity between 56 to 100 per cent is necessary for the germination of spore. The production of conidia on over wintering mycelium initiates the primary infection. These conidia infect young leaves, blossoms, and fruit which in turn play a role of secondary inoculums as and when leaves, shoots, and fruits develop. Powdery mildew is favoured by moderate temperature (12-26 °C), high relative humidity and do not require moist conditions to establish and grow. If the leaf surface is wet, the pathogen is not active. Conidia are disseminated throughout the orchard in wind currents and water splashes. Once the disease begins, it is a potential threat throughout the season. New leaves and shoots are more susceptible to infections than older leaves. Symptoms may develop as early as 5 days after infection. Numerous secondary cycles can occur under favourable conditions and, like many powdery mildew, cooler temperatures rather than relative humidity drive early secondary infection. Fruit infections were starts from early stage of fruit development, but russeting is only visible when size increases fruit and fruit begins to colour. Apparently, infection of lateral and fruit buds occurs within one month after they are formed. The infection remains latent until budbreak the following spring where they will serve as the initial source of inoculums. The lateral buds are susceptible to infection longer than the terminal buds, however, it is the terminal buds that are the likely source of overwintering of the fungus as infection can be greater than 50 per cent by terminal bud set.

Apple scab

Scab is not a new disease as it was recorded as early as 1819 in Sweden by Fries. The disease is severe during cool, moist spring and summer season but is almost absent in the dry and warmer areas. The disease was first detected in 1935 in Ambri variety in Kashmir, 1977 in Himachal Pradesh at Mauhli village and 1987 in Uttarakhand at Gangotri valley on about 35000 apple plants, and soon after in the same year at Purola-Naugao fruit belt were also infected. Yield losses during epidemic years can go up to 70 per cent or even more. It occurred in epidemic proportion in 1996 and 2008 in the Gangotri valley (Uttarakashi) of Uttarakhand resulting in a loss of up to Rs. 1.25 crores and 74 lakhs, respectively (Singh and Kumar 1999, 2004, 2007, 2008, 2009; Singh, *et al*. 2010). In 1996, the government had taken decision to purchased scab infected apples @ Rs. 2.00/ kg and destroyed on the spot. In 2008, scab has made nearly 23 per cent of the apple crop unfit for either market consumption or processing (Singh and Kumar 2009, Kumar *et al*. 1998, 1999). The losses due to disease result from reduction in fruit set due to attack on flower stalks, pedicel infection and early fruit infection cause premature fruit drops, spoil the shape and appearance of fruits, impairs the keeping quality of fruits, scabbed fruits encourage more storage rot, less Co_2 assimilation, restricted leaf growth, premature defoliation, stunted or reduced growth of young infected plants, high expenditure on pesticides, sprayers and spray operations and ancillary industries like sawmills and transport badly affected.

The symptoms occur both on foliage and fruit are most common but less distinct on the twigs. The first symptom of scab appears on the undersides of new leaves as olive green spots which become progressively brown and velvety in appearance. Later, the velvety surface disappears, the lesions appear metallic black in colour and may be slightly raised. Severely affected leaves may become dwarfed and curled and may later fall off prematurely. Individual infection appear as rough, circular, brown to black olive green spot which often appear slightly fuzzy or velvety in texture. Lesions along the veins or margins often cause affected areas to distort or crinkle (Singh and Kumar, 2005, 2008). Primary infection are usually limited to one or two distinct spot per leaf, whereas secondary infections are often much more numerous and covered the entire surface of the leaf areas. Twig and blossom infection appear as small scab spots, but at most places they are uncommon and of little importance. Lesions also develop as olivaceous spots on the pedicel.

The scab spots are usually more definitely defined on the fruit. The infections may occur on fruit of any age or size. The lesions on young fruits initially very small and they usually enlarge more slowly but turn brownish black and become almost black with the passage of time. Older lesions become bare, brown, and corky in the center as the fungus dies. Several lesions may join together and fruit become distorted and may cracks through and around the lesion. Cracking occurs because diseased skin cannot keep pace with the growth of the underlying flesh. Early lesions on fruit occur near calyx end, and stalk end lesions occur later. It has been observed that most of the lesions are at the stalk end as this part holds water which is favourable for germination of the spores (Singh and Kumar, 2005, 2008). Severely affected prematurely fruit may drop to the ground.

Disease Cycle: The disease has two distinct phases, i.e. saprophytic (perfect stage) and parasitic (imperfect stage). In winter, the fungus over-winters in infected dead apple leaves which lying on the orchard floor. During autumn, the fungus begins to form tiny fruiting bodies, which start to develop within the pseudothecia by late winter and probably continue to grow during warm period in the early spring. The ascospores continue to develop and mature in spring when weather conditions become favorable. A few ascospores in the pseudothecia are usually mature at the time of bud break (green tip), and maturity progresses slowly until about the tight cluster stage of blossom development. Most of the ascospores have matured by the end of bloom and forcibly discharge the ascospores into the air. All the pseudothecia and asci do not mature simultaneously.

Some may shed the ascospores before the apple buds start to open in the spring, however, most of the ascospores in the perithecia mature in the period during which the fruit buds open. When dead leaves containing perithecia become thoroughly soaked in the spring, the asci elongates, push through the ostiole, and discharge the ascospores forcibly into the air and are being carried through the air currents on to the susceptible host tissues. Ascospore discharge may continue for 3 to 5 weeks after petal fall. The maturity of ascospores is slow at 4-7°C but it is faster at 12-16°C, with an optimum at 20°C but beyond 24°C their formation ceases. Ascospores are blown to nearby trees by wind currents. The ascospores can germinate in a film of water on the surface of leaves and cause infection only when temperatures ranging from 10 to 18 °C. Thus, for infection the spores must be continuously wet for 28 h at 6°C, for 14 h at 10°C, for 9 h at 18-24°C, and for 12 h at 26°C. Upon germination on an apple leaf or fruit, the ascospore produces a disklike appressorium from which a slender mycelia tube pierces the cuticle, and after developing into a hypha of normal diameter, it grows between the cuticle and the outer cell wall of the epidermal cells. For a few days after infection, the epidermal cells show no injury at all, but by the time the lesion appears these cells show a gradual depletion of their contents, and they eventually collapse and die. Soon the palisade and later the mesophyll, cells exhibit the same reactions, while the fungus still remains largely in the subcuticular position. The parasitic stage invades the current year growth, which later reproduces countless number of secondary or summer spores. With the establishment of mycelium in the host, it produces enormous number of conidia which are pushed outward by rupturing the cuticle and form olive-green, velvety scab lesions within 8 to 15 days. Conidia remain attached to the conidiophores in dry weather, but upon wetting during the rains these are easily detached, and may be washed down or blown away to other leaves or fruit on which they germinate and cause infection in the same way ascospores do. Additional infections by conidia continue throughout the growing season following a rain of sufficient duration. Infection, however, are more abundant in the cool, wet periods of spring and early summer and again in the fall and in frequent or nearly absent in the dry hot summer weather (Singh and Kumar, 2005, 2008). This stage is more often known as secondary infection which is responsible for epidemics.

Epidemiology: For the development of the disease in large proportions four factors must become congruent viz., susceptible host, potential inoculum, favourable environmental conditions and the man. *V. inaequalis* completes the two phases during one annual disease cycle. Asexual phase in which it is a parasite on leaves, shoots, and fruit of certain species during the growing season and the sexual phase in which it is a saprophyte on fallen infected leaves. The pathogen normally survives the winter as pseudothecia on dead scabbed apple leaves that are lying on the orchard floor. Pseudothecia do not develop on a scabbed leaf until after the leaf falls and dies. Temperature, leaf moisture, time of leaf fall, time of infection, and apple cultivar were major factors affecing development of pseudothecia in Uttarakhand hills. Differences in temperature and moisture conditions after leaf-fall are mainly responsible for the differences in fungal development. As per our experimental results, the leaves falling during early stage (August and 1st week of September) would not contribute much in the buildup of primary inoculum for the ensuing apple season. In Uttarakhand Himalayas, the leaves falling late are likely to have more scab lesions per leaf and pose a greater risk of increasing primary inoculum significantly. The low-medium temperature during February, March, and April was more closely related to development of pseudothecia and time of ascospore discharge than was mean temperature and rainfall during May, June and July preceding discharge. Pseudothecial are produced within 4 weeks after leaf fall and temperature and moisture are the major weather variables that determine the number of pseudothecia formed. In spring numerous microscopic sacs of spores are produced just under the dead leaf surface. Sacs filled with the primary or spring spores of the fungus and produced on these dead leaves at about the time new growth first appears. The pseudothecia mature under Uttaranchal conditions by the end March (Purola-Naugon, Tuni, Koti-Kanasar, Chakrata, Nainbag, Gwaldam, Tal and Talwari), last week of April (Joshimath and Munsiyari) and 2nd week of May (Gangothri fruit valley). Each pseudothecium may yield about 1000-1200 unequally bicelled ascospores. The ascospores continue to develop and mature as spring progresses. Discharge of ascospores is directly dependent on the prevailing atmospheric temperature and continuous wetting of the infected leaves. Short interval intermittent rain or even heavy dew influencing the wetting and drying of the fallen leaves also increases the rate of maturity of ascospores and their discharge, but prolonged or continuous moisture can result in fewer pseudothecia, retarded maturation, or abnormal development. The ascospore maturity and discharge, as have been recorded, are maximum during end of bloom to petal fall stage. Mature ascospores are discharged into the air during periods of rain. In Uttarakhand hills, ascospores discharge season was observed in between three to eight week, respectively (Table 1). The ascospores usually become increases to a peak in May and then decreases during June intermingled with repeated summer spore infections. In daylight, discharge usually begins within 30 minutes after the start of the rain and is largely completed within 3 to 6 hours. When rainfall begins at night, discharge is often delayed until daybreak. On a single leaf there may be nearly 2000 pseudothecia with a total load of about 2 million ascospores. These ascospore discharges may continue for 3 to 5 weeks after petal fall. By the end of June most of the ascospores have been released. Continuous direct sunshine is lethal to spores. Cultivar may influence ascospore productivity, but ascospores mature at the same rate irrespective of the cultivar on which they are produced.

Table 1: Primary infection of ascospore on apple leaves at different place of Uttarakhand hills

Apple fruit belt	Phenological stage of tree and time for primary infection		
	Tree stage	**Time**	**Primary infection**
Gangotri Valley, Uttarakashi (>2500 m asl) Harsil, Dharali, Jhalla, Sukhi etc.	Bloom stage to fruit stage (Pea size)	Ist week to last week of May	Last week of May to 2nd week of June
Auli-Joshimath, Chamoli (2200 to 2500 m asl)	Pink bud stage to bloom and petal fall stage	1st week to 3rd week of May	Last week of May to 1st week of June
Syori-Naugao, Uttarakashi (1950-2200 m asl) (Joshimath, Syori, Koti, Talwadi Gwaldam)	Pink bud stage to Petal fall stage	Last week of March to 3rd week of April	3rd week of April to 2nd week of May
Tal-Talwari, Gwaldam, Chamoli (1750 to 1950 m asl)	Tight cluster to Petal fall stage	1st week to last week of April	3rd week of April to 2nd week of May
Tuni, Koti-Kanasar, Dehradun (1750 to 1950 m asl)	Pink bud stage to Petal fall stage	Last week of March to 2nd week of April	2nd week of April to 2nd week of May

The secondary infection through conidia takes place in an overlapping period of primary infection during spring. Conidia remain attached to the conidiophores in dry weather, but upon wetting during a rain they are easily detached and may be washed down or blown away to other leaves or fruit on which they germinate and cause infection. Free water or even very high atmospheric humidity has a very prominent role in rapid production of conidia. Conidia are then the principal source (up to 1,00,000 conidia in each leaf lesion) involved in the build up of the disease during the summer and early autumn. Conidia develops over a wide range of temperature range between 0-30 °C with an optimum at 16-20 °C and humidity up to 90 percent. Conidia dispersal takes place both under rainy and dry conditions depending upon the wind velocity, and usually it is more in the afternoon.

The Potential Ascospore Dose (PAD): Gadoury and MacHardy (1986) indicated that the potential ascospore dose could be used to forecast the onset of apple scab epidemic in commercial orchards, resulting in reduction of number of fungicidial applications (MacHardy 1996). Accordingly, we have studied different inoculums levels (PAD) under Indian conditions, where reduced spraying can be tolerated. The potential ascospore dose (PAD = LD x LLD x PD x AD x n) for each orchard was the product of the lesion density (number of lesions on leaves per square meter of orchard floor at leaf fall), leaf litter density (proportion of the orchard floor covered by leaf litter at bud break), pseudothecial density (number of mature pseudothecia / visible lesion multiplied by a lesion fertility factor), ascus density (number of asci /pseudothecium) and number of ascospores / ascus. To evaluate PAD, estimation of scab lesion on leaves / m^2 of orchard floor at leaf fall, percent shoot and fruit with scab were done during 1994 to 2012 at Harsil of Distt. Uttarakhasi. The PAD varied from year to year in the various orchards. The PAD in the spring has a great impact on disease development in the following growing season (Singh *et al.* 2015, Singh *et al*. 2016).

Degree days: Gadoury and MacHardy (1982) made a model to estimate the maturity of apple scab. They reported 95% spore maturation after 477 degree days. The ascospore discharge of 50 and 95% were reported after 498 and 900 degree days in South Africa. In Finland, the end of the primary inoculums period varied between 328 and 690 degree days in between 10 years of observation (Ylamaki, 1989). Stensvand *et al.* (1992), in Norway, found 50 and 95% ascospore discharge after approximately 250, 400, 350 and 600 degree days in 1989 and 1990.

At the G. B. Pant University of Agriculture, Ranichauri in India, the ascospore discharge data accumulated over fifteen years was plotted against the accumulated number of degree days from the date of first ascospore discharge. Degree days and ascospore maturation were released using standard regression analysis. A sigmoid curve (high-low values) was obtained when accumulated degree-days were plotted against cumulative per cent discharged ascospores. The curve was considered to occur in three identifiable phases i.e. lag phase, accelerated phase and final phase, is used in the apple scab management program of Uttarakhand. The slow buildup of matured ascospores during lag phase relatively easy to control with fungicides (Post infection strategy). At the time of accelerated phase, the crop is potentially at high risk, if proper control is not exercised. Protectant or post infection strategies can be employed, but a protectant schedule is usually preferred, especially if scab was not managed well during the previous year. The final phase is significant it identifies the end of the primary season, emphasis is placed on selecting on scheduling fungicides to control other diseases if scab is not observed. Cumulative degree-days were computed from daily maximum and minimum temperature values and base temperature of 0ΊC was used for all degree-day calculations. Degree-day accumulations were started at the date when the first ascospores were discharged. The mean number of cumulative degree-days for 50 and 75 per cent ascospore discharge were following degree-days (Table 2).

Table 2. Degree-day for primary infection of scab in different places of Uttarakhand

Apple fruit belts	Required degree-day for cumulative ascospores maturation (%)	
	50 per cent	75 per cent
Harsil, Uttarakhasi	899.5	1080
Sukhi, Uttarakhasi	557.2	842
Syouri, Uttarakhasi	286.7	456.35
Koti-Kanasar, Dehradun	278.45	412.25
Tal-Talwari, Chamoli	480.15	587.75
Auli, Chamoli	603.45	983
Joshimath, Chamoli	338.6	493.7

Mill's information: The Mills curves published in 1944, were the first attempted for correlation between the prevalent temperature and leaf wetting requirement for light, moderate and heavy scab infection forecasting to help growers for time of the application of fungicides for apple scab management. This Mills table is being determined when infection periods occur and tested for the appearance of primary scab under orchard conditions throughout the world, as such. The interpretations of this table found that the minimum leaf wetness required for ascospores infection was 9 hours and for conidial infection 5.9 hours and symptoms expression would take place within 9 days at optimum temperature range of 18.2-23.8^{0}C. The observation again indicated at 10°C, according to Mills table, the time needed for symptoms appearance was 16 days. However, in our result shows 5 to 8 light infection periods occurring each year during the month of April and May which could initiate primary infection and time required for symptom expression was 9 to 14 days under prevailing temperature conditions (Table 3). Whichever the infection time was more than practiced (1 to 4 days) as mentioned in Mills table. Six to eight moderate infection periods were recorded in each month during 1990-2012 and almost all indicated delay by a day in symptom expression (1-3 days) under orchard conditions. The third criteria as described by Mills was severe infection period, 2 to 5 infection periods were observed in most of the month at an average temperature (11.4 to 15.2^{0}C) and leaf wetness (23.4 to 27.2 hr) period and indicated 1 to 2 days delay in symptom expression. However, our observations indicated 2 – 3 day (for light infection), 1 – 2 day (for moderate infection) and 1 day (for severe infection) delay in symptom expression under orchard conditions in Gangotri valley 2 day (Light) 1 day (Moderate) and 1 day (Severe) delay in symptom expression under orchard conditions (Singh *et al.* 2016).

Table 3. Mills table and our University data to arrive at incubation period based on temperature and leaf wetness.

Average daily temperature (^{0}C)	Minimum wetting hours of leaves for infection (approx. hours)*		Days required (after infection for symptom appearance)
	As per Mills table	As per Univ. data	
25	11	9	
16&24	9	6	9
15	10	8	12
14	10	8	13
13	11	9	13
12	11-5	9	14
11	12	10	15
10	14	13	16
9	15	13	17

*The infection period is considered to start at the beginning of the rain

Scab predictive and warning service in Uttarakhand hills: Apple scab forewarning service carried out under NATP, ICAR, UCOST and NAIP project is being followed in Uttarakhand hills. Such forecasting, which usually begins in the early spring, predicts the time when initial disease may develop and when the threat of primary scab is over, and helps the orchardists in efficient use of spray chemicals. Ascospores emanating from the pseudothecia on the overwintered leaves in the spring from the main primary inoculums in most of the apple growing regions of the world. The maturity and discharge of these spores usually coincide with the pink bud to petal fall stage of the tree. Our experimental sites located at Harsil, Purola, Tuni, Koti-Kanasar, Gwaldam, Joshimath, Auli, Bona, Mukhtheswar, Ramgarh and Almora of Uttarakhand collect systematically all this basic information and issue the forecast under above said project. Ascospore dose measures the actual inoculums concentration in the orchard air at different stages of host phenology and this is dependent on, (i) ascospore productivity and, (ii) factors that influence spore release i.e. air temperature, light, time of days, climatic date, and leaf wetting by rain/dew. Numbers of traps are available for monitoring of ascospores dose in the air. Studies by large number of workers provide ample evidence of ascospore maturity coinciding with the dormancy break of apple trees. The percentage of coloured spores increased week by week until about bloom to early petal fall stage of ‗Delicious, cultivar and then diminished in Uttarakhand hills. Much reliance is given for spray programme commencing at Green tip to early petal fall stage of apple trees, and continuing the fungicidal spray at short intervals until the primary scab season is over. Such protective spray in the form of SAT (single application technique) or RSAT (reduced doses in SAT) are commonly practiced in several countries. Looking into 20 years data on tree phenology at Garhwal hills, is confident of utilizing tree phonological stages in developing a predictive equation for improving chemical control strategy (Singh *et al.* 2015, Singh *et al*. 2016) .

In Uttarakhand, apple scab predictor and µMETOS were able to predict infection periods correctly as tagged leaves showed new scab lesion accordingly. The Revised Mill's Table indicate the minimum number of hours of continuous wetting periods required for primary infection of apple leaves by ascospores of *Venturia inaequalis*.. Some ascospores are discharged at night or rain begins after sunset, so hours of leaf wetting should be computed from sunrise. For all other events, times should be computed from start of rain. Singh and Kumar (2009) developed a linear statistical model based on the accumulated degree days from the maturation of ascospore and PAD. The development and computation of mathematical models or predictive equations, and automatic monitoring of weather data for apple scab, majority of the orchardists in Garhwal hills and several other places of India still rely on initiating the first spray at green tip to early petal fall stage in spring, and following a 10 day spray schedule thereafter till the primary scab season is over. The above information collected from experimental sites on the infection period is passed on to the orchardists by blowing a characteristic signaling, telephonic communication, SMS, local news paper, Govt. organization and through personal contacts or messages flashed 4-5 times through ―All India Radio, Nazibabad" on the urgent need to undertake immediate spray or to reschedule already recommended spray programme. Such forewarning has benefited the grower in minimizing damages due to scab and also reduce fungicide usage (Singh *et al.* 2015, Singh *et al*. 2016).

Apple blotch

In 1995, an unknown disease characterized by severe defoliation of spotted leaves in midsummer was detected in 40 per cent orchards of Shimla district which spread to 90 per cent orchards in the state covering the entire four apple district in 1996. Amazingly, apple blotch burst out in Uttarakhand as well during 1996. It was recorded from Syori in Purola-Naugao and also from Gangotri valley in the same year. The survey team of GBPUAT, Ranichauri visited hilly areas of the state during 1998 detected the prevalence of apple blotch in most of the apple orchards of Uttarakhand as well. By 1998, about 70 per cent orchards in Syori and Gangotri valley had blotch infection. In Uttarakhasi district in additions to Tehri, infection was noticed in Harsil, Sukhi, Barkote, Koti-Kanasar, Arakote, Nainbag and Joshimath area and covered almost 26 per cent hectares. By 2000, about 36.38 per cent orchards become infected in Garhwal Himalaya. Disease severity was maximum (30-40%) in and around Naugaon-Purola and Chakrata where majority of leaves and fruits were affected.

Apple blotch occurs every year wherever apples are grown in India. It is known as premature leaf fall problem of apple in Uttarakhand, is caused by a fungus *Marssonina coronaria* (Ell. et J.J. Davis) J.J. Davis Syn. *Marssonina mali* (P. Henn.) with (Perfect stage, *Diplocarpon mali*) resulting in mid-season defoliation. The fungus infects leaves and fruit of apple. Dark brown patches develop on upper surface of leaves varies from 5-10 mm diameter typical blotch symptoms. Area around these spots become pale, the entire leaf soon turning yellow drops off prematurely. The yellowing advances towards petiole end and induce mid season defoliation. The blotches started its symptoms on the upper side of the leaf first in the 2^{nd} week of June and increase rapidly up to 2nd week of August irrespective of the weather conditions. However, the disease symptom on leaves followed by temperature above 18^0C and relative humidity above 75 per cent continuously for week, induce yellowing and defoliation process. In excessively humid conditions, the lower portion of the tree is defoliated within few weeks and only fruits are seen hanging on the naked branches. The mid-season defoliation may be responsible for poor growth and development of fruiting buds and result into low productivity in ensuing year. The disease also attacked mature fruits showing 3-5 mm diameter circular dark brown spots. Dark coloured pinhead like structures (acervuli) were visible in the necrotic areas on both leaf and fruit. The fruits hanging on the defoliated branches are exposed to direct rays of sun and become prone to sun scald thus affecting both the yield and quality adversely. Fruit bearing capacity of trees is also reduced in the subsequent years.

The fungus overwinters in the form of apothecia on fallen leaves. Primary infection is caused by ascospores produced on the overwintered leaves. The ascospores discharge begins during spring season but causes infection at a particular leaf age stage. Prolonged hot and dry weather affect the primary infection and disease conditions adversely. The disease first attacks plants growing in shady and high moisture conditions. It is severe when a cool, rainy period of a week proceeds several hot sunny days in the orchard. The inoculums of the disease get released at the pink bud stage but it causes the infection only at a particular leaf maturity stage when plant starts physiological process. The pathogen therewith the hormonal change induces yellowing and abscission of the leaves and defoliation occurs. In favorable weather conditions the leaves start defoliation within week whereas under unfavorable conditions the infected leaves could retain up to three months.

Canker disease complex: Canker is a diseased area on the stem or branch usually well defined this often results in the death of the bark within infected area. Stem and branch cankers cause huge losses through girding of branches, limbs and die-back of twigs resulting in death of plants. In north-west Himalayas, thirteen different cankers have been recorded so far and six of them namely, *Botryobasidium* (*Corticium*) *salmonicolor* (Berk. & Br.) Venkatarayan), *Botryosphaeria dothidea* (syn. *B. ribis*), *Coniothecium chomatosporum, Nummularia discrete*, *Sphaeropsis malorum* and *Chondrostereum purpureum* were found to be most prevalent. Pink disease starts primarily from the forks of thick branches and spreads on both sides of branches (upwards & downwards). Sunken, dull brown lesions are formed on bark of the trunk, branches and twigs. The mycelium remains superficial and transforms into pinkish incrustation during rainy season. The bark becomes minutely broken by numerous small protuberances consisting of white or buff coloured fungal structures. Later, these spread into star shaped openings and expose the pale or pink to salmon coloured blisters. The lesions which are exposed to bright light, develops orange red blisters which burst through the bark. Improperly cultural practices, warm weather, and high relative humidity cause overcrowding of branches and shoots, encourage the spread of the disease. Stem brown appears as brown, depressed spots around pruning cuts or insect injuries in summer. Usually these spots develops on sun burn or wounded surfaces of limbs and twigs as small, sunken reddish brown lesions with purplish margins. Sometimes the infected bark turns into blisters exuding a watery liquid on the surface of the lesions. By the following spring season a few pimple like elevations were develop on the bark of the lesion, consisting stromata or the flesh of the fungus (pycnidia) underneath. The bark becomes tan to burnt orange or brown, wrinkled, papery and easily flakes-off. The shoots above the cankered lesion show dieback and become wrinkled. The infected wood below the bark turns dark brown, slimy and gets cracked. It may produce an alcohol like smell. Large branches which have been girdled and may also be dieback. Stem black disease produces a jet black streak in a conical fashion and slowly surrounds the whole branch. As the stripe develops it slowly surrounds the branch. The infected branches raised blisters are formed which later become dry. Long vertical cracks contains black powder develop in the bark resulting in blackening of branches which later die. In the advanced stage canker is formed which may kill the branches beyond the affected area. The nail head canker appeared in bark and wood, slightly sunken, semicircular to V-shaped with healthy tissue scattered within the diseased area. The inner bark of freshly diseased tissues develops cream colored irregular patches alternating with brownish areas particularly along the margin of cankered portion. The smooth surface of the bark develops numerous star shaped blisters consisting of honey colored conidial masses. The surface of the cankered area becomes rough and exhibits several black, disc shaped areas which resemble thick heads of old fashioned iron nails. These are stromata of the fungus and commonly termed as ―Nail Head". They extend from wood to slightly above the surface. The invaded bark becomes brittle and black, and sloughs off easily in small chunks exposing the dead wood.

Cankers should be removed from the orchard, to reduce inoculums concentrations. Leaf scars should be protected with fungicides. All dead, injured and diseased-shoot must be removed and an overcrowding of shoots should not be allowed. Diseased portion should be well cut beyond the extent of infection. Application of Bordeaux mixture just prior to autumn rains and at the onset of leaf fall provides adequate control of the disease in north-west Himalayas. Scarification of the cankered portion, washing with sprit or mercuric chloride and application of fungicidal paints like Bordeaux, Chaubattia, Blitox, and Benomyl paints, and Cowdung paste are recommended to highly effective. Effective schedules have been developed for controlling important canker diseases

Sooty blotch and Fly speck

Sooty blotch and fly speck typically occurs together on the same fruit in most years with the onset of rains in late summer, and then increase in severity in the foggy weather and high humidity from July to September. This disease is found on late maturing varieties and under storage conditions. None of the commercial cultivars is resistant and Golden Delicious, Winter Delicious, Granny smith, Coxs Orange Pippin, Yellow Newton, Buckingham, Rymer, and Jonthan are highly susceptible. It is caused by two different fungi. Sooty blotch, caused by *Gloeodes pomigena* (Schw.) Colby, gives a smudged or sooty appearance to affected fruit which can be easily removed by rubbing leaving behind slight depression. They do little or no actual damage to the fruit, but their presence on the fruits surface lowers quality and the subsequent market value. The fungus survives from one season to the next as mycelium and dark minute pycnidia connected by loose, profusely branched, thread like fungal growths. The colonies appear as shades of olive green on mature fruit. They vary from discrete almost circular colonies to large colonies with diffuse margins, which are sooty in appearance. The large amorphous colonies that cover large portion of the fruit surface result from secondary spread on the fruit. Apparently, conidia of these fungi were aerially disseminated in orchards from spring until fall. Most conidia are liberated by early summer, but extensive secondary spread by chlamydospores and mycelia fragments occur throughout the seasons. Low temperature and rains during the months of June and July are necessary for disease development. The disease is more prevalent in orchards where fog, heavy dews, and shady area are common through the mid-to-late growing season. Consequently, this disease may be entirely absent during seasons when hot, dry weather prevails until harvest.

Fly speck is caused by *Zygophiala jamaicensis* Mason and *Microthyriella rubi* Petr. This fungus appears like true fly specks, but actually consists of definite, circular, black, often glistening spots on affected fruit. These spots occurs 10 to 50 in a group, scattered widely and larger in size than sooty blotch pycnidia. The spores are airborne for considerable distance, and initiate primary infections on newly developed plant parts. Five to 15 days are required for symptoms to develop on apples under cool, moist conditions. Growth of *Z. jamaicensis* occurred over a temperature range of 40-80^{0}F. Colonies are characterized by well-defined group of 6, 8 or sometimes 50 shiny, black, superficial pseudothecia on the surface of the fruit. This disease is found abundantly during rainy days and in less windy regions. Sooty blotch and flyspeck colonies commonly occur on the same fruit, but the colonies are mutually exclusive. These fungi occur superficially on the apple and can be removed by vigorous rubbing.

Pruning is the most important cultural practice for improving air movement and reducing drying time in the tree canopy. The combination of good dormant and summer pruning will aid greatly in controlling sooty blotch and fly speck. Dr. Floyd Hendrix Jr. (Georgia) has shown that a 5-7 minute dip in 500 ppm chlorine in the dump tank of a commercial packing line, followed by brushing and a fresh water rinse was effective in removing both diseases from apple fruits. Generally, recommended spray schedules in apple growing areas call for fungicide control of sooty blotch and flyspeck to start with the second to fourth cover spray, and continue until harvest. Both fungi are active during humid, cool spring weather, but may be entirely absent during hot, dry, summer weather. Singh and Kumar (2005) reported captan, thiram, and zineb controlled sooty blotch when applied at 14 days intervals. Dodine gave outstanding control of *G. pomigena* and Z. *jamaicensis* under severe conditions.

White root rot: The main causal organism of white root rot in India is *Dematophora necatrix* Hartig (*Rosellinia necatrix* Prill.) in apple tree has been increasingly imposing problem and resulting in the death of plants. The rainy season in the apple zone is during June to September, when also a higher incidence and severe symptoms of root rot are observed, indicating that the disease spread and severity are related to excessive soil moisture regimes. The higher elevation range was observed favourable for the spread of root rot being high rainfall area and low temperature conditions prevailing for long durations. The disease symptoms occurs on lateral roots, which turn into dark brown colour and become infested with white flocculent fungus during monsoon months. The earliest above ground manifestation of the disease is bronzing of the leaves, stunted growth and size. There is progressive decline in foliage and twig growth. Root rot affected trees are usually associated with a heavy blossom and fruiting next year, however in succeeding years, few leaves emerge and much of the immature fruits induce early colouration and fail to reach maturity. Severity in years leads to die-back/drying of twigs and branches. The fibrous roots are completely killed, and the tree dies as cortical and phloem cells are ruptured, which disrupt the translocatory system. The disease produces a white cottony thread like growth can be seen in the soil and roots during rainy season. The ascostomata of *Rosellinia* root rot are superficial, ostiolate, often as dense swarms on a common mycelia mat or subiculum, subglobose, smooth and dark. Ascospores are pigmented, aseptate, often with a minimum hyaline appendage. The disease symptoms occur on the underground parts of the tree but the effects are also manifested on the above ground parts. Infected trees often persist for 2-3 years depending upon the infestation of the fungus. In upland regions, the disease was prevalent on shallow soils overlying stony subsoil.

Collar rot: The disease is caused by the soil borne fungus *Phytophthora cactorum* (Lebert-Cohn) Schroet, are a chronic problem in northwest apple orchards, affects pome-fruit trees in heavy and poorly-drained soil. In gangotri fruit belt, the fungus has caused, in addition to collar rot, severe fruit rot, particularly in Delicious and Red Gold grown as dwarf trees. The attacked trees are recognized by chlorotic foliage with red colouration of vains and margins during rainy season the foliage takes purplish red colour. Collar rot is especially severe on trees that are grown on MM 106 rootstocks in clay-loam soil. The infection starts from the collar region and spread just below the soil level. The disease increases when the temperature is above 25^0C and the soil moisture is high. Drooping of foliage in the apical region of the twigs, loss of turgidity, blighting of emerging foliage and blossoms are the initial symptoms observed in bearing apple trees. At the base of the tree where the rot has penetrated, irregular shaped lesions from on the bark which look moist, soft and spongy. The bark at the soil level become slimy and rots resulting in cankered areas. If the bark is cut, the lesions underneath it show an orange brown colour with light and dark brown characteristic stripes. The wounds are irregular in outline but usually roughly oval which extend rapidly, often resulting in girdling of the tree. The infected tree begins to decline a few years before they die. The pathogen survives in the soil in the form of oospores and as mycelium in the infected wood. The oospore gives rise to sporangiophore, which bears sporangia. The sporangium first develops at the tip of a branch. As soon as it is mature, the tip swells slightly, proliferates, and turns the sporangium to a side as elongation of the branch proceeds. The sporangia are multinucleate, thin walled, hyaline, oval shaped with definite papilla at the apex. These sporangia may germinate directly by means of a germ tube, but most commonly the contents of the sporangium cleave to form a number of zoospores which emerge through the papilla and swim away. The zoospore are biflagellate, one flafellum possesses fine hairs while the other does not. After a few minutes of activity the zoospores lose their flagella, come to rest, and then germinate by a germ tube which penetrates the epidermis of the host directly or through stomata. Zoospore production occurs at temperature below 20^{0}C, whereas at higher temperature the sporangia behave as conidia (Singh and Kumar 2005, Jindal *et al.* 1990).

Crown Gall: The disease was observed in early 1940's by Singh (Jindal *et al.* 1990) on pome fruits in Kumaon hills of Uttarakhand, Punjab and Kashmir. Crown gall caused by *Agrobacterium tumefaciens* (Smith and Townsend) Conn. (Syn: *Rhizobium radiobacter* (Beijerinck and vanDelden) Young *et. al.*) causes huge economic losses around the world in pome and stone fruits nursery plants making seedlings unfit for further plantation in orchards. The formation of tumours or gall of varying size and form characterize crown gall. The disease first appears as small overgrowths or excrescencies on the stem and roots particularly near the soil line. Gall develops on roots, crowns and shoots of various nusery plants, which are thus unsalable because the crown gall is likely to continue on plants when they are planted in orchards and gardens. In early stages of gall development the galls are more or less spherical, white and soft. Gall varies in size from microscopic to more than 30 cm in diameter and can appear as big as 150 cm in diameter on the stems, branches, petioles and leaf. The galls reduce root development and plant vigor, galled plants in nurseries remain stunted and show chlorotic leaf growth. The plants with tumors are unsalable as their crowns or their main roots grow poorly and resulted in reduced yield and ultimate death of plants. The galls originate in a wound, at first they cannot be distinguished from callus, and however, development of these galls is more rapid than callus. As the tumours enlarge, their surfaces become more or less convoluted. Later on the tissues become dark broen or black, due to death and decay of the peripheral cells. Sometimes there is no line of demarcation between the tumours and the plant proper, the tumours appearing as an irregular swelling of tissues and surrounding stem or root. A pathogen *A. tumefaciens* incorporate its tumour inducing principle (TIP) in host genome and modify host cells. Incorporation of bacterial genetic material (tumour inducing plasmid) in the host genome makes the bacterium a genetic parasite, which hampers the prospects to develop resistant cultivars against this disease (Gupta *et al.* 2009, 2010).

Replant disease complex

Apple replant disease is a complex malady characterized by suppressed growth of young tree at an old orchard sites. The cause of this disease is largely unknown. Fungi, bacteria, nematodes, and nutritional factors may all play a part in this complex disease.. The major causes of replant disease complex involve both abiotic and biotic factors. The disease is characterized by slow growth of apple trees planted in the same spot where an apple tree grew previously by both abiotic and biotic factors affect the plant, is consider as ―specific" problem. However, ‗nonspecific" when old apple sites are planted with other fruit specific. Among abiotic factors related to soil conditions like nutritional deficiency (phosphoric ion), pH reaction and accumulation of phytotoxins. However, biotic agents are various types of microorganisms present in the soil include fungi, bacteria, actinomycetes, and nematodes. The associative actions of these microorganisms decompose old plant root system and release various types of toxins, which cause inhibitory effect to new plant root development. Only abiotic factors played a role to affect the new plantation growth by starving for nutrients deficient in the old plantation sites. Apple replant disease has no definite symptoms other then stunted growth of trees during the first few years of planting mostly during 2-4 year of planting. However, it depends on the huge amount of the old plant residue at the orchard site. Affected trees leaf out each spring vigorously with little or no shoot growth and correspondingly fewer leaves, which are often smaller and lighter green than leaves on healthy plants. Lateral roots are fibrous and hairy which blocks nutrients uptake causing thereby stunting.

The disease is particularly severe in light sandy soils. Removal of the old soil from the planting hole and replacement with fresh soil high in organic matter is effective in some locations i.e. Gangotri fruit belt. If possible, plant the new trees between the previous sites. Cultivate the soil well to a depth of 20 cm and keep it moist for one week before starting the fumigation. Fumigating the soil with temperatures above 15^0C at a depth of 20 cm in the planting row and seal the surface with plastic or wet the surface layer. At temperatures above 15^0C, leave the fumigant to work for seven days before disturbing the soil. Fumigation before a spring planting is usually done in the autumn and the soil left undisturbed until the spring. Before planting, cultivate the soil to allow the fumigant to escape. Delay planting until the odor of the fumigant has left the soil.

IDM Practices for Key Diseases

In north-west Himalayas, the farmers also face a lot of problems regarding lack of resistant varieties, rootstocks, poor adoption of improved cultural practices, inefficient biocontrol agents and poor availability of biopesticides. However, the apple crop is grown under fungicides umbrella and the IDM strategies are dominated by excessive use of fungicides in our state. There are two major disease of apple (powdery mildew, apple scab) and several minor diseases, notably blotch, canker disease complex, white root rot, collar rot, leaf spots, brooks fruit spot, fly speck, sooty blotch, crown gall, hairy root, and mosaic were common in northwest Himalayas. The Uttarakhand apple IDM program includes monitoring and cultural, chemical, and biological control practices integrated to control the major diseases (Singh and Kumar 2005). Plant pathologists of our University formulated the initial methods, and formal research projects provided the current recommended system. They also provide a picture of diseases, crop, and weather developments in commercial orchards around the state. The premature leaf fall is another new disease that a gaining importance in Uttarakhand. However in HP and J & K, premature leaf fall has established itself as serious disease. Seedling blight, powdery mildew, crown gall, root rot and hairy root remain the serious diseases of apple nursery in all the apple growing states and cause considerable loss. Disease incidence is highest in valley areas where maximum moisture was available during crop season and lowest in dry temperate regions. Several microbial antagonists in apple orchards were available in fallen leaves or tree to benefit the growers by antagonized to the different pathogen species. One approach to biological control of apple scab is to break the overwintering cycle of *V. inaequalis* by preventing the formation of pseudothecia, thus removing the source of ascospores, which are the primary inoculums in spring. Previous studies (Singh 2006) showed that bacteria and fungi isolated from apple leaves can significantly reduce pseudothecial formation in leaves infected with *V. inaequalis*.

The tools of IDM in apple orchards are orchard scouting, good sanitation of the orchard and perimeter, selective chemical controls, biological controls and weather monitoring. Regularly evaluate the disease management program and improve it when possible. The management schedule has been developed that allows flexibility in combining fungicides treatments to control the major disease complex at key points in the season. The broad-spectrum sterol-inhibitor fungicides that have the properties that will maximize the flexibility in timing and integrating pesticide application needed with this approach. Fungicides sprays for apple scab are applied after 12 days during the primary infection season or before predicted rain or after infection periods. Optimal timing of sprays to control other diseases is based on periods of inoculums production or of host susceptibility. As control measures for each disease have been refined, the timing of control measures has become more critical, compounding the problem of integrating disease control schedules. A greater degree of flexibility in timing fungicide application is needed for effective integration of control measures.

Orchard Sanitation: Orchard sanitation practices, collection and destruction of fallen leaves, mummified fruits, dead wood and pruning of diseased shoots/ twigs or other plant parts play a vital role in pest and disease control. The proper pruning of the trees is probably the most important operation in the orchard. Diseased portion should be cut well beyond the extent of infection. Judicious training and pruning help to reduce the canker by not allowing the branches to sun burn. When the trees are open for good air circulation and light penetration, several things happen, reduction of summer diseases (sooty blotch and flyspeck, mildew, scab), improved bud set (next year‘s apples), better quality apples (apples need sunlight to develop the color and sugars). The removal of the dead and diseased wood from the trees, from the orchard floor and the perimeter around the outside of the orchard is also very important. Sanitation practices that reduce the population density of pathogens indirectly by their action on the leaf litter may remove the leaf litter, render the leaf litter unsuitable for the saprophytic and sexual activities of pathogens that occur in dead leaves, or prevent discharged spore from escaping into the orchard air. Phylloplane microflora may interfere with the saprophytic phase of *Venturia inaequalis* and other pathogens indirectly by altering or decomposing the leaf litter. *Athelia bombacina* and *Chaetomium globosum* applied just prior to leaf fall would be beneficial to scab control through its effectiveness in suppressing the production of ascospores and, to a lessor extent, its ability to soften leaves, which would enhance decomposition by microbial leaf decomposers and promote removal of the leaf litter by earthworm. Urea is one chemical that could be utilized to accelerate leaf litter decomposition significantly. Addition of deodar needles, leaves of *Vilex negundo*, *Lantana camara*, cabbage and neem cakes provided 60 per cent control of soil borne pathogens. Soil amendments, dried leaves of *Vilex negundo*, *Melia azadirachta* (seeds) and mustard cakes were also effective in controlling collar rot. Soil solarization and planting of cabbage and garlic were effective against soil insect-pests and root rot and collar rot pathogens. Onion, tegetes, mustard, maize, wheat, and garlic were effective against nematodes and soil pathogens. Different canker causing fungi and gummosis are generally wound parasites. Adopting scientific pruning practices, scarification of dead/ diseased parts during dormancy and wound dressing with protective and organic chemicals. Use of Bordeaux mixture, Blitox-50, benomyl paints and Chaubattia paste help in the management of foliar, soil borne diseases, cankers, and dieback disorder as well as are effective insecticide and plant nutrient. In orchard, digging the basins of the tree with spades during winter (October-November) to expose the soil borne organisms to adverse climate conditions for decreasing the population. Selection of well-drained sites for establishment of new orchards and maintaining graft union above the ground level are important preventive measures for checking root rots and crown gall diseases. Foliar diseases could be checked by timely application of suitable fungicides at vulnerable phonological stages of the tree.

Nursery sanitation is necessary to avoid the introduction of infected material into nursery stock. The practices like destruction of infected plant material by uprooting and burning and rotation of nursery site are also helpful in preventing the disease to some extent. Most infections result from the grafting union so incidence can be reduced by budding instead of grafting. To avoid the dissemination of pathogen, the entire root system of apparently healthy grafted plants should be dipped in 1 per cent copper sulphate solution for half an hour prior to transplanting. Apple nursery raise only in solarised soil for management of all kind of soil borne pathogens and pests. The antagonists should be thoroughly mixed in FYM were used in nursery for controlling soil borne diseases and also providing nutrition to the plants for ideal vegetative growth. Apple rootstocks of M-2, M-4, MM-105, M-113 and MM-114 have been found resistant under field conditions through production of disease in a natural environment. Approach grafting has been recommended for the control of collar rot. Raising the grafting point at least 20 cm above the ground level and improved drainage helps in reducing collar rot. *Trichoderma viridae* or *T. harzianum* @ 0.4 per cent were mixed in soil or drench the soil with thiram 0.3% or aureofungin 0.04% for management of seedling blight. *Pseudomonas fluorescens* at 0.4 percent were mixed in the soil for management of hairy root disease in nursery. The presence of viruses in the mother stock can be tested by highly sophisticated techniques like enzyme linked immunosorbant assay (ELISA) or by biological indexing using indicator hosts.

Niterogenous compounds can have a major effect on the rate and extent of litter decomposition. Urea has several properties which make it a particularly useful chemical for a biological control strategy. When applied post-harvest application of urea to accelerate the rate of leaf litter decomposition directly or indirectly through microbial competition and suppress the formation of pseudothecia and productivity of ascospores (Burchill, 1968, Burchill and Swait, 1977, Gupta and Lele, 1980, Heye and Andrews, 1983, Thakur and Sharma, 1999, Singh, 2006). Stimulation of microbial activity as a consequence of reducing the C:N ratio is one of the reasons for more decomposition following urea treatments. Our study reveals that earlier leaf fall better the decomposition of apple leaf litter after urea treatment during the overwintering stages. The application of urea at leaf yellowing or before leaf fall stage enhances the rate of decomposition and thereby correspondingly affects the pseudothecial maturity as well as production of ascospores, which occurs in the fallen infected leaves, and secondly to its increasing microbial activity on the fallen leaves to an extent that other micro-organisms can compete with the scab-inducing fungus for nutrients and also act antagonistically towards the latter. In addition to complete inhibition of ascospore discharge by 5% urea, such spray was indicative of enhanced yield pattern. Urea reduces the number of pseudothecia in the leaf litter in three ways (Cook, 1969): (i) it creates an alkaline condition in leaves that reduces the number of pseudothecial initials, (ii) it promotes the softening of leaves, perhaps through microbial activities stimulated by urea, resulting in accelerated removal of leaves by earthworms, and (iii) it stimulates the buildup of microorganisms antagonistic to *V. inaequalis*.

Weather Monitoring: Seasonal and environmental influences on apple tree disease are great. Tree development is dependent on degree days. Most of the diseases infections are dependent on temperature and the time moisture is present on the apple leaves. Temperature and moisture are important tools for controlling insects and diseases. Insect development depends on the accumulation of degree days. Some pathogens are only active a certain time of the year. Diseases caused by these organisms are highly dependent on the environments somewhat less dependent on the degree of host stress. Most of the diseases that affect the flower, fruit, and leaves are triggered by excess moisture, so the diseases cause problems in the spring during period of rain, fog, and heavy dew. Some pathogens attack tree roots in the leaf fall, however, symptoms are not visible until the spring when the actively growing tree is unable to take up sufficient water and nutrients. Some pathogens weaken plants year round. These diseases are less dependent on the environment and more dependent on degree of host stress.

Chemical Control: Controlling diseases in apple orchards is difficult once trees are infected. There are no chemical controls available for many diseases, particularly root and crown rots and cankers. Chemical controls are directed at fungal and bacterial diseases of fruit and foliage. Avoid injuring trees, fruit, and beneficial organisms when using pesticides. The choice of which chemical to use can be very important to the population of beneficial insects in the orchard, because some chemicals are more toxic to beneficial insects. Proper application of chemicals is also important, the materials have to be applied at label rate, and otherwise resistance can develop. This has happened in many orchards around the country. Fungicides sprays are necessary only if the weather is rainy and leaves are likely to remain wet for 9 or more hours. Fungicide applications require careful attention to timing, as preventing early infection is the most important step toward successfully controlling later fruit infections. It is difficult to prevent secondary fruit infection once a primary infection occurs. To break the life cycle, single pre-leaf fall spray of 5% urea or other chemicals, particularly sterol biosynthesis inhibitors have suppressive effects on the ascigerous stage of the fungus and consequently allow reduced number of sprays the next summer. Copper compounds used to control fungal diseases may cause russeting on developing fruit. Lime sulphur @ 1: 20 (one litre lime sulphur in 20 litre of water) were apply every year in December or January after pruning, it help in managing powdery mildew, black spots, sooty blotch and stem diseases. The protective spray programme concept developed at College of forestry and Hill Agricultural, G B Pant University Agriculture & Technology, Pantnagar (Ranichauri).

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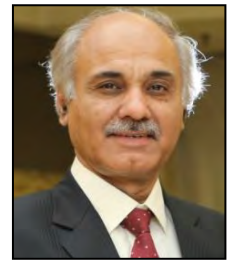
Lead Lectures

Chitosan: A Potential Non Toxic, Biodegradable Polymer for Plant Protection



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Chitosan as a commercial product has found its place in sectors like cosmetics, medicines and agriculture with a wide range of applications, since last three decades. Chitin, the parent material of chitosan is present in waste exoskeleton material of crab and shrimp harvests. Both chitin and chitosan have been reported to possess antiviral, antibacterial and antifungal properties and have found a promising place in plant protection. Those have been utilized for controlling diseases or reduce their spread, to chelate nutrients and minerals, preventing pathogens from accessing them and to induce and enhance plants innate defenses (El Hadrami *et al*., 2010). Chitin and its derivatives promise an alternative treatment to costlier and environmentally unsafe synthetic chemical pesticides due to their natural character and associated activities (Sharp, 2013; Deepmala, *et.al*. 2014). With reduced input costs and potential for increased yields, substantial benefits from applications of chitosan and its oligosaccharides to crops could be harnessed.

Chitosan- Source and Structure

Chitosan gained world-wide attention because it could be derived from the waste products that remain after processing edible crustaceans. Marketable shrimp and crab meats are removed, leaving some residual meat, mineral and chitin (Skjak-Braek *et al*., 1989). Chitosan, the most abundant naturally occurring amino-polysaccharide, possesses many unique physiochemical characteristics and biological activities (No and Meyers, 1997; Rabea *et al.,* 2003). It is a linear amino polysaccharide of glucosamine and *N*-acetyl glucosamine units, and is obtained by alkaline deacetylation of chitin extracted from the exoskeleton of crustaceans such as shrimps and crabs, as well from the cell walls of some fungi. Owing to its high biodegradability, nontoxicity, and antimicrobial properties, chitosan is widely-used as an antimicrobial agent either alone or blended with other natural polymers (No and Meyers, 1997).

Chitosan in plant defense:

Chitosan treatment in plants induces various biochemical and molecular changes in plants such as DNA damage, chromatin alterations (Hadwiger, 2008), activation of MAP-kinases (Yin *et al*., 2010), oxidative bursts (Paulert *et al*., 2010), callose apposition (Kohle *et al*., 1985), pathogenesis related protein synthesis (Loschke *et al*., 1983), phytoalexin accumulation, hypersensitive response (Hadwiger and Beckman, 1980), synthesis of jasmonic acid and abscissic acid and accumulation of hydrogen peroxide (Iriti and Faoro, 2009), and increase in cytosolic Ca^{2+}(Zuppini *et al*., 2003).

Chitosan in plant disease reduction:

Chitosan has potential in agriculture with regard to controlling plant diseases. These molecules were shown to display toxicity and inhibit fungal growth and development. Chitosan is also reported to be active against viruses, bacteria and other pests. Some of the mechanisms which have been attributed to reduction of plant diseases by the application of chitosan (El Hadrami *et al.,* 2010) are discussed below.

a) Direct antimicrobial activity: Chitosan application results in inactivation of virus and viroid replication, which leads to stoppage of multiplication and spread of these pathogens (Kulikov *et al*., 2006). Against, bacteria, fungi, oomycetes and other pests, chitosan is likely to operate indirectly *via* means such as the enhancement of host resistance. However, chitosan, at defined concentrations is also reported to have antimicrobial properties (Sudarshan *et al*., 1992). For instance, chitosan exerts an inhibitory action on the hyphal growth of pathogenic fungi such as *Fusarium oxysporum*, *Botrytis cinerea*, *Monilina laxa*, *Alternaria alternata* and *Pythium aphanidermatum* (Benhamou *et al*., 1992; El Ghaouht *et al*., 1994; Romanazzi *et al*., 2002; Ait Barka *et al*., 2004) besides inhibiting spore germination (Hadwiger and Beckman, 1980).

b) **Blocking of pathogen penetration sites:** Chitosan accumulate around the penetration sites and thus prevents the pathogen from spreading and invading to other healthy tissues as observed in potato tubers (El Hadrami *et al*., 2009). Chitosan application also results in faster wound healing in tissues due to its ability to bind various metals (Hirano *et al*., 1999).

c) **Chelation of nutrients and minerals:** Chitosan is a good chelator of minerals and metals. This property of chitosan has been effectively utilized for the control of plant pathogens as chitosan can chelate minerals (Fe, Cu etc.), and thus helps in preventing pathogens from accessing them (Bornet and Teissedre, 2007). In a recent study it was found that use of Chitosan + CuOH complex could effectively be used for management of various plant diseases since copper is a broad spectrum protectant fungicide. Chitosan on integration with copper ions could prolong protection on plant surface by chelating copper ions and thus could prevent washing off of the copper. While also the anti-microbial and plant defense inducing properties of chitosan could lower the amount of copper dose needed for disease management and thus would result into eco-friendly management of plant diseases (A. Rautela and J. Kumar, 2017; unpublished data).

d) Depolarization of biological membranes: Chitosan triggers, in a dose-dependent manner, a quick and transient depolarization of *Mimosa pudica* motor cell membranes accompanied by a transient rise in pH, which might be the early events that occur during the elicitation of plant defenses using chitosan (Amborabe *et al*. 2008). They determined the site of action of chitosan to be the plasma membrane H+-ATPase due to the inhibitory effect observed on the proton pumping and the catalytic activity of the enzyme. Treatment with chitosan induces a series of morphological and structural modification, leading to disorganized hyphae associated with inhibition of fungal growth. This was hypothesized to be due to polycationic properties of chitosan, allowing for changes in terms of membrane permeability and cytoplasmic aggregation (Benhamou, 1992).

e) Modulation of plant responses and signaling: Chitosan induces a series of plant responses both locally as well as systemically to alert healthy parts of the plant. These include early signaling events as well as the accumulation of defense-related metabolites and proteins such as phytoalexins and PR-proteins (El Hadrami *et al*., 2009; Wang *et al*., 2008). This biopolymer was shown to be an effective inducer of phytoalexins synthesis (Hadwiger and Beckman, 1980), and triggers callose formation (Conrath *et al*., 1989; Kohle *et al*., 1985), lignification responses (Hirano *et al*., 1999), and the production of proteinase inhibitors (Pena-Cortes *et al*., 1988).

f) Plant growth promotion: Improvements in plant growth have been reported after the application of chitin-based treatment to a range of crops, which are thought to be independent of the effects on pest and disease control. Significant improvements in growth have been reported in daikon radishes (*Raphanus sativus*) (Tsugita et al., 1993), soybean sprouts (Lee *et al*., 2005), sweet basil (Kim *et al*., 2005), grapevine (Ait Barka *et al*., 2004), as well as ornamental crops, such as *Gerbera* (Wanichpongpan *et al*., 2000) and *Dendrobium* orchids (Chandrkrachang, 2002). In orchids it was found that chitosan was effective at a very low concentration of 10 mg L^{-1} (Chandrkrachang, 2002; Nahar *et al*., 2012). This indicates that the chitosan was acting due to mechanisms other than simply improving nitrogen nutrition or as a carbohydrate energy source. It was found that the growth of orchids (*Dendrobium* and *Cymbidium* respectively) was enhanced when chitosan was supplied to micropropagated plants growing under aseptic conditions. These findings show that chitin can promote the growth of plants independent of its actions on plant growth promoting rhizobacteria (Nahar *et al.* 2012).

g) **Plant nutrition:** Chitin, and all its derivatives, have a high nitrogen content of 6.1%–8.3% (Yen and Mau, 2007). This is a comparable level to other organic fertilizers such as dried blood, bone meal, and hoof and horn meal (White, 2006). While chitin has a high thermal and chemical stability, making it possible to store dry product for a good length of time, it can quickly be utilized as both a nitrogen source and energy source by plants and microbes when added to crops. Spiegel *et al.* (1988) demonstrated that Chinese cabbages treated with chitin-based products grew faster than plants treated with a standard mineral fertilizer. The utilization of chitin by microbes will be slowest in cold and dry conditions (Yaroslavtsev *et al*., 2009). This could be of benefit if chitin was used in controlled-release fertilizers, as inorganic forms of nitrogen will not be released when plants do not need them in winter, and thus could minimize the leaching of nutrients from soils and their damaging impact on waterways. In addition to supplying nitrogen, the exoskeletons of crustaceans from which chitosan is commercially extracted are also high in calcium minerals where they aid structural rigidity. Therefore, chitin-based products that have only been partially purified will also contain substantial levels of calcium, an important macronutrient. The cationic properties of chitosan also make it suitable as a medium for supplying additional essential nutrients. The functional hydroxyl and amino groups on deacetylated chitosan allows the formation of coordination compounds (complexes) with ions of copper, zinc, iron and others, but not with those of alkaline metals (e.g., potassium) or alkaline earth metals (e.g., calcium or magnesium). This makes chitosan a sustainable alternative to synthetic chelation agents, such as EDTA that are routinely used to deliver iron and other nutrients to overcome their poor solubility in calcareous/neutral soils (Bohn *et al*., 2002).

h) **Abiotic stress resistance**: Chitosan has repeatedly been shown to possess antioxidant activity (Xie *et al*., 2001). The hydroxylated amino groups present on chitosan oligomers make them extremely effective scavengers of hydroxyl radicals, hydrogen peroxide and anion superoxide. Boonlertnirun *et al.* (2007) found that chitosan treatments had a significant effect on the growth or yield of drought-stressed rice plants compared to control plants, and that the effect was greatest when chitosan was applied before the onset of stressful conditions. The application of chitin-based products alongside a beneficial microbial agent augments and amplifies the effectiveness of each. Wang *et al.* (2007) found that the chitosan treatment alongside mycorrhizal inoculation aided the bioremediation of soil polluted with a range of heavy metals by *Elsholtzia splendens*. Angelim *et al.* (2013) recently showed that encapsulating a consortium of different PGPR within chitosan helped with delivery, and stimulated the growth and activity of the bacteria for bioaugmentation and biostimulation of hydrocarbon-polluted soils. An additional study on crude oil contaminated seawater found that chitin/chitosan encapsulation improved the effectiveness and survival of bioremediating chitinolytic bacteria (Gentili *et al*., 2006).

i) **Nuclear distortion and cell death**: Chitosan induces programmed-cell death andhypersensitive-associated responses in plants (Vasilev *et al*., 2009). Zuppini *et al.* (2003) studied the mechanism of programmed cell death mediated by calcium after application of chitosan, in soybean cells. Their findings showed that as low as 50 µg per ml of chitosan results in a massive influx of calcium into the cytosol along with an upregulation of the gene encoding for the chalcone synthase. Using *Arabidopsis* cell suspensions, Cabrera *et al.* (2006) reported that the size, the degree of acetylation and the concentration of the applied chitooligosaccharide elicitors was major determinant for the switching between the phenylpropanoid pathway relying on the activation of PAL and cell death involving the production of peroxides.

Chitosan as antifungal agent:

Soil amendment with chitosan has been shown to control several fungal diseases, especially *Fusarium* wilts (Rabea *et al*., 2003; Laflamme *et al*., 1999) and grey mould (Aziz *et al*., 2006). Importantly, these studies show chitosan to be fungistatic against both biotrophic and necrotrophic pathogens. The control of oomycete pathogens, *Phytophthora capsici* on peppers (Xu *et al*., 2007) and *Phytophthora infestans* in potato (O'Herlihy *et al*., 2003) has been achieved by chitosan applications. Qiu *et al*. (2014) evaluated the antifungal activity and effect of high-molecular weight chitosan (H-chitosan), low-molecular weight chitosan (L-chitosan) and carboxymethyl chitosan (C-chitosan) coatings on postharvest green asparagus. L-chitosan and H-chitosan efficiently inhibited the radial growth of *Fusarium concentricum* separated from postharvest green asparagus at 4 mg/ml, which appeared to be more effective in inhibiting spore germination and germ tube elongation than that of C-chitosan. Notably, spore germination was totally inhibited by L-chitosan and H-chitosan at 0.05 mg/ml. Reddy *et al*. (2000) found that stem scar application of chitosan inhibited growth and production of pathogenic factors by blackmold rot (*Alternaria alternate)* in challenged tomato fruit stored at 20 ?C for 28 days. Blackmold lesions were visible within 4 days of inoculation in control fruit, compared with >7 days in chitosan treated fruit. Macerating enzyme activity (polygalacturonase, pectate lyase, and cellulase) in the tissue in the vicinity of the lesions was <50% in chitosan-treated fruit compared with control fruit. Chitosan also inhibited production of oxalic and fumaric acids (chelating agents) and host-specific toxins such as alternariol and alternariol monomethylether by the fungus. Bhaattcharya (2013) reported that chitosan was effective against *Fusarium solani* at 0.20% chitosan dose, that led to the highest growth inhibition of fungal colony development (76.0%), lowest spore production (9×10^4/ml culture filtrate) and complete cessation of spore germination and germ tube emergence.

Stimulation of antagonistic biocontrol agents:

Antagonistic microbes employ a number of methods to attack plant pests and pathogens. This includes, but is not limited to, the production of chitinases (Maksimov *et al*., 2011), the production of toxins (e.g., antibiotics and toxins), direct parasitism, competition for nutriment, and induction of defense responses in the plant. Therefore, adding chitin-based products to the growing environment may aid beneficial antagonists by stimulating the production and activation of chitinases that can then be used to attack pests and pathogens, or be used as a stable nitrogen-rich polysaccharide food source that boosts the population to the level where other mechanisms control the plant pathogens. El Mohammadi *et al*. (2014) studied the effect of individual or combined application of *Trichoderma harzianum* and chitosan against *Fusarium oxysporum* f. sp. *radicis-lycopersici* (*Forl*) under *in vitro* and *in vivo* conditions. They found that *T. harzianum* significantly reduced the mycelial growth of the five Forl tested isolates. Chitosan applied at different concentrations (from 0.5 to 4 g/l) also significantly decreased the mycelial growth of the pathogen and a total inhibition was obtained at the concentration 4 g/l. Under greenhouse conditions, application of *T. harzianum* and chitosan (1 g/l) as root dipping treatment combined with chitosan (0.5 g/l) as foliar spray reduced FCRR incidence and severity by 66.6 and 47.6%, respectively. Treatments based on *T. harzianum* alone or in combination with chitosan led to an increase in the total phenols and to an enhancement of chitinase and β1-3-glucanase activities in leaves of treated tomato plants compared with the untreated ones.

Chitosan synergy with other plant protection agents:

Rahman *et al*. (2014) compared the antifungal activity of chitosan with DPn (average degree of polymerization) and FA (fraction of acetylation) and of enzymatically produced chito-oligosaccharides (CHOS) of different DPn alone and in combination with commercially available synthetic fungicides (Teldor (fenhexamide), Switch (cyprodinil+fludioxonil), Amistar (azoxystrobin), Signum (pyraclostrobin), and delan (dithianon)), against *Botrytis cinerea*, the causative agent of gray mold in numerous fruit and vegetable crops. CHOS with DPn in the range of 15–40 had the greatest anti-fungal activity. The combination of CHOS and low dosages of synthetic fungicides showed synergistic effects on antifungal activity in both in vitro and in vivo assays. Their study shows that degree of polymerization (DP) is an important factor on the antifungal activity and CHOS enhance the activity of commercially available fungicides. According to them, the mechanisms for the synergism in inhibition of fungal growth are not known but most likely, the synergism is due to the compounds different modes of action. Chitosan (125 ppm and 500 ppm) in combination with copper hydroxide (500 ppm) and *Trichoderma* have also been reported to curb late blight of potato caused by *Phytophthora infestans*. The mechanism behind the success of dual and triple combination is still not clear, but it is attributed to different modes of action of all the components and their interaction as well (Erraya and J.Kumar, 2014; Sajeesh, P.K. and J.Kumar, 2015; unpublished data).

Future prospects of chitosan in plant protection:

Sustainable agriculture has only a slim margin to make profits while guaranteeing food supply to a growing population in the age of high demand for blemish-free food and high cost inputs. The attention to naturally-occurring products with interesting antimicrobial and eliciting properties such as chitin and chitosan and their derivatives has been getting more attention in recent years. A number of modes of action have been identified for the beneficial effects of chitosan-based treatment on crops, including direct antibiosis and the induction of plant defences. However, their action in stimulating beneficial microbes has proved particularly impressive, with chitin/chitosan amplifying the effect of beneficial microbes in controlling pathogens, promoting plant growth and remediating soil pollutants. These products can be used in a numbers of ways to reduce disease levels and prevent the development and spread of pathogen, thus preserving yield and quality. Examination of better ways to incorporate these natural products into Integrated Pest Management strategies remains to be pursued in many major crops. Progresses in recent years allowed also for some understanding of the interactions between the chitosan effect and the octadecanoic pathway as well as the identification of the so-called chitin elicitor-binding proteins. These will lead to design specific chitin/chitosan applications/ formulations suitable for various stages of plant growth and development in order to achieve a better control of a specific disease. This effectiveness combined with the low cost, low concentration required, ample supply (recycled waste) and health/environmental safety lead to a forecast that a range of chitosan based products will become a more common feature in agriculture in the near future.

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Integrated Management of Wheat Rusts

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In meeting future food needs for the worlds growing population, it is important to improve the effectiveness of disease management as new higher yielding crop cultivars are developed. For developing countries, in particular, it is essential to strive for long-term consistency in disease management as well as short-term effectiveness. Despite the best efforts of plant breeders to produce resistant cultivars and of plant pathologists to develop and implement other forms of disease control, plant diseases cause at least 10% losses in global food production annually. Losses to diseases caused by fungi tend to be greater in the humid tropics where crops may be grown continuously throughout the year and weather conditions favor infection than in temperate regions. Losses to fungal diseases also tend to increase with increased intensity of crop production. It has been estimated that current crop production practices reduce combined yield losses to weeds, insects, and diseases worldwide by as much as 40% for maize, 50% for wheat, 75% for potato, and 80% for cotton. Epidemics of major crops in developing countries can mean extreme privation and, at times, even starvation for the poorer members of the population. Thus, the goal in breeding disease resistant cultivars of major crops should emphasize long-term reliability of the resistance.

Wheat is a source of food and livelihoods for over 1 billion people in developing countries. A major staple food crop in many countries, it is an important source of nutrition, providing on average 40 percent of per capita calorie intake. India with 97.4 million ton wheat production in 30.6 million hectare is second largest producer of wheat in the world. Drought, floods and diseases severely affect wheat production. Exacerbated by climatic stress, especially in rainfed areas, the impact of wheat diseases is expected to increase.

During the past decade a number of virulent strains of wheat rust diseases have emerged, causing global concerns to wheat production. The wheat stem rust race Ug99 is highly virulent on the majority of world wheat varieties – the risk that it could cause a global epidemic is real. Ug99 is well established in East Africa and Yemen and has spread to the Islamic Republic of Iran. In 2010 and 2013, a new, virulent strain of stripe rust, Yr27, has caused severe outbreaks and losses in many countries in North and East Africa, the Near East and South Asia. In India five new races of stripe rust were reported in 2014. Breakdown of Y9 resistance in mega wheat variety PBW 343 has become a matter of concern. There has been frequent breakdown of rust resistance in other popular wheat varieties in India in recent years. Due to ever changing genetics of these pathogens they need to be monitored continuously.

Wheat rusts

Stripe rust, leaf rust and stem rust are three important foliar diseases of wheat in wheat growing countries. Where favourable conditions occur and susceptible varieties are grown, significant yield losses may be incurred and even total crop loss. These three diseases have similar lifecycles. The three rusts of wheat can only survive on living plant material, with the dominant host being wheat and to a much lesser extent other cereals and grasses. This is why wheat rusts are of greater concern following wet summers when there has been opportunity for volunteer wheat to grow freely and carry over rust from the end of one season to the start of the next. All three rusts are wind dispersed and can be spread large distances (>1,000 km) by wind. This dispersal makes rust diseases common across a district. Therefore, inadequate rust control on one farm can have implications for rust development on neighbouring farms.

Even though these rusts are extremely damaging they can be effectively controlled through managing inoculum carry over during the summer/autumn, the cultivation of resistant varieties and/or the use of fungicides. Avoiding growing susceptible and very susceptible cultivars is the primary method of controlling rust. There is also a range of seed, fertilizer and foliar fungicides that contribute to effective rust control. Where an integrated management approach is utilized the effects of rust will be minimized.

i. **Stripe rust (Yellow rust)**

Stripe rust is caused by the fungus *Puccinia striiformis*. It is easily distinguished from other wheat rusts by the orange-yellow spores, which produce small, closely packed pustules developing into stripes along the length of the leaf veins. The spores occur on the upper surface of the leaves, the leaf sheaths, awns and inside of the glumes. Stripe rust requires cool and wet conditions to infect the crop. Free moisture on the leaves and an optimal temperature (10-15°C) are required for infection. Spores erupt within 10-14 days after infection. If the weather is conducive to stripe rust, the disease can cause up to 25% yield loss on varieties scoring moderately susceptible = 5 (MR-MS) or lower. This is provided there is inoculum from a neglected green bridge or from an infected crop. Major genes effective against different pathotypes of stripe rusts are YrA, Yr2, Yr5, Yr9, Yr10, Yr15, Yr18 and Yr27.

ii. **Leaf rust (Brown rust)**

Leaf rust is caused by the fungus *Puccinia triticinia* (previously called *Puccinia recondite* f. sp. *tritici*). The disease can also infect rye and triticale. Leaf rust produces reddish-orange coloured spores which occur in small, 1.5 mm, circular to oval-shaped pustules. These are found on the top surface of the leaves, distinguishing leaf rust from stem rust which is found on both surfaces of the leaf. The spores require 15 to 20̊IC temperature and free moisture (dew/rain/irrigation) on the leaves to successfully infect wheat. The first signs of the disease (sporulation) occur 10-14 days after infection. Removal of volunteer wheat plants, which forms a green bridge for the fungus through the summer, can eliminate or delay the onset of leaf rust. Genes effective against different pathotypes of leaf rusts are Lr1, Lr3, Lr10, Lr13, Lr 19, Lr23, Lr24, Lr26, Lr 28, Lr34.

iii. **Stem rust (Black rust)**

Stem rust is caused by the fungus *Puccinia graminis* f. sp. *tritici*. In addition to wheat it can also attack barley, rye and triticale. Stem rust produces reddish-brown spore masses in oval, elongated or spindle-shaped pustules on the stems and leaves. Unlike leaf rust, pustules erupt through both sides of the leaves. Ruptured pustules release masses of stem rust spores, which are disseminated by wind and other carriers. Stem rust develops at higher temperatures than the other wheat rusts within a range of 18-30°C. Spores require free moisture (dew, rain or irrigation) and take up to six hours to infect the plant and pustules can be seen after 10-20 days of infection.

Stem rust has had the ability to cause significant economic damage (50-100% of yield). This has happened when conditions are conducive for the disease and susceptible varieties are grown, or a new stem rust pathotype has developed, which has overcome the wheat's resistance. Inoculum must be present for the disease to develop. Practising crop hygiene by removing volunteer wheat, which forms a green bridge for the fungus through the summer, can eliminate or delay the onset of stem rust. Twenty effective stem rust resistance genes, namely, Sr 13, 14, 22, 24, 25, 26, 27, 28, 29, 32, 33, 35, 36, 37, 39, 40, 43, 44, 45, 1a.1R, Tmp are available against different virulent pathotypes of stem rust.

Distribution of wheat rusts in India

Based on the geographical conditions, wheat growth, occurrence and dispersal of diseases, wheat cultivation in India has been divided into six major wheat growing zones, and there is distinct occurrence of wheat rust(s) in each zone, namely, stripe rust in Northern Hills Zone (NHZ), which covers Western Himalayan regions of J&K (except Jammu and Kathua distt.), H.P. (except Una and Paonta Valley), Uttarakhand (except Tarai area), Sikkim and hills of West Bengal and N.E. States; stripe and leaf rusts in North Western Plains Zone (NWPZ), which covers Punjab, Haryana, Delhi, Rajasthan (except Kota and Udaipur divisions), Western UP (except Jhansi division), parts of J&K (Jammu and Kathua districts), HP (Una dist. and Paonta valley) and Uttarakhand (Tarai region); leaf rust in North Eastern Plains Zone (NEPZ), which covers Eastern UP, Bihar, Jharkhand, Orissa, West Bengal, Assam and plains of NE States; leaf and stem rust in other three zones viz., Central Zone (CZ), which covers MP, Chhattisgarh, Gujarat, Rajasthan(Kota and Udaipur divisions) and UP (Jhansi division); Peninsular Zone (PZ), which covers Maharashtra, Karnataka, Andhra Pradesh, Goa, plains of Tamil Nadu, and Southern Hills Zone (SHZ), which covers Hilly areas of Tamil Nadu and Kerala comprising the Nilgiri and Palni hills of southern plateau.

Integrated management of wheat rusts

Disease management strategies have been put to two distinct categories, eradicative control measures designed to eliminate the entire pathogen population eg., pesticides, vertical or complete resistance. These tend to select for resistant variants of the pathogen. Because all individuals are affected, so the pathogen must adapt or die, and management control measures designed to reduce the pathogen population by destroying a portion of the population eg., horizontal or partial resistance, antagonism, cultural practices, quarantine - These do not apply heavy selection pressure to the pathogen. Portions of the pathogen population remain unaffected, no pressure to adapt.

Economical and sustainable disease control can be obtained through the establishment of an integrated disease management system. The first integrated management system was developed by Dwight Isely to manage the population of cotton boll worm (*Anthonomus grandis*), which gave positive results for over 60 years in the United States Later, several other integrated management systems were developed and their basic concept was introduced to develop integrated management systems for diseases as well. Although there are several definitions of the integrated management system, according to Ledbetter et al. (1979) cited by Blair and Edwards (1980), it is a system where all the possible pest control techniques are used to keep the pest population below the economic threshold. Each technique is ecofriendly and is compatible with the objectives of the user. Integrated management is more than merely the control of pests through chemicals. In several cases it includes the biological, cultural and sanitary control techniques for a complex of pests. Thus the pillars of an integrated management system include several and all possible control measures and in case of wheat it should include cultivar resistance, seed health, cultural practices and fungicides (Mehta 1993; Cook, 2000; Zambolim et al., 2001). As a rule, an integrated management system must always be eco-friendly. Some of these aspects are discussed below:

Genetic resistance:

Integrating genetic resistance is environment friendly, and selecting genes for rust resistance is relatively easy compared to some other foliar diseases. Genes get defeated over time as diseases adapt, and hence the breeders need to keep looking for new genes and incorporating these into new varieties to maintain a good level of resistance. According to Van der Plank (1963), there are two kinds of resistance; one is referred to as vertical (specific resistance) and the other as horizontal resistance (partial resistance). Vertical resistance is also known as complete resistance, specific resistance and monogenic resistance. The resistant cultivars can be classified into three groups: (a) specific resistance; (b) partial resistance and (c) generalized resistance.

(a) Cultivars with specific resistance

Cultivars with specific resistance are those which show resistance to a few races of a pathogen but not to all. Breeding for specific resistance is simple and is inherited according to Mendel‘s law of inheritance. Biffen (1905), studied this for the first time and reported that for yellow rust of wheat the plants segregated in a ratio of 1:3 (one resistant plant and three susceptible plants). Since then numerous studies have been made and several resistant cultivars against a number of diseases were created. The resistance is considered specific when the cultivars are resistant to a single or few races. By and large, this kind of resistance is governed by a single dominant gene. When a resistant cultivar is crossed with a susceptible cultivar, in the F2 generation segregation of plants can be observed. If the resistance is controlled by a major gene the plants segregate in a ratio of 3:1 (three resistant and one susceptible) and when the resistance is recessive the plants segregate in a ratio of 1:3 (1 resistant and 3 susceptible).

To control diseases plant breeders and pathologists have been using major gene since it is simple and easy to select because of the clear difference between resistant and susceptible plants. However, cultivars with this kind of resistance last only for a short duration because the resistance is lost as soon as a new race of the pathogen capable of attacking the cultivar evolves in nature (Van der Plank, 1963). It is for this reason that the sowing of a single cultivar in a large area should be avoided (also see chapter on disease control by cultural practices). Breakdown of stripe and leaf rust resistance in a number of popular wheat varieties in this decade has been due to the resurgence of new races of rust pathogens. Virulence and aggressiveness are the two terms to express the parasitic ability of a pathogen to cause disease. In fact, virulence is the capacity of a pathogen (race or pathotype) to overcome the resistance gene of the host plant. Aggressiveness is the ability of a virulent pathogen to colonize the host and develop symptoms at a rapid pace. A virulent pathogen may be aggressive or not depending upon the environmental conditions, nonspecific resistance, latent period, etc.

(b) Cultivars with partial resistance

Non-specific resistance is also referred to by different terms, like horizontal resistance, field resistance, non-specific resistance, polygenic resistance, uniform resistance, stable resistance and partial resistance. Here again, the terms partial resistance and non-specific resistance are widely used. Partial resistance is effective against all the races of the pathogen and is governed by different genes. Contrary to specific resistance, partial resistance is of longer duration. The genes that govern this type of resistance are denominated as ―minor genes" or non-specific genes and are not easily identifiable. Being polygenic in nature breeding for partial resistance becomes difficult. The difference between resistant and susceptible plants is not very clear and hence selection of plants is hampered or becomes doubtful.

To accumulate partial resistance in a cultivar against a given pathogen, it becomes necessary to know different sources of the partial resistance. If there is no way to identify the genes that govern partial resistance, how can one be sure that different sources of partial resistance which show some level of partial resistance have the same or the different genes? If the genes are the same the breeder will be wasting his time and if the genes are different it will be possible to increase the level of resistance through breeding procedures. However, partial resistance can easily be lost during the traditional process of breeding. That being the case, it will be necessary to use different breeding procedures such as recurrent selection which is being used by several breeders (Singh *et al*. 2007).

For an effective selection for this kind of resistance the quantity of inoculum present in the field becomes very important. This is because partial resistance only reduces the rate of infection. If the selection for resistance is made in populations planted beside a highly susceptible cultivar, then the partial resistance may be ignored or else may be under estimated. Normally, the selection pressure in the experimental fields is very high and for this reason some breeding material with lower level of partial resistance may be lost. However, for the selection of high level of partial resistance even a high natural selection pressure is felt desirable (Mehta and Igarashi, 1978). These are some of the aspects which make breeding for this kind of resistance rather difficult.

Partial resistance is preferred when the rate of infection of a disease is very high as is the case with biotrophic leaf rust and stem rust pathogens. Efficiency and economy in controlling the diseases will depend on the level of partial resistance of a given cultivar. The higher the level of partial resistance the higher will be the efficiency and economy in controlling the disease through the use of fungicides.

Partial resistance is considered durable. On the other hand, resistance governed by specific genes can also be long lasting in some cultivars and hence long durability does not necessarily mean partial resistance. Partial resistance governed by non- specific polygenes could last for several years more than the resistance governed by a combination of specific genes. Durable resistance against stem rust of wheat for example, is conferred by a combination of specific genes like *Sr2*, *Sr23*, *Sr36*, whereas for leaf rust it is conferred by the combination of specific genes *Lr13* and *Lr34* (Roelfs 1988a, b; McDonald 2010).

Roelfs (1988a, b) and Singh *et al*. (2007), reported that some wheat cultivars having the gene *Sr2* in combination with other genes are being cultivated in North America to control stem rust without having been attacked by stem rust in the past 30 years. Similarly, examples of durable resistance for leaf rust are based on the utilization of a group of specific genes like *Lr12*, *Lr13* and *Lr34*. There exist other examples of durable resistance using a combination of specific genes. At times, this kind of resistance is referred to as ―multigenic resistance" (Knott, 1988; Parlevliet, 1988).

Sometimes partial resistance is confused with ―tolerance". The concept of the word ―tolerance" is completely different from the concept of resistance. A cultivar tolerant to a particular disease is in fact susceptible and no resistance mechanism operates against the disease but it tolerates the infection and could perform well in the field.

(c) Generalized resistance

When dealing with partial resistance one should specify the pathogen in question. While partial resistance is effective against all the races of a single pathogen, the cultivars with generalized resistance offer partial resistance against all the pathogens and their respective races. This may be considered as a modified form of partial resistance. One practical method for this kind of resistance was suggested by Robinson (1976) and it includes polycrossings between different cultivars susceptible to a specific race of each pathogen against which partial resistance is desired. It was suggested that polycrossing and high selection pressure should be exerted continuously for 6–8 generations until a uniform cultivar with a satisfactory level of partial resistance is achieved against different pathogens and their races. In this method complete selection pressure can be exerted only in the absence of specific resistance. When specific resistance is operating the partial resistance cannot be easily identified in the segregating populations. So far, success in this methodology has not been obtained.

Finally, it is evident that for the Integrated Disease Management system,cultivar resistance plays an important role. As far as rusts are concerned, spectacular achievements have been obtained in the creation of new and resistant wheat cultivars. In Brazil, for example, the majority of wheat cultivars until the 1980‘s were susceptible to two rusts, because most of the cultivars were introduced from other States or from other countries. Today, most of the wheat cultivars are of Brazilian origin, although some have CIMMYT germplasm when used as parent. These cultivars have wide adaptability and disease resistance. It is believed that these cultivars possess genes for specific resistance as well as for partial resistance. Rajaram et al. (1988) reported that during the last several years semi-dwarf cultivars occupied over 50 million hectares in the world without having reported any severe leaf or stem rust epidemics. The modern tendency is to develop new wheat cultivars with a combination of specific and non-specific resistance genes against major diseases.

Use of Multilines

Multilines are lines that are agronomically similar to each other but differ genetically as regards their resistance to different races of a pathogen. Multilines may be referred as a different form of specific resistance. Each line has specific resistance to a particular pathogen and when several such lines are mixed together they form a ―multiline". Due to their large diversity, the multilines have a special advantage over the specific resistance cultivars since they reduce the initial inoculum (Xo) as well as the rate of infection (r). Each line contributes to an additional genetic factor without phenotypic uniformity of the mixture. Multilines are created based on appropriate knowledge about the characters of agronomically compatible lines and genetically incompatible ones and are mixed in equal proportions. The use of specific resistance can be more advantageous when more resistance genes are introduced in a cultivar.

The advantages of the use of multilines were recognized in 1898, but investigations into multilines were intensified only in 1960 (Bourlaug 1953). The wheat breeding program of the Rockefeller Foundation in Mexico, released two multiline wheat cultivars in 1960. The first commercially used multiline wheat cultivars in Colombia were Miramar 63 and Miramar 65. Research on multilines was also started in India and in 1979 a multiline KSML 3 was released in the State of Punjab. In the same year a multiline cultivar called Tumult was released in Holland and another named Crew was released in the United States in 1982. Multiline cultivar of oats composed of 13 pure lines in two maturity classes were cultivated with success in more than 40,000 ha in the State of Iowa, USA (Browning, 1988). However the development and utilization of multiline cultivars was not significantly successful mainly because of the time-consuming and expensive development process. Besides, the genetic diversity of multiline was very much reduced because of its pure line nature.

Use of cultivar mixture

Because of their excessive uniformity, multilines lost their importance and a new concept of cultivar mixture was introduced. Within the Integrated Disease Management concept diseases can be kept under low intensity in cultivar mixture without the use of fungicides. Advantages of cultivar mixture in wheat, soybean, maize, rice, oats, beans, onion and gram (chickpea) were reported by several researchers. In East Germany for example, about 60 % of barley used for malt was cultivated through the cultivar mixture. The use of cultivar mixture to control diseases was studied by Wolfe (1988) for 11 years using 152 types of mixtures and in 122 types of mixtures an increase in yield of about 8 % was obtained. Most of these studies were performed considering agronomical and pathological aspects (Faraji, 2011). There is a concern among scientists that in a cultivar mixture natural selection of the pathogen with combined virulence may occur.

Another alternative strategy to the use of multilines and cultivar mixture is the pyramiding of resistant genes in an agronomically desirable cultivar. The more the major resistance genes are incorporated in a cultivar the more it becomes resistant to different races of the pathogen. Incorporation of major resistance genes is a relatively simple process and the cultivar with different resistance genes will be long lasting because its resistance will not be easily met by the creation of new races of the pathogen. This is a modern tendency in developing new disease resistant cultivars in several breeding programs.

Cultural Practices

i. Diversification of sowing dates and cultivars

The severity of some diseases could be reduced by simply changing the seeding dates and/or by diversification of cultivars. Stem rust of wheat for example, is controlled in the South of Brazil by changing the sowing dates.

Diversification of cultivars is another strategy to reduce the severity of diseases. As far as possible, more than one cultivar should be planted in a particular area and planting the whole area with a single cultivar should be discouraged even when a particular cultivar is most preferred by the farmer.

ii. **Fertilizer application**

The growth and the productivity of a plant will depend on the availability of the macro and micro nutrients in adequate and balanced quantities. If these nutrients are not available in sufficient quantities in the soil, it will be necessary to complement them to the economic threshold level. The principal macronutrients like N (nitrogen), P (phosphorus) and K (potassium) are needed in large quantities by plants and are responsible for increments in yield. Balanced fertilization implies consideration of a series of factors (EMBRAPA, 2011). Although health and vigor of the plant have a major influence on its predisposition to diseases, no generalization can be made for all the host-pathogen interactions with respect to a particular nutrient. Some diseases are not influenced by nutrients while others show drastic effects. Although resistance is genetically controlled, it is expressed through the physiological process inter-connected with the nutritional state of the plant and the pathogen (Hubber, 1976).

Chemical control

iii. Fungicides and their application in the field

Fungicide management remains the primary response to epidemics (outbreaks) of rusts when varietal resistance or other cultural methods do not provide satisfactory control. Within the Integrated Management concept use of fungicides also play an important role, however, they are applied only when their use becomes necessary. Although the cultivars have specific and non-specific genes against rusts, they are not protected against all the races and hence one or two applications of some specific fungicides become necessary.

Considering different problems involved in fungicidal applications like development of new mutants of a pathogen resistant to fungicide or to a group of fungicides, their toxic and residual effect, fungicides are being used rationally.

Disease Forecast Modeling

Besides the above mentioned aspects, in recent years emphasis has been given to the disease forecasting computer models. Through such models it is possible to provide estimates of disease likelihood and forecast outbreaks which in turn avoid unnecessary fungicidal applications. They give guidelines for timely applications and consequently make the control measures more cost effective. Computer modeling when validated should necessarily become a part of the integrated disease management systems.

Traditional plant disease climatological models have used accumulated hours of wetness duration combined with temperature requirements to predict the infection process and identify times of high disease risk. These types of models use recorded weather data to track enough favorable disease hours to warrant management action. Remote sensing coupled with GPS system is being used to monitor the occurrence of disease and this would help farmers in using need based fungicide applications to save the crop from possible damage due to rusts.

New tools for introgression and pyramiding of rust resistance genes for durable rust resistance

i. Marker assisted selection and breeding

Precise transfer of major (seedling resistance) and minor (adult plant resistance) genes with the help of gene linked molecular markers have become popular. Marker assisted transfer is very useful in particular in case of minor genes because impact of minor is difficult to monitor on phenotypic level.

Summary

The ultimate goal of the integrated management of wheat rusts would be to contribute to national food security through the prevention and management of emerging wheat rust diseases and sustainable enhancement of wheat productivity. This would lead to improved awareness level and surveillance, preparedness and response capacity of the wheat growers. Enhancement of surveillance and early warning systems, development wheat varieties possessing durable rust resistance using marker assisted breeding, enhancement of national wheat variety registration processes for release and promotion of resistant varieties, enhancement of seed systems for quick multiplication and distribution of quality seeds of resistant varieties, improvement of wheat rust management at the field level through participatory farmer training to minimize risks with judicious use of fungicides, biological control measure and improve yields under local farming conditions would help sustaining the wheat production under climatic changes.

Activation of Defence against Fungal Pathogens in Plants and their Health Management Strategies

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Plants are constantly being challenged by aspiring pathogens, but disease is rare. Why? Broadly, there are three reasons for pathogen failure. Either (1) the plant is unable to support the niche requirements of a potential pathogen and is thus a nonhost; or (2) the plant possesses preformed structural barriers or toxic compounds that confine successful infections to specialized pathogen species; or (3) upon recognition of the attacking pathogen, defense mechanisms are elaborated and the invasion remains localized. All three types of interaction are said to be incompatible, but only the latter resistance mechanism depends on induced responses. Successful pathogen invasion and disease development occurs, if the preformed plant defenses are inappropriate, the plant does not detect the pathogen, or the activated defense responses are ineffective. Plants are compelled to withstand stresses of all kinds, be it biotic, abiotic or anthropogenic as a consequence of their immobility. One of the most difficult and intriguing aspects in the study of biology is understanding of the significant events of the interaction between a plant and a pest/pathogen at the cellular and subcellular level. However, advances made in the formulation of concepts and techniques of modern, quantitative cell biology in recent years have paved the way for a basic understanding molecular events in developing resistance during host-pathogen interactions. In spite of this what still eludes our grasp is the answer to the high degree of specificity of the host-pathogen combinations observed in nature. In fact, if one considers the multitude of microorganisms to which plants are being continuously exposed in nature, the significance of specificity becomes more apparent. Until and unless the mechanisms whereby a host and pathogen 'recognize' the potential for establishing a compatible or incompatible relationship are identified, and the devices whereby specificity for that relationship is established, it cannot be claimed that a full understanding of host-pathogen interactions has been achieved.

Recognition and Specificity

The success or failure of infection is determined by dynamic competition and the final outcome is determined by the sum of favourable and unfavourable conditions for both the pathogen and host cells. There is evidence that tolerance of the parasite by the host increases with increasing antigenic similarity, whereas, resistance of the host is characterized by an increasing disparity of antigenic determinants. In this context, the concept of common antigens has acquired a special meaning due to its coincidence in compatible host-parasite relationships and because it may give some clue to the high degree of specificity. Recognition is thought of as a process initiated by binding of pathogen signal compounds and host cell receptors, where receptor includes all kinds of molecules that recognize a specific configuration of signal compounds. Molecular recognition and specificity determined at the host-pathogen interface are much more complex than have been presumed. The involvement of cross-reactive antigens (CRA) in host-parasite compatibility is strongly supported by immunolocalization in tea leaf tissues. Immunogold localization of CRA has also been successfully demonstrated for the first time in tea leaf tissues using IgG of *Exobasidium vexans,* causal agent of blister blight disease. With the advent of immuno-cytochemistry subcellular level studies have gained enormous importance in substantiating preliminary findings with novel and sophisticated techniques. An attempt was made to detect pathogen (*E. vexans*) in tea leaf tissue during development of blister blight disease following indirect immunofluorescence. Encouraging results were also obtained following immunogold cytochemical labelling of ultra thin tea leaf sections.

The initial infection process involving adhesion/recognition events between plants and pathogens is essential for the establishment of pathogenesis. The extracellular matrix (ECM) is a biologically active part of the cell surface composed of a complex mixture of macromolecules that, in addition to serving a structural function, profoundly affect the cellular physiology of the organism. The plant ECM has undoubtedly a central role both in plant development and in the interactions with pathogenic and other symbiotic microorganisms. Fungal interactions with plants that result in plant diseases cause one of the most serious problems in the production of food and fibre. Other types of fungi (Mycorrhizae) that establish mutually beneficial symbiotic relationships with plants enhance plant nutrition as well as plant immunity. A basic requirement for proper functioning of even a simpler cellular system is communication between its components. In this sense, communication means transmitting information to and receiving information from the environment, then transforming it to signals or instructions which the cell can understand and respond to. This exchange of information can be mediated by soluble agents (transmitters) or by direct cell-cell interaction. It is assumed that compatibility and incompatibility are initiated by surface-surface contact. Antigens may involve information transfer and/or the maintenance of membrane intrigrity during the cell-to-cell interaction of host and parasite. When two cells touch, the interfacial energy in the area of contact becomes very low. This can have a large effect on both the protusion of membrane proteins in that area and on their local aggregation resulting in protein transfer following cell-cell contact. The mutual recognition of different cell types could result from the transfer or interaction of membrane proteins by these mechanisms. Membrane proteins aggregate in response to a variety of triggering substances including antigens and mitogens.

The relative unspecificity of fungi and hosts in all kinds of mycorrhiza comes as a surprise to those who might be led to expect that organisms which form permanent mutualistic associations would be more likely to be highly specific than pathogenic biotrophs whose association is temporary, ending perhaps with the premature death of the host. Their specificity is not close; a single fungal isolate may form vesicular arbuscular mycorrhiza with a wide range of species of host of all the phyla of land plants. Specificity seems to be closer in the competition of natural vegetation than in pure culture. Mycorrhizal fungi have extensive compatibility with potential hosts which perhaps only limited by the inhibitory properties in the host, which itself can be universal or selective in response to the fungi. The use of anti-idiotypic (IT) antibodies approach to detect ligands and receptors will help to understand the complex network of signal transduction pathways that operate after first recognition event.

Plant defense responses

Higher plants protect themselves from various stresses, such as pathogen attacks, wounding, application of chemicals including phytohormones and heavy metals, air pollutants like ozone, ultraviolet rays. Plant resistance to disease may be thought to be mediated primarily through changes in metabolites. Defense gene expression is to be a great extent regulated through the production of metabolites which act as signals. Equally, several of the anti-microbial compounds that are produced are chemical toxins. It is also the case that pathogens often generate metabolites which suppress plant defences and cause disease symptoms. Plant pathogen interactions therefore, represent complex metabolite exchanges which have been considered as ideal scenario for investigation using metabolomic approaches to elucidate some key metabolite changes occurring during interactions of pest and pathogens with selected crops. During plant-pathogen interactions, resistance responses are activated when plant resistance (R) genes correspond to pathogen avirulence (avr) genes. Besides, in incompatible interactions synthesis of a collective set of host-encoded novel proteins such as pathogenesis-related proteins (PRPs) impedes pathogen progress. Accumulation of such protective plant proteins specially induced in biotic and abiotic stresses have been intensively studied in several plant species, which are mainly of agricultural interest.

Pathogenesis related proteins

Proteins that are induced exclusively during disease development in compatible host-pathogen combinations have hardly been considered as PRps. PRps have been grouped in to five main classes consisting of the 10 major acidic PRps of tobacco characterized both by biochemical and molecular biological techniques and designated as PR-1 to -5. A unifying nomenclature was proposed based on their grouping into eleven families, classified for tobacco and tomato, sharing amino acid sequences, serological relationships and/ or enzymatic or biological activity. The criteria for inclusion of new families of PRps were (a) protein(s) must be induced by a pathogen in tissues that do not normally express the protein(s), and (b) induced expression must have shown to occur in at least two different plant-pathogen combinations, or expression in a single plant-pathogen combination must have been confirmed independently in different laboratories. Each PR family is numbered and the individual family members are assigned lower case letters in the order in which they are described. In accordance with the recommendations of the Commission for Plant Gene Nomenclature, PR-genes are designated as *ypr*, followed by the same suffix as of the family. Later on three more peptides, which were capable of inducing defense responses of plants, were identified. So far, 17 families of PRps have been recognized. However, the properties of all these proteins have not yet been elucidated. Besides proteins newly defined mRNAs (cDNAs) are often considered as additional members of the existing families where shown to be induced by pathogens or specific elicitors.

Localization of the major, acidic PRps in the intercellular space of the leaf seems to guarantee contact with invading fungi or bacteria before these are able to penetrate. However, few of the inducible acidic PRps associated with SAR have been shown to possess significant anti-pathogenic activity. It could be that PRps make cells less conducive, but any such evidence is lacking. Elucidation of the biochemical properties of the major, pathogen-inducible PRps of tobacco and subsequent cloning of their cDNAs and/ or genes revealed that proteins with substantial similarity to the classical PRps, which are mostly acidic and extracellular proteins, the homologous counterparts are mostly basic and localized intracellularly in the vacuole. As far as it has been possible to deduce, they possess the same type of enzymatic activities, but their substrate specificity and specific activity may be rather different. PRps are, as such, a collective set of novel proteins which a plant produces in reaction to a pathogen mainly in incompatible interactions and thus impedes further pathogen progress. The “related situations” in which PRps were found to be induced, seem to prove the point: application of chemicals that mimic the effect of pathogen infection or induced some aspects of the host response, as well as wound responses that give rise to proteins that are also induced during infections, can induce both PRps and acquired resistance. The occurrence of homologous PRps as small multigene families in various plant species belonging to different families, their tissue-specific during development and consistent localization in the apoplast as well as in the vacuolar compartment and their differential induction by endogenous and exogenous signaling compounds suggest that PRps may have important functions extending beyond their apparently limited role in plant defense.

Hypersensitive reaction

The hypersensitive response (HR) is manifested upon activation of plant defense against invading pathogens which is usually associated with the expression of chemical and molecular markers such as salicylic acid and synthesis of PR proteins some of which have glucanase and chitinase activities leading towards synthesis of phytoalexin for plant defences. During the hypersensitive reaction cellular damage and death is a major stress to the plant, as exemplified by high increases in abscisic acid and ethylene. It is possible, therefore, that PRps are stress proteins directed to alleviate harmful effects of cellular degradation products on thus far untouched neighbouring cells. Both acidic and basic PRps may be induced by high concentrations of ethylene or physiological necrosis, or wounding. Such induction in the absence of pathogenic attack might be taken to indicate protection of cellular structures, either physically to stabilize sensitive membranes or macromolecules, or chemically to keep potentially harmful saprophytic microorganisms on tissue surfaces or in intercellular spaces in check. In virtually any natural stress condition e.g., heat, cold, drought, osmotic stress, water logging, anaerobiosis, metal toxicity, etc., plants are known to react by the synthesis of novel, and sometimes partly overlapping, sets of proteins.

The various conditions under which PRps occur are reminiscent of those under which heat-shock proteins (HSP) are induced. These proteins are ubiquitous in living organisms and associated with the acquisition of thermotolerance to otherwise lethal temperatures, but a causal connection is not evident. Interestingly, the promoters of all three tobacco PR-1 genes that are expressed, as well as of a different type of PR in parsley, contain a heat shock regulatory element, but the proteins are not induced to detectable levels by heat shock. Nevertheless, PRps might have an analogous function, though quite different, chaperonin-like function: unlike PRps, HSP are intercellular proteins that do not accumulate during heat shock. However, the specific occurrence of individual PRps in some floral organs, but not in others, points to other, more specific roles. The relative ineffectiveness of PRps in determining resistance to pathogens does not preclude an involvement in defense. PRps might be involved in recognition processes, releasing defense-activating signal molecules from the walls of invading pathogens. This would hold particularly for chitinases and glucanases that could liberate elicitor-type carbohydrate molecules from fungal and bacterial cell walls. Thus, a β-glucanase induced in soybean seedlings by infection or chemical stress releases elicitor-active fragments from cell wall preparations of the fungus *Phytophthora megasperma* f.sp. *glycinea*. Such elicitors could help stimulate defense responses in adjacent cells and thus accelerate and enhance these reactions, as well as induce acquired resistance to further infection. A role of PRps as specific internal signal generating enzymes would be consistent both with their occurrence in specific organs and with their induction during the development and in response to stressful pathogen infections. The major chitinase of bean leaves first to be induced by ethylene and located in the vacuole, appears to be also induced in abscission zones at the stem petiole-junction together with a PR-1-like protein, two isoforms of β-1,3-glucanase, other chitinases, and a thaumatin-like protein.

Some events such as signal perception, signal transduction and defence gene activation, similar to those found in plant-pathogen interactions have also been found in the plant interaction with AMF. AM fungi secrete similar chitin elicitors, which could induce a defence response. For instance, the elicitor derived from an extract of extraradical mycelium of *Glomus intraradices* was able to induce phytoalexins (glyceollin) synthesis in soybean cotyledons. Chalcone synthase, the first enzyme in the metabolism of a flavonoid compound in *Medicago truncatula* was induced by *G. intraradices.* Furthermore, a more hypersensitive-like response, commonly observed when the plant is confronted with a pathogen, could be observed in compatible AM associations. An oxidative burst could be detected at sites where hyphal tips of *G. intraradices* attempted to penetrate a cortical root cell of *M. truncatula*. Moreover, necrosis and cell death have been observed at sites of *Gigaspora margarita* infection of *Medicago sativa* roots. Transient increases of catalase and peroxidase activity were also observed in mycorrhizal plants, during appressoria formation and fungal penetration into the tobacco, onion and bean roots, which coincided with the accumulation of salicylic acid (SA), a signal molecule involved in the signal transduction pathway activated in plant-pathogen reactions.

Genes encoding enzymes that catalyse core reactions of the metabolism of phenlypropanoid have been expressed in cells with arbuscules. *In situ* localization of phenlyalanine ammonia lyase (PAL) and chalcone synthase (CHS) transcripts were observed in cells containing arbuscules. However, expression of other genes encoding enzymes such as chalcone isomerase (CHI) or isoflavone reductase was not significantly affected in mycorrhizal roots. Genes involved in the catabolism of reactive oxygen species, such as catalase and peroxidase have also been localized in bean and wheat root cells containing arbuscules which play a role in the catabolism of hydrogen peroxidase and/or in cross-linking reactions between proteins and polysaccharides in the interface between the arbuscule and the plant cell plasma membrane. Corroborating the biochemical data, differential gene expression of acidic and basic forms of chitinase and β-1, 3-glucanase has been observed during mycorrhiza formations in different plant-fungal combinations

Induced resistance

The response of biotic and abiotic elicitors treated suspension-cultured tea cells always indicated more significant chitinase activity in comparison to β-glucanase activity. The PR-3 (Chitinase) and PR-2 (β-glucanase) were immunolocalized in the leaf tissues and in the cultured tea cells as evident by bright apple green fluorescence following labelling with FITC. Accumulation of PR-3 (Chitinase) was also confirmed by ultrastructural immunocytochemical studies in cellular compartments.The versatile multicomponent defense system of plants is adequate to provide them protection against most of their potential pathogens only a few of them can overcome this defense and cause disease. Just before or concomitant with the appearance of a hypersensitive reaction (HR) the synthesis of PR-proteins is increased. In addition to the localized HR, many plants respond to pathogen infection by activating defences in uninfected parts of the plant (systemic acquired resistance, SAR). As a result, the entire plant is more resistant to secondary infection. SAR is long lasting and confers broad-based resistance to a variety of pathogens. The synthesis of antimicrobial products, including phytoalexins and PR-proteins, correlates well with the development of both HR and SAR.

Activation of inducible defence responses is likely to be based upon recognition of pathogen-associated molecular patterns, which bind to plant receptors. The potential use of induced or acquired resistance in disease management has been evaluated. Developed biological and chemical products that activate resistance have been applied in cereals, pulses and oil seed crops, plantation as well as horticultural crops which may be utilised under commercial practices for induction of resistance. Most of the defense-related genes which express during the early stages of AM fungal penetration are also activated by pathogen infection, treatment with elicitors, or by SA. In this context, the induction of defence gene expression could be considered to be a result of fungal elicitor recognition and signal transduction pathway activation. The weak and transient character of the plant defense response could be a consequence of the low capacity of the fungus to trigger such a response and/to induce a plant mechanism which suppresses an already activated defence response at several levels to allow for fungal growth within the plant tissue.

Accumulation of basic forms of chitinase and β-1.3-glucanase transcripts have been observed in the intercellular region between cortical cells containing arbuscules, suggesting that these enzymes might be involved in the control of intraradical fungal growth. Interestingly, the accumulation of β-1,3-glucanase mRNA in cells containing arbuscules was modulated by phosphorus (P) concentration. The level of mRNA accumulation increased as concentration of phosphorus decreased. In comparison, the amount of basic chitinase transcripts did not change with mycorrhization or P concentration. The enzymatic activity and chitinases and β-1, 3-glucanases could form part of the defence response by the plant to the invading fungus. A specific induction of a class III chitinase gene family in mature *M. truncatula* mycorrhizae is evident, which may be involved in suppression of plant defence reactions in the later stages of the AM development.

Expression of Genes involved in the Defense Reaction

Cultured plant cells are suitable experimental material to study the response of plant cells in some plant diseases because the signal molecules distribute simultaneously to each cell. Isolated bean cell culture following treatment with elicitor prepared from *Colletotrichum lindemuthianum* very rapidly accumulated mRNA for the key enzymes such as phenylalanine ammonia lyase (PAL), chalcone synthase (CHS) and chalcone isomerase (CHI) for isoflavonoid phtoalexin biosynthesis reaching to a maximum level 3h after treatment and then decreased to the original level. The mRNA encoding cinnamyl-alcohol dehydrogenase, an enzyme specific to the synthesis of lignin monomers, accumulates in cultured bean cells very rapidly following treatment with fungal elicitior. Similarly, the transcription of genes encoding chitinase, which is responsible for the defense reaction by the degrading the cell wall of pathogenic fungi, is activated very rapidly following treatment with fungal elicitor. The rapid activation of these gene expressions in plant cells after elicitor treatment or fungal attack indicates that in plant cells very rapid steps may be involved in the signal transduction system from the recognition of microorganisms to the transcriptional activation of these genes.

Hydroxyproline-rich glycoproteins (HRGPs) are usually found in low amounts in the cell wall of higher plants. However, larger accumulations were found in melon seedlings infected with *Colletotrichum lagenarium* and many host-parasite combinations. It is believed that HRGPs play a role in resistance of plants to pathogens by acting as a structural barrier and as an agglutinin. A remarkable increase in HRGPs occurs not only during infection but also following wounding and elicitor treatment. The activation of these genes is slower than compared with the PAL or CHS genes, which suggests the involvement of a secondary signal substances which originates indirectly from host cells.

The pattern of activation, structure and genomic organization of a gene (*prpl*) encoding a pathogenesis-related protein (PR1) in potato cultivar carrying resistance gene *R1* elicited by infection of *Phytophthora infestans* have been demonstrated. The coding sequence of the *prpl* and the deduced amino acid sequence are strikingly similar to that of a 26-kDa heat shock protein from soybean. Genes encoding enzymes concerned with phenylprpanoid biosynthesis are activated very rapidly after the elicitor treatment, but are restored to the original level within several hours. The mechanism of this rapid decline of the accumulation of the product of PAL, may play a role as a regulation signal in gene expression of the phenylpropanoid biosynthetic pathway, because *trans*-cinnamic acid inhibits the transcription of PAL and CHS genes in cultured bean cells.

Profiling of global Avr/R gene-triggered gene-expression responses points to a certain degree of constitutive activity of R-gene-pathways. In the absence of infection, mutants disrupted in distinct R pathways display reduced (or elevated) expression of defined gene sets. This result supports the notion that R activation is tightly controlled. Ectopic R expression can activate defense pathways in the absence of pathogen. After pathogen recognition, repression of these pathways is completely removed and they operate with maximal capacity, fully activating (or repressing) their target genes. The outcomes are the production of potentially toxic secondary metabolites, programmed cell death and the creation of a locally inhospitable environment for the pathogen. R- protein activation may be negatively regulated by intramolecular mechanisms, although how this is achieved and how they are activated will require more examples and more detailed biochemistry and structural biology. The role of accessory and partners proteins in R activation is just at its beginning, and will require both clever forward and reverse genetics approaches combined with proteome based solutions. Signaling pathways leading from activated R proteins are being chipped away, and emerging concepts suggest that the resistant state is achieved by breaching quantitative activation thresholds, possibly driven by a central SA-driven positive feedback loop. In depth understanding of how the plant immune system functions may one day lead us to the development of controlled, brad-spectrum resistant crops without the deleterious fitness costs.

Plant health management strategies

One of the greatest challenges now is to feed an increasing world population without exacerbating current environmental problems. Our approach should be to increase the utilization efficiency of scarce non-renewable fertilizers, which has the potential to simultaneously increase plant productivity and reduce pressures on environment. Soil microbes offer largely unexplored potential to increase agricultural yields and productivity in a low-input manner. Soil biota provide a number of key ecological services to natural and agricultural ecosystems. Increasingly, inoculation of soils with beneficial soil biota is being considered as a tool to enhance plant productivity and sustainability of agricultural ecosystems. In the development of sustainable crop production practices, the use of microbal inoculants as replacement for chemical fertilizers and pesticides is receiving attention. From the plant’s perspective, biological control can be considered a net positive result arising from a variety of specific and non-specific interactions.

Many of the microbes isolated and classified as biocontrol agents (BCAs) can be considered facultative mutualists, because survival rarely depends on any specific host and disease suppression will vary depending on the prevailing environmental conditions. Further down the spectrum, commensalism is a symbiotic interaction between two living organisms, where one organism benefits and the other is neither harmed nor benefited. Most plant-associated microbes are assumed to be commensals with regards to the host plant, because their presence, individually or in total, rarely results in overtly positive or negative consequences to the plant. And, while their presence may present a variety of challenges to an infecting pathogen, an absence of measurable decrease in pathogen infection or disease severity is indicative of commensal interactions. Neutralism describes the biological interactions when the population density of one species has absolutely no effect whatsoever on the other. Related to biological control, an inability to associate the population dynamics of pathogen with that of another organism would indicate neutralism. In contrast, antagonism between organisms results in a negative outcome for one or both. Competition within and between species results in decreased growth, activity and/or fecundity of the interacting organisms. Biocontrol can occur when non-pathogens compete with pathogens for nutrients in and around the host plant. Direct interactions that benefit one population at the expense of another also affect our understanding of biological control. Parasitism is a symbiosis in which two phylogenetically unrelated organisms coexist over a prolonged period of time. In this type of association, one organism, usually the physically smaller of the two (called the parasite) benefits and the other (called the host) is harmed to some measurable extent. The activities of various hyperparasites, i.e., those agents that parasitize plant pathogens, can result in biocontrol. And, interestingly, host infection and parasitism by relatively avirulent pathogens may lead to biocontrol of more virulent pathogens through the stimulation of host defense systems. Lastly, predation refers to the hunting and killing of one organism by another for consumption and sustenance. While the term predator typically refer to animals that feed at higher trophic levels in the macroscopic world, it has also been applied to the actions of microbes, e.g. protists, and mesofauna, e.g. fungal feeding nematodes and microarthropods, that consume pathogen biomass for sustenance. Biological control can result in varying degrees from all of these types of interactions, depending on the environmental context within which they occur. Significant biological control, as defined above, most generally arises from manipulating mutualisms between microbes and their plant hosts or from manipulating antagonisms between microbes and pathogens.

Species of *Trichoderma* exhibiting good biological control activity have also proved to be particularly amenable to studies because, as a rule, they are ubiquitous, easy to isolate and culture and grow rapidly on many substrates. These species compete well for food and site, grow well on root surfaces, produce a wide range of antibiotics and act as mycoparasites utilizing an enzyme system capable of attacking a wide range of plant pathogenic fungi. Those *Trichoderma* isolates that have exhibited good biological control activity most frequently belong to one of four species-aggregates: *T. hamatum*, *T. harzianum*, *T. koningii* and *T viride*. Biological control activity of these isolates has been demonstrated *in vitro* and glasshouse studies where the environment is controlled and in numerous field trials. The ability of microorganisms to withstand biotic and abiotic stresses successfully in various climatic conditions and to support plant growth and development has made them an excellent source for valuable bio-products and genes that can be used to develop transgenic crop plants. The enormous functional diversity across the country needs to be deciphered and utilized to interweave microbes in agriculture sector.

The arbuscular mycorrhiza is clearly a multifunctional symbiosis, an obligatory lifelong interaction involving close physical and biochemical contact, whose other services from plant host perspective include plant pathogen protection, phosphorus uptake and mediation of water status. Given the potential benefits to agricultural productivity, it is not surprising that manipulation of AMF communities either by inoculation with particular strains or through management of resident communities has been attempted at the field scale. Different hypotheses have been proposed to explain bioprotection by AM fungi. These include (a) improvement of plant nutrition and root biomass in mycorrhizal plants, which could contribute to an increased plant tolerance and compensate for root damage caused by a pathogen, (b) changes in root system morphology, (c) modification of antagonistic microbial populations in the mycorrhizosphere, and (d) competition between AM fungi and pathogenic fungi to colonize root tissues, with the possible induction of resistance mechanisms.

The role of Mycorrhizal fungi in control of various soil borne plant diseases has also been worked out with a positive impact in sustainable agriculture. Besides, the association of AM fungi with plant nematodes and the beneficial effect of mycorrhizal symbiosis on plant growth had also led to investigations into the potential of AM fungi to limit yield losses due to nematodes. During colonization, AMF can prevent root infections by reducing the access sites and stimulating host defense. Various mechanisms also allow AMF to increase a plant's stress tolerance. This includes the intricate network of fungal hyphae around the roots which block pathogen infections. AMF protect the host plant against root-infecting pathogenic bacteria. The damage due to *Pseudomonas syringae* on tomato may be significantly reduced when the plants are well colonized by mycorrhizae. The mechanisms involved in these interactions include physical protection, chemical interactions and indirect effects. The other mechanisms employed by AMF to indirectly suppress plant pathogens include enhanced nutrition to plants; morphological changes in the root by increased lignification; changes in the chemical composition of the plant tissues like antifungal chitinase, isoflavonoids etc., alleviation of abiotic stress and changes in the microbial composition in the mycorrhizosphere.

Mycorrhizal colonization significantly reduced the percentage of disease severity and incidence in infected bean plants. Among the potential mechanisms involved in the resistance of mycorrhizal systems, the induction of plant defense is the most controversial, where a number of biochemical and physiological changes have been associated with mycorrhizal colonization. Alteration in isoenzymatic patterns and biochemical properties of some defense-related enzymes such as chitinases, chitosanases and β-1,3-glucanases have previously been shown during mycorrhizal colonization. These hydrolytic enzymes are believed to have a role in defense against invading fungal pathogens because of their potential to hydrolyze fungal cell wall. Stimulating the host roots to produce and accumulate sufficient concentrations of metabolites which impart resistance to the host tissue against pathogen invasion have also been reported. AM colonization can reduce root diseases of horticultural crop and plantation crop caused by fungal pathogens.

Direct (via interference competition, including chemical interactions) and indirect (via exploitation competition) interactions have been suggested as mechanisms by which AM fungi can reduce the abundance of pathogenic fungi in roots. These have generally been proposed in response to observations of negative correlations in the abundance of AM fungal structures and pathogenic microorganisms in roots. Presumably, pathogenic and AM fungi exploit common resources within the root, including infection sites, space and photosynthates within the root. Interference competition may also arise if carbon availability within intercellular spaces and the rhizosphere or the number of infection loci within the root system is reduced as a result of AM fungal colonization. Moreover, increasing the richness of AM fungal taxa colonizing the root system may result in more intense competition with a pathogenic fungus.

TERI (The Energy and Resources Institute) has developed an *in vitro* based mass production technology which successfully produces pure inoculum in large quantities and overcomes the limitations of the soil based system. This inoculum has a long shelf life and is very concentrated with a small quantity itself carrying a very large number of propagules. This facilitates the application of desired amounts as it can be easily transported and mixed with a substrate of choice and applied as required. They have been able to develop modern biotechnologies concerning mycorrhization with proven impact. This technology coupled with bacterization would be more meaningful to 'biotize' *in vitro* propagated plantlets for transient transplant shock during acclimatization. The modern 'hairy-root technology' has played a significant role in establishment of AMF with transgenic host plants. The use of dual technology is promising as micro propagated plantlets are suitable platforms for understanding the mystery of host-endophyte interaction, excessive production of secondary metabolites, heavy metal tolerance, bio protection, bioremediation and growth promoting activity. This will also help to unravel impediments for the growth and development of AMF in culture. Besides, this technology offers an opportunity to apply molecular approaches to understand host-symbiont interactions, secretion of flavonoids and signal transduction pathways. This may result in a more efficient and at the same time agriculturally and environmentally sustainable use of soil microorganisms for crop production.

Resource-poor farmers worldwide have been key contributors to food security. To sustain the key contribution to food security by resource-poor farmers, their problems and needs, which are manifold, must be addressed on technological, economic and political fronts. The range of their problems and needs cover (a) institutional support for ensuring adequate seed replacement, (b) augmentation of irrigation systems and adoption of water saving technologies,(c) fertilizer price policy to make fertilizer use technology more viable, (d) better integration of crop and livestock through diversification and mixed farming, (f) enhancing literacy levels, (g) co-operative efforts in production, processing and marketing, (h) ensuring adequate financial support, domestic market reforms and links to world trade, and (i) providing information and communication technology. Therefore, support to resource-poor farmers must receive highest priority in national and international policies geared to provide food security on one hand and fight hunger and poverty on the other.

Role of Disease Management Strategies to Improve the Yield of Wheat

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All three wheat species are grown in India. Bread wheat (*T. aestivum*) contributes approximately 95% to total production while durum wheat (*T. durum*) and *Dicoccum* wheat (*T. dicoccum*) contribute approximately 4 and 1 per cent, respectively to total production. Since the initiation of the Green Revolution in the mid-sixties, India achieved remarkable increase in production and productivity of wheat. The era of semi-dwarf wheat which started in 1960‘s became an instant success and these genotypes revolutionized the wheat production in coming years – leading to ―Green Revolution”. This achievement in India‘s wheat production has been perhaps the most important and unparallel in the history of developing world. The most serious constraints to wheat production are biotic stresses. Through concerted research efforts in the form of protection technologies, a check has been kept on the management of various diseases and insects pests and India in particular has not faced any rust epidemic since last five decades because of proper deployment of rust resistance genes in different wheat growing zones of the country. The expected onslaught of climate change is also a worrisome aspect and breeding strategies have to be reoriented to care of the biotic stresses.

Major biotic constraints to wheat production in India and their eco-friendly management

It is estimated that, on an average, 10% of the crop is lost due to biotic stresses, annually. Among these the fungal diseases such as rusts, foliar blights, loose smut and powdery mildew are the major constraints and Karnal bunt from export view point as it is a quarantine issue with several countries which have zero tolerance policy to Karnal bunt. Rusts are economically most important. India, Pakistan, Bangladesh and Nepal grow nearly 37 mha of wheat of which about 30 mha is at risk to leaf rust losses. Losses were negligible during last decade in India due to widespread use of resistant varieties. The black or stem rust (*Puccinia graminis* Pers. f. sp. *tritici* Erikss. & Henn) is important in warmer areas whereas the brown or leaf rust (*P. triticina* Eriks.) in the entire country and the yellow or stripe rust (*P. striiformis* Westend.) in cooler areas. Wheat yellow rust is a threat to about 10 million hectares of North-western plains zone (NWPZ) and Northern hills zone (NHZ) of India. In 2001, a new pathotype 78S84 of *P. striiformis* with virulence to PBW 343 (*Yr* 3, 9, 27 virulence) was detected whose inoculum got built up slowly and slowly due to cultivation of PBW 343 over a large area. PBW 343 was high yielding and occupied 6-9 million hectares area in different years. It became popular amongst farmers in the hilly regions and Eastern India as well. The stripe rust pathogen survives in Northern India and as a result of continuous growing of susceptible varieties in the major wheat belt of NWPZ, the inoculum built up also increased in hilly areas. Since 2006-07, the stripe rust is occurring in high intensity in one or the other parts of NHZ and NWPZ. Emphasis was laid for growing rust resistant wheat varieties such as PBW 550, DBW 17 and WH 542 of bread wheat in disease prone areas. Due to congenial weather for stripe rust, two pathotypes, 78S84 (*Yr* 27 virulence on PBW 343) and 46S119 (*Yr* 9 virulence) were most prevalent during 2010-11 crop season and most of the varieties grown in NWPZ became susceptible. During 2010-11, stripe rust appeared in in some parts of J & K , foot hills of Punjab and Himachal Pradesh, parts of Haryana and *tarai* region of Uttarakhand, wherever susceptible varieties were grown. In Punjab, especially in the districts of Ropar, Nawan Shahar and Hoshiarpur, the disease was well spread over large area in most of the varieties being grown by the farmers. During 2012-13, the disease was reported in Yamuna belt of Haryana. During 2013-14, farmers have been advised to grow stripe rust resistant varieties, WH 1105, HD 2967, DPW 621-50, WH 542, PDW 314 (d), WHD 943 (d), DBW 16 especially in disease prone areas in NWPZ. Likewise, stripe rust resistant varieties, HS 507, HS 490, HPW 349, VL 829 and VL 892 have been recommended for growing in NHZ. For NHZ, varieties (VL 829, HS 375, HS 507, HS 490, VL 907, VL 832, HPW 155 and HS 365) possessing resistance to stripe rust and also high yielding have been recommended. As above varieties are not completely resistant so if need arises, chemical spray with fungicides (Propiconazole or Tebuconazole or Triademefon @0.1%) have been recommended. Recently, two new pathotypes, 110S84 and 110S119 developed and therefore made most of the varieties susceptible to yellow rust were as varieties like WB 02, PBW 723 (Unnat 343), HD 4728, DBW 90, PBW 644, WH 1080, WH 1142, DBW 71, TL 2942, TL 2969, HS 507, HS 542, VL 829, VL 892, KRL 210, HD 3171, K1317, and Unnant PBW 550 were found resistant to these.

Although, the occurrence of new races in *Puccinia* fungi is not an unusual phenomenon, but the appearance of Ug 99 race of stem rust in Kenya carries special significance world over. This is because of the fact that Ug 99 has knocked down the stem rust resistance gene *Sr31* which had been providing wide spectrum of resistance against stem rust disease in modern wheat varieties. Seven variants of Ug 99 (TTKSK, TTKSF, TTKST, TTTSK, TTKSP, PTKSK and PTKST) have been reported so far from different countries (Uganda, Kenya, Sudan, Yemen, Iran, South Africa, Zimbabwe and Egypt). Till date, Ug 99 could not be detected in India. Both short and long term strategies to combat the menace of Ug 99 have been brought out. It is not an important issue to debate on whether or not the Ug 99 will reach the Indian wheat fields but, the more important point is to pin-point the wheat growing areas which could become vulnerable to Ug 99 in the country. Realizing the potential and magnitude of the threat, IIWBR under the aegis of ICAR took pro-active steps to prepare against this threat and strategic actions were initiated to address this threat. There are nearly two dozens of Indian wheat varieties in seed chain which have been found to be resistant against Ug 99 race of stem rust. Screening of Indian wheat material for Ug99 at Kenya since 2005 resulted into identification of Ug 99 resistant lines (released varieties in seed chain-DDK 1009, DL 153-2, DL 788-2, HD 4672, HI 8498, HI 8627, HP 1744, HP 1761, HS 295, HS 420, HUW 234, Lok-1, MACS 2846, NIDW 295, NW 2036, PDW 291, UP 2338, VL 829, WH 147, WH 542 & WH 896) and genetic stocks (FKW1, FLW1, 4, 5, 8, 12, 20, 24, 26, 28, 30, GIANT 3, HD 29, HIND 162, KBRL 10, 13, 22, PUSA 5-3, SEL 212, SG 22 & SG 8809). For keeping vigil on new rust races, trap plot nurseries are being planted all over the country. Extensive and systematic crop health monitoring implemented under AICW&BIP has contributed significantly in keeping vigil on rust new virulences and their management ahead the pathogen cause economic losses.

The Karnal bunt and the flag smut (*Urocystis tritici* Korn), are found to attack the wheat crop in southern Punjab, Northern Rajasthan, Delhi and Western Uttar Pradesh. Karnal bunt (KB) of wheat caused by *Neovossia indica (Tilletia indica)* was first reported from India by Mitra in 1931 and it continued to be a minor disease till 1968. However, in 70s and 80s of 20th century, it emerged as an important disease of wheat in the country. Also since production is increasing, the prospects of exporting wheat can be hampered by occurrence of Karnal bunt due to quarantine issues by several importing countries which insist on zero tolerance of Karnal bunt infection for accepting wheat from such areas where it is occurring. The incidence of Karnal bunt in Indian wheat has come down drastically over the years except 2012-13 crop season. During 2013-14 and 2014-15 crop season, average KB incidence was more in North India. During 2016-17 the average incidence of KB was 17.7% incidence whereas states like Maharashtra, Gujarat and MP remained free from KB Most of the present day varieties in North India are susceptible to moderately resistant to Karnal.

Many genetic stocks have been developed and besides wheat, resistance was also identified in *S. cereale*, *Triticale* and several accessions of *Aegilops* spp. Resistance to Karnal bunt has been incorporated in high yielding wheat varieties, PBW 343 and WH 542. Karnal bunt resistant donor W 485 has been utilized for the development of wheat variety, PBW 502 which is occupying large areas and also remained in the seed chain in top 5 varieties for 3-4 years. Nine resistant loci were identified in a set of four resistant stocks (ALDAN ‗S'IAS 58, H 567.71/3*PAR, HD 29 and W 485) and later four loci from four other genetic stocks (CMH 77.308, FRAME, HP 1531 and MRNG) were identified. Karnal bunt can be managed well by growing resistant varieties and following zero tillage for 3-4 years. If required, fungicidal spray with Propiconazole at ear head stage can be given for managing the disease.

Among other major biotic constraint, spot blotch caused by *Bipolaris sorokiniana* is important in the hot and humid environments of North -eastern plains zone (NEPZ) and Indo-gangetic plains of India also. Many tolerant varieties and genotypes *viz.*, DBW 189, HI 1612, HS 645, KARAWANI/4NIF-/3/SOTY//NAD63/CHRIS, PBW 778, UAS 462 (d), UP 2992, UP 2993, VL 1013 have been identified. Until now, there have only been limited studies conducted on identifying molecular markers linked to spot blotch. However, microsatellite markers have been used by many researchers. Powdery mildew, a destructive foliar disease caused by *Erysiphe graminis* f. sp. *tritici* Em. Marchal has recently assumed importance in NWPZ, NHZ and Southern hills of India. Losses from this disease have increased in recent years in NWPZ as most of the varieties do not possess sufficient level of resistance.

Keeping in view the global climate change and mycotoxin risk, work on *Fusarium* spp. causing head blight or head scab of wheat is in progress. Sources of resistance have been identified and incorporation of resistance from Sumai 3 and Frontana is continued. Loose smut (*Ustilago tritici* Pers. Rostr.) is another disease prevalent throughout the country but is well managed due to large scale use of fungicides for seed treatment which provide effective control. The stinking smuts, also called the bunts, are found only in the hills of northern India; they include the smooth-spored *Tilletia foetida* (Wall) Liro and rough-spored *T. caries* (DC.) Tul & C.Tul, can be managed with seed treating fungicides. The foot rots caused by *Helminthosporium sativus* and some other fungi have been frequently reported from Rajasthan, Madhya Pradesh, Maharashtra and some other states. The tundu disease, in which a bacterium [*Corynebacterium tritici* (Hutch) Burk.] and a nematode [*Anguina tritici* (Steinb.) Chit] are associated, also takes a toll of the crop in western U.P, Delhi, Southern Punjab and northern Rajasthan. The disease has been managed by putting the seed in saline water and sieving off the gall before sowing. Under the AICW&BIP, every year, wheat material is evaluated at hot spots for region specific diseases like powdery mildew, head scab, foot rot, flag smut and hill bunt and resistant sources have been identified for incorporating resistance in popular cultivars. As knowledge of diversity of pathogen is indispensable for developing resistant wheat varieties for different biotic stresses, so variability among important wheat pathogens have been studied with host-pathogen interaction as well as molecular approaches only for rusts but also for other pathogens (head scab, blight, Karnal bunt). With recent occurrence of wheat blast caused by *Magnaporthe oryzae* pathotype *Triticum* in Bangladesh, preparedness is in full swing to prevent entry of this disease in India and anticipatory research to tackle it in future. Strict vigil is being kept all along Indo- Bangladesh borders since 1996 and capacity building is done. Indian wheat varieties (140 Nos.) are sent to Bolivia (South America), USA and Bangladesh to screen against wheat blast and an adhoc IMP is developed in case of any emergency situation especially in West Bengal and Assam.

Potato Virus Y Management in Canada: Results of Nearly A Decade of Study on Commercial Potato Farms and Experimental Field Trials

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Introduction

Potato virus Y (PVY; family *Potyviridae,* genus *Potyvirus*) is a virus occuring in all major potato growing regions of the world and which has major economic impact due to yield loss and effects on potato tuber quality. New Brunswick (NB), Canada is an important potato producing region in eastern North America, with potato accounting for more annual revenue than all other agricultural production in the province combined. Thus, research into the biology, epidemiology and management of PVY is of significant interest to local industry and government. For nearly a decade, Agricultural Certification Services, Inc. has undertaken as its major research focus a program dedicated to understanding the mechanisms and management of on-farm PVY spread. This program has followed a two-pronged approach of studying PVY spread on commercial farms in the region, as well as conducting field trials to test management strategies in and experimentally controlled situation.

PVY is transmitted between potato and other susceptible plants during the growing season, and geographically and between seasons by the movement of infected tubers. Potato seed certification systems have reduced the propagation of PVY by infected tubers, but PVY spread during the growing season is a continuing problem requiring vigilant management by individual growers (Gray et al. 2010).In the field, aphids spread PVY non-persistently between susceptible plants. Aphids aquire PVY from the sap of an infected plant during feeding, then over a short period of time they can transmit it to other plants until the virus is cleaned from their mouthparts. Though potato is the primary host, and Green Peach Aphid (*Myzus persicae*) widely considered the most efficient vector aphid, a range of important crops like tomato and tobacco, and several common weed species can harbor PVY, and many if not most aphid species are capable of transmitting the virus.

Effective on-farm control of PVY is the product of two main strategies: (1) reduction of PVY inoculum, and (2) minimizing PVY spread in the field. A robust seed certification system and selection of seed sources tested as PVY free or with low (<1%) PVY incidence is crucial, yet not alone sufficient. Other measures such as control of volunteer and weed plants in the field, crop rotation, safe disposal of cull potatoes and avoidance of nearby potato fields or other susceptible crops can also limit exposure to PVY. Despite these measures, it may be impossible to completely isolate a potato crop from sources of PVY inoculum. Thus, season-long management of PVY spread is necessary, mostly through foliar spray of chemicals to kill, incapacitate or interfere with feeding of aphids.

Observations of effective PVY management in commercial potato fields

Nearly a decade ago, it was recognized that PVY levels in the seed potato industry in NB, Canada were high, averaging nearly 12% in seed lots tested under the local seed certification system in 2009. Also, PVY was widespread, with 88% of tested lots having some detectable level of PVY infection. Given the ubiquity of

PVY in the industry, a concerted effort was undertaken to determine science-based best management practices (BMPs) to reduce on-farm spread of the virus. Commercial growers were surveyed to determine what range of managementpractices were being used to combat PVY, with the ultimate aim of correlating these practices with reductions in PVY spread.

A wide range of practiceswere being employed in NB fields, most notable among them being spraying of mineral oils and insecticides to kill or incapacitate aphid vectors or interfere with PVY acquisitionor transmission, and planting seed potatoes with low PVY incidence. Among different growers in the region, there was considerable variation in these practices, and controversy over the relative merits of themfor combatting PVY spread and the influence of uncontrolable factors such as aphid abundance and weather.

From 2010 to 2014, we partnered with 16 growers to study PVY spread in 56 fields representing 13 commercially important potato varieties. We measured initial PVY inoculum in these fields then tracked its spread to initially virus-free test plants and ultimately into tubers at harvest of the crop. In each field, 100-120 test plants were identified and individually monitored through the season by leaf tests and ultimately tubers sampled shortly before harvest. PVY was detected by ELISA and RT-PCR (Singh et al. 2003), and correlated with the frequency, concentrations and types of mineral oil and insecticide spray used by the grower, as well as aphid abundance measured weekly in each field and publically available climatological data compiled from several Environment Canada weather stations in the region. Using multiple logistic regression analysis, we were able to model PVY spread in the study fields from this large data set, identifying statistically significant factors in PVY spread and quantifying their relative magnitude of effect.

From our data, the factors most strongly correlated with PVY spread tended to be most important early in the growing season, including the initial PVY inoculum planted in the field, the abundance of aphids early in the season and the number of days from planting until first applications of mineral oil and/or insecticide spray. Two of these factors - initial PVY inoculum and beginning time of thespraying program - were directly under the control of individual growers and had a significant and cost-effective impact on ultimate PVY spread. The importance of planting low-PVY seed to minimize PVY spread cannot be overstated and was clear from our studies in North America (Fageria et al. 2013, MacKenzie et al. 2014, MacKenzie *et al*. 2016), as well as recent European studies (Steinger et al. 2014). Due to cost or availability, several of our partner growers did not always plant low-PVY seed and together with other poor management practices suffered PVY spread as high as 76% in one study field.

Through the season, the most effective management factors for reducing PVY spread were the number of mineral oil and insecticide sprays and the types of insecticides used. We found that the number of combined mineral oil-insecticide sprays (tank-mixed and applied simultaneously), and to a lesser degree mineral-oil sprays alone, were strongly correlated with reductions in PVY spread. This link was particularly significant for the number of sprays that occurred before mid-season and those including the fast-acting insecticides lambda-cyhalothrin (Silencer®, Matador®) and flonicamid (Beleaf®). The effectiveness of mineral oil spraying was not a surprise in these data, as its protective effect has been widely observed and exploited over the last 50 years (Al-Mrabeh et al. 2010). Notable from our data, however, was that while the total number of mineral oil sprays was highly correlated with reduced PVY spread, the rate of application (litres/acre) was not, suggesting the frequency of mineral oil spray is more important than the amount. More controversial from our findings was the even stronger effect of combined mineral oil-insecticide sprays. Earlier studies have argued against effectiveness of insecticides as they would act too slowly to kill or sufficiently intoxicate aphidsto prevent virus acquisition. Some of thiscontroversy may be due to the wide range of available insecticide chemistries and modes of action, retention and active lifetime on the foliage, or the range of species responses including developing resistance to many agents.Statistically, our results showed number of combined mineral oil-insecticide sprays as one of the most strongly correlated factors driving PVY spread across this study, compared to all other factors related to inoculum, aphids, weather, or other management factors. More convincingly, when insecticide sprays were divided into numbers of those of the lambda-cyhalothrin and flonicamidtypes identified by other researchers as most effective they maintained correlation with reduced PVY spread,whileother insecticide types were not significantly correlated.

From our studies, it was clear that the most important factors correlating with PVY spread were under the control of individual growers, i.e. planted inoculum level and frequency and types of foliar spraying. While uncontrolled factors such as aphid abundance and weather were also associated with PVY spread, they had less measurable impact and weaker statistical support. From our statistical modelling, the average impact of a doubling of aphid abundance observed would be associated with about a 9% increase in PVY spread, or a major increase in mean overwintering temperature of 5˚C would correlate with even less of an increase in PVY spread. In contrast, a 3% decrease in PVY inoculum or spraying the crop with 7 combined mineral oil-insecticide sprays - fewer than what most growers currently do in NB - would individually decrease PVY spread on average by 9%; applied together, these simple management decisions would presumably decrease PVY spread even more.

Experimental field trials testing PVY management practices

Following the observational studies described above, experimental field trials to test the efficacies of different types, rates and combinations of mineral oil and insecticide foliar sprays for reducing PVY were undertaken in NB and Manitoba in the 2014 to 2017 crop seasons. In each of these five trials, experimental plots were planted with certified PVY-free Russet Burbank or Goldrush seed, supplemented with known virus-infected seed to raise PVY inoculum to between 2.3% and 3%. These near identical trials were set up to test nine treatments of: two mineral oil-only treatments at different application rates, two insecticide-only treatmentsof differing numbers, and fivecombined mineral oil and insecticide treatments, compared through different crop years and between two distant and climatically distinct potato producing regions in Canada. In each trial, control and treatment plots were replicated four times (totalling forty 100m^2 plots of 200 plants each), with all PVY inoculum plants identified and marked, as well as 1000 initially virus free test plants to track PVY spread.

PVY spread varied widely across the trials, despite the consistent design, PVY inoculum and treatments tested. In control plots unsprayed by mineral oil or insecticide, PVY spread from inoculum plants to 9% to 84% of test plants in the different trials. While the individual ranking of treatment effectiveness and the degree of reduction in PVY spread varied from trial to trial, a general pattern of treatment effect was consistent across trials, and mirrored results from our observational studies described above. The most effective treatments were consistently from among the combined mineral oil and insecticide treatments, reducing PVY to as low as 4%. These were followed by mineral oil-only sprays in effectiveness. Lastly, insecticide-only sprays did not significantly reduce PVY spread at all compared to control plots.

Rates of mineral oil application were also tested, as there is some controversy about effectiveness of different application rates, typical manufacturer suggested rates, and the potential for phytotoxicity of oil at high application rates. From our data, no significant difference was found in the effect on PVY spread of application rates of 1.5 litres/acre and 3 litres/acre, well below the manufacturer suggested rate of 4 litres/acre. This was consistent with our findings from our observational studies described above, which also showed significant impact of oil sprays, but no effect of varied rates generally between 1 and 2 litres/acre used by commercial growers in NB. Initial results from our NB field trials was recently published (MacKenzie et al. 2016), while final results from Manitoba will be compiled after completion of the 2017 trial.

Best management practices for reducing on-farm PVY spread

Our experimental trials and observations of PVY spread in commercial potato operations in Canada over the last near-decade has produced significant insights regarding the management of on-farm PVY spread. Probably the most cost-effective strategy to reduce PVY at harvest was to plant low-PVY seed, minimising potential inoculum for later spread. Absolute elimination of PVY inoculum is difficult, however. Thus, during the growing season, we have observed greatest control of PVY spread in crops that were sprayed frequently (i.e. weekly) and season-long with mineral oil, most often tank-mixed with insecticides particularly of the lambda-cyhalothrin (pyrethroid) and flonicamid chemistries. These sprays are most beneficial when initiated as soon possible after first emergence of the crop, to avoid a window of unprotected access of potato foliage for aphids. These results have shown that those growers who plant low PVY seed and most aggressively managed their crop consistently achieved greatest control of on-farm PVY spread. Industry-wide, over the years these practices have dramatically reduced PVY in the commercial seed crop in NB, with levels dropping from 11.8% mean PVY, and only 12% clean seed lots in 2009, to 0.4% mean PVY and 70% clean seed lots in 2016.

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Potential Use of Microbes for Root-Knot Nematode Management in Medicinal and Aromatic Plants and Improve Production of Plant Secondary Metabolites

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Most of the cultivated and economically important plants are subjected to biotic stresses that can jeopardize crop yields and cause relevant economic losses. Among the various biotic stresses, plant parasitic nematodes are cosmopolitan parasites of agricultural crops including medicinal and aromatic crops which exploit entire parts of the host, and thus affect sustainable agricultural production worldwide. Plant parasitic nematodes constitute one of the most important groups of pathogenic organisms prevalent in and around the root playing a significant role in the plant growth and yield reductions. Undoubtedly, these nematodes are associated with most of the medicinal plants and cause significant damage, but the magnitude of crop damage has been established in only a few medicinal plants (Pandey *et al*., 2017). Large number of plant parasitic nematodes is associated with MAPs but few of them cause most serious problem in these plants. Mainly root-knot nematodes (*Meloidogyne incognita* and *M. javanica*), root lesion nematode (Pratylenchus *thornei*) and stunt nematode (*Tylenchorhynchus vulgaris*) influence yield of important medicinal plants. The economically important MAPs which suffer root-knot nematode infestation are: Ashwagandha, Serpagandha, Brahmi, Menthol mint, Henbanes, Basil, Opium poppy, Coleus, Kinghao, and Safed Musli (Pandey, 1998a, 1998b; Pandey, 2003a, 2003b; Senthamarai *et al*., 2006). Some of the models and techniques have been suggested to avoid the economic loss caused by this pest to MAPs (Pandey *et al*., 1999; Reddy and Pandey, 2013; Singh *et al*., 2016a).

The past few years have growers a steep increase in the MAPs cultivation area mainly because of elevated net returns and better demand in the market worldwide. Although, same time the devastation caused by PPNs has augmented enormously in organic soil and this may be owing to the constant farming of nematode susceptible plants. Also the range of chemical arsenal to fight with PPNs has been reduced. The main motive behind this situation is improved awareness about the adverse result of chemical fertilizers or pesticides. They are highly significant for national health programs, pest control as well as in agriculture sectors, *viz.* suppression of human health diseases, but the existence of these pesticide chemicals in the natural environment produces adverse effects on ecosystem and furtive long acting toxic effects on human health. Therefore, successful development of chemical nematicides for field exploitation is need of an hour. Consequently it has become inevitable to cope up these nemtodes through non-chemical tactics. Though, several non-chemical management tactics like fallow, flooding, changes in time of sowing / planting material, tillage practices, crop rotations, use of antagonistic crop, trap crop/ cover crop, use of nematode free planting materials or seeds, solarization and organic amendment (Sikora, 1992; Pandey, 1998b; Pandey *et al*., 2009; Van Bruggen and Finckh, 2016).

Management practices for plant parasitic nematode

Several strategies have been and are being applied to help sustain environmentally friendly agricultural techniques for a more effective utilization of beneficial/antagonistic microbial properties. It has encouraged researchers to utilize the range of micro-organisms to endow with benefits to MAPs production and is inspiring in markets for biofertilizers and biopesticides as well as plant growth promoting microorganisms (PGPMs) (Pandey *et al*., 2003; Bhattacharyya and Jha, 2012; Singh *et al*., 2016a). The ultimate objective is to optimize the properties of the microbes in rhizospheric firstly by managing the native microbial communities *via* exploitation of microbes as plant growth promoters or antagonistic agents. However, plant-microbe interaction are affected by several ecological factors, therefore before applying the microbes it is necessary to consider the impact of environmental stress factors to manage proper interaction between host plant and microbes. Furthermore, in recent years conventional and organic farmers signify an interest in application of microbial based products, suggesting that the potential role of bioinoculants will rise in future.

Most of the alternative tactics mentioned here are efficient in dropping nematode density or improving plant growth (Pandey *et al*., 2016; Briar *et al*., 2016). Nevertheless, they cannot eliminate nematodes from an infestation site, which means that nematode severity can persist, particularly if vulnerable plants are grown constantly without any nematode management. Information about various techniques and principles is an essential preliminary point for reducing nematode severity, but the existing information may not be enough to deal with nematodes in a specific circumstances. The specific knowledge is need of urgency on the dynamics and damage nematodes thresholds for various plant cultivars in the agricultural system, on the efficacy of management tactics that are possible for that plant, on the situation that manipulate these methods, and on the economics of the proposed options. Obtaining this facts base is a formidable task, requiring detailed and applied studies information, to gain information that is highly specific for a particular pathogen and plants in a particular area. The data obtained in one agricultural land may not apply elsewhere. Thus, the areas that are mainly successful in developing a complete finding base on plant parasitic nematode and plant biology will have a determined benefit in managing their nematode problems. Local validation by informed farmers or growers at the agricultural land level will be essential in accelerating and optimizing this management practices.

Now days, organic growers have shifted towards the use of beneficial organisms in soils for managing *M. incognita* together with cultural practices. Microbial antagonists are important in the regulation of *M. incognita*, independent of farming system (Van der Putten *et al*., 2006; Radwan *et al*., 2012). Several microbes are antagonistic to plant parasitic nematodes and some of these organisms reduce nematode populations and (or) disease development (Dong and Zhang, 2006; Timper, 2011). However, anatgonistic microbes often are not thought of as suitable substitutes for various pesticides/nematicides. Reasons for this include need of broad spectrum activity, inconsistent performance, and slower (sometimes less complete) action by the microbial agents when compared with pesticides. However, the introduction of beneficial organisms to the soil for nematode management *via* augmentative biological control has had limited success (Tian *et al*., 2007; Sikora, 2013). In addition, only some organisms have been developed into commercial antagonistic formulation/products available to the grower. This is because the leap in identification of a potentially useful microbial agent to develop formulation, wide scale testing, shelf-life development, registration, marketing, and delivery has evidently proved so great that research has not resulted in many commercial successes for plant-pathogenic nematode management. Commercially available biocontrol products for soil-borne plant-pathogenic nematode include microbes such as *Bacillus, Burkholderia, Fusarium, Gliocladium, Pythium, Streptomyces, Talaromyces, and Trichoderma* (Pandey and Kalra, 2003; Adam *et al*., 2014). There are only few commercial biological control products for nematode management available in the markets which are considered for use in organic farming (Hallman *et al*., 2009). *Burkholderia* and *Paecilomyces* based commercial formulations are available for nematode management.

Management of plant parasitic nematodes has been defined as a diminution in nematode population density which is accomplished through the action of microorganisms other than nematode resistance to host plants. It occurs naturally, through the manipulation of the environment or by following the introduction of antagonists (Sikora, 1992). Application of antagonistic microbial agents is a promising option to expensive and environmental hazardous toxic nematicides, limited and inadequate cultural control practices and the lack of resistant varieties. A wide range of antagonistic microbes have been exploited to reduce the population of phytonematodes below the economic threshold level in medicinal and aromatic plants (Ramakrishnan *et al*., 2010; Pandey *et al*., 2016) which could play a significant role either singly or can be integrated with other practices to develop integrated nematode management practices (INMP). Biological control of plant parasitic nematodes using their natural enemies has been studied extensively in the last two decades and many successful cases have been reported but limited field experiments have been carried out (Gupta and Pandey, 2015). Studies conducted by various researchers indicate that microbial agents may play a significant role in limiting phytonematode population (Pandey *et al*., 2003; Pandey *et al*., 2011b, Gupta *et al*., 2015b). The results of the studies have been carried out on major medicinal plants like *Artemisia annua, B. monnieri, Chlorophytum borivillianum* , *Hyoscyamus* spp., *Mentha arvensis, R. serpentina, Withania somnifera* etc. which have proven the efficacy of microbial agents (*Paecilomyces lilacinus, Trichoderma harzianum, Glomus aggregatum, G. fasciculatum, G. mosseae, Bacillus megaterium, B. subtilis, B. flexus, B. aryabhattai, Pseudomonas fluorescens*) in the management of nematodes and for sustainable productivity of plant secondary metabolites in medicinal plants.

Pandey *et al*., (2003a) observed the positive effects of different organic materials *viz. Mentha* distillates, *M. koengii* distillates, neem compound, *A. annua* marc and Vermicompost along with bioinoculants *viz. G. aggregatum* and *T. harzianum* individually as well as in different combinations for the root-knot nematode, *M. incognita* management on *B. monnieri.* Likewise, a study by Senthamarai *et al*., (2006) also showed the positive influence of *P. fluorescens* and *T. viride* on different growth parameters of *C. forskohlii* and management of nematode reproduction in *C. forskohlii*.

Recently, biological control has been focused on microorganisms producing mycolytic enzymes, especially chitinases (CHIs), which are known to hydrolyze chitin, a major component of nematode egg shells. Biological control strategies based on chitinolytic microorganisms is an important approach for facilitating sustainable agriculture (Chavan and Deshpande, 2013; Brzezinska *et al*., 2014). The concept of biological control of plant parasitic nematode diseases by application of antagonistic bacteria has shown great promise in the recent years.

The presence of anatagonistic microbes in the crop rhizosphere soils is highly beneficial as they are able to suppress plant pathogens near the root zone and provide sustainable protection against the root diseases. Since *M. incognita* is obligate parasite of plants, they can survive in residues of infected host for only short periods, until they are consumed by their own reserves (Cortada *et al*., 2009). Application of the bacterium, *P. chitinolytica* reduced the *Meloidogyne* infection in tomato crop (Spiegel *et al*., 1991). Jung *et al*., (2002) reported the effect of chitinase-producing *Paenibacillus illinoisensis* KJA-424 on egg hatching of root-knot nematode (*M. incognita*). In recent past literature pertaining to the effect of chitinase producing microbes on nematode development in the host plant with improved plant growth has accumulated to quite a large extent (El-Hadad *et al*., 2010; Huang *et al*., 2015).

Microbial consortia on plant parasitic nematode management

In environmental conditions different factors are responsible for the microbial community in the plant rhizosphere. It is well known that when medicinal plants are treated with microbial consortia the properties of these microbes are generally increased (Dubey *et al*., 2016). However, an accurate selection criterion should be adopted while selecting the microbes to use as component of microbial mixture. Otherwise, inaccurate selection may lead to reduced efficacies of beneficial microbes against the various targeted phytopathogens. Generally, in natural conditions microbes live in communities, thus they provides specific benefit to the plants when applied in mixture. Recently, few microbial consortia were developed and exploited against limited number of MAPs phytopathogens (Sarma *et al*., 2015). However, recently interest has been given to utilize the mixture of beneficial microbes that are able to induce resistance of host plants against various biotic stresses (Ghorbanpour *et al*., 2015)

Exploitation of microbial mixture consisting of efficient strains may be an advanced technique compared to individual microbes for biological control. Additionally, combination of microbes may improve reliability, consistency and efficacy of the microbes under diverse conditions (Guetsky *et al*., 2001; Sarma *et al*., 2015). Utilization of various microbial species in combination may further have the benefit of increasing biocontrol efficacies and thereby restrict plant pathogens. Combination of these antagonistic microbes may promote the development of host plants under phytopathogen infection as the host plants will be better equipped with several mechanisms to tolerate various stresses. When phytopathogens come in close proximity with the plants, defense pathway are activated in a similar way as it is stimulated by single biocontrol agent (Spadaro and Gullino, 2005).

Development of microbial consortia thus provides a greater opportunity to increase the diverse traits of microbes that are difficult to search in individual microbes. Additionally, development of effective microbial combination also has marketable significance as commercialization of these products is necessary for its utilization by the users. Only in fewer cases it was manifested that the development of combination based on prior information of microbe‘s compatibility were successful and effective against the target phytopathogen including plant parasitic nematodes. Thus, to reduce the failures of microbes due to microbial incompatibility prior to experiment, evaluation for synergism of microbes is essential. Therefore, identification of microbes with different traits including ISR and activation of antioxidant machinery inducing activities is important and integration of microbial mixture bearing those properties is the need of sustainable agricultural practices. Hence, applying microbes as a mixture has advance potentiality particularly in current agriculture system and is being looked upon with great hope to diminish the load of chemical/synthetic fertilizers and pesticides.

Pandey *et al*., (2011b) recently showed that the mutualistic endophytes (*T. harzianum* strain Thu and *G. intraradices*) and bioinoculants (*P. fluorescens* and *B. megaterium*) when grown individually and in combination enhanced the plant biomass, oil yield of menthol mint (*M. arvensis* cv. kosi) and also reduced the reproduction potential and population development of root knot nematode, *M. incognita* under glasshouse conditions. Additionally, bioinoculants *B. megaterium* (ATCC No. 14581), *P. fluorescens* (ATCC No. 13525), *T. viride* (MTCC No. 167), *P. lilacinus* (PDBC PL55) and *G. intraradices* were also studied for the management of *M. incognita* in *W. somnifera* cv. Poshita under greenhouse conditions (Gupta *et al*., 2016c). The study demonstrated that the rate of nematode infestation in *W. somnifera* was directly proportional to *M. incognita* (number of J2) population. Recently, Gupta *et al*., (2015a) highlighted the application of selected potential rhizospheric microbes *viz. B. megaterium, T. harzianum* ThU and *G. intraradices*, singly as well as in consortia for the management of *M. incognita* and augmentation of phytochemical contents in Chamomile. A subset of *Bacillus* spp., namely *B. flexus, B. subtilis*, *B. megaterium* and *B. aryabhattai*, was evaluated against the most devastating *M. incognita* infestation and essential oil yield enhancement in *O. basilicum* var. CIM-Soumya (Sweet basil) by Gupta and Pandey (2015). It was also demonstrated that the rhizospheric microbes, viz., *B. megaterium*, *G. intraradices, T. harzianum* ThU and their combinations significantly reduced *M. incognita* (Kofoid and White) Chitwood infestation and enhanced bacoside content in *B. monnieri* var CIM-Jagriti (Gupta *et al*., 2015b). Recently, it was reported that the different chitinolytic microbes *viz., Cellulosimicrobium cellulans* MTN13, *Flavobacterium johnsoniae* MTN 20*, Chitiniphilus* sp. MTN 22 and *Streptomyces* sp. MTN 14, singly and in combination managed *M. incognita* infection and enhanced secondary metabolites in *W. somnifera* cv. Poshita (Gupta *et al*., 2016c).

Mechanism adopted by microbes for nematode management

The exploitation of microorganisms antagonistic to nematodes or compounds produced by these microbes could endow with additional opportunity for controlling the damage caused by nematode in plants. Such antagonistic microbes can produce substances that may limit the loss caused by these nematodes, e.g. by producing antibiotics and a variety of enzymes. These microorganisms can also function as competitors of nematodes for colonization sites and nutrients (El-Hadad *et al*., 2010). Thus the development of substitute control strategies and long-term integrative approaches is urgently needed in order to replace synthetic nematicides. In recent years, biological control has become a promising alternative to chemical control in the management of nematode disease (Radwan *et al*., 2012; Gupta *et al*., 2015a). The antagonistic microbes bring about induced systemic resistance (ISR) fortifying the physical and mechanical strength of cell wall and change the physiological and biochemical reaction of plants leading to synthesis of defense reaction against challenge inoculation of phytopathogens. Defense reaction usually occurs owing to accumulation of PR proteins such as chitinase, phenylalanine ammonia lyase, peroxidase, phenolics and phytoalexins (Kloepper *et al*., 1992; Whipps, 2001).

Host plants always remain in association with a variety of microorganisms such as bacteria and fungi which can be either beneficial or pathogenic. Plants have to make out identities of the microbes and activate their respective mechanisms either to attract the desired microbes or to keep away the pathogenic ones. When plant is attack by phytopathogens, plants activate their effective and rapid defense mechanisms to defend themselves by managing the population of the pathogens. Recognition and identification of pathogens by host are the key points in activation of effective and quick defense responses (Verhagen *et al*., 2010). When phytopathogens come in contact with the host, defense responses are triggered in a similar way as it is stimulated by beneficial microorganisms (Shoresh *et al*., 2010; Singh at al., 2016b). However, extent and level of induction of the defense responses are much more when the plants are bioprimed with beneficial antogonistic microbes. The combination of *P. lilacinus* KIA and *Rhizobium* sp. was found to be very effective in reducing reproduction of the *M. javanica* in chickpea roots. *P. lilacinus* KIA strain had the capability to parasitize females and eggs of nematodes, whereas the *Rhizobium* strain had ability to produce antibiotics and phytoalexins. The combined effects of the microbial combination thus led to a better inhibition of the nematodes multiplication and enhanced plant growth (Siddiqui and Akhtar, 2009).

One of the most common and initial resistance mechanisms against invading phytopathogens by plants is oxidative damage. Host plants control the levels of reactive oxygen species (ROS) in a way that the production of ROS, H_2O_2 (hydrogen peroxide), O^{2-} (superoxide radical) and PCD (programmed cell death) is sensitive to the pathogen but not to the plant. H_2O_2 further provides strength to the cell wall through helping the process of lignifications and callose deposition, contributing in cross-linking of cell wall polymers and proline or hydroxyproline rich proteins during the pathogen infection conditions and thereby directly curb or limit the growth and development of the invading phytopathogens (Singh *et al*., 2013).

However, pathogens such as phytonematode disrupt the host oxidative burst by secreting various chemicals and as a result the plant defense responses are compromised. Martvnez-Medina *et al*., (2017) highlighted the role of SA/ *P. fluorescens* CHAO elicitors in the removal of high concentrations of the toxic ROS *via* an increase in the activity of their scavenging antioxidant enzymes *viz.* superoxide dismutase (SOD), peroxidase (POX), and catalase (CAT) in tomato challenged with *M. javanica*. An improvement in antioxidant enzyme activity was linked to an increase in plant resistance. Plants are believed to initiate the antioxidant machinery to weaken and neutralize the oxidative damages caused by increased ROS levels within the cell compartment. ROS also triggers different signaling pathways such as ethylene, jasmonic acid and salicylic acid mediated pathways and activates pathways leading to expression of several defense genes against pathogens (Conklin and Barth, 2004). Higher activities of PAL and PO were reported in combination of chitinolytic microbes treated *W. somnifera* compared to control and other treatments (Gupta *et al*., 2016c). Singh *et al*., 2016 proposed that chitinase production and ROS generation work together with compounds that can move systemically and thereby improves the generation of ROS in lateral parts of the infected plant. The application of beneficial microorganisms also triggered induced phenol accumulation in host plant compared to untreated ones (Singh *et al*., 2015).

Beneficial bacteria do not obviously injure their host/cause localized necrosis; therefore, the eliciting factors produced by ISR-triggering microbes must be different from the elicitors of phytopathogens (Kim *et al*., 2011). Several microbial strains can act as elicitors of ISR and the expression of ISR is dependent upon the interaction between host plant and strains (Derksen *et al*., 2013). The expression of ISR is similar to systemic acquired resistance (SAR) upon pathogen infection. The reduction in pathogen invasion is associated with the reduced colonization of induced tissues which imitates upon the ability of plant to oppose phytopathogens (Van Loon, 2007). Salicylic acid is an essential signaling molecule in systemically induced resistance responses; however, research on microbes mediated ISR signaling has demonstrated that jasmonic acid and ethylene play the key roles in defense. Thus, expression of ISR is dependent not only on a diverse category of biological stimulation but also occurs through various defense-related activities (Bhattacharyya and Jha, 2012).

The ISR inducers such as application of beneficial microbes were believed to be sensed by the host plants and ultimately respond through magnified immune responses. ISR responses were found to be directly linked to remodeling of the defense enzymes involved in host defense such as PR proteins, PAL, peroxidases (PO), superoxide dismutase (SOD), and polyphenol oxidase (PPO) (Jetiyanon, 2007), and enhanced accumulation of phenols. The enhanced activities of ISR indicates the capability of antagonistic microorganisms single as well as in combination to modulate the plant's gene expression pattern in a way that primarily helps in suppression of the pathogens.

Several reports have highlighted that rhizosphere of plants is one of the most fascinating microbial habitats, as it is shaped by the soil type, the plant species and the microorganisms (Lavania *et al*., 2006; Gupta *et al*., 2016a and b). The development of rhizosphere microbial communities is influenced by the plant species, but in turn, microorganisms exert profound effects on the plant growth. The roots of the plant become quickly colonized by a diverse microflora of microorganisms that may have either beneficial or harmful effects on the host. This rhizosphere effect is mainly due to the presence of mineral nutrients for the host roots along with the accumulation of plant root exudates. Microbial inoculation was also found to significantly increase growth, enhanced defense system, and uptake of mineral nutrients in plant (Babalola, 2010). Soil properties and plant species diversity are the key determinants in preservation and constancy of soil microbial diversity. Rhizospheric microbes have been reported to be drivers of microbial community shift in the plant rhizosphere (Hartmann *et al*., 2009).

Conclusions

The microbial inhabitants of the rhizosphere represent a potential reservoir of biocontrol agents that are capable of reducing the phytonematode population. Application of antagonistic beneficial microbes has emerged as an environment-friendly approach to promote plant growth effectively under biotic stress conditions including nematode infestation. Thus, an important factor in development of beneficial microbes as efficient biocontrol for commercial exploitation involves their interaction with the indigenous microbial community structure and function. Development of microbial based feasible and approaching technology is thus an urgency which can not only act in improved agronomic cultivations with higher economic benefits to the farmers, but is also valuable for the better crop yield and disease management. The previous finding also proposed that novel beneficial strains can be applied as multifunctional biocontrol agents for the development of suitable functional regime as microbial-based formulations. Additionally, the application of antagonistic microbes with rich nematode inhibiting activities might be helpful in the development of environment-friendly and efficacious biocontrol tactics in the near future.

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Forecasting of Plant Disease Distribution under Climate Change Scenario-Using CLIMEX Software

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ABSTRACT

CLIMEX is a computer software program that estimates the potential geographical distribution and seasonal abundance of a plant disease in relation to climate. Climate change is the biggest threat of the present century. Climate change is the result of the acceleration in the increase in temperature and CO_2 concentration over the last 100 years. Climate change may alter the distribution and activity of native and alien plant pathogens. Spot blotch in wheat caused by *Biopolaris sorokiniana* was minor disease limited to eastern India. However, disease is widely prevalent in almost in all wheat growing areas. Under climate change scenario there is need to anticipate invasion risks from new diseases. CLIMEX is a powerful software tool to predict future disease epidemics and provide support for developing strategies against spot blotch disease of wheat.

Introduction:

Climate change is the biggest threat of the present century. According to a study (Meckinnon, 2012), it is already contributing to the death of nearly 4, 00,000 people a year and costing the world more than US$ 1.2 trillion, thus wiping 1.6% annually from the global GDP. Climate change is the result of the acceleration in the increase in temperature and CO_2 concentration over the last 100 years (Sinha, 2011).

Up to the 1990s, there was little information about climate change impacts on plant disease. For example, in a review on the impacts on plant health of increasing atmosphere concentrations of ozone, SO_2 and CO_2, Coakley (1995) stated that disease development may increase, decrease or remain stable depending on the particular pollutant and host-pathogen interaction. Similarly, Manning and von Tiedemann (1995) recognized that, at that time, there was limited knowledge about observed and predicted impacts of climate change on plant epidemics. However, plant pathologists already realized in the 1990s that climate change was clearly set to pose a challenge to many patho-systems. Referring to tree fungal pathogens, Lonsdale and Gibbs (1995) made the point that environmental change, especially when combined with pathogen and host introductions, may result in unprecedented effects.

It is now recognized that climate change will affect plant diseases together with other components of global change, *i.e.* anthropogenic processes such as air, water and soil pollution, long-distance introduction of exotic species and urbanization (Gurr *et al.,* 2011and Bradley *et al.*, 2012). Predictions on how changes in climate will affect plant health at various spatio-temporal scales (from seasons to centuries, from the genetic to the eco-system level, from farms to watersheds and entire continents) are based on: (i) Already observed effects of climate change on plant diseases, (ii) Extrapolation from expert knowledge and experimental studies and (iii) Computer models.

It is widely acknowledged that climate change is likely to be pervasive across the planet, and will thus be relevant to most of the many existing (and yet to arise) plant health issues. Past reviews on the topic agree that climate change is a challenge that needs to be addressed together with the several problems already faced in agriculture, forestry, landscape management and nature conservation. It is important to study the interconnections among climate change and other drivers of global change in affecting plant health, also because declining plant health may result in climate change feedbacks (through changes in carbon sequestration and albedo patterns; O'Halloran *et al.,* 2012).

We need to anticipate invasion risks from both exotic and indigenous pests (Sturrock, *et. al.,* 2011) under climate change scenario. Ecological niche models, or species distribution models, are powerful tools to predict future disease epidemics, and provide support for developing strategies against new threats. Ecological niche models are defined here as correlative models that predict a species' potential geographical range based on two types of geo-referenced data, biological data describing the species' known distribution (presence and absence) and environmental data which describe the landscape conditions where the species is found (Venette and Cohen, 2006). A broad of algorithms are used in these models. Because of their reliance on environmental data, e.g., climatic or weather data, these models are well suited to studies of the effect of climate change on plant disease, and exotic pest introductions.

The ability of ecological niche models to use limited data such as species presence and generic environmental data makes them complementary to simulation models (Sinha, 2011). In many cases correlative approaches can provide a reasonable indication of high-risk areas for prioritization. One may distinguish different classes of ecological niche models. Climate envelope models, which involve climate matching, have been used to create predictive maps of critical pests' risk. CLIMEX and NAPPFAST, for instance, have been used by plant pathologists for forecasting plant disease occurrences. CLIMEX (Sutherest *et al.,* 2004) exemplifies well these tools, and has been used by plant pathologists to predict the likelihood of pathogen establishment under current climatic conditions or, more rarely, under climate change scenarios (Paul *et al.,* 2005).

The ecological niche model approaches discussed here currently can only utilize presence/absence and environmental information to predict disease risk at a specific geographic point, usually a grid cell a GIS raster file. This makes ecological niche models useful for identifying current high-risk locations or interactions in future scenario analysis (Sinha, 2011). Future challenges exist in analyzing the distribution of plant diseases. This departs from many ecological distribution model application, because it involves (i) an interaction between at least one host and a pathogen species, (ii) pathogen reproduction, evolution, and dispersal, at extremely variable rates and (iii) human intervention as a defining factor of agricultural systems. Thus information about the spatial structure of the host availability and the risk of disease build-up in neighbouring areas are important features to assess risk at any given location (Garrett *et al.,* 2006). These effects should be incorporated into ecological risk models in a GIS (Geographical Information System) to achieve a more completed picture of risk.

Spot blotch in wheat caused by *Biopolaris sorokiniana* was minor disease limited to eastern India (Sinha, 2011). However, disease is widely prevalent in almost in all wheat growing areas. Under climate change scenario there is need to anticipate invasion risks from new diseases. CLIMEX is a powerful software tool to predict future disease epidemics and provide support for developing strategies against spot blotch disease.

Methodology:

1. CLIMEX software, disease incidence data for the India as well as for South Asia.
2. Development of baseline model to characterize suitability of regional climates for facilitating stem rust infection using CLIMEX model (Sutherest *et al.,* 2004):

(i) Database climate normals with monthly/weekly for 35 locations along with known locations of Asia; mean max and min air temp, precipitation, RH (morning & afternoon) from 1971-2000.

(ii) Develop CLIMEX indices for each locations using eco-climatic index estimation of Eco-climatic index (EI); EI = [100/52 $\sum$ (TI_w x MI_w)] x [(1-CS/100) (1-HS/100) (1-DS/100) (1-WS/100)]. Whereas; TI_w= temperature index for week (w); MI_w= moisture index for week (w), CS= annual cold stress, HS = annual heat stress, DS = annual drought stress and WS= annual wet stress.

3. For compare locations and EI values are assigned between 0 and 100 (Salinari *et al.,* 2006): 0 unsuitable; 1-10 marginal; 11-25 favourable; ≥26 highly favourable for establishment.

4. **Model parameters selection:** Parameters estimates selection based on the available information on the pathogen and its past or current distribution.

(i) **Temperature:** DV0 (lower limit of growth); DV1 (lower optimum for growth); DV2 (upper optimum for growth); DV3 (upper limit for growth). Values to be derived through laboratory experiment or its geographic distribution.

(ii) **Soil moisture:** SM0 (lower limit of growth); SM1 (lower optimum for growth); SM2 (upper optimum for growth); SM3 (upper limit for growth). Cold, heat, dry and wet stress would be adjusted as 0 or values if available.

Model values would be exported to GIS to interpolate values between weather data centres (stations) and measure map attributes. Interpolation through optimized inverse distance weighting method.

Sensitivity analysis of CLIMEX: Baseline model would be tested to evaluate impact of parameter uncertainty on results. Parameters on temperature and high RH hours on pathogen population growth would be adjusted accordingly one by one with constraints DV0<DV1<DV2<DV3 and SM0<SM1<SM2<SM3.

Remember:

- CLIMEX forecasts the effect of climate change on species distribution, using simulation and modeling techniques. CLIMEX attempts to mimic the biological mechanisms that limit species' geographical distribution and determine their seasonal phenology and relative abundance.
- CLIMEX enables you to assess the risk of a pest establishing in a new location and the potential success or failure of a biological control agent with no knowledge of the species, except for knowing the current locations they do occur.
- CLIMEX model forecasts a species' potential geographical range based on geo-referenced data, species distribution (presence and absence) and environmental data which describe the landscape conditions where the species is found.
- Future distribution of an epidemic provides support for developing strategies against new threats.

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Professor M. J. Narasimhan Merit Academic Award

MJN 01: Studies on Anthracnose of Pomegranate Caused by *Colletotrichum gloeosporioides*

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Pomegranate (*Punica granatum* L.) is an important commercial fruit crop grown in tropical and sub-tropical regions. The crop is affected by many diseases causing large revenue losses in terms of exchange and one such disease is anthracnose. The survey conducted during 2014-15 in different districts of Southern Karnataka on anthracnose disease of pomegranate (*Colletotrichum gloeosporioides*) revealed that the maximum per cent disease index (37.05) was observed in Chitradurga and least (26.39) PDI in Kolar. Different isolates of *C. gloeosporioides* (Cg1 to Cg19) from different locations showed diversity in cultural and morphological characters. Malt extract medium supported maximum growth (87.50 mm) of the pathogen. Temperature of 30^{O}C, 6 pH with12 h alternate light and dark were best for optimum growth of thepathogen. Starch as carbon source and Calcium nitrate as nitrogen source were the best for mycelial growth with 80 mm and 86.33 mm diameter respectively. *In vitro* screening of fungicides against *C. gloeosporioides* showed two combination product Hexaconazole + Zineb, Trifloxystrobin + Tebuconazole and a non-systemic fungicide Captan exhibited cent per cent inhibition at 100, 250, 500 and 1000ppm concentrations. Similarly, systemic fungicides Hexaconazole, Propiconazole, Penconazole, Tebuconazole and Carbendazim showed cent per cent mycelial inhibition at 500, 1000 and 2000 ppm concentrations. The bioagents viz. *Trichoderma viride* and *T. harzinum* showed 90 to 100 per centinhibition of the pathogen followed by the botanical Nagadhale leaf extract (68.28 %) in dual culture technique.

MJN 02: Early Detection and Management of White Rust Disease (*Albugo candida*) in Rapeseed Mustard

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Among various diseases reported to occur on rapeseed mustard, white rust caused by *Albugo candida* is considered as one of the most important disease due to its destructive nature, wide distribution and grain yield losses of 17-34 per cent. The present investigation was carried out with the objectives of: early detection of *A. candida,* the cause of white rust disease; evaluation of rapeseed-mustard genotypes in field and in glasshouse (at cotyledonary and true leaf stage) and evaluation of some new fungicides for the effective management of the disease. The early detection of *A. candida* was done by PCR-based assay and light microscopy. In PCR based assay the primers ITS1 (3‘-GAGGGACTTTTGGGTAATCA-5‘) and Short ITS JV34 (3‘-CGCCATTTAGAGGAAGGTGA-5‘) and JV37 (3‘-GTCAAGCAAAACAT-5‘) were used to amplify the ITS region of *A. candida* and *Alternaria brassicae*. PCR amplification of *A. candida* from inoculated symptomatic and asymptomatic leaves yielded PCR products of 1200 bp and 600 bp of ITS1 and Short ITS primers, respectively whereas no bands were amplified in *A. brassicae*. This confirmed the presence of *A. candida* in asymptomatic inoculated leaves at early stage i.e. 1, 2, 3, 4, 5 and 6 DAI. In light microscopy the presence of pathogen structures were observed from inoculated symptomatic and asymptomatic inoculated leaves. This presence of pathogen structure viz. mycelium and sporangia was observed in asymptomatic leaves at early stage at 6,7,8 and 9 days after inoculation and from symptomatic leaves at 10 and 11 days after inoculation whereas no fungal structure in healthy mustard leaves after staining with 1 percent cotton blue in lacto phenol and 0.4% trypan blue. A large number of rapeseed-mustard materials collected from different sources evaluated in field and in glasshouse (at cotyledonary and true leaf stage) revealed that for the confirmation of resistant sources against white rust disease it is very essential to evaluate Brassica materials first in field and then in glasshouse at both the stages i.e. at cotyledonary and true leaf stage under high disease pressure because some Brassica materials escaped from the disease in field but found susceptible in glasshouse at both the stages (EC-399299) or only at true leaf stage (Katili local, *E. sativus*, Basanti and Banarasi rai, PWR-14-8, PWR-14-9, PWR-14-10, PWR-14-11, RMT-1-10-1, IC 597942 and IC265495). Among various fungicides Metalaxyl 8%+Mancozeb 64% (Ridomil MZ @ 0.25%) and a biological origin Azoxystrobin (Amistar 25 EC @ 0.1%) were found highly effective in inhibiting sporangial germination *in vitro* and were found highly effective in controlling white rust disease (no occurrence of disease) in glasshouse and field and in increasing grain yield and test weight followed by Propiconazole, Tebuconazole+Trifloxystrobin, Trifloxystrobin, Kresosim methyl (each at 0.1%). Garlic bulb extracts (2%) was also found effective in managing the disease even better than some old recommended fungicides.

MJN 03: Native *Trichoderma* species Exhibiting Crop Specificity in Growth Promoting Effect

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Trichoderma spp. is well recognized as biocontrol agents for soil borne plant pathogens and potential plant growth stimulators. They are perpetual inhabitants of highly interactive niches, viz. rhizosphere and rhizoplane of plants. It is already well known fact that plants actively select specific rhizosphere and rhizoplane microflora for establishing their own secure and beneficial habitat. Hence, it is conceivable that *Trichoderma* might also be specifically harboured in plant roots. The possibility of *Trichoderma* being crop specific is least exploited, as yet. The present investigation was therefore undertaken to ascertain the occurrence of crop specificity in growth promoting effect of native *Trichoderma* spp. isolated from rhizosphere and rhizoplane of three economically important crops *viz*. rice (*Oryza sativa*), wheat (*Triticum aestivum*) and chickpea (*Cicer arietinum*). Also, the selected isolates were tested for their antagonistic potential against phytopathogens namely, *Rhizoctonia solani* (isolates of rice and chickpea), *Sclerotinia sclerotiorum* (isolate from chickpea) and *Bipolaris sorokiniana* (isolate from wheat).A total of 27 *Trichoderma* isolates each from rice and wheat and 24 isolates from chickpea were isolated from the soil samples of rhizosphere and rhizoplane of healthy plants standing amidst diseased fields of these crops. Seeds of the respective crops were bio-primed with talc based formulations of the isolates. PBAT-1 was taken as standard check while untreated seeds served as check. *In vitro* (paper towel method) and glass house studies were conducted for evaluation of growth promoting potential of the isolates in their native crops. Step-wise screening regime was followed and only the superiorly performing isolates were selected while the rest were discarded. Finally two promising native isolates viz. TRS-R8 & TRS-R4 (rice), TRP-W8 & TRS-W4 (wheat) and TRP-C4 & TRP-C3 (chickpea) were selected from each crop. Subsequently, they were tested in their native as well as other two crops. Results analysed in terms of seedling vigour index (SVI) and plant vigour index (PVI) revealed that *Trichoderma* isolates, namely, TRS-R8 (4115 and 6204), TRP-W8 (3865 and 9919) and TRP-C4 (5303 and 5212), exhibited growth promoting effect in all the crops used in the study but performed significantly better in their native crops as compared to other isolates, standard check (3342 to 4402 and 4863 to 8770) and check. The results highlighted that native *Trichoderma* spp. could also possess certain degree of crop specificity in casting growth enhancing effect. The finally selected isolates (TRP-W8, TRS-W4, TRS-R8, TRS-R4, TRP-C4 and TRP-C3) were also tested for their antagonistic potential against above mentioned phytopathogens *in vitro* using dual culture technique. The finally selected isolates parasitized the test pathogens completely (100%) within 7 days of contact. These results underlined another important point that although the native *Trichoderma* isolates might be crop-specific in promoting growth but antagonism is manifested in generalized manner only. All the selected *Trichoderma* isolates (06 no.) were identified as *Trichoderma viride* (now *T. asperellum*) with the help of Bio-Log system (Version 4.2, GEN II). The present study revealed that rhizospheric and rhizoplanic native *Trichoderma* isolates had pronounced growth promoting effect in their respective crop as compared to other crops. So far, crop specificity in the growth promoting potential of native *Trichoderma* spp. has been least exploited. Future studies involving systematic field experiments and molecular approaches would help to understand the underlying mechanism. In-depth research in this area would obviously ensure more diversified usage of *Trichoderma* spp.

MJN 04: *In vitro* Evaluation of Secondary Metabolites Isolated from Endolichenic Fungi against Crop-Pathogenic Microbes

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Endolichenic fungi, an emerging group of endosymbiotic microorganisms, consist of fungal strains that live within the lichen thalli in much the same way as endophytic fungi live within healthy plant tissues. These fungi coexist with the mycobiont and live in very close association with the photobiont. They have been discovered within living, apparently healthy lichen thalli and are more closely related to endophytes than lichen-associated fungi. Besides being so diverse, they are also valuable source of various bioactive compounds including some novel metabolites, such as cucurbitarins, chaetoglobosin, terpeniods, naphthalene derivatives, heptaketides, polyketides, alkaloids, pyridoxatin, variecolortide, thiopyranchromenone and chromone derivatives, which can serve as ultimate, readily renewable and inexhaustible source of novel natural products displaying broad spectrum of biological activities. But besides being so rich in secondary metabolites, only a limited number of strains have been chemically investigated.

Lichen samples were collected from Syahi Devi forest, Almora district, located between 79°33' 42.30" E and 29°34' 50.35" N at an elevation of 2049 m in Kumaun region of Uttarakhand. Samples then washed thoroughly with running tap water to remove extra soil, then serial washed 20 times (1 min each time) in autoclaved double distilled water, then dipped in 20% H_2O_2 (1 min), followed by washing it with 5% NaOCl (1 min) and 70% ethanol (30 sec). After that incubated at 25°C, then the developed fungal colonies were identified under compound microscope. Fermentation was carried out in Erlenmeyer flasks, each containing 80 gm of rice and 120 ml distilled water and autoclaved. After cooling to room temperature, each flask was inoculated with 5 ml of the spore inoculum and incubated at 25°C for 40 days. Extracts were obtained in ethyl acetate and evaporated to dryness to get the crude extract. Identification and quantification of secondary metabolites present in the extract was carried out by gas chromatography coupled with mass spectrometry. Pathogenic bacterial strains *viz*. *Agrobacterium tumefaciens*, *Erwinia crysanthemi*, *Ralstonia solanacearum*, *Xanthomonas campestris*, *X. oryzae* and *X. phaseoli* were purchased from Indian Type Culture Collection (ITCC), ICAR, New Delhi, while some were provided by the Department of Botany, Nainital, Kumaun University. Evaluation of antimicrobial activity of endolichenic fungi extracts was done by disc-diffusion method. The evaluation of MICs was done using the broth dilution method with slight modifications described by the Clinical and Laboratory Standard Institute. The data were subjected to Agglomerative Hierarchical Clustering analysis (AHC) by using PAST and XLSTAT statistical computer software for evaluating correlation between antibacterial activity and endolichenic extract.

The metabolites isolated from 04 endolichenic fungi displayed a plethora of compounds. *Mucor* sp. showed the predominance of 6-Hydroxy-7-isopropyl-1,4 a-dimethyl-1,2,3,4,4a,9,10,10a, while Cylobutanecarboxylic acid, 2,6-dimethylnon-1-en-3-yn-5 was the major compound isolated from *T. viride*. *P. citrinum* has the highest content of Spiro[benzofuran-2(3H),1'-[2] cyclohexene]-3,4 while *A. niger* has the preponderance of Phenol, 3,5-dimethoxy-, acetate.The crude extracts of endolichenic fungi exhibited significant inhibitory activity against tested bacteria. Among all the tested crop pathogens *A. tumifaciens* was found to be the most susceptible against all the tested fungal extracts and showed zone of inhibition more than 10 mm in all fungal extracts. However, *R. solanacearum* was the most resistant pathogen since it showed zone of inhibition less than 10 mm against all the tested fungal extracts. Extract of *A. niger* came out as a broad spectrum antibiotic since it showed maximum zone of inhibition against 03 out of six pathogens (*X. oryzae*, *X. Campestris* and *A. tumefaciens*) and showed minimum inhibition against *E. chrysanthemi* (8.66 mm; MIC = 300 mg/ml)

Since, antimicrobial potential of endolichenic fungi has never been evaluated against crop pathogens; hence, this study for the very first time reports the inhibition of crop infecting bacteria by endolichenic fungi. Results of this study therefore indicate that extracts from endolichenic fungi could be alternative agents to cure the diseases caused by the target pathogens. Use of endolichenic fungi may not only help to reduce the dependency on chemically synthesized antimicrobials but will also overcome the loss of lichen diversity for their bactericidal use.

MJN 05: Induction of Resistance in Tomato Seedlings against Alternaria Blight through SA, ABA and *Pseudomonas fluorescens* strain PBAT-2

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Alternaria blight of tomato is one of the most destructive diseases causing significant qualitative and quantitative losses at all growth stage of plant. As the disease severity is more during fruiting stage, the toxic effects of fungicides also restrict the applicability of these chemicals. Induced resistance can be an alternative to chemical fungicide for the control of early blight of disease tomato. In present investigation, three resistance inducing agents namely Salicylic acid (SA), Abscisssic acid (ABA) and Plant growth promoting rhizobacteria (PGPR) *Pseudomonas fluorescens* strain PBAT-2 (*Psf*) are treated to tomato seedlings under glass house condition and their impact on reduction in disease severity, activity of defense related compounds namely Peroxidase (POD), Polyphenol oxidase (PPO), Phenyl ammonialyase (PAL) and total phenolic content and expression of defense gene viz Pathogenesis related gene PR-1 and β-1,3-glucanse (GLU) was studied. All the three treatment namely SA, ABA and *Psf* exhibited significant reduction in disease severity as compared to control under glasshouse condition. Significant increase in activity of POD, PPO, PAL and total phenol content has been recorded in all the three treatments while minimal activity was recorded in control. POD, PPO and PAL level remain significantly higher at 24h and 48h post *Alternaria solani* inoculation followed by start declining. However, total phenolic content increased upto 72h. In SA and ABA treated leaves, the expression of PR-1and GLU gene was rapidly upregulated at 24 h after inoculation of *A. solani*. As PR-1 gene is an indicator gene of systemic acquired resistance. It implies that both in SA and ABA treatment systemic acquired resistance confers resistance in tomato plants against *A. solani*. There was no expression of PR-1 and GLU transcript in *Psf* treated plant as PGPR has no role in induction of PR protein in Induced systemic defense response (ISR). On the basis of findings of glasshouse, biochemical and gene expression analysis, it may be concluded that SA, ABA and *Psf* could induce resistance in tomato plants against *A. solani* causing early blight disease.

MJN 06: Combination of Copper-Chitosan-Trichoderma mediate Defense Induction in Potato against Late Blight Pathogen

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Late blight disease is a serious threat for the production of important horticultural crops like potato and tomato. Due to aggressive nature of pathogen and explosive nature of the development, it is important to develop innovative methods for management of this disease. Although copper (Cu), chitosan (Chi) and *Trichoderma* (Tri) individually have been widely used to protect plants from a variety of pathogenic diseases, their combination has been found to significantly reduce late blight disease of potato at field level. Though action of the physical mixture of the three ingredients suggests an integration of defence induction mechanism with fungicidal protection yet the mechanism behind the triple combination induced resistance needs to be understood. The aim of this research was to assess the effect of combination of Cu-Chi-Tri on defence induction in potato against *Phytophthora infestans*. Experiments were performed using susceptible potato variety Kufri Jyoti and experiments were conducted under field as well as glass house conditions for establishing reproducibility of results. Technical grade CuOH (Spiess Urania, Germany), Chitosan 651 (Mahtani chitosan Pvt. Ltd, Veraval, Gujarat) and talc-based formulation of copper tolerant and chitosanolytic *Trichoderma* (TCMS 36 strain) prepared in the Biocontrol lab, G.B. Pant University of Agriculture & Technology, Pantnagar was used singly as well as in dual and triple combinations. A total of 10 treatments were evaluated under controlled and natural conditions. Under glass house conditions treatments were given using a hand sprayer and plants were challenge inoculated by *P. infestans* 24 hours after treatments. In glass house, 24 hr after treatments, the potato plants were challenge inoculated with *P. infestans* zoospore suspension. In field experiment, natural inoculum was assured by growing the susceptible potato varieties. Under glasshouse conditions, disease was recorded 98 hr post inoculation by measuring the percentage infected leaf area (PLA). Under field conditions, disease severity was observed before and after application of the treatments and increase in disease severity was calculated. Microscopic quantification of trichomes was performed using Olympus IX81 motorized inverted differential interference contrast (DIC) microscope with magnification of 40x. Biochemcally SOD was estimated by the procedure of Beauchamp and Fridovich (1971) and $H_2O_2$was estimated by the method of Alexieva *et al.* (2001). Proline content was determined by the method of Bates *et al.* (1973). In the present study it was observed that a triple combination comprising of Cu-Chi-Tri was effective in controlling the late blight disease and slowed down its progress. Based on the estimation of the disease severity, it was found that triple combination was effective in controlling the progress of the disease both under field and glass house conditions, compared to other treatments evaluated in the study. It was observed that leaves treated with the triple combination had shiny leaves with dense growth of trichomes, compared to other treatments and control. Therefore, it is speculated that triple combination might be strengthening physical defense in potato plants by increasing the no. of trichomes and thus inhibiting penetration and spread of the late blight pathogen, which requires high humidity on the leaf surface for germination and penetration. On estimating biochemical markers of defense induction, it was observed that proline concentration increases in plants treated with triple combination. Proline makes the plants tolerant to abiotic stresses and is recently reported to be involved in initial defense induction against pathogens (Qamar *et al*., 2015).Increase in concentration of proline suggest that, in plants treated with triple combination defense reactions are initiated which stop/ inhibit spread of the pathogen. This observation is further supported by observed increase in concentration of SOD and H_2O_2. Both SOD and H_2O_2 are involved in the initial defense reactions and induction of hypersensitive response (Lakimova *et al*., 2005) against pathogens. The observation that SOD and H_2O_2 increase by triple combination supports the hypothesis that triple combination may induce ROS and hypersensitive response for inducing defence against *P. infestans* invasion. The result from glass house and field trial suggest that oxidative burst might be the intial mechanism for checking the entry of the pathogen, which triggers the downstream biochemical mechinery for defence induction. Thus, decrease in disease severity in plants treated with triple combination may be due to increase in number of trichomes as first line of defence, followed by induction of biochemical pathways and hypersensitive response for restricting entry of the pathogen. Results suggested that triple combination of Cu-Chi-Tri evaluated in this study is effective in managing late blight of potato by inducing the general defense pathway in potato plant. Further, due to reduced dosage of Cu used in the combination, it will be environment friendly and less phytotoxic. The combination involves copper (fungicide), chitosan (plant strengthner) and Trichoderma (a well-known biocontrol agent), suggesting that the components of the triple combination will have different mechanisms for disease management. Due to multiple sites of action this combination may provide a durable and long lasting management strategy for late blight pathogen.

MJN 07: Conjunctive Impact of Root Associated Bioagents, Methyl Jasmonate and Salicylic Acid Induced Resistance through Enhanced Phenylpropanoid Activities and Plant Growth Promotion in Wheat (*Triticum aestivum* L.)

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Impact of root associated bioagents *Trichoderma harzianum, Bacillus* spp. *Pseudomonas* spp. and inducer molecules methyl jasmonate and SA mediated induced systemic resistance and their integration on the spot blotch pathogen through enhanced phenylpropanoid activities in wheat (*Triticum aestivum* L.) was evaluated. The bioagent was applied as seed treatment, whereas MeJA and SA were applied as foliar application. The results show manifold increase in salicylic acid (SA) and phenolics in the leaves of the plants treated with the bioagent alone or in combination with MeJA. Further, the activities of defense enzymes consisting of catalase, ascorbate peroxidase and PAL as well as total phenols and acid soluble lignin were enhanced significantly in the plants under treatment. Significant decrease in the disease severity and area under disease progress curve were also observed in the treatments. Up-regulation of phenylpropanoid cascades in response to exogenous application of MeJA, SA and the bioagent indicates that PAL is the primary route for SA and lignin production in wheat. Further, the increased accumulation of SA and individual phenolics appear closely related to induction of phenylpropanoid networks and induced systemic resistance in wheat. Elevated level of SA in the wheat after exogenous application of MeJA, SA and *T. harzianum* indicated novel insight into the mechanisms and cross-talk among various networks in mitigating oxidative stress and simultaneously restricting pathogen development in wheat. These results suggest that exogenous application of MeJA with *T. harzianum* inducing JA- and/or SA-dependent defence signalling after pathogen challenge may increase the resistance to spot blotch by stimulating enzymatic activities and accumulation of phenolic compounds in cooperative manner. This study apparently provides the evidence of biochemical cross-talk and physiological responses in wheat following MeJA, SA and bio-agent treatment during the bio-trophic infection.

MJN 08: Development of Integrated Management Module for Sheath Blight Disease of Rice caused by *Rhizoctonia solani* AG1-IA: A Success Story for Endemic Area

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Sheath blight (ShB) disease of rice caused by *Rhizoctonia solani* AG1-IA is is one of the most destructive and notorious problem in rice. The fungus has been found to cause complete failure of rice crop due to cultivation of susceptible varieties in heavily infested fields. In view of lesser effectiveness of chemical fungicides and higher cost of treatment in rice ecosystem, a series of investigations were carried out to device an effective and sustainable integrated management module for endemic area of ShB disease of rice. Twenty rice cultivars were evaluated for their relative susceptibility to *R. solani* under pot condition. The variation in the synthesis of total phenol (TP) and salicylic acid (SA) as influenced by host reaction and subsequently their impact on the disease etiology was also studied. The cultivars inoculated with 2 g *R. solani* (1×10^6 CFU/g) expressed varied responses. The cv. Shanthi expressed resistance, whereas the cvs. PS-5 and PS-4 were found highly susceptible to the fungus. The increase in SA and TP concentration was recorded highest in cv. Shanthi (16 and 21%, respectively) and lowest in cv. PS-5 (6 and 9%, respectively). The cv. Shanthi exhibited lowest disease severity (0.6 at 0-5 scale), whereas cv. PS-5 exhibited highest disease severity (4.6 on 0-5 scale). The study revealed that the cvs. Shanthi may be exploited for commercial cultivation in the endemic zone of ShB fungus, but farmers continue to grow susceptible Basmati rice due to its high cash value and demand of the variety. To tackle this situation, further investigations on the effectiveness of twelve native rhizospheric isolates of fungal and bacterial biocontrol agents (BCAs) and twelve fungicides were carried out *in vitro.* Based on relative performances, six BCA isolates and six fungicides were evaluated in pots for their effectiveness against *R. solani* on the susceptible rice cv. PS-5. Plants grown in inoculated soil developed necrotic lesions and plants exhibited 24-30% decrease in growth and yield. However, soil application of BCAs and fungicides minimized the negative impact of ShB pathogen. Among the BCAs, *Pseudomonas putida* AMUPP-2 was found most effective followed by *Trichoderma harzianum* AMUTH-3*, P. fluorescens* AMUPF-1*, Bacillus subtilis* AMUBS-1*, T. viride* AMUTV-3 and *Aspergillus niger* AMUAN-1. Among the fungicides, azoxystrubin was found most effective followed by flusilazole, propiconazole, difeconazole, tebuconazole and hexaconazole. The study revealed the antagonistic potential of *P. putida* for the first time against *R. solani* and the relative effectiveness of *P. putida* was higher than *P. fluorescens* and *T. harzianum* and propiconazole. Based on compatibility tests of BCAs with fungicides *in-vitro*, effectiveness of above three BCAs and three fungicides (azoxystrubin, flusilazole and propiconazole) was evaluated against ShB under pot condition as soil treatment at 15 and 45 days after planting (DAP). Application of azoxystrubin + *P. putida* at 15 DAP and subsequent treatment of *T. harzianum* or *P. putida* at 45 DAP was found most effective and suppressed the disease severity (35-44%) and soil population (48-61%) of *R. solani*. The treatment promoted the plant growth variables by 29-34%. To ascertain the performance of the integrated management module, trials were conducted in two fields, one in the experimental plots and other in the farmer‘s field during two consecutive years. In experimental plots, combined treatment of azoxystrubin + *P. putida* at 15 DAP followed by application of *P. putida* or *T. harzianum* at 45 DAP was found highly effective against *R. solani* and suppressed the disease incidence and severity by 64-78% and enhanced the yield by 32-39%. Second field trial conducted in the farmer‘s field at Iglas, Aligarh also revealed greater effectiveness of integrated treatment of azoxystrubin + *P. putida* at 15 DAP followed by application of *P. putida* or *T. harzianum* at 45 DAP. The IDM module significantly decreased the disease incidence by 85% and improved the rice yield by 45% compared to epidemic condition

MJN 09: Potential of *Brassica juncea* as Biofumigant for the Management of Damping-off in Tomato

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Damping-off is one of the serious most diseases in vegetable nurseries. In tomato, 72.3 to 100% incidence of damping-off disease is reported by many researchers. Fungicides though are the most common means to check the disease in nursery, frequent and intensified use of these chemicals is hazardous to humans and environment. Alternative disease management strategies, thus, are being emphasized with an objective of reducing crop losses besides minimal ecological implications. Among different alternatives to chemical control, biofumigation i.e. suppression of soil borne pests and diseases by glucosinolate containing plants arising from the biocidal properties of hydrolysis products of glucosinolates especially isothiocyanates, released from incorporated tissues of *Brassicaceae* plants, has been considered to be most promising eco-friendly management option for the soil borne plant pathogens. Keeping this in view, the present investigation was carried out to evaluate the potential of three *Brassica juncea* varieties viz., Kranti, Varuna and Divya as biofumigant alone and also in combination with Pant Biocontrol Agent-3 (consortium of *Trichoderma asperellium* and *Pseudomonus fluoroscens*) for the management of damping-off disease in tomato.*Pythium aphanidermatum* was isolated from infested soil following bait technique and *in vitro* toxicity of the volatiles released from the *B. juncea* varieties against soil borne pathogens was evaluated using head space technique. To evaluate *B. juncea* as biofumigant for the management of damping-off in tomato in glass house conditions, *B.*

juncea varieties were chopped at 50 % flowering stage and were incorporated into the pots containing *P. aphanidermatum* inoculated soil. Pots were covered with 100 micron polythene sheet for 14 days and after uncovering the pots, those were kept as such for 3 days. Thereafter, tomato seeds (var. S-21) were sown in the pots as per treatment. In the field conditions, *B. juncea* varieties were grown up to 50 % flowering stage and were incorporated into the soil after chopping. Plots were covered with 100 micron polythene sheet for 14 days and after uncovering the pots, those were kept as such for 3 days. Thereafter, tomato seeds (var. S-21) were sown in the plots as per treatment. Quantification of sinigrin was done through high performance liquid chromatography. At 100 mg per plate dose of crushed leaf powder, *P. aphanidermatum* showed highest sensitivity to Kranti variety with growth inhibition of 81.05% followed by Varuna (65.21%) and Divya (54.79%). *Rhizoctonia solani*, *Fusarium oxysporusm*, *Sclerotinia sclerotiorum* and *Sclerotium rolfsii* were most sensitive to the volatiles released from Kranti variety followed by Varuna and Divya. Growth inhibition by Kranti was found to be 90.41, 92.08, 91.66 and 92.88 % over control for *R. solani*, *F. oxysporusm*, *S. sclerotiorum* and *S. rolfsii,* respectively. Incidence of pre-emergence damping-off was found minimum in the treatment Kranti+PBAT-3 in both glasshouse and field conditions (4.47% in glasshouse and 11.67% in field) as compared to control (42.20% in glasshouse and 37.67% in field). Post-emergence damping-off incidence was recorded to be lowest in the treatment Kranti+PBAT-3 in glasshouse as well as in field (6.98% in glasshouse and 5.47% in field) as compared to control (26.98% in glasshouse and 14.56% in field). Maximum shoot length and root length were attained in the treatment Kranti+PBAT-3 in both glasshouse and field conditions (36.67 cm shoot length and 10.08 cm root length in glasshouse; 35.62 cm shoot length and 10.05 cm root length in field). Maximum fresh weight of shoot and root were recorded in the treatment Kranti+PBAT-3 in glasshouse as well as in field conditions (6.10 g shoot weight and 1.87 g root weight in glasshouse; 6.12 g shoot weight and 0.63 g root weight in field). Dry weight of shoot and root were also found to be highest in the treatment Kranti+PBAT-3 in glasshouse and also in field condition (1.27 g shoot weight and 0.46 g root weight in glasshouse; 0.98 g shoot weight and 0.15 g root weight in field). Highest plant vigour index was attained in the treatment Kranti+PBAT-3 in glasshouse as well as in field condition (4466.03 in glasshouse and 4034.03 in field). Maximum Sinigrin content was found in Kranti (21.17 μM/g) followed by Varuna (15.37 μM/g) and Divya (9.74 μM/g) through HPLC. It justified the results of the previous experiments. Thus, from the results of different experiments, it could be concluded that *B.juncea* tissue degradation products containing higher concentrations of biocidal compounds like isothiocyanates have greater potential in managing damping-off disease in tomato and also other soil borne plant pathogens. Combination of *B. juncea* biofumigants with application of biological control agents effectively controlled tomato damping off and enhance plant growth parameters. Among different *B. juncea* varieties, Kranti emerged as potent biofumigant as it resulted in the minimum incidence of pre and post-emergence damping off. Therefore, biofumigation with Kranti and seed biopriming with PBAT-3 could be a handy option to manage damping off disease of tomato in nursery.

APS Student Travel Award

APS 01: Pathogenic Characterization of *Albugo candida* isolates the cause of White Rust Disease in Rapeseed-Mustard

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Rapeseed-mustard comprise the most important edible oilseed crops in India. White rust incited by *Albugo candida* (Pers. ex. Lev) Kuntze. affects these crops in India as well as other countries and is one of the major constraints for their low productivity. *A. candida* exhibits specialization on different cruciferous species and on cultivars within species. Depending on the severity of infection, the yield losses caused by white rust or a mixture of white rust and downy mildew, range between 17% to 60%. Most of the Indian cultivars are susceptible to white rust and there is lots of variability in *A. candida* affecting rapeseed mustard in different parts of India. The identification of *A. candida* races is very difficult and there is no reliable and validated method available till now, most of the races have been designated on the basis of infectivity on different *Brassica* species. However, theoretically races cannot be identify on the basis of species, it should be identify on the basis of isogenic lines/genotypes/cultivars. Therefore, the present investigation focuses on to carry out re-designation of *A. candida* races on the basis of infectivity of *A. candida* isolates on different genotype/cultivars of different *Brassica* species. For this pathogenic characterization of *A. candida* isolates (collected from major *Brassica* growing states/geographical areas of India), have done during 2016-17 under controlled environment glasshouse facilities at GBPUAT, Pantnagar, Uttarakhand. Nineteen different genotype/cultivars of different *Brassica* species were taken for host differential study against fifteen different *A. candida* isolates, at two different growth stage of the plants i.e. cotyledonary as well as true leaf stage. Studies conducted for the host differential as well as to find out most susceptible stage of different *Brassica* species against *A. candida* isolates. Disease reaction of all the isolates on different varieties of *Brassica* species were taken following 0-7 rating scale (Leckie *et al.,* 1996). At cotyledonary stage, different genotypes such as Bhawani, Tobin, Candle, *Eruca sativa,* Kiran, GSL-1, Donskaja, Cutlass, Bio-YSR, NRCDR-515 and *Raphanus sativa* showed ‗NN' disease reaction i.e. no sporulation with almost all isolates of *A. candida*. Genotypes such as Varuna showed S2-4/5 or S3-6/7 and *Sinapis alba* showed S1-2/3 or S2-4/5 disease reaction as well as disease score with almost all the tested isolates (15 no.). Among the isolates Bangalore, Simour and Karnal were found to be more virulent and showed different disease reaction with different genotypes**.** At true leaf stage, different genotypes such as Bhawani*, Eruca sativa, Sinapis alba*, Kiran, GSL-1, Sangam, Donskaja, Bio-YSR, NRCDR-515, *Raphanus sativa* and *Brassica oleraceae* showed ‗NN' disease reaction i.e. no sporulation with almost all isolates of *A. candida*. Genotypes such as Varuna and Pusa bold showed S1-2/3 or S2-4/5 or S3-6/7 disease reaction as well as disease score with almost all the tested isolates (15 no.). Among the isolates Jammu, Kanpur, Bangalore and UDSC were found to be more virulent and showed different disease reaction with different genotypes. The same experiment will be conducted during 2017-18 for the confirmation of the results. Molecular characterization of the *A. candida* isolates are undergoing for the validation of host differential studies as well as identification of *A. candida* races.

APS 02: Studying Interaction between Chitosan and Copper for Effective and Eco-friendly Management of Plant Diseases

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Spraying copper fungicides for managing plant pathogens is one of the most traditional methods of plant disease control. Since copper-based products have broad-spectrum activity and are acceptable under organic farming system, these would continue to be important for managing plant diseases. However, accumulation of copper when used intensively remains a concern that necessitates reduction in the doses of copper going into the environment. Chitosan, the N-deacetylated derivate of chitin exhibits variety of anti-microbial properties as well as play role in eliciting host plant defense. Chitosan has also drawn particular attention as effective biosorbent. It has been proved that chitosan has the best metal chelating property. By integrating the two important properties of chitosan, *viz.,* ‗antimicrobial property' and ‗metal chelating property' antimicrobial chitosan-metal (in this case chitosan-copper) complexes could be formed for management of plant pathogens, in particular the oomycetes. The metal-chitosan complex could play an important role in disease management by creating a defense layer on leaf surface with the help of chitosan as well as metal ions. Further, chitosan couldplay a crucial role in such a complex because by chelating metal ions it could prevent washing of copper ions from plant surface, thereby enhancing persistence of chemical for longer duration on leaf surface during wet seasons. Present study, therefore, focuses on interaction of chitosan particles with copper ions obtained from three different copper ion sources to find out which copper compound could efficiently interact with chitosan particles and thus could be used in field application as ‗chitosan-copper complex' for management of plant diseases. Chitosan (80% DDA) and Copper Hydroxide (CuOH) technical grade (TG, 62.3% a,i.), commercially available copper hydroxide (CuOH) fungicide ‗Kocide' (77% WP) and ‗Copper (II) sulphatepentahydrate ($CuSO_4$)' of analytical grade were used for the study. Samples were prepared by mixing 1g of chitosan into 50 ml of copper solution (100 ppm). These samples were used for batch adsorption studies carried out at room temperature with 50 ml of working Cu (II) ion solution (100 ppm) from different copper sources. At pre-determined time intervals (0 min, 60 min and 120 min) the adsorbent was removed by filtration through Whatmann filter paper no 3 and filtrates were collected for analyzing the residual Cu ions concentration in the solution. The adsorbent remained there on filter paper after filtration of copper-chitosan solution, was collected and dried at room temperature for 24 hours. Theses dried samples were used for SEM and EDS analysis to further confirm the presence of copper on chitosan surface. AAS studies revealed maximum uptake of Copper by chitosan in the complex ‗Chitosan+CuOH' (TG) (99.42%), followed by ‗Chitosan+CuSO4'(76.93%) and then ‗Chitosan +Kocide'(65.51%). In control (Chitosan + distilled water) no Copper was detected. SEM images also revealed presence of Copper on chitosan surface. But contradicting result was obtained in case of ‗Chitosan+$CuSO_4$', where, even after adsorption of copper, no copper was visible on chitosan surface. EDS analysis further confirmed the presence of Copper in all the above mentioned samples including ‗Chitosan+$CuSO_4$. Thus the study highlights the use of ‗Chitosan+CuOH (TG) for the management of plant diseases, since copper ions from CuOH (TG) were adsorbed effctively on the chitosan surface thus forming ‗chitosan-Cu complex'. The study revealed that the use of Chitosan + CuOH (TG) complex could effectively be used for management of various plant diseases since copper is a broad spectrum protectant fungicide. Chitosan on integration with copper ions may prolong protection on plant surface by chelating copper ions and thus could

prevent washing off of the copper. While also the anti-microbial and plant defense inducing properties of chitosan could lower the amount of copper dose needed for disease management and thus wouldresult into eco-friendly management of plant diseases.

APS 03: Identification and Characterization of Biotic (*Fusarium udum*) and Abiotic (NaCl) Stress Responsive WRKY Transcription factors in Pigeonpea

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WRKY proteins constitute one of the largest transcription factor families in higher plants, and they are involved in multiple biological processes such as plant development, metabolism, and responses to biotic and abiotic stresses. Genes of this family have been well documented in response to many abiotic and biotic stresses in various plant species. Moreover, potentiality of a specific gene may vary depending on stress conditions and genotypes. A total of 97 CcWRKY genes were identified in this study using computational prediction method. Structural analysis found that CcWRKY proteins contained a highly conserved motif WRKYGQK. Phylogenetic analysis of CcWRKYs together with the homologous genes from the representative species could classify them into three groups. Finally, the transcriptional profiles of these 35 CcWRKY genes in root tissue after 24 h of biotic and abiotic stresses inoculation were systematically investigated using qRT-PCR analysis in wilt resistant and susceptible cultivars of pigeonpea in presence of *Pseudomonas fluorescence* strain OKC. Results showed that the expression level of 35 CcWRKY genes varied significantly under biotic and abiotic stress treatments, which could be defined as biotic and abiotic stress-responsive genes. Particularly in presence of OKC we found higher fold change in expression pattern of 28 CcWRKY genes in Asha and 13 CcWRKY genes in Bahar to biotic while 23 CcWRKY genes in Asha and 17 CcWRKY genes in Bahar to abiotic stress response. This was the first study to identify the organization and transcriptional profiles of CcWRKY genes, which not only facilitates the functional analysis of the CcWRKY genes, and also lays the foundation to reveal the molecular mechanism of stress tolerance in this important crop.

Session 01:

Host Plant Resistance, Microbial Diversity/Biodiversity for Crop Improvement, Sustainable Utilization and Conservation of Natural Resources

LP 01: Diversity, Diagnosis and Management of *Xanthomonas* species causing Bacterial Leaf Spot Disease of Pepper and Tomato in India

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Bacterial leaf spot caused by *Xanthomonas* spp. is one of devastating diseases leading to significant crop losses up to 23–44% which once spreads; it is very difficult to manage especially in regions with warm and humid climate. In India, for the first time the disease was reported from Puna, Maharashtra in 1948, then it has also been reported from Kerala, Karnataka, Uttar Pradesh, Uttarakhand, Himachal Pradesh, Uttarakhand and Maharashtra. The present study was under taken to characterize and identify prominent species of Xanthomonas causing bacterial leaf spot disease on pepper and their genetic diversity in India. Thirty one isolates of Xanthomonads isolated from infected leaf and fruit samples of tomato, chilli and bell pepper from 5 different states of India *viz.,* Himachal Pradesh, Karnataka, Uttarakhand, Tamil Nadu and Haryana were characterized as they produced translucent, yellow, raised colonies on YGCA medium, Gram negative, rod shaped, positive in starch hydrolysis, variation in pectin utilization. These isolates showed symptoms on chilli cv. Pusa Jwala and tomato cv. Pusa Ruby and they were grouped into pepper-tomato group (XCVPT), belonged to *Xanthomonas euvesicatoria*. Two set of primers *i. e.* Bs-XeF & Bs- XeR and Xeu 2.4 & Xeu 2.5 specific to *X. euvesicatoria* were used for further confirmation and the primers amplified DNA of all the isolates at 173bp and 208 bp respectively. Genetic diversity of 31 isolates of *X. euvesicatoria* along with four out group bacteria *Pseudomonas fluorescence* DTPF-3, *X. campestris* pv. *campestris* Xcc-4, and Xcc-C23 and B. subtilis DTBS-5 was done by REP, ERIC and BOX- PCRs fingerprinting. Out of 12 DNA types, maximum isolates of *X. euvesicatoria* (12 isolates) belong to DNA type 2 isolated from tomato plants from different states of India and formed separated group from isolated from pepper. High level of genetic diversity among the *X. euvasicatoria* isolates was observed. All out group bacteria were separated from *X. euvesicatoria* isolates. The bacteria have a very limited survival period of days to weeks in the soil, and thus their survival is almost always in association with debris from infected or diseased plants. The pathogens have been reported to persist in association with roots of wheat as well as a few weed species; weeds, however, are considered to play only a minor role in pathogen survival. The primary management strategy of bacterial spot begins with use of certified pathogen-free seed and disease-free transplants. The bacteria do not survive well once host material has decayed, so crop rotation is recommended. Once the bacteria are introduced into a field or greenhouse, the disease is very difficult to control. Pepper plants are routinely sprayed with copper-containing bactericides to maintain a "protective" cover on the foliage and fruit. Strains of the pathogen resistant to copper and/or streptomycin are fairly common and can be detected by plating bacteria on media containing these compounds. Although resistant cultivars are available and widely planted, there are strains of the pathogen able to overcome all of the currently known major resistance genes. Currently, three independently segregating genes form the basis for resistance to bacterial spot in commercial cultivars of bell peppers. Strains of the pathogen that react differently with the resistance genes of the pepper plant are designated as races. With the report of a fourth resistance gene in 1998, 11 races can be differentiated using peppers. Resistance has not been as easy to find and use in tomato. Biological control options for bacterial spot are limited. However, a biological control method that uses bacterial viruses (bacteriophages) that specifically kill the bacterial pathogens is now available. Treatments with these bacteriophages, marketed as ―AgriPhage," have been successful in reducing disease, especially in greenhouse transplant production.

LP 02: Strategy of Plant Disease Management under Organic Farming Conditions

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In our country, during 2016-17 around 11.8 lakh ha area has been occupied under certified management for organic farming (OF) and the country has the largest number of organic producers in the world. Sikkim is the recognized organic State, while Madhya Pradesh State has the largest area under OF. With impressive progress in OF, plant disease management becomes imperative to sustain crop productivity which is generally low than the conventional farming. Use of synthetic pesticides is not allowed in OF. Hence, plant protection strategy is not directed at killing the pests, but focuses on keeping the diseases and pest population as low as possible.

The disease management in OF is based on the following four strategies:

I. Prevention of pathogen's entry into the field at pre-planting stage

It mainly involves field sanitation, inactivation of pathogen by soil solarization, anaerobic soil disinfestation and bio-fumigation.

II. Limiting pathogen's entry by reducing initial inoculum at planting stage and thereafter

It is achieved through use of healthy seed of a recommended variety obtained from organically produced crop, temporal and spatial isolation, crop rotation and control of insect-vectors.

III. Restricting establishment of pathogen in the host and minimizing dispersal of inoculum

(a) **Soil and crop management:** A healthy and well nourished plant is generally less vulnerable to the attack by the pathogens. Major emphasis is given on balanced supply of nutrients through organic amendments and cover crops along with higher water-use efficiency. Drip irrigation is preferred over sprinkler or flood irrigation in order to contain diseases. High plant density is avoided as it builds humid microclimate that predisposes plants to diseases.

(b) **Inducing plant resistance:** A variety may not be resistant to all the major diseases. Therefore, plant growth promoting rhizo-bacteria (PGPR) or fungi which are known to induce systemic resistance in plants may be applied to impart resistance in above-ground plant parts.

(c) **Bio-control:** Wide variety of microbial antagonists are prevalent in organically managed soil. Such antagonists act against the pathogen and reduce the soil-borne inoculum. These may be applied as seed inoculant or soil drench. Besides, natural enemies of insect –vectors may be released in the crop.

IV. Curative methods of disease management

Pesticides from natural sources, e.g., water-based plant extracts, toxins produced by bacteria and mined products are allowed in OF for disease management. Copper and sulphur fungicides are subjected to regulated use due to accumulation of their toxic residues in plant parts and in natural enemies of insect-vectors. Some mineral or vegetable oils are permitted for use as spreader-sticker. Microbial extracts are also allowed against diseases. Since natural pesticides are less effective than synthetic ones, the pesticide application efficacy becomes important.

Way forward: OF is in its infancy in India and many developing countries as well. In recent years, demand of organic products is increasing due to public awareness on the hazards of agro-chemicals. Growers are therefore attracted towards OF as high priced organic products make farming very remunerative.

Conversion of conventional farming into organic farming takes several years to establish chemical and microbial equilibrium. During the transition period, disease outbreaks may occur. For effective management of diseases in OF, research efforts require a systems approach in which scientists from different disciplines should work together on the aspects of improving soil fertility through organics and cover crops. Potential sources of organics that promote bio-control and induced systemic resistance in plants should be searched and effective curative methods of disease management using natural sources need to be devised.

IL 01: Soil Suppresiveness –An Ecological Approach to Plant Disease Management

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Practicing eco- sensitive agriculture is the only solution to fulfil mankind‘s needs on sustainable basis. This is more important for developing nations which supports more than 90 per cent world population (considering developed countries as those with HDI > 0.90) with very less and ever depleting natural resources. Developing soil suppressiveness for managing soil borne plant pathogens is one such approach. Soil is a complex mix of organic and inorganic matter that includes thousands of different species, the vast majority of which are still undescribed. Some of the organisms are pests which cause significant crop losses while others perform ‗environmental services‘ such as biological control of pests, aeration, drainage, nutrient and water cycling.

As a dynamic living resource, soil is the basis of sustainable agriculture, as well as the physical support for most other human activities. Disease suppressive soils have been recognized for over 100 years and the mechanisms by which disease suppression is brought about has been the subject of study for nearly four decades. Disease suppressive soils are defined by Cook and Baker (1983) as soils in which the pathogen does not establish or persist, the pathogen establishes but causes no damage or the pathogen causes some disease damage, but the disease becomes progressively less severe even though the pathogen persists in soil.

The concept of disease suppressive soil has been described in terms of general suppression and specific suppression.

1. General suppression of a pathogen is directly related to the total amount of microbial activity in the soil or plant at a critical time in the life cycle of the pathogen. The general suppression is non-specific, operates against most, if not all pathogens and involves the activities of many resident soil organisms.

2. Specific suppression operates against only certain types of pathogens. Specific suppressiveness has been described for *Fusarium* wilts, *Gaeumannomyces graminis* var. *tritici, Phytophthora* spp., *Pythium* spp., *Rhizoctonia solani* and *Thielaviopsis basicola.* In all cases, a particular pathogen causes significantly less disease in suppressive soils than in other soils (conducive soils); the effect is lost when soil is treated with biocides, indicating the involvement of microorganisms.

How long does it take for a soil to become suppressive? Suppression develops over a period of time. The duration will depend on the conditions and the return of organic residues. We can also define pathogen-suppressive soils into two different broad types of diseases suppressiveness *viz*., natural and induced. Natural suppressiveness is frequently associated with the physical properties of soils and is relatively independent of crop history. On the contrary, induced suppressiveness is wholly dependent on agricultural practices. The isolation, identification, and culture of the antagonistic microorganism(s) responsible for suppressiveness in soils opens up the exciting possibility for controlling plant diseases by adding these antagonists to previously conducive soils or substrates.

Role of abiotic factors in soil suppressiveness :

Crop rotation: In the long term trials at Avon, South Australia, it was found that the influence of rotation on the control of root fungal disease was greatly reduced once the level of soil suppression had increased. Rotations that include a break crop such as grain legume or canola greatly reduce root disease in cereals because these crops do not host the cereal root disease fungi. Canola has a second beneficial effect, the release of chemicals into the soil which kill root disease causing fungi and other soil organisms. Rotations will continue to play an important role in root disease control (Stephen Naete, 1997).

Tillage: Results from the long term trials in South Australia indicate that increased root disease does occur when conservation farming is first introduced, but this can be significantly reduced over time without the reintroduction of burning and tillage. The adoption of conservation farming practices results in the formation of a whole new soil environment and, consequently, the balance in the food web is adjusted. Different elements of the conservation farming system impact on the soil biota in different ways. Soil organisms are concentrated into the top 10cm of soil. The use of minimum tillage reduces soil mixing, maintaining biota concentrations near the surface rather than diluting them through a greater depth. The greater the number of tillage passes, the greater the risk of soil erosion which results in the removal of topsoil, the home of the soil biota and when soil is lost from a paddock it will take soil organisms along with it.

Micronutrients in suppressiveness: When a plant becomes infected by a fungus, its natural defenses are triggered and it causes increased production of fungus inhibiting phenolic compounds and flavonoids both at the site of infection and in other parts of the plant. The production and transport of these compounds is controlled in large part by the nutrition of the plant. Therefore, shortages of key nutrients (K, Mn, Cu, Zn, and B) in soil and then in plants reduce the amount of the plants natural antifungal compounds at the site of infection. Many of the micronutrients are implicated in phenol metabolism from control of carbohydrate movement into synthetic pathways (boron) to the final polymerization of lignin (Fe and Mn).

Soil moisture and temperature: The severity of the soil borne diseases is proportional to the amount of soil moisture and is greatest near the saturation point. Such an example is *Pythium*, which causes damping off of seedlings and seed decay. The increased moisture seems to affect the pathogen primarily, which multiplies and moves best in wet soils (Agrios, 1997). Increased moisture may also decrease the ability of the host to defend itself through reduced availability of oxygen in waterlogged soil and by lowering the temperature of such soils.

Role of biotic factors in soil suppressiveness

Soil biota in suppressive and non-suppressive soil: Naturally, all soils have the capacity to suppress disease. But the microbial activity depends on soil moisture, temperature and the ratio of carbon to nitrogen, is the precursor to suppression. Conditions that change biological activity or relationships between organisms can effect suppression. Warm, moist soils with high levels of carbon to nitrogen will have higher levels of microbial activity and a relatively higher level of suppression.

Suppressive soils management includes

1. Incorporation of root colonizing rhizosphere microorganisms: These organisms can promote Phytostimulatory and biofertilising effects plant health by making the plant ‗stronger'. Many rhizosphere microorganisms can induce a systemic response in the plant, resulting in the activation of plant defence mechanisms.

2. Better agronomic practices: Adaptation of cultural practices has been proposed as a means to decrease the soil inoculum potential or increase the level of suppressiveness to diseases Indeed, disease suppressiveness has been obtained through crop rotation, biofumigation, intercropping, residue destruction, organic amendments, tillage management practices and a combination of those regimes

a. Biofumigation: This strategy better adapted to the cooler regions of the World, it involves fermentation of organic matter under plastic results in anaerobic conditions in soil and which leads to production of toxic metabolites. Both these processes contribute to the inactivation or destruction of pathogenic fungi (Block *et al.,* 2000). Many species of Brassicaceae (Cruciferae) produce glucosinolates, a class of organic molecules that may represent a source of allelopathic control of various soilborne plant pathogens. For example, soil amendment with *Brassica napus* seed meal controlled root infection by *Rhizoctonia spp*. and the nematode *Pratylenchus penetrans*. Similarly degradation of garlic, onion, and leek tissues releases sulfurous volatiles such as thiosulfinates and zwiebelanes which are converted into disulfides that have biocidal activities against fungi, nematodes and arthropods (Arnault *et al.,* 2004).

b. Soil solarization: Solarization or solar heating is a method that uses the solar energy to enhance the soil temperature to levels at which many plant pathogens will be killed or sufficiently weakened to obtain significant control of the diseases.

c. Residue management: Plant residues left on or near the soil surface may contribute to an increase of disease suppressiveness through the promotion of the general microbial activity.

d. Organic amendments: The mechanism of disease mitigation by organic amendment is due primarily to amplified competition for available nutrients and suitable ecological niches through enhancement of edaphic microorganisms or parasitism or antibiosis by antagonists that also proliferate with organic amendment. This approach to disease control is important in sustainable agriculture, since it reuses natural resources in the process of disease control without using chemicals

Conclusion

The phenomena of disease suppressive soils have been documented for numerous plant-pathogen systems around the world. Harnessing the potential of these soils as a practical means to manage diseases in agro-ecosystems has long been a goal of plant pathologists. The findings reported here and those of other investigators demonstrate that the manipulation of microbial communities to induce a disease suppressive soil environment does possess potential as a tool in the management of soilborne plant diseases. The initial objective of biological control is to maximize soil suppressiveness through the manipulation of resident antagonists. These microorganisms probably resided in equilibrium with pathogens and plants before the intervention of agriculture. However, the residents may not be present at sufficient levels for effective disease control at specific vulnerable sites on the plant or at specific vulnerable stages of crop growth. In these circumstances, the population has to be enhanced with inoculant formulation, knowing that the site conditions are favourable for the control agents.

OP 01: Organic Farming Increases Protein Content in Wheat (*Triticum aestivum* L.)

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Wheat (*Triticum aestivum*) is a very important cereal crop grown all over the world. It is an essential component of human food which is consumed in a variety of ways. Nutritionally, it provides carbohydrate and protein. Protein is one of the most important ingredients of human health. Normally wheat contains 140 mg protein / g when grown inorganically. But in the present experiment when wheat was grown in a soil supplemented with several uncommon components of organic materials, in addition to traditional organic manure, the protein content increased in comparison to inorganically grown wheat.

OP 02: Evaluation of Linseed (*Linum usitatissimum* L.) Germplasm for Identification of Resistant Genotypes against *Alternaria* Blight and its Management

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Alternaria blight of is an important disease of Linseed (*Linum usitatissimum* L.) that hampers its productivity and oil content. Studies on symptoms appearance of *Alternaria* blight of linseed were first appeared on lower leaves as black point that gradually increased in size to become circular to oval or irregular in shape. During severe infections, spots coalesced and covered the large area of the leaves. Microscopic examination of pathogens in diseased tissue revealed that *A. linicola* Groves & Skolko and *A. lini* Dey were two fungi associated with the spots on leaves and capsules. Studies of relative dominance of pathogens associated with the diseased tissue revealed the dominance of *A. linicola* (95.86-98.63%) in comparison to *A. lini* (1.31-4.14%) during different growth period of linseed crop. During study of variability of pathogen, five isolates of *A. linicola* were isolated and variability in growth and pathogenicity were observed. Isolate of Kanpur was found more virulent in comparison to other isolates. Sixty three genotypes were evaluated against this disease under artificial epiphytotic condition to known the level of resistance and susceptibility in different genotypes under artificial inoculated conditions. Out of Sixty three genotypes screened, 2 genotypes namely –LCK-152, LCK-7002, rated as resistant, under both the years. While 4 genotypes namely- BUAPUR LOCAL, CR-M-6X22-9,EC-9832, OLC-48 in 2015-16 and 3 genotypes in 2016-17 rated under highly susceptible lines against this disease. Chemicals and neem oil caked were sprayed on the linseed crop to known the potential of the fungicides against *Alternaria* blight**.** Minimum disease severity with maximum seed yield was recorded with three sprays of Mancozeb @ 0.2% followed by Propiconazole@0.1% and Hexaconazole@0.1%, respectively. Maximum yield was obtained with the spraying of Mancozeb@0.2% followed by Hexaconazole@0.1%.

OP 03: Potent Resistant Donors and Phylloplane Microbes against *Ascochyta rabiei* Infecting Chickpea

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The *Ascochyta rabiei* fungus causing *Ascochyta* Blight (AB) in susceptible chickpea results in 3 to 4 times higher yield reduction compared to resistant genotypes. Therefore, identification of resistant sources and use of phylloplane microbial agents offered ample scope for sustainable management of AB disease. A total of 209 lines/cultivars of chickpea were evaluated against AB along with CDC frontier (fair resistance) and L-550 (Susceptible) as check cultivars. Based on controlled environmental screening, lines/cultivars/ namely KWR 108 (5), BRC-1 (5), NBeG 510 (5), GL 13001 (5), IPC 2005-45 were showed moderately resistant (MR) and none of them showed resistance against AB The 1-9 rating scale of Pande *et al.* (2012), was used for disease scoring. A total of 100 morphologically different phylloplane bacteria and 30 different fungi were isolated and screened against *A.rabiei* under confrontation assay. Among them, the bacterial isolates designated as PPB-3, 6,7, 11, 18 exhibited maximum inhibitory activity and fungal isolates such as PPF 4, 5, 8, 11 and 12 against both the pathogens by inhibiting mycelia growth under *in vitro* and hence were selected for further evaluation under microplot field trials. Based on microscopic observation and gram reaction, the bacterial isolates PPB-3, 6, 7, 11, 18 were belonged to *Bacillus spp.* and *Psuedomonas* spp.The PPF isolates 4, 5, 8, 11 and 12 were belonged to species of *Trichoderma*, and *Fusarium*. These microbes will be further characterized using 16S rDNA and Internal Transcribed Spacer (ITS) sequence analyses for bacteria and fungi, respectively. This needs to be validated under field condition. The resistant donors could be used in breeding programme to develop AB resistant varieties.

OP 04: Evaluation for Relative Tolerance in Rice Germplasm against Rice Root Knot Nematode, *Meloidogyne graminicola*

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Commonly cultivated rice cultivars *viz*. Sugandh-5, Sadabahar, Sharbati, Swarna and R-Dhan were evaluated for tolerance/resistance against field population of *Meloidogyne graminicola.* Three week old rice seedlings were planted in the earthen pots filled with the field population of *M. graminicola* at 1500 J_2/kg soil. The cv. Sugandh-5 and R-Dhan expressed greatest susceptibility showing 42-57 galls/root system, followed by the cvs., Sadabahar, Sharbati and Swarna. The nematode reproduced on all the cultivars producing the greatest number of egg masses on the cv. Sugandh-5 and R-Dhan, 34 - 40% greater than rest of the cultivars. The increase in the soil population of rice root-knot nematode varied with the cultivars ranging from around 2.5 times (146% cv. R-Dhan) to 5.5 times (444% cv. Sugandh-5) in comparison to control pots. Among the five cultivars tested in the study, the cvs. Sadabahar and R-Dhan were found tallest whereas, the cv. Swarna was shortest. Plants grown in nematode infested soil became 13% (cv. Sugandh-5) to 28% (cv. Swarna) shorter than the control. The overall order of decrease in the shoot length was Sugandh-5 > Sadabahar > R-Dhan > Sharbati

> Swarna. Decrease in the root length of rice plants in nematode infested soil ranged from 17 (cv. Sadabahar) to 35% (cv. Sugandh-5) over control. Nematode infection significantly suppressed the dry matter production of rice plants that varied with the cultivar. Greatest decrease in the dry weight of shoot was recorded in cv. Sugandh-5 (14%) followed by cvs. Sadabahar (12%), R-Dhan (11%), Swarna (10%) and Sharbati (8%). Decrease in the dry weight of root ranged from 19% (cv. Sadabahar) to 23% (cv. Sugandh-5), and overall order of decrease was Sugandh-5 > Sadabahar > R-Dhan > Sharbati > Swarna. The evaluation test has revealed a moderate degree of tolerance in the cv. Sharbati to *M. graminicola.* Whereas, the cv. Sungandh-5 was found highly susceptible and its cultivation should be avoided in the rice root knot nematode infected areas.

OP 05: Morphological and Biochemical Diversity of *Bipolaris maydis*

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A survey was conducted by our team during Rabi and kharif season of 2016-17 in major Maize grown areas of Bihar, Punjab, Uttarakhand, Karnataka and Uttar Pradesh for observing incidence of disease and collection of Maydis leaf blight samples. This disease was most prevalent on all the locations surveyed, highest severity recorded in Bihar and eastern UP. Thirty Five isolates of *Bipolaris maydis* from maize leaf blight samples were characterized morphologically, physiologically and biochemically *in-vitro*. The isolates were evaluated for their morphological variability, considering colony color, sector formation, growth pattern and conidial symmetry. Diversity analysis of cultural characteristics of *Bipolaris* spp. was done on four different cultural media at room temperature. Maximum radial growth was recorded on maize leaf extract agar and corn meal agar with excellent sporulation in compression to others. Effect of pH, temperature and light durations on pathogen growth was studied. The isolates were evaluated for extracellular enzymes activity in solid medium and later quantification of enzymes was done. Variations among the isolates were found for enzymatic activity, and esterase and pectinase was the enzyme that showed the highest activity indices.

OP 06: Development of Stable Allohexaploids (*Sinapis alba* + *Brassica juncea*) Resistant against *Alternaria brassicae* and High Temperature

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Wild relatives of *Brassica* are a rich reservoir of genes that are invaluable in improvement of cultivated species. *Sinapis alba* is a close relative of crop *Brassicas* that possesses several desirable traits such as tolerance to *Alternaria* black spot disease, heat stress, insect pests and nematodes. This study is aimed at developing and characterizing hybrids between *Brassica juncea* and *S. alba* with the ultimate goal of transferring genes for tolerance to *Alternaria brassicae* and heat stress, the traits that are lacking in cultivated Brassica. We generated three hybrids between *B. juncea* and *S. alba* through protoplast fusion. The hybridity was confirmed through cytology and molecular markers. While two of the hybrids were symmetric, the third one was asymmetric and had greater resemblance to *B. juncea*. Hybrids showed intermediate morphology to the parents and were fully male and female fertile and also set seeds upon back crossing with the parental species. In vitro leaf assay and filed inoculation studies revealed that the hybrids are highly resistant to *A. brassicae*. Besides, hybrids set seeds at temperature of >38°C while the parents failed to produce seeds indicating that hybrids possess heat tolerance. These stable hybrids provide a reliable genetic resource for transfer of genes from *S. alba* into cultivated Brassica species.

OP 07: Microbial Modulation of Physiological and Biochemical Responses and Systemic Defense Mechanism against *Rhizoctonia solani* Kóhn Causing Banded Leaf and Sheath Blight in Maize (*Zea mays* L.)

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Plant-associated beneficial microbes have been explored to fulfill the imperative function for plant disease management. However, their impact on the host secondary metabolite production and disease management remains elusive. The current work has shown that rhizosphere microbes *viz*., strains of *Bacillus* spp. singly as well as in combination modulated the biosynthetic pathway of secondary metabolite and systemic defense mechanism against *Rhizoctonia solani* in maize. Interestingly, bioagents were modulated cascades related to phenylpropanoid pathways in plants treated with the microbial combination in the presence as well as in absence of *R. solani* stress. Further, these microbes not only augmented defence responses biochemically *via* enhancement in chlorophyll a, defense enzymes and phenolic compounds but also strengthened host surface which restrict the penetration and further invasion in the deeper tissues. Furthermore, elevated lignification and callose deposition in the microbial combination treated plants corroborate well with the above findings. Furthermore, correlation analysis clearly indicated that enhanced accumulation of lignin in the plant cell significantly affects the pathogenic infection and invasion of the tissue leading to reduction in disease development compared to other treatments. Overall, the results provide novel insights into the underlying mechanisms of priming by beneficial microbes and underscore their capacity to trigger defence responses under biotic stress. Thus, it is concluded that combined applications of bioagents play an important role in disease control by the three factors acting in a cooperative manner and thus, could be used in the integrated disease management practices.

PP 01: Studies on Morphological and Cultural Diversity of *Colletotrichum falcatum* incitant of Red Rot of Sugarcane

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Cultivation of sugarcane in India dates back to the vedic period. It had been one of the important crops in India since time immemorial with ample mention in ancient literature including Puranas. It plays very crucial role in national rural economy of the country. About 45 million farmers their dependents and laborers makes about 7.5 % of the rural population depends on sugarcane for their livelihood. Red rot disease is one of the most widespread and has been a constraint for sugar and sugarcane production. This disease has been responsible for the failure of many popular and high yielding cultivars. The pathogen infects various parts of the cane plant but stalk is most vulnerable. Its symptoms are highly variable depending upon the susceptibility of cultivar, pathogen virulence and environment. The pathogen shows great diversity as number of pathotypes are known to occur in nature which have been classified on the basis of host differential reaction. According to new classification isolates have been given numbers as Cf01, Cf02, Cf03, Cf04, Cf05, Cf06, Cf07, Cf08, Cf09, Cf10 and Cf11. Being facultative in nature the pathogen undergoes mutation quickly and as a result new races develop at very fast rate. Keeping this in view, the present study was undertaken to assess the variability among existing pathotypes and on the emergence of new races in nearby area. Out of 11 pathotypes available, 5 pathotypes viz. Cf01, Cf03, Cf07, Cf08 and Cf09 and two field isolates for comparison were selected for present study. Cultures were procured from Sugarcane Breeding Institute, Coimbtore and maintained on PDA. Field isolates were collected from freshly infected stalks of sugarcane variety Co 1148 and CoS 8436 were designated as Pantnagar isolate and Bilaspur isolate respectively. Cultural characteristics of known pathotypes and field isolates were studied on Oat meal agar medium. Observations were recorded for type of colony, colour, colony margin, topography, colony diameter, sporulation, size, colour and shape of conidia. Morphological and cultural studies indicated similarities between Pant isolate and Cf08 and Bilaspur isolate and Cf09, thus both isolates were not different from pre-existing pathotypes of *Colletotrichum falcatum.* Studies also revealed that colony colour of different isolates varied pure white in case of Cf01, Cf03, Cf07 and Cf09 and Bilaspur isolate to grayish or dull white in case of Cf08 and Pant isolate. Margins of colony were generally smooth in all the cultures except Cf08 and Pant isolate. Topography of cultures was either flat mycelia growth or raised fluffy growth. Colony diameter was almost same in all the cultures. Cf03, Cf09 and Bilaspur isolate had maximum colony diameter (90mm). Very high sporulation was seen in Cf01, Cf03, Cf08, Cf09 and Bilaspur isolate whereas, Cf07 had very poor sporulation. Conidial length was maximum (37 µm) in Cf03 and minimum (32µm) in Cf07. Similarly maximum width (12µm) was observed in Cf03 and minimum width (10.2µm) in Cf01. Present investigation clearly shows the existence of variability amoung different pathotypes and field isolates.

PP 02: Molecular Breeding Strategies for Enhancing Disease Resistance in Plants

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There is an urgent need to develop strategies which helps in providing long-lasting resistance against a broad spectrum of disease causing pathogens. Marker-assisted selection for plant resistance is the most important tool in molecular breeding at the applied level. Molecular breeding approaches involving DNA markers, such as QTL mapping, marker-aided selection, gene pyramiding, allele mining and genetic transformation have been used to develop new resistant crop cultivars. These techniques provides a high-throughput alternative to conventional methods and allows rapid introgression of disease resistance genes into susceptible varieties as well as the incorporation of multiple genes into individual lines for more durable resistance. With the help of QTL mapping the roles of specific loci governing resistance can be described and the interactions between resistance genes, plant development and environment can also be analyzed. QTL mapping is successfully used in introducing quantitative resistance in a number of crops for example in rice for blast fungus, potato for late blight, maize for gray leaf spot, tomato for bacterial wilt, and the soybean for cyst nematode. Gene pyramiding is another approach which allows stacking of multiple genes/QTL from multiple resistant parents in a single genotype and develops durable resistance expression. Allele mining is an approach which can be used to identify new haplotypes and development of allele-specific molecular markers for use in marker-assisted selection. Allele mining approach results in enhancing genetic recombination in rice these new recombinants act as a source of resistance against blast disease. Hence, molecular breeding is an important approach for stacking multiple genes in crop plants against various disease causing pathogens.

PP 03: Distribution and Incidence of Apple Powdery Mildew in a Mixed Cultivar Orchards and Relationship to Disease Severity

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Apple powdery mildew epidemics, caused by *Podosphaera leucotricha* (Ell. and Ev.) Salm can be readily described in terms of the disease triangle. The role of different environmental factors, *viz*., temperature, relative humidity, leaf wetness, sunshine and rainfall were studied in relation to disease development. The present experiment was conducted during the season 2003 to 2005 to determine a simplified assessment procedure by which apple powdery mildew severity/index could be predicted from incidence data and develop incidence-severity relationship in apple cultivars under Uttaranchal hilly conditions. The use of percentage scales and keys of visual disease severity, remote sensing, and some indirect methods like spore counts and disease incidence are considered valid approaches for disease assessment. The relationship between increase in incidence of powdery mildew in relation to severity can be established either by making sequential records in one tree during the progress of an epidemic or by assessing many trees with different amounts of disease at one point of time. The combination of several factors like the presence of susceptible host, virulent pathogen, and congenial environment for disease development during receptive phenological stage of apple tree, was responsible for the incidence of the powdery mildew on apple.

PP 04: Screening of Cluster Bean Genotypes against *Rhizoctonia bataticola* under Screen House Conditions in Artificial Disease Stress Conditions

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Cluster bean (*Cyamopsis tetragonoloba*) has been grown in India since ancient time for vegetables and fodder purposes. Guar, a versatile crop with industrial uses and export potential, has transformed economic status of large number of farmers. In recent years, it suffers severely from the vagary of diseases caused by fungi and bacteria. Dry root rot caused by *Rhizoctonia bataticola* is the major disease responsible for its low productivity in Haryana and Rajasthan. Present investigation was carried out during *kharif* 2015 in the Department of Plant Pathology, CCS Haryana Agricultural University, Hisarto screen sixteen cluster bean genotypes viz.; HG-100, HG-182, HG 2-20, HG-884, HG-365, HG-563, HG-876, HG-75, HFG-119, RGC-0033, RGC-1038, RGC-1019, RGC-1003, GAUG-0013, RVG 2-30, FS-277, under artificial inoculated disease stress conditions in screen house. Based on the reaction of clusterbean genotypes to R. *bataticola*, the genotypes were categorized as resistant (1-10% plant mortality), moderately resistant (10.1-25.0% plant mortality), moderately susceptible (25.1-50.0% plant mortality), susceptible (50.1-75.0% plant mortality) and highly susceptible (75.1-100% plant mortality). Out of Sixteen genotypes screened, none of the genotype was found resistant to *R. bataticola*. Pre-emergence and post-emergence plant mortality was observed in all the genotypes. Two genotypes viz. HG-100 and HG-75 were categorized as moderately resistant with a total plant mortality of 16.7 per cent and 20.0 per cent, respectively. Five genotypes viz. HFG-119, RGC-0033, RGC-1003, RGC-1019, and RGC-1038 were categorized as moderately susceptible. Seven genotypes of the clusterbean viz., HG 2-20, HG-365, HG-563, HG-876, HG-884, GAUG-0013, and RVG-2-30 were susceptible with a plant mortality of 50.1-75.0 per cent. Two genotypes viz. FS-277 and HG-182 were highly susceptible with a total plant mortality of 89.9 per cent and 79.9 per cent, respectively.

PP 05: Survival and Viability of Inoculums of *Uromyces fabae* and off Season Germination of Urediospore

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Pea (*Pisum sativum* L.) is a cool season crop grown in different part of the world. It is a good source of protein, fiber and also a good nitrogen fixer. Pea is affected by various diseases among these rust is very important caused by *Uromyces fabae.* The disease incurs 4- 62 per cent losses depending on the duration of favorable weather. An experiment was conducted for survival, viability and germination of the urediospores. The spores were stored at room temperature along with crop residue infected in the previous year and germination was tested in a drop of water at room temperature (25 ±2 ^{0}C). The germination was not observed in aeciospore and teliospore. Out of 1000 only two urediospore germinated and indicated that urediospore may survive in the crop residue and serves as a source of primary inoculum.

PP 06: Biochemical Analysis of Okra Genotypes Resistant and Susceptible to Root and Collar Rot Incited by *Macrophomina phaseolina*

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Twenty okra genotypes were screened for their resistance to root and collar rot incited by *Macrophomina phaseolina* under field conditions. Based on their disease reaction, they were grouped into four categories *i.e.,* resistant, moderately resistant, susceptible and highly susceptible. The biochemical analysis of the resistant and susceptible genotypes revealed that the total soluble sugar, reducing sugar and non reducing sugar decreased following inoculation by the pathogen. The decrease in total soluble sugar, reducing sugar and non-reducing sugar were 21.54, 21.73 and 21.42 per cent in resistant variety, whereas in highly susceptible variety it was 6.06, 6.10 and 3.03 per cent, respectively. The total phenol content, soluble protein and peroxidase activity increased on inoculation with the pathogen. In the resistant variety, the increase in phenol content, soluble protein and peroxidase activity was 23.4, 32.56 and 63.86 per cent whereas in moderately resistant variety this was 19.85, 21.63 and 55.29 per cent, respectively. Susceptible and highly susceptible genotypes had low to moderate increase in the three parameters.

PP 07: Common Fungal Diseases of Honey Bees in District Uttarakashi, Uttarakhand (India)

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Beekeeping is an agro-based subsidiary occupation, providing supplementary income to the rural people of Uttarakhand state. Honeybee‘s diseases are causing considerable expenses to beekeepers in the area. Therefore, the present investigation was aimed to provide a detailed protocol for various fungal diseases with their control measures to assist beekeepers and farmers entering in the field of beekeeping. Two fungal diseases are causing serious problems in honeybee colonies in the region. The genera *Ascosphaera* and *Aspergillus* of Ascomycetes class has been identified to cause chalk brood and stone brood diseases in honeybees. Control measures have also been provided for suitable management of colonies for diseases prevention. The best ways to prevent bee diseases is to apply *Terramycin* or *Sulfazole* and other available therapeutic medicines to bee‘s food during spring and rainy seasons.

PP 08: Disease Reaction of *Linum usitatissimum* L. Germplasm towards *Melamspora lini*

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Linseed is an important oilseed crop of Himachal Pradesh. However, its cultivation is concentrated in the Palam area of Kangra and Mandi districts, accounting for almost the whole area and production in the state. Linseed rust is caused by a fungus, *Melamspora lini*. Rust is the main problem of linseed growers as it causes reduction in seed yield and weakening/disfiguring of fibre in flax. Diseased plants become very conspicuous in the field because of the bright orange color of the affected part. The leaves die prematurely; the brown black telia appear as crust covered by epidermis. With this view disease reaction was studied under 4 locations including the disease hotspots in Himachal Pradesh i.e. Palampur, Malan, Kangra and Dhaulakuan. Thirty genotypes were scored for linseed rust at four locations *viz.,* Experimental farm of CRSKHPKV, Palampur, Rice and Wheat Research Centre (RWRC) Malan, Shivalik Agricultural Research and Extension Centre, (SAREC) Kangra and Hill Agricultural Research and Extension Centre Dhaulakuan (HAREC) during 2013-14. Each experimental plot had plot size of 1 X 1 m^2. Screening was done only under natural epiphytotic conditions in the field according to the scale devised by AICRP on linseed for linseed rust. Ninteen genotypes *viz*., Himalini, Janaki, Jeewan, KL-241, KL-257, Nagarkot, Him Alsi-1, Him Alsi-2, Binwa, Surbhi, Baner, Bhagsu, Hearmies, Rajeena, Mariena, Giza-5, Giza-7, Giza-8 and Ariane were highly resistant (disease score 0 at all the locations); seven genotypes *viz*., Nataja, Viking, Giza-6, Faking, Ayoyagi, Flak-1 and Canada were resistant (disease score 1 or < 1), while two genotypes i.e. KL-263 and B-509 were moderately resistant (disease score 2 or < 2), Belinka-60 was moderately susceptible (disease score 3 or < 3) and Himani was susceptible (disease score 4 or < 4). The genotypes categorized as highly resistance/resistant to rust need further evaluation under artificial conditions for their use as source of resistance in the future breeding programmes.

PP 09: Screening of Okra Germplasm for Resistance to Yellow Vein Mosaic Virus under *Tarai* Condition of Uttarakhand

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Okra (*Abelmoschus esculentus* L. Moench) is an important vegetable crop grown throughout the world mainly for its immature fruits. Yellow Vein Mosaic Virus (YVMV), transmitted by white fly (*Bemisia tabaci* Gen.) is the most serious disease of okra affecting both yield and fruit quality. Since the disease cannot be controlled properly by chemical means, the only practical solution of this problem is to develop tolerant/resistant varieties. The present investigation was carried out on thirteen genotypes of okra were screened for resistance to Yellow Vein Mosaic Virus (YVMV) at Vegetable Research Centre of G. B. Pant

University of Agriculture and Technology, Pantnagar. The experiment was evaluated in randomized block design with three replications in three different *kharif* seasons during 2014 to 2017. They were evaluated for YVMV at three stages of the crop (30, 60 and 90 DAS). Among the genotypes, four genotypes namely 2014/OKYVRES-5, 2014/OKYVRES-6, 2014/OKYVRES-10 and 2014/OKYVRES-11 were found tolerance to YVMV in all the three seasons under *Tarai* condition of Uttarakhand. On the basis of pooled data, among these genotype the highest yield per hectare found in the genotypes viz. 2014/OKYVRES-5(104.30 q/ha), 2014/OKYVRES-10(102.84 q/ha) and 2014/OKYVRES-11 (96.71 q/ha) which have also showed tolerance capacity to YVMV.

PP 10: Response of Newly Collected *Acetobacter* isolates in Sweet Corn (*Zea maidis* L. *saccharata*)

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The present research was undertaken in order to study the effect of *Acetobacter isolates* on performance of sweet corn and response of nitrogen fixing ability of newly collected endophytic bacteria *Acetobacter spp.* in sweet corn. It comprised of experiments in order to select effective local isolate(s) of *Acetobacter* in especially for N accumulation, yield and yield attributing characters of sweet corn at maturity of crop. The highest green cob yield (28.67g/plant) of sweet corn was obtained from plants raised from seeds inoculated with isolate No.18 which was followed by isolate No.16 (25.35 g/plant). Similarly, highest N uptake was associated with *Acetobacter* isolate No.18 (329.66 mg/plant) followed by *Acetobacter* isolate No.16 (301.64 mg N/plant). Overall findings of the experiments the performance of *Acetobacter* isolate No.18 was found superior followed by *Acetobacter* isolate No.16 with most important BNF parameters related to N and biomass accumulation. Microbial dynamic study also supported that isolate No.18 and 16 were well adapted to the rhizosphere of sweet corn and both the isolates retained their highest cell counts in soil taken from sweet corn rhizosphere during pot experiment. Hence, it was concluded that isolate No18 and 16 were most potent N_2 fixing local *Acetobacter* isolate for sweet corn cultivation in Chhattisgarh.

PP 11: Influence of Substrate Pasteurization, Bag Dimensions and Organic Supplement Practices on Yield and Yield Attributing Parameters of Indian Oyster Mushroom, *Pleurotus pulmonarius*

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Pleurotus mushroom, generally referred to as ‗Oyster mushroom or Dhingri' in India is relatively new to the mushroom industry. In India, Odisha is a leading state in terms of oyster mushroom production. The condition in most of agro-climatic situation in Odisha are suitable for growing oyster mushroom from month of July to February comprising of the rainy and winter season. *Pleurotus pulmonarius* is a potential protein source

especially in developing countries, besides having minerals and vitamins. Besides its edibility it has also got pharmaceutical properties. Hence, *Pleurotus pulmonarius* could well be incorporated in to the mushroom farming system during winter season besides the ruling species, as this species was not in cultivation earlier. Four different substrate pasteurization methods along with untreated done (control) were evaluated for their yield potential and superiority of steam treatment of substrate in terms of realization of mushroom yield (98.90%) was established in the investigation. However, yield obtained (96.63%) out of the treatment pasteurized with chemical was statistically at par with the steam treatment, through it was associated with longer incubation period (17.50 d) and crop duration (24.25 d). The untreated substrate (control) produced the lowest yield (79.28%). Nine organic supplements including control were evaluated for their influence on yield and yield attributing parameters of *Pleurotus pulmonarius.* The biological efficiency was reported numerically highest (93.37%) in boiled wheat which was at par with the yields realized from chicken manure (93.07%), boiled maize (92.53%), rice bran (92.33%), untreated control (91.07%), maize meal (91.10%) and bengal gram powder (90.99%). Among the six diverse bag dimensions, 30 X 25 cm bag accommodating 1500g substrate was superior in respect of biological efficiency.

PP12: Evaluation of Pathogenicity Proving Techniques for the Screening of Resistant Varieties against *Xanthomonas campestris* pv. *campestris* causing Black Rot of Cabbage

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Six different inoculation techniques, such as (1) Hand atomizer spray (2) Carborundum abrasion method (3) Multi-needle pricking method (4) Injection infiltration method (5) Hydathodes inoculation method and (6) Scissor clipping, used for evaluation. From the study it is revealed that the pathogen could successfully cause infection of the cabbage host plant by with varied incidence and intensity and with some variation in symptom expression when inoculated by different inoculation techniques. From the data it is revealed that the lesion progress was highest (71 mm) after 32 days of inoculation in case of Carborundum abrasion method followed by Hydathode inoculation method and Multi needle pricking methods giving average lesion progression of 69 and 61 mm, respectively after 32 days. Control plants *viz.,* 1. Inoculated with sterile distilled water 2. Inoculated with media and these control treatments performed by using all methods mentioned above, plants inoculated with sterile distilled water were unable to initiate the disease and there by not shown characteristic disease symptoms but plants inoculated with media has shown some chlorotic areas due to salts present in culture media.

PP13: Assessment of Elite and ISH Genotypes of Sugarcane against Red Rot (*Colletotrichum falcatum*) Disease

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Twenty four elite and ISH (Inter Specific Hybrid) genotypes of sugarcane (*Saccharum* spp. complex) were screened against red rot caused by *Colletotrichu falcatum* by plug method at Main Sugarcane Research Station, Navsari Agricultural University, Navsari during 2013-2016. Only one genotype SES 594 gave resistant reaction. Nine genotypes viz., ISH 175, ISH 287, ISH 12, ISH 176, ISH 118, ISH 110, ISH 117, ISH 114 and ISH 115 were found moderately resistant reaction. Seven genotypes were showed moderately susceptible. The rest of genotypes exhibited susceptible/ highly susceptible to red rot by plug method.

PP14: Screening of Genotypes against Major Diseases of Soybean in North Plain Region of India

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Soybean [*Glycine max* (L.) Merrill] is the most widely grown as an important oil seed crop across the world as well as in India. Despite of its huge potential, this crop is susceptible to numerous diseases which is a major yield constraint for achieving higher productivity levels in soybean. In India, about 35 diseases have been reported on soybean, among which 14 are considered to be economically important based on the magnitude of yield losses. Among the different diseases infecting soybean, a few were distributed throughout the soybean cultivated areas of the country, while others were restricted to only specific regions i.e. Yellow Mosaic Virus confined in north and rust in southern part of India. The present study was conducted at Pantnagar (hot spot) in Augmented Design using 165 genotypes of soybean which were screened against three important diseases of soybean prevalent in the Northern Plain region of India i.e. YMV (Yellow Mosaic Virus), RAB (*Rhizoctonia* Aerial Blight) and BP (Bacterial Pustule). The results obtained from the present study revealed that none of the genotypes were immune against any of the three diseases, whereas, two genotypes PS 1225 and PS 1480 were found to be highly resistant against all the three concerned diseases *i.e*., YMV, RAB and BP. Also, it has been observed that 33 genotypes were identified to be highly resistant for YMV and BP while for YMV and RAB, 10 genotypes were found to be moderately resistant. The rest all genotypes showed varied reaction for the concerned diseases which ranged from moderately resistance to high susceptibility. These two potential genotypes are suggested for utilization in breeding programme from soybean improvement as well as for broadening the genetic base of soybean varieties.

PP 15: Occurrence and Distribution of Root Rot of Sesame in Major Sesame Growing areas of Telangana

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A roving survey was conducted during 2017 summer season in different major sesame growing areas of Telangana to assess the status of root rot incidence of sesame and to collect diseased samples infected by *Macrophomina phaseolina* under field conditions. Survey was carried out in ten mandals of the three major sesame growing districts of Telangana. A total of 60 fields covering 3 districts were surveyed and information on soil type, cultivars grown, disease incidence and agronomic practices followed were recorded. Mean maximum dry root rot incidence was recorded in Nirmal district (11.98%) followed by Nizamabad (6.78%) and Jagtial (5.90%). The highest disease incidence of 15.00 per cent was recorded in Babapur village of Nirmal district and least disease incidence of 2.50 per cent was recorded in Korutla village of Jagtial district. Sesame root rot disease was more prevalent in sandy loam soil areas followed by clay loam and minimum in clay soil areas. Disease incidence was also higher in areas where farmers used susceptible varieties (VRI-1 and private variety) and in areas where irrigation was less frequently given which indicates that *M. phaseolina* flourishes well and causes more damage to plants when there is less availability of soil moisture.

PP 16: Cultural, Morphological, Physiological and Biochemical Characteristics of Bacterial Pustule of Soybean (*Xanthomonas axonopodis* pv. *glycines*)

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The identification of the pathogen *Xanthomonas axonopodis* pv. *glycines* involved in causation of the disease was done by conducting studies on its morphological, biochemical, cultural and physiological features of the pathogen as per the standard microbiological procedures. The bacterium was gram negative, rod shaped with round ends. The cells measured 0.4 -0.25 x 1.25- 3.00 mm in size. The biochemical features of the pathogen revealed that the bacterium liquified the gelatin, produced the H2S, positive for starch hydrolysis and acid produced by carbon sources (sucrose, glucose and dextrose) but it was negative for acid production by nitrogen (peptone) sources. Among the eight different solid media tested, NGA medium was significantly supported for the luxurious growth of the pathogen as evidenced by the maximum recovery of bacterial colonies (96.00). Significantly least number of colonies (39.40) was recorded on Xan-D medium. The XPS agar medium supported absolutely no growth of the bacterium. Circular, flattened, slightly raised, convex with yellow to bright yellow colour on SX and NA medium. They occurred singly or rarely in aggregates. Whereas, on both YDCA and GYCA, colonies were circular, slightly raised, glistering with yellow colour. Highly irregular to irregular, slightly raised, light yellow coloured colonies were observed in NGA media. Optimum temperature

requirement for the growth of pathogen was studied and found that the temperature level of 30oC was optimum in which significantly maximum numbers of bacterial colonies were recorded. The pathogen colonies were reduced below and beyond of 30oC. Similarly, the effect of hydrogen ion concentration on the growth of pathogen was studied and found that pH of 7.0 as optimum where maximum numbers of colonies were recorded. The colonies were found reduced beyond and below pH level of 7.0.

PP 17: Variability among *Rhizoctonia solani* isolates inciting Sheath Blight Disease of Rice

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Sclerotial disease of rice (*Oryza sativa*) caused by *Rhizoctonia solani* is an important disease in India. The present investigation is carried out for the identification of virulent isolate under *in-vitro* conditions. To determine the virulence diversity of isolates, two rice cultivars [Tetepand Pusa Basmati-1] were artificially inoculated with 50 isolates of *R. solani* and tested in glass house. On the basis of virulence reaction on different cultivars, the isolates were categorized into four groups; highly virulent, moderately virulent, less virulent and avirulent. Pathogenicity studies revealed that considerable variation found among the isolates with respect to virulence and relative lesion lengths. However, it is to be noted that the isolates with least latent period had highest relative lesion height. Isolate RS49 from Varanasi is the most virulent isolate and produced highest relative lesion height (58.0cm) and (35.5 cm) in case of cultivars PB-1 and Tetep while the isolate RS 46 from Gazipur was less virulent and produced lowest lesion length in PB-1(6.5 cm) and RS36 was found lowest lesion length on Tetep (2.00cm). Therefore the isolate RS 49 can be used in future for screening the rice genotypes for resistance against sheath blight disease. Once the pathogenicity is defined, it revealed that all isolates were virulent to two cultivars with different levels of virulence that were depicted by rice genotypes after artificial screening under greenhouse. The most virulent isolate could be further utilized for screening rice genotypes against sheath blight disease and thus could be used in selection of putative rice genotypes showing resistance to the disease and selected genotypes would be utilized in breeding programmes regarding development of sheath blight resistance of rice varieties.

PP 18: Screening of Promising Genotypes of Soybean against Bacterial Pustule (*Xanthomonas axonopodis* pv. *glycines*) under Glasshouse and Field Conditions

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Resistance genotypes are tools to combat the pathogens, this can be used as one of the strategies for the management of disease simultaneously. In the present investigation, an attempt was made to identify the resistant sources against the bacterial pustule of soybean. Totally 10 genotypes of soybean collected from MARS Dharwad soybean centre, UAS Dharwad were screened in glass house conditions at Department of Plant

Pathology, College of Agriculture, Dharwad during 2014-15. Results of the present investigation, depicted that the entries DSb 12, DSb 24, DSb 25, DSb 26, DSb 23-2 and JS 335 recorded a disease grade of 3 showing moderately resistant reaction for bacterial pustule of soybean. Among the exotic lines screened EC 1028, EC 118420, EC 15966, EC 457286 showed absolute resistant reaction for bacterial pustule these lines can be further used in developing resistant sources against bacterial pustule infection.

PP 19: Pathogenic Variability in Zonate Leaf Spot of Sorghum

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Zonate leaf spot, which is caused by *Gloeocercospora sorghi* is destructive among the foliar diseases of sorghum. It occurs in almost all the areas where the crop is grown including many countries in North and South America (Argentina, Venezuela), Central America (Salvador, Panama, Nicaragua), West Indies, India, Pakistan, Korea and Japan. In India, Zonate leaf spot was drastic in the states of Andhra Pradesh, Tamil Nadu and Uttar Pradesh. It is severe and occurred on sorghum grown in the semi-arid region at Jhansi, Uttar Pradesh and disease incidence approximated was 8-78% at an early leaf stage while, increasing to 25-83.5% at the flowering stage. The objective is to evaluate the pathogenic variability for 30 isolates of *G. sorghi* obtained from different locations of Uttarakhand. These isolates also exhibited significant variation for disease reaction on a set of five different sorghum lines in greenhouse tests. Pathogenicity test with the isolates showed mixed reaction to CSV 1955, CSH13 and SPH1752, while SPH1794 was resistant; PC4 was susceptible to all the isolates among five sorghum lines. Isolates could be divided into 3 pathotypes groups according to differential reaction.

PP 20: Evaluation of Antifungal Activity of Plant Oils against Major Seed-Borne Fungi of Rice

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Rice (*Oryza sativa* L.) is one among the foremost important cereal crops of the world and it is a primary food crop for half of the world‘s population. Globally, 158.8 million ha of rice is grown with production of 738 million tons among them 90% of rice grown and consumed in Asia alone. The majority of the rice (90%) is being produced in Asian countries with China and India being the major producers. Good quality seed should possess major characteristics such as viability, purity, free from varietal mixtures and free from seed borne pathogen infection and high yielding potential. In present investigation we isolated and identified four fungal genera from rice as *Curvularia lunata, Fusarium moniliforme, Helminthosporium oryzae* and *Sarocladium oryzae*. Among them, the most predominant one was *H. oryzae*. This was followed by *S. oryzae and F. moniliforme*. Least incidence was observed with *C. lunata* with the variety ADT 45 and White ponni. Six essential oils *viz*., Lemongrass (*Cymbopogon citratus*), Palmarosa (*Cymbopogon martinii*), Citronella

(*Cymbopogon nardus*), Eucalyptus (*Eucalyptus globulus*), Geranium (*Pelargonium graveolens*) and Tulasi (*Ocimum sanctum*) extracted by hydro distillation process were screened against four major seed borne pathogens of rice. *In vitro* evaluation of six essential oils at 0.1 per cent by poisoned food technique showed varied fungicidal properties against *C. lunata, F. moniliforme, H. oryzae and S. oryzae*. Among them, *C. citratus, C. martinii* and *P. graveolens* oils were found to be more effective and caused complete mycelial growth inhibition of pathogen even at 0.1 per cent concentration. However, oils of *C. nardus, E. globulus* and *O. sanctum* were not resulted in complete inhibition of mycelial growth of *C. lunata, F. moniliforme, H. oryzae* and *S. oryzae* at 0.1 per cent concentration.

PP 21: Quantitative Analysis of Tannic Acid in the Roots of Infected and Fresh Plant of *Chlorophytum borivillianum*

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Chlorophytum borivilianum is medicinal plant which contains Tannic acid, a polyphenolic compound having chemotherapeutic properties and antioxidant properties. The aim of the study is to analyze the tannic acid in the roots of infected and fresh plant of *C. borivilianum*. RP-HPLC with UV detector method developed for the quantitative estimation of tannic acid in the roots of *C. borivilianum*. Tannic acid were determined on C-18 column using mobile phase consist methanol : water (50:50 v/v) with 4.5 pH at flow rate 1 ml/min, run time was 10 min to obtain separation, wavelength of detection 270 nm. Using these conditions, the standard was run at different concentration from 20μg/ml to 100μg/ml. After running the standard linear graph is plotted between peak area and Concentration of tannic acid. With the help to which analyze the sample concentrations.

PP 22: Identification of Resistant Sources against Botrytis Grey Mould in Chickpea Germplasm (*Cicer arietinum* L.)

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Botrytis grey mould (BGM), incited by *Botrytis cinerea* Pers. ex. Fr., is considered a major destructive foliar disease of chickpea especially in chickpea-growing countries like India, Bangladesh, Nepal and Pakistan. Cool humid weather is favourable for the development of BGM and can cause significant yield loss up to 90%. The development of resistant cultivars would reduce the need for chemical fungicides, prevent environmental pollution and considered best among various management approaches. However, till now only few resistance varieties against the disease has been reported. Therefore, for the present study eighty chickpea germplasm has been evaluated for the source of resistance under epiphytotic conditions at Norman E. Borlaug Crop Research centre (NEB-CRC) of GBPUA&T, Pantnagar during *Rabi* season 2015-16 and 2016-17. Among them four entries CSJ515, GJG0904, GNG2263 and PG160 showed resistant reaction and Twelve ICWA15, ICWA25, ICWA27, GL29098, GJG1001, BG3069 GNG2302, IPC2012-30, AKG1109, GAG1107, PG172, and JG74315-

2 showed moderately resistance reaction. These resistant germplasm can be used for the incorporation of resistance in breeding programmes against Botrytis grey mould of chickpea and may be exploited as resistance sources in high yielding varieties.

PP 23: Screening of Soybean [*Glycine max* (L.) Merr.] Genotypes for Yellow Mosaic Virus (YMV), Rhizoctonia Aerial Blight and Bacterial Pustules for Disease Resistance

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Yellow mosaic virus (YMV), Rhizoctonia aerial blight (RAB) and Bacterial pustules (BP) are major disease of soybean, which can cause up to 80 % yield loss in severe cases. Chemical or cultural control of YMV is neither economical nor environment-friendly. Deployment of genetic resistance is considered to be the effective way to control it. Therefore, present study was conducted to identify stable sources of resistance for YMV disease. A 121 soybean germplasm lines, collected from different sources were screened for YMV, RAB and BP disease reaction at their hotspots consecutively for 2 years (2014-15). It could identify 21 resistant genotypes for YMV , 119 genotypes for RAB and 56 genotypes for BP that showed stable disease reactions over the years. The findings of the study thus strongly indicated the need for broadening the genetic base of the present Indian soybean cultivars, and also suggested the use of exotic collections for genetic enhancement of soybean. Moreover this genotypes can be crossed (Highly Resistance X susceptible) to develop the mapping population to identify the QTLs for resistance and then subsequently can be used for marker assisted breeding(MAS).

PP 24: Screening of Rice Genotypes against Brown Leaf Spot of Rice

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Rice is one of the most important cereal crops, which is a staple food crop of 60 per cent of world population. Brown leaf spot disease occurs in environments where water supply is scarce and it is often combined with imbalances in plant mineral nutrition especially the lack of nitrogen. Brown spot disease is characterized by oval spots on the leaves, about the size and shape of the sesame seeds. In the present study forty five genotypes/varieties were screened for resistance under drill sown field conditions against brown leaf of spot rice caused by *B. oryzae* at Agricultural Research Station, Mugad, Dharwad, during *kharif* 2016. Among the genotypes screened none of the variety showed immune reaction to the disease, seven varieties *viz.,* Wari Sali, Gouri Sali, Kari Kantiga, Bili Nellu, Dodda Mollare, Medium Sali, Bilidadi Muratiga found be highly resistant to the disease. Resistant reaction was noticed in Dodiga, Champakali, Bangar Kovi, Jadu Batta, Dada Bangar Kaddi, Case Batta, Hegge, Nere Mulga, Honni Kottu, Farm Vallya, Alur Sanna, Zhadgi, Honasu, Mutalaga, Kari Esadi, Chipiga, Jiggavaratiga, Kagi Sali, Karakala Doddiga, Bidar Local-3, Konnur Batta, Mysore Sanna, Chitiga, Nadantara Sali, Wari M.S, Betiga, Navali Sali, Bees Geenasali, Udar Sali, Bol Sali, Jeer

Sali, Bidar Local-2 and Bilidadi Goratiga. Five varieties (Bili Doddiga, Bili Kalavi, Murakata Batta, Kiriga Jivile, Hakkala Sali) showed moderately resistant reaction. None of the variety was found to be highly susceptible reaction to the disease

PP 25: Screening of Cucumber Genotypes against Powdery Mildew under Natural Epiphytotic Conditions

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Cucumber (*Cucumis sativus* L.) is one of the oldest cultivated vegetable crops belongs to the family cucurbitaceous with 7 pairs of chromosomes and several distinct morphological features stands apart from other species with 12 pairs of chromosomes which are indigenous to tropical Africa. Now a day‘s powdery mildew has become a major disease in cucumber, since there is no detailed quantitative information on effective management of the disease resistance genotypes plays an important role to combat against pathogen. This can be used as one of the strategy for the management of the disease. Twenty three genotypes were screened against *E. cichoracearum* under natural epiphytotic conditions in the field to identify the resistance source during late *kharif* 2016 none were found to be immune or and resistant. However, fifteen genotypes *Viz.,* Swathi, BSS-949, JK-special, Mahy Sylvia, Malini, Shirakawa, Yummy, Kareena, Green long, Ajeeth-99, White long, Encounter-962, Shalini, Ranebennur local and Sarpan hybrid were found to be moderately resistant with five grade and five genotypes *Viz.,* Chetak, Gullakai, Khushi, Sribasava and Harini were found to be moderately susceptible with seven grade and Mangalore local, Dharwad green and chitra showed highly susceptible reaction with maximum reaction of nine grade.

PP 26: Selection of Host Differentials for the Identification of *Albugo candida* isolates, the Cause of White Rust Disease in Rapeseed and Mustard

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White rust/ blister of rapeseed-mustard caused by *Albugo candida* is one of the important diseases of rapeseed-mustard in India causing a significant yield loss. Among various management practices breeding for resistant genotypes / varieties considered as most eco-friendly, economic and effective method for the control of plant diseases. Present investigation was undertaken by cross inoculating different Brassica genotypes/ varieties (29 no.) with different *A. candida* isolates (15 no.) collected from different geographical locations for the identification of host differentials as well as resistant sources. On the basis of more or less similar phenotypic disease reaction different Brassica genotypes can be grouped as under and could be used as host differentials: Group 1: Varuna, RH-30, Kranti; Group 2: EC 399313, EC 399301,Pusa Bold; Group 3: Pusa Kalyani, BSH-1; Group 4: TL15, PT303, Bhawani; Group 5: Torch, Tobin; Group 6: Candle; Group 7: *Eureca sativa*, Group 8

S.alba, Group 9: Ragini; Group 10: DLSC-1, Kiran; Group11: GSL1, Wester; Group 12: Sangam; Group 13: Donskaja; Group 14: Cutlass; Group 15: BIOYSR; Group 16: NRCDR-515; Group 17: Heera; Group18: *Raphanus sativus;* Group 19: *Brassica oleracia.* These host differentials of *Brassica* genotypes/ variety could be used for further study for the identification of *A. candida* isolates as well as resistant sources against the white rust disease.

PP 27: Breeding for Resistance to Mungbean Yellow Mosaic Virus and Rust in Soybean at Pantnagar

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Soybean [*Glycine max* (L.) Merrill] is economically the most important legume crop for world. In India it was considered number one oil seed crop which has occupied significant place in Indian agriculture. *Mungbean Yellow Mosaic Virus* is one of the most important diseases of soybean specifically in north India. Through systematic screening of about 4000 germplasm lines, only two lines *viz*. UPSM 534 (PI 171443) and *Glycine formosona* (a wild soybean) were resistant to yellow mosaic first time reported in 1974 from this centre. Genetic studies revealed that resistance to yellow mosaic in UPSM 534 was controlled by 2 pairs of recessive genes i.e. rym1 and rym2 (Singh and Malik, 1978) whereas, in case of wild soybean one dominant gene is responsible for imparting resistance. These sources were extensively utilized in hybridization programme and single cross F_1s (in case of UPSM 534) and BC_1's/ BC_2's (in case of *G. formosana*) were routed through pedigree selection under hot spot situation of Pantnagar and the first YMV resistant soybean variety using UPSM 534 as a donor, PK 416 was released in 1985, followed by PS 564 and PS 1042 *etc*. Now all breeding lines (> 500) have a PK/PS number carry YMV resistance either from UPSM 534 or *Glycine soja* or any other PK line having derived its resistance from one of these two donors. For durable resistance gene pyramiding approach is under progress in order to accumulate the resistance from both the sources. Yadav *et al*., (2015) did whole genome sequencing of MYMV susceptible variety JS 335 and resistance genotype UPSM 534 (PI 171443) to find out genomic region associated with resistant gene. They indicated a single nucleotide polymorphic SNP on chromosome 18 (LGG) with a possible associated with MYMV resistant gene. Marker assisted selection using liked marker will help in accelerated introgression of MYMV resistance gene in dominating but susceptible varieties of soybean. Soybean rust was first time noticed at Pantnagar in 1970. The lines identified to be resistant from germplasm were PI 200 465, PI 200 466, PI 200 477, PI 200 490, PI 200 492 and PI 224 268 all having a Japanese origin. The genetic data on segregation for resistance to rust was controlled by a single dominant gene. Ankur a variety released in 1974 from this University followed by PS 1024, PS 1029 and PS 1042 which were tolerant to rust. Combination breeding has been initiated at the centre in order to combine resistance for YMV and rust in background of high yielding widely adapted varieties of soybean to cater the need for the nitch areas.

PP 28: Impact of Soil Extracts from Amended Soil with Organic Matters and Micro Nutrients on Red Rot Disease and Yield Parameters in Sugarcane

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Sugarcane (*Saccharum officinarum* L.) is one of the most important sugar producing crop in tropical and subtropical countries of the world. India is the second largest producer of sugarcane and sugar next only to Brazil. It is a multi-product crop and has immense potential for diversification. Beside the production of sugar, green top of sugarcane is used as fodder, molasses for ethanol and for various byproducts, pressed mud for manure, bagasse for paper and pulp and cogeneration and fly ash for various industrial products. The enormous fuel potential of sugarcane is being utilized. The emerging scenario of this crop as renewable energy crop in India for the production of ethanol provides enough scope to increase the sugarcane production further. Among various diseases, red rot is one of the important and dreadful diseases caused by *Colletotrichum falcatum* Went. It not only reduces the yield but also reduces the juice quality. In general, the estimated losses varies from 3-25% in sugar content and 30-90% in cane yield and it is therefore, obvious to control disease to reduce the quantity and quality losses in crop production. Just to find out some alternative means for the control of red rot, effort have been made to use soil amendment with organic matters and application of micro nutrients to reduce the incidence the present investigation was carried out. Ten sources of organic matters *viz.* Fresh sugarcane bagasse, Tea waste, Cow urine, Cow dung, Banana peels skin, orange peels skin, vermicompost, Wheat bran, Wheat straw and poultry manure were used. Ten (10) gram of each was mixed separately with 1 kg of soil and allowed to recycle for 25 days in plastic pots. After complete decomposition soil extracts were prepared by mixing water (1:2 W/V) and used for *in vitro* screening. Similarly, *in vitro* evaluation of micronutrients *viz*. Zinc. Iron, Sulphur, Boron, Manganese, Molybdenum and Copper were used against test fungus at 100, 500 and 1000 ppm concentration. The field experiment was conducted at Norman E Borlaug CRC, Pantnagar with sugarcane variety Co 1148 as planting material. Planting was done in first week of April in RBD with recommended package and practices of cultivation. Micronutrients used were, Zn @ 25 kg/h (Zinc sulphate), Mn @ 25 kg/h (Mangnese sulphate), Cu @ 5 kg/h (Copper sulphate), S @ 40kg/h (Elemental sulphar), B @ 10kg/h (Borax) , Mo @ 750g/h (Ammonium molybdate) and Fe @ 0.1% (Ferrous sulphate) alone and in various combinations in ratio of 1:1:1. All these except Fe were applied as furrow application at the time of planting. Fe was applied as foliar sprays at tillering stage. Data reveals that, minimum growth or maximum inhibition of mycelium was obtained in Wheat straw amended soil extract (24.68%). Among micronutrients, Zinc and Borax at all three concentrations, were highly effective in inhibiting the mycelial growth (60.64%).Mangnese sulphate, Copper sulphate and Ferrous sulphate also showed inhibition ability at higher concentration (1000ppm). Under field conditions, application of Zinc showed lesser disease incidence (14.92%) followed by Boron (18.75%) as compared to check (47.07%). Application of Zinc and Boron not only reduced the disease incidence but also enhanced growth parameters of sugarcane crop such as number of tillers, number of milliable canes, cane height, cane girth, cane weight, intermodal length, sucrose percent, CCS percent, CCS yield and cane yield. Based on present investigation it is concluded that, application of Zinc sulphate and Boron reduce the red rot incidence possibly through enhancing resistance.

PP 29: Molecular Characterization of Chickpea Genotypes for Botrytis Grey Mould Disease using SSR Markers

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Chickpea (*Cicer arietinum*) is one of the oldest and widely cultivated pulse crops in the world. Chickpea is a self-pollinated crop, with 2n=2x=16 chromosome and a genome of 740 Mb. Chickpea is susceptible to biotic stresses. Botrytis Grey Mould caused by *Botrytis cinerea* is second most important foliar disease of chickpea after Ascochyta Blight. The disease reached epidemic proportions in India during 1978-79 crop season, destroying about 20,000 ha of chickpea. The present study was carried out using nine different primers (TA118, TA25, TA144, TR29, TA2, TA110, TS57, CaSTMS7 and CaSTMS24) for their validation of linkage with Botrytis Grey Mould on 26 genotypes along with the field screening of genotypes. Molecular analysis of 26 genotypes with primer TA144 showed amplification ranging between 230-290bp and gave the high resistance in sixteen genotypes, two genotypes were found moderately resistant, six varieties were found moderately susceptible and only two genotypes were found susceptible to disease. Six genotypes were found highly resistant, five genotypes were found moderately resistant, three genotypes were moderately susceptible and eleven were found susceptible with primer TR29. From present investigation it can be concluded that most of the genotypes showed good correlation between molecular and field screening.

PP 30: Identification of Suitable Crop Beneficial Microbe(s) for Rapid Dissipation of Pendimethalin Herbicide

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The investigation was carried out in a sandy loam soil with *Rabi* season chickpea to evaluate the identification of suitable crop beneficial microbe(s) for rapid degradation of pendimethalin herbicide. In this connection 15 soil samples were collected from different plots of a long term herbicidal trail where different herbicides were applied in *kharif* and *rabi* seasons continuously for last five years. Eleven crop beneficial microbial isolates were collected from these soil samples belonged to genus *Rhizobium, Pseudomonas, Azotobacter* and *Azospirillum,* which seem to herbicides tolerant. These isolates were further characterized with respect to their cultural characteristics, Dehydrogenase activity. Isolates which shown good growth in their respective culture media containing 5000 ppm pendimethalin considered as potential isolates. In another study under *in vitro* conditions these potential isolates were further tested for their efficiency of pendimethalin degradation. In this regard 3 rhizobial and 4 phosphobacterial isolates were taken and tested in single and dual combination. In this study dual inoculation of rhizobial isolate *Rhizobium*-3 and phosphobacterial isolate PSB-4 was found best for rapid degradation of herbicide pendimethalin. These native isolates had soon highest Dehydrogenase activity over control at 50 DAS. The combined application of *Rhizobium*-3 and PSB-4 also found supreme to increase the chickpea yield at highest level by mobilizing more nitrogen and phosphorus in crop rhizosphere.

PP 31: Evaluation of Phenolic Acids Imparting Resistance in Lentil against *Fusarium oxysporum* f. sp. *lentis*

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It is well established fact that phenolic compounds impart resistance in plants. Keeping this in view, present study was conducted to ascertain phenolic compounds responsible for imparting resistance in lentil. For this, three varieties with resistant, tolerant and susceptible reaction towards wilt pathogen *F. oxysporum* f.sp. *lentis* were selected. Antifungal activities of five phenolic acids namely chlorogenic acid, salicylic acid, p-coumaric acid, protocatechuic acid and cinnamic acid were evaluated by bioassay at four concentrations (25, 50, 75 and 100 ppm). All phenolic compounds inhibited the radial growth of pathogen at all concentrations but chlorogenic acid and cinnamic acid were found effective at all concentration, where maximum inhibition of 86.84 per cent was observed at 100 ppm concentration followed by p-coumaric (82.89 %). Changes in phenolic acid content of these varieties due to attack of the pathogen was observed by employing water culture technique and samples were taken at 1, 3 and 5 days after inoculation where in cv. DPL-62, chlorogenic acid (157.44 µg/g) and protocatechuic acid (46.25 µg/g) were produced significantly one day after challenge inoculation which reduced with time on third and fifth day. In cv. PL-4 also, chlorogenic acid increased significantly to 120.98 µg/g compared to control (24.62 µg/g), whereas in susceptible variety L-9-12, though chlorogenic acid (55.59 µg/g) produced more than control but when compared to resistant and tolerant varieties it was low, suggesting role of chlorogenic acid in resistance against the wilt pathogen.

PP 32: Lichenicolous fungi: Hidden Possibility for Novel Organism Discovery

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The immense importance of fungi in our daily life is well recognized. Everyone is well aware about the Penicillin; a globally known antibiotic drug which is till date serving the mankind was extracted from a fungi. The fungi become very important in case of plant pathology, agronomy and many other branches of agriculture. An estimate of occurrence of 1.5 million fungi was made but only 0.1 million fungi have been identified so far. The lichens besides their own fungal partner i.e. mycobiont; provide an underexplored but potential habitat for other fungal groups. The lichenicolous fungi one of them are highly specialized and successful ecological group of ascomycetes and ascomycetous anamorphic organisms that develop obligatory on lichen thallus. Till date 1800 lichenicolous fungi have been identified, however, there is an estimate of occurrence of about 3000 lichenicolous fungi in world. The present paper describes the lichenicolous fungal biota of Uttarakhand. Lichenicolous fungal wealth of Uttarakhand comprises 64 species of lichenicolous fungi belonging to 40 genera, colonizing 67 different lichen species. *Lichenostigma cosmopolites* showed broad range of distribution i.e. was found growing on 9 different lichen species. Lichen species *Rusavskia elegans* hosted maximum (8) species of different lichenicolous fungi. The hidden potential of a large number of fungi is still unexplored, lichenicolous fungi can provide some new novel organisms to science.

PP 33: Fungi Associated with Decomposing Leaf Litter of Brown Oak (*Quercus semecarpifolia*): A Case Study from Chopta, Garhwal Himalaya

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Plant litter represents a major source of organic carbon in forest soils. Its decomposition is a complex process that involves mineralization and transformation of organic matter. Decomposition of plant litter is a key step in nutrient recycling. As most of the plant biomass-derived carbon in the temperate and boreal forests is mineralized in the litter layer, an understanding of this process and the microorganisms involved is essential for the identification of factors that affect global carbon fluxes. Fungi are considered the primary decomposers of dead plant biomass in terrestrial ecosystems. However, current knowledge regarding the successive changes in fungal communities during litter decomposition is limited. Present study, fungi associated with leaf litter of *Quercus semecarpifolia* was conducted during October 2016 in Chopta, Garhwal Himalaya. During the investigation it was found that the development of fungal community in the decomposing leaf litter of *Q. semecarpifolia* was found effectively. A total of 17 genera were recorded by using adhesive tape method. In which *Alternaria*, *Torula* and *Periconia* were most common fungi. This result indicates that litter decomposition is a highly complex process mediated by various fungal taxa.

PP 34: Effect of Organic Amendments on Nematodes Population on Maize

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Experiment was conducted to examine the effects of organic amendments on nematode communities in field soil seeded to maize. The experimental design was replicated randomized complete block design with farmyard manure @ 12 t/ha, vermicompost @ 8 q/ha and poultry manure @ 4 t/ha have potential to suppress nematode population significantly. Among the all amendments, poultry manure was found superior in reducing the nematode population and increasing yield of maize than vermicompost and farmyard manure. Application of carbofuran, vermicompost and poultry manure alone with combination significantly increased plant growth and decreased the nematode population over control. Maximum plant height was recorded in carbofuran 1.0 kg a.i/ha+ poultry manure 4t/ha treated soil and minimum in carbofuran 1.0 kg a.i/ha treated soil. Maximum nematode population was recorded in vermicompost @8q/ha treated soil and minimum in carbofuran 1.0 kg a.i/ha+poultry manure 4t/ha.

Session 02:

PGPR, Bio-inoculants, Nano-technology and Biotechnological Approaches for the Management of Plant Diseases

LP 01: Biopesticides: Regulatory Requirement, Commercialization and IPR Related Issues

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Biopesticide formulation based on bacteria, fungi, viruses, nematodes, protozoa etc. are known as microbial pesticides. These microbial pesticides also include antagonistic organisms for biological control of plant diseases. Nine microbes namely *Bacillus subtilis, Gliocladium* spp., *Trichoderma* spp., *Pseudomonas Fluorescens, Beauvaria bassiana, Metarrhizium anisopliae, Verticillium lecanii,* Grannulosis viruses and nuclear polyhedral viruses (NPV) have been included in a schedule vide an amendment in insecticides Act, 1968 for the commercial production of biopesticide and published in the Gazette of India dated 26th March 1999. To date 26 more microbes have been included in the schedule to the Insecticide Act 1968 for production of microbial biopesticides. *Trichoderma viride, T. harzaianum, Pseudomonas, Beauvaria bassiana, Metarrhizium anisopliae* and *Bacillus subtilis* have curved a niche for themselves in India as important biocontrol agents for management of various pests and diseases. However, their reach is still limited to some selected states in our country. The major reason for this phenomenon is the mushrooming of some spurious producers. This not only sows the seeds of doubt in farmers mind about the profitability of microbial biopesticides but also the ill effect of these biopesticides. The research on biocontrol agents (BCAs) can be fruitful only when we commercialize and register the product based on superior strains. To achieve this, certain norms specified by Central Insecticides Board are to be followed. The mass production of microbes based formulation is also very important part in the development of technology. Although the biological control ability of *Trichoderma* has been shown for many years, the ability of these fungi to increase the rate of plant growth and development, especially to enhance the production of more robust roots is now being documented. Besides such potentialities, certain *Trichoderma* species are highly efficient producers of many extracellular enzymes and are used commercially for production of cellulases and other enzymes that degrade complex polysaccharides. They are frequently used in the food and textile industries. During the presentation we will discuss about these parameters setup by CIB and other aspects related to commercialization, registration and IPR issues of microbial-based biopesticides.

IL 01: Host Responses to Fungal Biotroph Pathogen Challenge: A Molecular Insight into *Erysiphe pisi* - Pea Interaction

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Plant signalling mechanisms are not completely understood in plant–fungal biotrophic pathogen interactions. Further, how such interactions are influenced by compatible rhizosphere microbes are also not clearly understood. Therefore, we explored the pea-*Erysiphe pisi* (obligate biotroph) system to understand the interaction and introduced compatible rhizospheric bio-agents *Trichoderma asperellum* (T42) and *Pseudomonas fluorescens* (OKC) singly or in combination to assess their influences on pea while under the pathogen challenge. We investigated the responses of pea through activation of G-protein subunits, MAP Kinases, signature genes of phytohormone signalling, NADPH oxidase gene, ROS generation, antioxidant enzymes, phenol accumulation, ABC transporter gene and lignifications through transcript accumulation pattern, spectrophotometric analysis, HPLC analysis and staining of cross sections of pea stems. We observed that mostly the transcripts of Gα1 and 2 subunits of pea G-proteins were accumulated when the plants were challenged with *E. pisi* and treated with OKC and T42. Interestingly, activities of pathogen responsive MAPK homologs MAPK 3/MAPK 6 and the enzyme serine threonine kinase were down regulated and the results indicated non-participation of the MAPK cascade in this interaction. In addition, OKC and T42 pre-treatment stimulated activities of NADPH oxidase, peroxidases, phenylpropanoid genes leading to lignifications in pea during infection by *E. pisi.* Further, down regulation of the lignifications-associated ABC transporter gene in the pathogen challenged plants indicated passive diffusion of the monolignols across the membrane from symplast. The signal transduction was possibly mediated through JA in pea under the stimulus of the microbes as evident from the activities of *LOX1* and *COI1* genes and the cumulative effect of the co-inoculated microbes had a suppressive effect on *E. pisi* conidial development on pea leaves.

IL 02: New Substrate for Mass Multiplication of *Trichoderma harzianum* and *Pseudomonas flourescens*

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Use of fungitoxicants and antibiotics for plant disease‘s management has helped enormously for increasing the food grain production but on other side it has pose a serious threat of ecosystem imbalances. Biological control has immerged as one of the feasible alternative of these chemicals for plant disease management. Some of the microorganisms like *Trichoderma harzianum* and *Pseudomonas flourescens* are popularly being used on mass scale for these purposes. In addition to suppressing the diseases in plants these microorganisms are also help ful in growth promotion and as inducers of systemic resistance. For large scale application these microbes need to be produced at mass acale. Investigations were undertaken to test the suitability of various de-oiled cakes of TBOs *viz.*, Neem, Jatropha, Mahua and Karanja for mass multiplication and longevity of *Trichoderma harzianum* and *Pseudomonas flourescens in vitro*. In addition, all these cakes were also tested for supporting the population dynamics and longevity of two microorganisms in rhizospheric soil. In case of *Trichoderma harzianum,* among four de-oiled cakes, Neem cake was found to be best substrate for supporting the population dynamics and longevity of *T. harzianum in vitro*. Neem cake maintained with 25% moisture was also able to support the longevity of *T. harzianum* for more than 120 days with a considerable level of population. *T. harzianum* population were further hiked when these cakes were amended with various sources of carbon, nitrogen and different vitamins. Population density gets increased with the incorporation of additional sources of carbon, nitrogen and vitamins to these de-oiled cakes. Among various sources of carbon, nitrogen and different vitamins, sucrose, calcium nitrate and thiamin respectively were the best sources when amended to any of these cakes, while fructose, urea and biotin were little inferior for mass multiplication of *T. harzianum*. Application of *T. harzianum* grown on Jatropha cake to the sterilized and unsterilized soil planted with tomato supported the highest population dynamics for longer period than other substrates used. Jatropha cake with 25% moisture supported the population dynamics for more than 135 days, while others didn't. Application of *T. harzianum* grown on different oil cakes to the sterilized soil without planting supported the population dynamics up to 90 days only, while in unsterilized soil, *T. harzianum* survived up to 120 days. Application of *T. harzianum* grown on different cakes, FYM and vermicompost enhanced the plant height, greenness and fruit yield. Application of *T. harzianum* grown on these cakes to soil was also able to induce the systemic resistance in plants against foliar diseases.

In case of *P. flourescens,* among four de-oiled cakes Jatropha and Mahua cakes were found to be best substrate for supporting the population dynamics and longevity of *P. flourescens in vitro*. All these cakes, supported the population of *P. flourescens* up to 120 days. Highest population of *P. flourescens* was noticed on Jatropha and Mahua cakes after 45 days of inoculation when maintained with 15% and 35% moisture respectively, while on Neem and Karanja cakes highest population of *P. flourescens* were noticed after 60 and 45 days of inoculation when maintained with 25% and 35% moisture respectively. Jatropha and Mahua cakes were better than Neem and Karanja cakes for supporting population and longer shelf life of *P. flourescens in vitro.* Increasing the moisture level resulted in enhancement of total viable count of *P. flourescens* on all these de-oiled cakes *i.e*. Neem, Jatropha, Mahua and Karanja cakes. After duration of 120 days also the viable counts of *P. flourescens* remains at the level of $X10^8$. Four different concentrations of extract of de-oiled cakes of Neem, Jatropha, Mahua and karanja were also tested for their ability to enhance multiplication of *P. flourescens* after 7 days and 15 days duration. Increasing in the moisture level resulted in enhancement of total viable count of *P. flourescens* on all these cakes. Increasing concentration of extract (30%) of all these cakes, resulted in increasing the population of *P. flourescens.* Increasing the dilution of stock of initial inoculums resulted in decrease of total viable counts of *P. flourescens.* Population of *P. flourescens* was comparatively lesser after 15 days than after 7 days of inoculation. Tomato plants grown in sterilized soil either applied with a mixture of *P. fluorescens* grown on Jatropha cake +*T. harzianum* grown on Jatropha cake resulted in highest recovery of *T. harzianum* after 45 days of application. Application of mixture of two bio-agents resulted in comparatively lower recovery of *P. fluorescens* but it was better for root and shoot growth enhancement. Tomato plants grown in sterilized and unsterilized soil either applied with a mixture of *P. fluorescens* grown on Jatropha cake + *T. harzianum* grown on Jatropha cake applied with a mixture of *P. fluorescens* grown on Neem cake + *T. harzianum* grown on Neem cake, showed highest root length, highest shoot length and highest fruit yields also. Combined application of bio-agents *P. flourescens* and *T. harzianum* grown on any of these cakes to the sterilized soil resulted in three time increase in root length, 1.5 times increase in shoot length and five time increase in fruit yields of tomato crop.

IL 03: Marker Assisted Transfer of Major and APR Genes for Durable Rust Resistance in Bread Wheat (*Triticum aestivum* L.)

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Wheat (*Triticum aestivum* L.) is one of the most important cereal crops in the world grown in maximum acreage and diverse growing situations contributing 20 per cent calorie and 20 per cent protein requirement of the global population. India is the second largest wheat producer in the world with 97.4 million ton wheat production in 2016-17. Climate change and global warming have profound effect on resurgence of new races/pathotypes of different disease causing organism. It has also been proved that yield potential of high yielding varieties is seldom realized due to disease pressure. Therefore, development of disease resistance varieties has been one of the important goals in crop improvement. Wheat is affected by several diseases, but rusts caused by *Puccinia* spp. are the most important. The impact of rust on yield reduction in wheat ranges from 10% under moderate and 65% under intense epidemics. In India too, the losses caused by rust infection are around 40% under conducive environment.

The three important rusts of wheat, black or stem rust caused by *Puccinia graminis* Pers. f.sp. *tritici*, brown or leaf rust incited by *P. triticina* and yellow or stripe rust caused by *P. striiformis* are known to cause significant losses to wheat production. Wheat rusts have been under the control for last few decades mainly because of development of rust resistant wheat varieties. However, yellow rust epidemic in 2010-11 and breakdown of Yr9 resistance in mega wheat variety PBW 343 and susceptibility of other high yielding varieties like UP 2338, DBW 17, HD 2967 after a small period of their release warrants attention to develop wheat varieties with durable rust resistance. So far, major emphasis has been on utilization of major genes that provide high degree of resistance. However, once varieties become popular and occupy larger areas, there is tendency towards evolution of new virulent races that knock down the major genes, which are race specific. On the contrary, adult plant resistant (APR) genes are having minor effects and are race non-specific. APR genes have not been utilized due to difficulty in phenotypic selection. However, recently, a few APR genes have been characterized and molecular markers have been developed for them. Use of APR genes will eliminate the need of frequent replacement of varieties, which often become susceptible. Temperature, inoculum density and host growth stages usually have some effect on the expression on resistance. Rust resistance may also be governed by several oligo-genes in combination and also polygenes where individual gene effects are unknown. To overcome the short duration nature of resistance conferred by major genes, emphasis has now been shifted towards pyramiding of minor genes. International centre for maize and wheat improvement (CIMMYT) has started large scale breeding based on APR genes. Since, these genes are not race specific, these will check the frequent evolution of new races also. Use of molecular markers has emerged as a powerful and efficient approach to complement classical plant breeding for improving crops. Transfer and pyramiding of major as well as minor genes for yellow and brown rust resistance have been taken at GBPUAT, Pantnagar with funding support of Department of Biotechnology, Government of India. Considering the importance of yellow rust in Northern Hills Zone (NHZ) and yellow as well as brown rusts in North Western Plains Zone (NWPZ), two major yellow rust resistance genes, Yr10 and Yr15 from the donor genotypes Avocet/Yr10 and Avocet/Yr15, respectively were mobilized in two recipient genotypes, UP 2855 and UP 2572, and three APR genes, Lr34/Yr18, Lr46/Yr29 and Lr67/Yr46 were transferred to recipients from the donor genotypes, UP 2425, Pavon 76 and RL 6067, respectively. Both recipient and donor genotypes were sown in two dates and sufficient crosses were attempted. Emasculation and pollination was carried out at flowering stage to generate sufficient F_1 seeds for backcrossing. All the donors were closely examined for their reaction for leaf and yellow rust to check their effectiveness under field conditions. For the validation of donors individual plants were tagged for leaf collection and DNA was extracted using CTAB method. DNA Quantification was done and stored at -20°C.

Recurrent parents (UP 2855 and UP 2572) and donor genotypes (UP 2425, Pavon 76 and RL 6067) were sown in two dates of sowing and crosses were attempted between the recurrent parents and donors to develop near isogenic lines (NILs). In addition to APR genes crosses were also attempted to mobilize major genes for yellow rust resistance (Yr10 and Yr15 using Avocet/Yr10 and Avocet/Yr15 as donors, respectively. Individual plants were tagged for leaf collection and DNA was extracted using CTAB method. DNA Quantification was done and stored at -20°C. Emasculation and pollination was carried out at flowering stage to generate sufficient F_1 seeds for backcrossing. All the donors were closely examined for their reaction for leaf and yellow rust to check their effectiveness under field conditions. F_1 seeds from recipient parents were harvested and stored in paper bags. SSR markers, Psp3000, Xgwm 11, CsLV 34, Xwmc44 and Xbarc 98 were used to validate the donors for Yr10 and Yr15, Lr34/Yr18, Lr46/Yr29 and Lr67/Yr46, respectively. Parental polymorphism survey has also been done to facilitate the maximum recurrent parent genome using background selection. Pyramiding of these race non-specific genes is expected to confer durable rust resistance in wheat. It is envisaged that near isogenic lines (NILs) thus developed in the next three crop seasons will not only be ready for the release as a variety possessing durable rust resistance but also these could be used as mapping population for the detection of QTLs for rust resistance.

OP 01: Proteomic Approach to Identify *Meloidogyne incognita* and Nematicidal Potential of Oil Cake

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Root-knot nematodes are one of the most destructive nematode pests that damage economic crops worldwide. *Meloidogyne* species found in warm/tropical areas are considered to as thermophiles, while those appearing in colder parts of the world are characterized as cryophiles. In this experiment, study was based to identify the species and control the root infectivity caused by *Meloidogyne* species. Proteomic approach was applied to identify the *Meloidogyne* species from tomato root sample. Isolated adult female and infective juvenile stages of *Meloidogyne* species were targeted to mass spectrometric instrument to generate protein profiles, and number of protein peaks obtained. Significant marker protein peaks of *Meloidogyne incognita* were obtained. Perineal pattern examination was also performed to confirm the above results. Oil cakes of different plants were used to control the infective juveniles of *Meloidogyne incognita*. Obtained results were proved that oil cakes were significantly killing the juveniles (J_2) and also control the penetration in tomato roots. This study provides fast and reliable technique to identify *Meloidogyne* species and give opportunity to use eco-friendly control approach to minimize the crop loss.

OP 02: Detection and Elimination of *Phytoplasma* Associated with *Catharanthus roseus*

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In the present investigation, *in vitro* therapy of tetracycline was carried out for the presence of Phytoplasma and an attempt was made to control the disease caused by Phytoplasma. *Catharanthus roseus,* an important plant species in India, well known for its medicinal values was attempted to eliminate the phytoplasma infection. The nested PCR with known primers (R16F2/R2) of phytoplasma DNA from phytoplasma infected samples yield ~1200 bp bands of the phytoplasma 16S rDNA. No amplicon was found in DNA sample of healthy/non symptomatic *C. roseus* plants. Positive samples with phytoplasma primers were processed for treatments through tissue culture. About 3 cm long nodal segments excised from phytoplasma-infected *C. roseus* plants (nested PCR positive) were surface sterilized and aseptically inoculated on Murashige and Skoog‘s (MS) medium. The efficacy of tetracycline was tested at various concentrations. Medium supplements with tetracycline were used and ten shoots cultures were transferred. Regenerated plants from infected *C. roseus* after tetracycline treatments were again subjected to PCR assays for detection of phytoplasma. The results showed that the optimum frequency of elimination of phytoplasma was achieved with treatment of 80 mg/L of tetracycline application followed by 60 mg/L.

OP 03: Studies on Root Endophytic Aquatic Hyphomycetes *Cylindrocarpon aquaticum* as Plant Growth Promoter

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The occurrence of endophytic fungi is now well known and has been also reported as source of valuable secondary metabolites useful to plants as bio-controlling agents and bio-fertilizers. Aquatic hyphomycetes, a peculiar group of aquatic fungi abundantly present in submerged leaf litter, are now also reported as endophytes of riparian plant roots. One of aquatic hyphomycetes *Cylindrocarpon aquaticum* recovered from the living roots of *Eupatorium adenophorum*as an endophyte was evaluated for its role in plant growth through pot experiments in glass house conditions. The present endophytic fungus was found very effective to enhance the growth of test plants, spinach (*Spinacia oleracia* L.) and wheat (*Triticum aestivum* L.). The growth of these plants were measured in terms of increased shoot and root lengths, shoot and root diameters, total fresh weight and total dry weight of test plants and compared with control pot plants. The used root endophytic fungus was found as plant growth promoters and shows a significant effect on the growth of test plants Spinach, in all parameters except on root length, while in the case of Wheat it shows significant effect in all parameters ($p< 0.001$, significant). The dry biomass of the test plants increased by more than double (in spinach 0.521 and in wheat 0.201 g/plant) as compared to control (0.242 and 0.092 g/plant respectively).Thus, the present findings provide a new area in bio-prospection of endophytic aquatic fungi, which may be an alternative source of bioactive chemicals in agriculture.

OP 04: Evaluation of Chitosan for Management of Banded Leaf and Sheath Blight of Maize

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Banded Leaf and Sheath Blight disease is most prevalent in south and south-east Asian countries. It is caused by a soil borne pathogen *Rhizoctonia solani* f. sp. *sasakii* (Kuhn) Exner [Teleomorph: *Corticium sasakii*, syn. *Thanatephorus cucumeris* Frank (Donk)]. The pathogen is notorious due to wide host range and is difficult to manage using conventional management strategies. Therefore, alternative management strategies, such as using organic molecules are needed for eco-friendly management of BLSB. Chitosan, an amino polysaccharide made up of glucosamine and N-acetyl glucosamine units linked by β-1, 4 linkage was earlier reported having antifungal activity. Present study was done to evaluate antifugal activity of chitosan against *Rhizoctonia solani* f. sp. *sasakii*. The EC_{50} value was 0.8 mg/ml in growth inhibition assays. Chitosan exhibited fungistatic activity, as recovered mycelium after fifth subsequent sub-culture on PDA. Maximum inhibition (71.1 %) of mycelial growth was observed in third generation. The antifungal activity might be attributed to the direct effect of chitosan on fungal mycelium by changing ultrastructure of fungal cells and enhancing chitosanase activity. Transmission Electron Microscopy of *Rhizoctonia solani* f. sp. *sasakii* revealed abnormal cells with increased vacuoles and shrinkage of protoplast in the presence of chitosan (@ 0.8 mg/ml). Chitosan reduced the pathogenicity after prolonged exposure as recovered mycelium produced small lesions (25.7 cm to 32.5 cm) on the maize (variety Vivek QPM 9) plants compared to untreated control (41.7 cm). Chitosan treatment exhibited indirect antifungal activity by significantly enhancing activities of defense related enzymes like PPO, PAL and SOD. The study suggests chitosan as anviable alternative for management of Banded Leaf and Sheath Blight in maize. However, exploration of its mechanism of action is needed.

OP 05: Candidate Pathogenicity Genes Based Novel Microsatellite Markers from *Rhizoctonia solani*

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Sheath blight of rice caused by *Rhizoctonia solani* AG1IA is one of the important diseases of rice. Each year, the sheath blight causes up to a 50% decrease in the rice yield under favourable conditions around the world. Effector genes play an important role in the virulence behaviour of the pathogen. Nine microsatellite markers were developed from different candidate genes for pathogenicity *viz*. Beta lactamase super family domain-containing protein, Response regulator receiver protein, Calcium hydrogen antiporter, Psuedouridine synthase, Vacoular assembling protein VPS41, Hypothetical protein *R. solani* AG1IA 00332, TBCA domain-containing protein, Candidate gene hypothetical protein AG1IA00598 and Candidate gene hypothetical protein AG1IA08741. Twenty-four isolates of *R. solani*AG1IA collected from Uttar Pradesh, Uttarakhand and Haryana state of India were tested for the presence of theses pathogenicity genes. All the 24 isolates were confirmed as *R. solani* AG1IA by using species specific primers i.e. AG-common primer (forward) (5′-CTCAAACAGGCATGCTC-3′) and AG1IA specific primer (reverse) (5′-CAGCAATAGTTGGTGGA-3′). DNA amplification by using SSR markers successfully produced at least one bright and distinct amplicon (343-1000 bp). The number of alleles detected by these primers was 23, 22, 16, 21, 20, 12, 54, 27 and 19 respectively. The highest number of alleles (54) was detected by TBCA, SSR primer followed by candidate gene hypothetical protein AG1IA00598 primer (27).

OP 06: Plant Growth Promoting Rhizobacteria as Biological Control of Soil Borne Disease of Beans

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Common bean (*Phaseolus vulgaris* L.) is an important grain legume for the direct human consumption in the World. There are several diseases which infect the bean plants among them bean wilt caused by *Fusarium oxysporum* f. sp. *phaseoli* is one of the most important diseases among worldwide. Fungal pathogen *F. oxysporum* f.sp. *phaseoli* was isolated from the infected roots of bean plants. The Pathogen identified based on morphological characteristics which include hyphae, conidia and micro conidia and comparing that with the standard text. A total no. of 24 rhizobacterial isolates was isolated from the rhizosphere of different crops. Under *in vitro* conditions, among 24 isolates 5 exhibited potential of acting as biocontrol agents in which isolate I-5 exhibited minimum radial growth (28.00 mm), resulting in inhibition of by 68.89 per cent over control. These five selected isolates subjected to biochemical test like Starch Hydrolysis, Catalase, Oxidase, Arginine hydrolysis, Gelatin liquefaction,H_2S, Indole test, Anaerobic activity, Urease, Nitrate and Methyl red test for the identification of the isolates. Further identification of the isolate I-4, I-5, I-20 and I-21 were subjected to 16S rDNA analysis, isolate I-1 were identified on the basis of biochemical test. The results of BLAST search of 16S rDNA sequence of different isolates compared with the available 16S rDNA sequence in the National Center for Biotechnology Information (NCBI) indicated that I-4 and I-20 was closely related to *Bacillus cereus*, I-5 related to *Stenotrophomonas maltophilia,* isolate I-21 with *Pseudomonas* sp. Under *in vivo* conditions application of PGPR isolates enhanced growth parameters such as per cent germination, shoot length, fresh weight of shoot, dry weight of shoot, fresh weight of root and dry weight of root compared with control.

OP 07: Application of Rhamnolipids Biosurfactant against Post Flowering Stalk Rot of Maize

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Maize is the third most important food crops after rice and wheat in India. It is cultivated throughout the year almost in all the states for various purposes including grain, fodder, green cobs, sweet corn, popcorn, baby corn etc. Ubiquitous incidence of diseases in the pre-harvest stage is major factor adversely affecting productivity. Post flowering stalk rot (PFSR) of maize is an important disease in India. It is a _complex‘ disease caused by *Fusarium verticillioides* and *Macrophomina phaseolina* in combination or alone. Yield loss is directly affected by premature plant death or by reduced kernel filling and lodging. Present investigation was carried out on the bio-control efficacy of rhamnolipids (RLs) Biosurfactant (25, 50 and 100 ppm) against both pathogens *in vitro* adopting poison food technique. The Biosurfactant inhibited mycelial growth of *F.verticillioides* by 44% at 100ppm followed by 36.6% at 50ppm and 24% at 25ppm, while *M. Phaseolina* was inhibited by 71.1% at 100ppm followed by 70% at 50ppm and 68.5% at 25 ppm. Rhamnolipid was further evaluated by seed treatment (50 and 100 mg/lit) of maize (variety PC4) against charcoal rot caused by *M. Phaseolina* during *kharif* 2017.Seed germination was significantly high (87.50 %) in the seed treated with biosurfactant (50 mg/lit) as compared to untreated check (62.50%). Maximum disease inhibition (35.92%) was found in seed treatment @ 50 mg/lit followed by 100 mg/lit (20.35%) which was significantly higher than control. Highest grain yield (54.20q/ha) was obtained in the seed treatment @100 mg/lit. However, the investigation will be further repeated.

OP 08: Microsatellite Based Diagnostic Assay for Rapid and Sensitive Detection of Brown Rust of Wheat

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Early detection of infection is very important for efficient management of brown rust of wheat. To monitor and quantify the occurrence of this fungus, a diagnostic method based on real-time PCR was developed. The developed PCR based assay showed amplification product of ~180 bp in genomics DNA of Pt pathotypes using primer pair FDL-Pt-SSR7F and FDL-Pt-SSR7R. No amplification was observed in black and yellow rust pathotypes affecting wheat and barley. SYBR Green based quantification assay for the detection of *P. triticina* in infected wheat seedlings (Pt 77-5) was developed and validated. The detection limit for Pt genomic DNA was in the range from 100 to 0.001 ng/µl and showed 98% level of sensitivity. The developed quantitative real-time PCR method proved to be rapid, sensitive, specific, cost-effective and reliable for the identification and quantification of *Pt* in plant hosts.

PP 01: Growth Performance of Native *Trichoderma* Strains from Southern Districts of Tamil Nadu on Different Culture Media

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The genus of *Trichoderma* is ubiquitous in soil and recommended as good biocontrol agent. The growth, antagonistic activity varies depends on the medium and nutrient availability. Thus, this study was conducted to evaluate the growth performance of *Trichoderma* strains on different culture media *viz*., are Potato dextrose agar (PDA), Carrot agar (CA), Corn Meal Dextrose agar (CMD), Trichoderma Specific Medium (TSM), Oatmeal Agar (OMA) and to find best among them. A Total of twenty five *Trichoderma* isolates were evaluated which has been isolated from the soil samples collected from different locations of Southern districts of Tamil

Nadu, the average growth rate were calculated (ALGR) to check the growth performance. The results suggested that the growth will be different based on medium. Highest growth rate was observed on PDA (2.77 cm/day) followed by CA (2.63cm/day), OMA (2.60 cm/day). Least growth was measured in TSM (0.63m/day) these results suggest that PDA is best media for the *in vitro* and TSM may useful only for isolation.

PP 02: Marker Assisted Breeding for Biotic and Abiotic Stress Tolerance in Soybean

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Soybean is the world‘s leading oilseed crop with major uses in human foods, animal feed, as well as in many industrial products. Additionally, healthy aspects of soya foods go beyond the oil and protein and include minor compounds with nutraceutical properties such as isoflavones, saponins and tocopherols. Biotic and abiotic stresses adversely affect soybean growth and yield. Plant breeders have used conventional breeding methods for the improvement of these traits in soybean variety; however, it takes a decade long to establish a new soybean variety. The conventional breeding process can be accelerated through the application of molecular approaches. Molecular markers have proved to be a new tool in soybean breeding by enhancing selection efficiency in a rapid and time bound manner. DNA-based markers have a huge potential to improve the efficiency and precision of conventional plant breeding via marker-assisted selection (MAS).The limitations of conventional breeding such as linkage drag and lengthy time consumption can be overcome by utilizing DNA markers in plant breeding. The breeding strategies for which MAS is used most frequently, are selection of simple traits or QTLs from breeding lines/populations, introgression of genes from breeding lines or wild relatives, MABC and pyramiding of genes.

PP 03: Characterization of *Pseudomonas aeruginosa* as Plant Growth Promoting Rhizobacteria

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Pseudomonas aeruginosa is most important Plant Growth Promoting Rhizobacteria. The isolate *P. aeruginosa* was characterized for cultural, morphological and biochemical and physiological tests. The *P. aeruginosa* colony was grey colored on nutrient agar medium with entire margin, convex, translucent, circular in shape and characterized as gram negative, rod shaped bacteria and showed negative reaction for Methyl red, Voges- Proskauer, Indole production, Carbohydrate fermentation (Sucrose, Glucose, Lactose, D-Manitol, Trehalose, D-Galactose, D-Xylose, Sorbital, L-Rhamanose , D- Fructose and L-Arbinose) and positive for (oxide, catalase, citrate utilization, nitrate reduction, urease, gelatin liquefaction, motility test, ONPG, PQQ test, starch hydrolysis). The *P. aeruginosa* showed confluent growth at low temperature i.e. 10°C while failed to grow at 50°C and 60°C. Growth of strain was subjected to grow at pH range of 5, 6, 7, 8, 9, 11 and 12. All pH supported the growth of strain. Salt tolerance was examined using NaCl concentration of 1, 2, 3, 4, 5 per cent and it revealed that *P. aeruginosa* was able to tolerate all the NaCl concentration.

PP 04: Evaluation of Bioagents, Elicitors, Amino Acids, Antibiotic and Copper Fungicide for Induced Systemic Resistance in Citrus against *Xanthomonas axonopodis* pv.*citri*

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Citrus canker is one of the most devastating disease caused by *Xanthomonas axonopodis* pv.*citri* and of great economic importance. Considering the seriousness of the disease present investigation was carried out with the objectives to study defense related parameters for the developments of induced resistance in citrus against *Xanthomonas axonopodis* pv.*citri* using bioagents, antibiotics, elicitors and chemicals. The enzymatic activity of the antioxidant enzymes viz; Phenylalanine ammonia lyase (PAL), Catalase (CAT) and Peroxidase (PO) against *X. Axonopodis* pv.*citri* for different treatments was evaluated. The results from the study revealed that pretreatment of citrus plants with Pant bioagent 2, Pant bioagent 3, L-methionine, GABA and Salicylic acid induced the levels of plant defense and thus induced disease resistance against *X. Axonopodis* pv.*citri*. These compounds can be used as effective alternative compounds to copper bactericides for the management of citrus canker. Since the use of copper bactericide for long term induces copper resistance in Xanthomonands population.

PP 05: Application of Agricultural Biotechnology for Crop Disease Management

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Agricultural biotechnology is application of scientific technique to improve plants, animals and microorganisms. As agricultural production increases to encounter the demands of a growing world population, so has to take the step of biotechnology research to conflict plant diseases. Diseases can be caused by a variety of complex plant pathogens including fungi, bacteria, viruses and nematodes, and their management requires the use of techniques. A lot of agricultural crops are being threatened by a wide variety of biotic stresses by lowering of vegetable and fruit quality leading to wipe out entire harvests. About 42 per cent of the world‘s total agricultural crop is destroyed yearly by diseases and pests. The biotechnological techniques are bringing tremendous changes in crop production by making plants resistant to diseases. The different biotechnological techniques include genetic engineering (transgenic), recombinant DNA technology, plant tissue culture, RNA interference, biochemistry and genetics and molecular markers. Genetic engineering has been used to manage plant virus diseases. Molecular markers (RAPD, RFLP, SSR) are being used in several areas relevant to identification of disease resistance genes (Ex: *Fusarium oxysporum* in tomato). The recent biotechnology techniques CRISPR-Cas system has emerging techniques in disease management in food grain, vegetable and horticultural crops. The CRISPR-Cas is used to target the mildew-resistance locus O (*MLO*) in wheat generating the plants resistant to powdery mildew disease moreover make rice resistant to bacterial leaf blight, caused by *Xanthomonas oryzae* pv. *oryzae* by impairing down the transcriptional regulation of S-genes by the effectors. It can be concluded that the plant breeders and plant pathologist have lot of opportunity to develop resistance against many fungal, bacterial, viral and nematode diseases in future by using all the biotechnological tools.

PP 06: Conventional to Modern Biotechnological Pathway- A Potential Technology for the Control of Whitefly Transmitted Viral Diseases

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The worldwide expansion of agriculture has also resulted in the emergence and spread of numerous diseases and insect pests. Of particular importance are insect-transmitted viruses, especially in tropical and subtropical regions of India. The whitefly *Bemisia tabaci* (Genn.) causes direct damage by feeding and is the predominant vector of plant viruses (begomovirus, criniviruses, ipomoviruses, torradoviruses and carlaviruses) that cause disease in different crop worldwide. The past few years have witnessed upsurges in the *B. tabaci* and its transmitted begomoviruses, particularly, in Northern India, where management has been hard-hit owing to emergence of new viral strains as well as development of resistance in this pest to several classes of insecticides. So, recent progress in understanding the molecular mechanisms underlying the roles of resistance genes has promoted the development of new anti-virus strategies. Engineered plants, in particular plants expressing RNA-silencing nucleotides, are becoming increasingly important and are likely to provide more effective strategies in future for whitefly mediate viral diseases.

PP 07: *In vitro* Testing of Compatibility of Promising *Trichoderma* and *Pseudomonas* isolates for the Consortium

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Among various biocontrol agents strains of *Trichoderma* and *Pseudomonas* have been proved promising against many plant pathogens and their formulations are quite popular among the farmers. Therefore the present study was conducted to check the compatibility among promising *Trichoderma* and *Pseudomonas* isolates for the development of consortium to increase the efficacy. Dual culture plate method was used to study the compatibility among four *Trichoderma* isolates viz. Th14, TCMS36, Th19, Th17 and two *Pseudomonas* isolates viz. Psf173 and Psf2. The results indicated that all the combinations of *Trichoderma* isolates i.e. Th17+TCMS36, Th19+TCMS36, Th14+TCMS36, Th17+Th19, Th19+Th14 and Th14+Th17 were found compatible with each other. Among *Trichoderma* and *Pseudomonas* isolates three combinations i.e.

Th19+Psf173, TCMS36+Psf173 and Th14+Psf173 showed compatible reactions while Th17+Psf173 showed incompatibility. However all the combinations of *Trichoderma* and *Pseudomonas* isolates (Psf2) showed incompatible reactions. These compatible strains of *Trichoderma* and *Pseudomonas* could be better exploited in consortium with increased efficacy for the management plant diseases and in improving soil and crop health under sustainable agriculture.

PP 08: Genome Editing Technologies for Enhancing Plant Disease Resistance

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One of the greatest challenges for agricultural science in the 21st century is to improve yield stability through the progressive development of superior cultivars. The increasing numbers of infectious plant diseases that are caused by plant-pathogens make it ever more necessary to develop new strategies for plant disease resistance breeding. Targeted genome engineering allows the introduction of precise modifications directly into a commercial variety, offering a viable alternative to traditional breeding methods. Genome editing is a powerful tool for modifying crucial players in the plant immunity system. New alleles can be introduced by random mutagenesis, although this is usually followed by the time-consuming screening of large populations to identify mutants. Genome-editing technologies (GETs) allow site-specific mutagenesis to be achieved, overcoming the limits imposed by previous methods. Artificial zinc-finger nucleases (ZFNs) and transcription activator-like effector nucleases (TALENs) contain a DNA cleavage domain from the restriction enzyme Fok I fused to an engineered DNA-binding domain. The CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats)/Cas9 is based on RNA-guided engineered nucleases. Such genome-editing technology holds great promise due to its simplicity, efficiency and versatility. Such technologies allow specific mutations to be introduced into effector targets, reducing the pleiotropic effects of complete gene deletion and help to bring about gain-of-function mutations that may promote the use of a quantitative grading of resistance as a valuable approach to protecting crops.

PP 09: Marker Assisted Breeding through DNA Based Markers against Pathogenic Fungi and Bacteria in Wheat and Rice

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Wheat and Rice are the two most important cereal crops for India and world which together covers a vast cropping area and provides the calorific requirement to millions of peoples. Both these crops are infected by a number of pathogenic fungi and bacteria which reproduce sexually to generate an enormous amount of genetic variability by their infective spores and strains on real time basis. DNA markers due to their abundance are ideal to counteract the astronomical menace of pathogens. Also, there is a need not to depend on single marker system but to choose from a variety of DNA marker systems like RFLP, AFLP, RAPD, SSR, ISSR, STS, CAPS etc. whichever works best to counteract the particular disease at a particular moment of time. Bacterial leaf blight, stripe rust, leaf rust, *Fusarium* head blight and powdery mildew are some of the major pathological diseases which are reported to be corrected by introgression of QTLs using SSR, RFLP, STS, CAPS etc. Hence, due to the evolution of pathogen it is needed to find associated DNA markers with pathogens on timely basis.DNA markers also possess a lot of potential of improving and speeding up the conventional plant breeding process by marker assisted selection. Marker assisted selection can help in screening disease resistance lines. Some of the SSR markers like *Xpsp3000*, *CSLV34*, *Xbarc8* and *Xgwm582* in association with genes which are responsible for rust resistant in wheat.QTL mapping studies in different crops have provided DNA marker trait association. This put forward the reason for greater adoption of DNA markers in future. Due to the phenomenon of linkage a marker can be used detect the presence allelic variation in genes associated with traits. Concerns for sustainable agriculture and greater production for feeding the growing population have put a lot of pressure on breeder for release of new varieties with desirable traits. Marker assisted selection can be a panacea in fulfilling this objective since it increase the efficiency and Precision also. Marker assisted selection along with conventional breeding is needed to maximize the probability of success of plant breeding *viz.* durable disease resistance. QTL mapping, marker assisted back crossing, gene pyramiding, early generation selection has been greatly assisted by molecular markers. This saves time and speeds up the process.

PP 10: Role of Plant Growth Promoting Rhizobacteria in Biocontrol of Plant Diseases and Sustainable Agriculture

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Pathogenic microorganisms affecting plant health are a major and chronic threat to sustainable agriculture and ecosystem stability worldwide. To solve this problem the usage of PGPR is best option. Plant Growth Promoting Rhizobacteria (PGPR) is the important group of microorganisms, which play a major role in the biocontrol of plant pathogens. PGPR can profoundly improve seed germination, root development, and water uptake by plants. These rhizobacteria stimulate plant growth directly by producing growth hormones and improving nutrient uptake or indirectly by changing microbial balance in favor of beneficial microorganisms in the rhizosphere and can suppress a broad spectrum of bacterial, fungal, nematode, and even some viral diseases. PGPR have been tested as biocontrol agents for suppression of plant diseases and also as inducers of disease resistance in plant. In particular, strains of *Pseudomonas*, *Stenotrophomonas*, and *Bacillus* have been successfully used in attempts to control plant pathogens and increase plant growth. The use of Plant Growth Promoting Rhizobacteria (PGPR) is a better alternative to solve this problem. They play an important role to increase in soil fertility, plant growth promotion, and suppression of phytopathogens for development of ecofriendly sustainable agriculture.

PP 11: Effect of Seed Bio-Priming on Morpho-Physiological Traits, Disease Management and Seed Quality of Barnyard Millet (*Echinochloa crusgalli*)

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An experiment was conducted during *Kharif*, 2016 at Crop Research B-Block, Plant Pathology Division, College of Forestry, Ranichauri, V. C. S. G. Uttrakhand University of Horticulture and Forestry to evaluate the effect of seed bio-priming on morpho-physiological traits, disease management and seed quality of barnyard millet (var. PRJ-1). The treatments included bio-agents applied through seed bio-priming with bio-agents (*Trichoderma asperellum Th*-14, *T.harzianum Th*-21, *Pseudomonas fluorescens Psf*-171 and *P.fluorescens Psf*-4) alone or in combination with FYM colonized by bio-agents and one standard fungicide was used to compare (*i.e* seed treatment with Carbendazim) for assessment of morpho-physiological traits and disease management in barnyard millet While, in laboratory experiment, treatments included bio-priming of threshed seeds with bio-agents, and seed treatment with fungicide (Carbendazim) for recording seed quality parameters. Maximum number of leaves per plant, stem diameter, number of effective tiller plant^{-1}, plant height, number of fingers ear^{-1}, ear length, ear diameter, 1000 grain weight, biological yield, grain yield plant^{-1} and grain yield was recorded in treatment T_5 (Seed bio-priming with *T. asperellum Th*-14+ FYM colonized by *Th*-14) while, minimum was recorded in T_{10} (control). Similarly T_5 (Seed bio-priming with *T.asperellum Th*-14+FYM colonized by *Th*-14) also showed minimum days to 50 per cent flowering, days to maturity and disease (Sheath blight and brown leaf spot) incidence than other treatments including control. However, maximum first count per cent, germination per cent, root, shoot and seedling length, seedling fresh and dry weight, vigour index-I and II were measured when seeds were treated with T_1 (Seed bio-priming with *T.asperellum Th*-14) as compared to other treatments and control. From the present investigation, It may be concluded that the tested bio-agents applied through seed bio-priming alone or in combination of colonized FYM with bio-agents enhanced the growth parameters, yield and its contributing traits, reduced disease severity as well as improved seed quality parameters in barnyard millet (var. PRJ-1) though the performance of the treatment T_5(Seed bio-priming with *T. asperellum Th*-14+ FYM colonized by *Th*-14) was found better for most of the parameters studied under present environmental materials and conditions.

PP 12: Use of Nanotechnology in the Management of Plant Diseases

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Nanotechnology is one of the most fascinating and rapidly advancing science and possess potential to revolutionize many disciplines of agriculture sciences. There is an increasing demand for safe and health food. Nanotechnology provides new agrochemical agents and new delivery mechanisms to improve crop productivity

and it promises to reduce the use of pesticide. Nanotechnology can boost agricultural production, and its applications include: nanoformulations of agrochemicals for applying pesticides and fertilizers for crop improvement. The application of nanosensors/ nanobiosensors in crop protection for the identification of diseases and residues of agrochemicals, nanodevices for plants genetic manipulation, plant disease diagnostics and postharvest management. Precision farming techniques could be used to further improve crop yields but not damage soil and water, reduce nitrogen loss due to leaching and emissions, as well as enhance nutrients long-term incorporation by soil microorganisms. Nanotechnology uses include nanoparticle-mediated gene or DNA transfer in plants for the development of insect-resistant varieties, food processing and storage, nanofeed additives, and increased product shelf life. Nanotechnology promises to accelerate the development of biomass-to fuels production technologies. Efficiently utilises modern technology for crop management, is called Controlled Environment Agriculture (CEA). CEA technology, as it exists today, provides an excellent platform for the introduction of nanotechnology to agriculture. With many of the monitoring and control systems already in place, nanotechnological devices for CEA that provide ―scouting" capabilities could tremendously improve the grower‗s ability to determine the best time of harvest for the crop, the vitality of the crop, and food security issues, such as microbial or chemical contamination.

PP 13: Studies on Antagonistic Activity of Potential Isolates of *Trichoderma* and *Pseudomonas fluorescens* against *Fusarium oxysporum* f. sp. *ciceri* causing Chickpea Wilt

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Chickpea is an important pulse crop of India inspite of its great importance, average productivity of the crop in India is very low (9.67 q/ha). Among various factors contributing to low average production of chickpea, early and late plant mortality caused by *Fusarium oxysporum* f. sp. *ciceri* is an important constraint. Still there is no effective chemical to manage the disease under field conditions as well as chemicals also causes ecological problems. Biological control has attained greater importance in modern era of agriculture sciences and is becoming a critically needed component of plant disease management particularly in reducing soil borne diseases. In the present investigation some potential *Trichoderma* and *Pseudomonas fluorescens* isolates were found to have strong antagonistic potential against *F. oxysporum* f. sp. *ciceri*. Maximum per cent mycelial parasitization was observed with TCMS-36 (46.2%) followed by Th-75 (44.44%) and TCMS-4 (42.36%), whereas maximum inhibition zone was observed with Psf-28 (0.15 cm). The minimum plant mortality under glasshouse was observed with TCMS-5 (7.9%) followed by Th-69 (8.3%) as compared to carbendazim (7.92%) and control (28.5%).The *Trichoderma* and *Pseudomona s*isolates were found more effective and could be exploited for the management of chickpea plant mortality and in improving soil and crop health under sustainable agriculture after proper testing in field.

PP14: Effect of Culture Filtrates of *Trichoderma* spp. on the Development of White Mould of Pea caused by *Sclerotinia sclerotiorum*

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White mould caused by *Sclerotinia sclerotiorum* is an important disease of pea in India. In view of economic significance of the disease, a study was undertaken to evaluate relative effectiveness of seed treatment and soil application of culture filtrates of *Trichoderma harzianum*, *T. virens*, *T. viride, T. hamatum, T. koningii, T. atroviride, T. Auroviride* and *T. longibrachiatum* to control white mould fungus, *S.sclerotiorum* on pea, *Pisum sativum* cv. Vasundhra. Culture filtrates of *Trichoderma* spp. were applied @ 10 ml/kg seed (seed treatment) or 10 ml/kg soil (soil application). The pea cv. Vasundhara was found highly susceptible to the white mould fungus and developed characteristic symptoms. Irregular water socked spots appeared on the stem, which later spread to branches and leaves. The lesions enlarged followed by soft watery rot of the affected parts. The treatments with *Trichoderma* culture filtrates suppressed the disease severity and improved the plant growth and yield of pea. Application of *T. Harzianum* resulted in the maximum disease control and subsequent increase in the plant growth and yield over control with relatively greater effects of seed treatment. Next in effectiveness was *T. hamatum,* which significantly increased the plant growth and yield. The overall, order of effectiveness of *Trichoderma* spp. in controlling the disease and enhancing the pea yield was: *T.harzianum>T. hamatum>T.viride> T. virens> T. atroviride> T. longibrachiatum>T. koningii> T. auroviride*. The study has demonstrated that seed treatment with culture filtrates of *T. harzianum* and *T. hamatum* effectively controlled the white mould disease (22-25%) and significantly improve pea yield (9–12%).

PP 15: Interaction of *Trichoderma harzianum* and *Alternaria brassicae* on *in vitro* and *in vivo*

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The effect of a phylloplane isolate of *Trichoderma harzianum* was investigated on *Alternaria brassicae.* The dual inoculation test revealed that *T. harzianum* caused 60-70% suppression in the radial growth of *A. brassicae*. The treatment with 100% culture filtrate of *T. harzianum* caused maximum inhibition in the colonization and conidial germination of the pathogenic fungus in the dual inoculation test. Mustard cv. Varuna was grown in field, where the effects were evaluated. The plants (7-8 week) were sprayed with conidia suspension of *A. brassicae* (10^5 conidia/ml, 5ml/plants in two sprays on consecutive days). Thereafter plants were applied two foliar sprays (weekly) with the spore suspension of *T. harzianum* (10^7 spores/ml, 5ml/plant) and culture filtrate. The application of spore suspension reduced the leaf spot severity by 12-17%, whereas, treatment with culture filtrate suppressed by disease by 19-24%. The phylloplane population of *A. brassicae*

was also adversely affected due to the *T. harzianum* treatments. The biocontrol agent was re-isolated from the mustard leaves, although its population was much low.

PP 16: Efficacy of Indigenous Microbial Bio-inoculants for Sustainable Crop Disease Management

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The bio-inoculants are the crop beneficial micro-flora which enhances the plant growth either by supplying nutrients or by reducing the disease causing microbes associated with the plant system. Plant diseases are among the major constraints in the production of food crops and inflict significant losses to global agriculture. Pesticides are widely used to control plant diseases but their application is costly and, in some cases, may bring more environmental disadvantages than benefits. The microbial bio-inoculants to control plant diseases are an economically viable and ecologically sustainable method of disease management. Bio-control by Rhizobacteria could involve PGPR and non-PGPR bacteria in the way that suppress plant diseases which indirectly enhance the plant growth by protecting plants against plant pathogens. Bio-inoculants formulations can be seen as a tool for developing a more rational pesticide use strategy. Important bio-inoculants that directly parasitize plant pathogens include fungal and bacterial bio-inoculants for plant disease management Biological control/IPM practitioners, organic growers, and other parties willing to promote bio-inoculants must understand that the inoculants are most likely to succeed as commercial products, available as practicable, stable, efficacious formulations. In this present paper, dissension have been made to find out suitable method for development of microbial bio-inoculant which can act as potential bio-control agent.

PP 17: Antagonistic Activity of Rhizobium for the Management of Plant Pathogenic Fungi

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Rhizobia are a group of soil micro-organisms that are well known for their ability to colonize root surfaces and form symbiotic associations with legume plants. Rhizobia play a major role in biological nitrogen fixation, phosphate solubilisation and produce plant growth regulators that stimulate and enhance plant growth but also significant disease suppress to growth of many soil-borne plant pathogenic fungi belonging to different genera like *Fusarium*, *Macrophomina, Pythium, Sclerotium* and *Rhizoctonia*in various leguminous crop. Soil borne plant pathogenic fungi can cause enormous losses in yield of legume plants. *Rhizobium* spp. Produce antifungal secondary metabolites for the control of plant disease caused by pathogenic fungi. Antagonistic activity of rhizobia is mainly attributed to production of certain metabolites such as hydrocyanic acid (HCN), siderophore, ACC deaminase, chitinase, β-1,3-glucanase, and antibiotics.

Rhizobia are also inducing systemic resistance and enhance expression of plant defense-related genes, which effectively immunize the plants against pathogens. It can be concluded that inoculation with specific *Rhizobium* spp.exerts significant enhances plant growth and disease management against plant pathogenic fungi in field conditions.

PP 18: Comparative *in vitro* Efficiency of Antimicrobial Peptides against *Xanthomonas* spp.

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Genes encoding for proteins that have antimicrobial activities like low molecular weight anti microbial peptides (AMPs) are active against a wide range of plant pathogenic bacteria. In this study, nine different antimicrobial peptides (AMPs) viz. D4E1, PEP11, ESF1, ESF4, ESF5, ESF6, ESF12, ESF13 and ESF17 were used to check the efficacy against *Xanthomonas* spp. The D4E1 was the most effective AMP against all three bacteria [*X.axonopodis*pv. *punicae* (Xap); *X.axonopodis*pv. *citri* (Xac); *X. axonopodis*pv. *malvacearum* (Xam)] which was succeeded by PEP11, ESF1 and ESF17 while ESF12 was the least effective amongst all. It was revealed that, ESF13 was not effective against all the three bacteria while ESF4 was not effective against Xap and Xam while ESF6 was not effective for Xap. AMPs tested in vitro at a concentration of 500 ppm with micro-dilution broth method through ELISA reader showed that the inhibition of growth of Xap was greater than 90% (MIC90) in D4E1, PEP11, ESF17, ESF5 and ESF12. For xac, % growth inhibition was greater than 90% (MIC90) in D4E1, PEP11, ESF17, ESF5 ESF6, ESF1 and ESF12 while for Xam, the growth inhibition was greater than 90% (MIC90) in D4E1, PEP11, ESF17, ESF1 and ESF12. Percent growth inhibition recorded or observed in D4E1, PEP11, ESF17 and ESF12 were comparable to that of Streptocycline. It was revealed that the peptides can be used effectively for further crop improvement and for further studies substituting the chemicals for all the three bacteria are D4E1, PEP11, ESF1, ESF17, ESF5, ESF12.

PP 19: Plant Growth Promotion and Disease Suppression Potential of *Pseudomonas fluorescens* against Early Blight and Wilt of Tomato in Central Himalayas

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Plant growth-promoting rhizobacteria play a vital role in the suppression of plant diseases. *Pseudomonads* are well known to show the growth promotion activity in plants and simultaneously activating the disease incidence delay. Effect on growth attributes and disease incidence with the interaction of different strains *of Pseudomonas fluorescens* were studied in tomato under protected environmental conditions. The strains were isolated from different soil samples collected from various geographical regions of central Himalayas. Promising strains of *Pseudomonas* were applied as seed bio priming (SB), SB+ Root Dip (RD), SB+RD+ Drenching (DR) and SB+RD+DR+ Spraying (SPR) individually and in combination with different strains and evaluated for their effect on growth promotion and management of early blight caused by *Alternaria solani* and wilt caused by *Fusarium oxysporum f. sp. lycopersici*, an important disease of tomato in central Himalaya. In seedling stage, the combination of different strains had additive effect in enhancing the growth parameters seedling length, shoot and root fresh and dry weight with no disease during seedling stage. The minimum disease incidence and maximum number of fruits per plant were recorded in treatment SB+RD+DR+SPR where disease is highly controlled even after 60 days of transplanting.

PP 20: Application of *Trichoderma* in Organic Farming

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*Trichoderm*a biocontrol agent, is a kind of fungi belonging to the genus *Trichoderma* and class ascomycetes. Having antifungal activities and hence used as bio fungicides as well as in bioremediation. It can compete with the fungal as well as bacterial pathogens through various mechanisms like competition, enzyme secretion, mycoparasitism, antibiosis etc. and hence plays a significant role in the environment. Its natural occurrence is in soil, agricultural land or woody substrate. It produces chitinase enzyme which disintegrate the cell wall of the fungal pathogen. It rapidly colonises at the rhizospheric region and hence protects the roots from fungal pathogens i.e. it helps in root development also. It is also a good growth promoter. Some transgenic plants have also been developed by the introduction of endochitinase gene from *Trichoderma* into plants such as tobacco, potato etc. due to which plants show increased resistant to fungal growth. *Trichoderma* strains are also good bioremidiants which has ability to degrade the wide range of pesticides in the soil. These bioagents are economical in many cases like they are relatively safer than the organic pesticides, no harmful effect on human, wild life and other beneficial organism. They does not cause resistant to pathogens, also they are good for non-target organisms. It has long-term effect in the soil i.e. one time application of *Trichoderma* in soil remains forever. They can survive in the soil even in the worse condition by forming chlamydospores. As the farming of today is mostly based on modern technologies, they have serious repercussions. Chemical based agriculture has diverted the environment mostly to unhealthy condition. Most of the diseases to human being, wildlife and also environmental hazards like pollution, increased residues of pesticides, tolerance of insects to insecticides etc. are the cause of chemical pesticide in the soil. Hence, the application of *Trichoderma* having several economic effects in the soil is the alternative of chemical fertilizers.

PP 21: Role of Plant Growth Promoting Rhizobacteria (PGPR) in Plant Disease Management

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Plant growth promoting rhizobacteria (PGPR) are naturally occurring soil bacteria that aggressively colonize plant roots and benefit plants by providing growth promotion. They are known to enhance plant growth by direct and indirect means. Direct mechanisms of plant growth promotion by PGPR can be demonstrated in the absence of plant pathogens or other rhizosphere microorganisms, while indirect mechanisms involve the ability of PGPRs to reduce the deleterious effects of plant pathogens on crop yield. PGPRs have been reported to directly enhance plant growth by a variety of mechanisms, such as fixation of atmospheric nitrogen that is transferred to the plants, production of siderophores that chelate iron and make it available to the plant roots, solubilization of minerals such as phosphorous and synthesis of phytohormones. The indirect means by which PGPRs enhance plant growth is through suppression of phytopathogens by a variety of mechanisms. These include the ability to produce siderophores that chelate iron, making it unavailable to pathogens, the ability to synthesize anti-fungal metabolites such as antibiotics, fungal cell wall lysing enzymes or hydrogen cyanide, which suppress the growth of fungal pathogens. The ability to successfully compete with pathogens for nutrients or to exclude specific niches on the root and the ability to induce systemic resistance in plants are the other mechanisms. *P. fluorescens* strains exhibited substantial antagonistic activities against the fungal isolates on three culture media tested: King‘s B (KB), potato dextrose agar (PDA) and a mixture of both (KB + PDA). As compared to the untreated control, the mycelial growth decreased and in bioassay, *P. fluorescens* strains significantly reduced the disease incidence and severity by in tomato plants. The different efficacy of the biocontrol agents could be due to the influence of several factors, including the efficiency of the strain, the type of pathogen and the host.

PP 22: Application of Nanotechnology in Plant Pathology

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Crop cultivators continually battle with fungal diseases affecting them. Plant pathogenic fungi must be controlled if consumer demand for premium quality and diverse foods is to be met; while high quality cereals, fruits and vegetables are an indicator of economic growth in developing countries. Due to the extensive use of fungicides and pesticides there is rapid increase in ecotoxicity and development of resistance in plant pathogenic microbes. Nanotechnology has emerged as a tool to explore the darkest a venue of Science and technology. It provides opportunities in areas of medicine and healthcare, biotechnology, materials and manufacturing, energy, information technology in conjunction with the national security. Recently, work has begun to explore application of nanotechnology in plant disease management. Different types of nano materials like copper, zinc, titanium, magnesium, gold, alginate and silver have been developed, but silver nano particles (Nano-Ag) have proved to be most effective as they exhibit potent antimicrobial efficacy against bacteria, viruses and eukaryotic microorganisms. Surega (2015) studied the effect of plant mediated silver nano particles and showed various level of inhibition on mycelial growth of *Fusarium oxysporum* f.sp. *lycopersici*. The plant mediated silver nano particles caused *F. oxysporum* f.sp. *lycopersici* mycelial deformity with crinkled hyphal surface. Similar result were also found by Krishnaraj, *et al.* (2012), Gopinath and Velusamy (2013) and Yehia and Ahmed (2013) who reported that the green synthesized silver nano particles possessing strong antifungal activity against the various phytopathogenic fungi like *F. oxysporum* and *Penicilium expansum* etc.

PP 23: Role of Nano-Technology in Plant Disease Management

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Conversion of macro materials into nano sized particles (1-100nm) exhibits novel characteristics and behavioural patterns which are entirely different from the original. These particles can be produced by different methods namely biological and chemical. Nano particles generally commercially produced by chemical methods can be used against plant pathogens hence play a great role in plant disease management ensuring food safety, bio security and sustainable development. They can also be used against small sized virus particles because of their ultra-small size. Nano particles can be used as diagnostic probe and biomarkers or rapid diagnostic tool for detection of plant diseases and their causal organisms. Nano forms of silver, silica, carbon, iron, copper are used in nanotechnology. The nano particles are known to have antimicrobial and stress resistance properties involved in enzyme deactivation and growth enhancing effect. Nano formulations of the existing pesticides or fungicides can be used by reducing the size of the active ingredients to nanoscale. This is done by nano encapsulation. Plant disease detection and identification at nano scale is more precise and accurate and is time saving than traditional methods. Nanotechnology is a safe and eco-friendly way of plant disease management. But the irrational use of it may lead to release of toxic substances to the nature.

PP 24: Targeted Genome Editing Techniques to Develop Disease Resistance in Plants

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The field of genome editing is experiencing rapid growth as the new technologies continue to emerge. With previous technologies, the integration of genes in the genome is completely random, which can results in inactivation of an endogenous gene or even silencing of transgene. A technology that allows introducing gene at a precisely identified chromosomal locus and manipulating the array by genome editing was needed. Zinc-finger nucleases (ZFNs), transcription activator-like effector nucleases (TALENs) and Clustered regularly interspaced short palindromic repeat (CRISPR)/CRISPR associated protein 9 system, (CRISPR/Cas9) offer potential for efficient targeted plant genome engineering. These techniques creates *in vivo* double-stranded breaks at target loci that stimulate the cellular DNA repair mechanisms followed by non-homologous end joining (NHEJ) and homologous recombination, resulting in targeted gene insertion or gene replacement. In plants, the use of these sequence-specific nucleases for targeted genome modifications has many applications, ranging from dissecting gene function to creating plants with new traits such as disease resistance. These are much easier to produce, more efficient and is suitable for high-performance and multiplex genome editing in a variety of cell lines and in living organisms. The development of the TALEN and CRISPR/Cas9 systems is an important step in the progress achieved in modern genomic engineering.

PP 25: Molecular and Biotechnological Approaches in Plant Disease Management

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Despite substantial advances in plant disease management strategies, our global food supply is still threatened by a multitude of pathogens. The traditional method of identifying plant pathogens is through visual examination. This is often possible only after major damage has already been done to the crop, so treatments will be of limited or no use. This changed situation warrants us to react all the more proficiently and successfully to this issue. Biotechnological techniques can be used to determine the type and sources of host resistance. The advancement of recombinant DNA technology makes it possible to isolate individual genes and incorporate resistance genes into otherwise agronomically acceptable cultivars. Genes pyramiding and candidate gene approach was made easier with molecular markers. ELISA and polymerase chain reaction (PCR) techniques are used in the identification of viral and bacterial disease and also new formats using antibody based detection for very rapid presumptive on-site diagnosis have become available. RNA interference has been emerged as a method of choice for gene targeting in fungi, viruses, bacteria and plants as it allows the study of the function of hundreds of thousands of genes to be tested. Advances in molecular biology have opened up possibilities of identifying and isolating any gene for an organism, and mobilizing and expressing it in a different organism of one‘s choice.

PP 26: Plant Growth Promoting Rhizobacteria for the Management of Nematode Disease in Plants

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Plant-parasitic nematodes are considered worst enemies of mankind because of devastation they cause to crops. There is hardly any crop which is not affected by nematodes. The management of nematode diseases in the sustainable agriculture has become a challenge for plant nematologist. An alternative to chemicals that fulfil all requirements and brings sustainability of agricultural crops is the range of rhizospheric microorganisms which attack the plant-parasitic nematodes. Microorganisms that can grow in the rhizosphere provide the front-line defence for roots against pathogen (nematode) attack and are ideal for use as biocontrol agents. Plant growth promoting rhizobacteria (PGPR) are the important group of microorganisms, which play a major role in the biocontrol of plant parasitic nematodes. A large number of rhizobacteria are known to reduce nematode populations and important genera include *Agrobacterium, Alcaligenes, Bacillus, Clostridium, Desulfovibrio, Pseudomonas, Serratia* and *Streptomyces*. As a group of important natural enemies of nematode disease, microorganisms exhibit diverse modes of action: these include parasitizing; producing toxins, antibiotics, or enzymes; competing for nutrients; inducing systemic resistance of plants; and promoting plant health. They act synergistically on plants through the direct suppression of nematodes, promoting plant growth and facilitating the rhizospheric colonization and activity of microbial antagonists.

PP 27: Gene Technology for Papaya Ring spot Virus Disease Management

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Papaya (*Carica papaya*) is severely damaged by the Papaya Ring Spot Virus (PRSV). This study focuses on the development of PRSV resistant transgenic papaya through gene technology. The genetic diversity of PRSV depends upon geographical distribution and the influence of PRSV disease management on a sequence of PRSV isolates. The concept of pathogen-derived resistance has been employed for the development of transgenic papaya, using a coat protein-mediated, RNA-silencing mechanism and replicas gene-mediated transformation for effective PRSV disease management. The development of PRSV-resistant papaya via post-transcriptional gene silencing is a promising technology for PRSV disease management. PRSV-resistant transgenic papaya is environmentally safe and has no harmful effects on human health. Recent studies have revealed that the success of adoption of transgenic papaya depends upon the application, it being a commercially viable product, bio-safety regulatory issues, trade regulations, and the wider social acceptance of the technology. This present study discusses the genome and the genetic diversity of PRSV, host range determinants, molecular diagnosis, disease management strategies, the development of transgenic papaya, environmental issues, issues in the adoption of transgenic papaya, and future directions for research.

PP 28: Effect of Composite Culture of *Azotobacter* and Phosphate Solubilizing Bacteria on *in vitro* Propagated Banana

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A green-house study was conducted during 2016-2017 to assess the effect of composite culture of *Azotobacter* and Phosphate solubilizing bacteria on growth performance of *in vitro* propagated Banana cv. Grand Naine in Raipur. The primary hardening carried out in micropots in cocopeat media and secondary

hardening in polythene bags in media mixtures of soil, sand and vermicompost in 3:1:1 comprising of 5 treatments replicated four times. The treatments wereT_1 Control, T_2 100 % RDF, $T_3$50 % Organic manure + 50% inorganic, T_4Inoculation of composite culture + 75% NPK (inorganic), T_5Inoculation of composite culture + 25%NPK (organic) + 75% NPK (inorganic). This study indicates that growth attributing characters *viz.* plantlet height, plantlet girth, no. of leaves per plantlet, root length and shoot N uptake were significantly influenced by inoculation along with organic manure. Maximum survival (100.00 %) was with composite culture inoculation whereas in other treatments survival percentage ranged from 87.5-93.5%.T5 recorded best results in terms of plantlet height (20.45 cm), plantlet diameter (11.60cm) no. of leaves (5.25), length of primary roots per plantlet (12.32 cm) followed by T4. Nitrogen uptake by banana significantly increased from 9.17 at control to 28.21 mg per plantlet at T5.Using composite culture along with organic manure in *in vitro* mass propagation method may be adopted to produce healthy planting materials of banana for commercialization.

PP 29: Effect of Growing Season, PGRs and Rooting Media on Survival Percentage, Rooting and Vegetative Growth Characters of Hard Wood Stem Cuttings of Lemon (*Citrus limon* Burm.) cv. Pant Lemon

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The present investigation was carried out at Horticulture Research Centre, Patharchatta, G. B. Pant University of Agriculture and Technology, Pantnagar during September 2013 to April 2014. The experiment consisted of fifty six treatment combinations, which comprised of seasons viz; rainy and spring season, PGR concentrations viz. IBA 500 ppm, NAA 500 ppm, IBA 500 ppm+IBA 500 ppm and control and seven growing media viz; Soil, Soil+FYM, Soil+Vermi compost, Soil+Cocopeat, Soil+Sand+FYM, Soil+Sand+Vermi compost and Soil+Sand+Cocopeat. The experiment replicated thrice with 10 cuttings in each treatment and treated cuttings were planted in 300 CC capacity root trainers under shade net. The results indicated that among the various treatments, rainy season planted cuttings showed better results for most of root and growth parameters studied including higher survival percentage (77.37 %). Similarly, higher shoot and root growth characters were recorded with IBA 500 ppm in comparison to other treatments. Among seven growing media, Soil+Sand+FYM improved survival percentage (82.33%), average dry weight of cutting (8.05 g) and reduced the thickness of roots (1.08 mm) while higher rooting percentage (64.26%), number of primary (9.03) and secondary roots (16.67), average length of longest root (7.81 cm), length of sprout (7.10 cm) and average fresh weight of cutting (12.24 g) were recorded with Soil+Sand+Cocopeat.

PP 30: Evaluation of Potential Biocontrol agents for the Management of Sheath Blight of Rice

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Rice is a staple food for majority of the world population. Globally, Asia is the hub of 90 percent of world aggregate rice production with India responsible for 21 percent. Sheath blight caused by *Rhizoctonia solani* is the most important and devastating disease in rice. This disease causes 10-30 percent yield loss worldwide and may reach up to 50 percent during prevalent years. Keeping in view of public health, environmental safety and the ill effects of chemical pesticides, other sustainable disease control strategies such as biological control by antagonistic microorganisms is gaining momentum. The present investigation was undertaken to study an effective management strategies for sheath blight by using potential biological control agents. In present investigation eight potential biocontrol agents were evaluated for the management of sheath blight. Four isolates of *Trichoderma* (TCMS 9, 36, 43, 14), two isolates of *Pseudomonas fluorescens* (Psf 173, 2), one isolate of *Bacillus* spp. (N18) and one consortia of *Trichoderma* and *Pseudomonas* named PBAT 3 (Th 14 + Psf 173) were used. One fungicide carbendazim was used as standard chemical check and untreated was used as control. The plan of work involved isolation, identification (Pathogenicity test) and morphological characterization of the pathogen; field experiment for the management of sheath blight by using these potential isolates in 10 different treatments (3 replications) in RBD with different mode of applications like; soil treatment, seed biopriming, root dip treatment followed by three sprays of biocontrol agents. Disease assessment was done on the basis of disease incidence and disease severity. Effect on crop health improvement was recorded through plant growth parameters and yield attribute. All biocontrol agents when applied as seed + soil + foliar spray found effective in reducing disease. Minimum sheath blight disease incidence and severity were recorded with carbendazim (8.70% and 9.98%), PBAT3 (10% and 12.59%), followed by *Bacillus* N 18 (11.20% and 14.73%). But maximum yield was observed in PBAT3 (56.33 q/ha) followed by *Bacillus* N 18 (54.66 q/ha).

PP 31: Antagonistic Assessment of Biocontrol agents by Producing the Volatile and Non Volatile Compound against Phytophthora Blight in Pigeon Pea

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Pigeon pea is an important pulse crop of the world which is an important source of protein and other nutrients. Phytophthora leaf blight is a major disease of pigeon pea which is caused by *Phytophthora drechsleri* f.sp. *cajani. In vitro* evaluation of different isolates of *Trichoderma* and a strain of *Pseudomonas fluorescens* against *P. drechsleri* f.sp. *cajani* was carried out to test the efficiency of these antagonists as biocontrol agents against the test pathogen. Ten isolates of *Trichoderma* sp. were tested against the blight pathogen under dual

culture experiments. Volatile and non-volatile metabolites released from the antagonists were also tested against the pathogen. Percent inhibition in the mycelial growth of the pathogen was determined. All Trichoderma isolates showed significant inhibitory effect on the pathogen in all the experiments. Under dual culture tests maximum and minimum percentage of inhibition was showed by AN-33 (81.7%) and AN-37 (63.4%) respectively. Under volatile experiments AN-48 (62.6%) and AN-6 (46.9%) showed maximum and minimum percent inhibition respectively. Under non-volatile experiments, the highest inhibition of pathogen was observed at 15% concentration of the culture filtrates of the bio agents. At this concentration AN-33 exhibited the maximum (72%) and AN-6 showed the minimum (43.5%) inhibition to the pathogen growth. *Pseudomonas fluorescens* showed significant inhibition in the mycelial growth of the pathogen under dual culture test with percentage inhibition of 43%. The study suggests that the *Trichoderma* spp. has a potential to be used as biocontrol agents against Phtophthora Blight of pigeon pea. Trichoderma isolate AN-33 was identified as the most effective isolate out of the ten isolates studied.

PP 32: Improvement of Commercial *Trichoderma* Strains through Mutation for Integrated Disease Management

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Species of the fungal genus *Trichoderma* have broad environmental opportunism, evolving from a mycoparasitic lifestyle to avirulent plant symbionts. Some *Trichoderma* strains are used as biological control agents for plant disease management and also as growth promoting agents. Thus, it has the potential as a preferred input in Integrated Disease Management (IDM) systems. For improving the antagonistic and growth promoting potential of biocontrol agents such as *Trichoderma*, induction of mutation has been successfully used in recent years. Being the safest and most reliable alternative to pesticide abuse in agriculture, the generation of efficient mutants of leading biocontrol agents becomes prime need of the hour. Keeping gravity of the issue in view, present study was designed to induce mutation in two commercially available biocontrol agents *viz*. PBAT-1 (*T. harzianum*, Pantnagar strain) and Th-3 (*T. harzianum*, IARI, New Delhi strain). The emphasis was laid on obtaining mutants with enhanced growth factors in comparison to parent strains. Attempts have been made to induce mutation using a chemical mutagen (ethyl methane sulphonate, EMS) and a physical mutagen (UV radiations). Two ways were employed for treating the samples with the mutagens. First way was exposure to chemical mutagen followed by physical mutagen, while the second way was vice-versa. Aliquots of conidial suspension of the two commercial strains were treated with 40 $\mu l\ ml^{-1}$ of 0.2 M EMS while exposure to UV radiations was given from a distance of 20 cm for 20 and 40 minutes. Resultant mutants of PBAT-1 were obtained with faster growth rate, profuse conidiation and extended longevity of conidia as compared to the parental strain. In case of Th-3, mutants were obtained with faster growth rate and enhanced pigmentation. It is also possible that induction of mutation might lead to generation of strains differing from parent on other aspects too like compatibility with fungicides, production of secondary metabolites and phytohormones, etc. With precision and integrated approach, this method might work wonders in the field of biological control.

PP 33: Effect of Nutrient Sources on the Biomass Production of *Trichoderma harzianum* Th14

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The genus *Trichoderma* comprises a great number of fungal strains that act as biological control agents, the antagonistic properties of which are based on the activation of multiple mechanisms. *Trichoderma* strains exert biocontrol against fungal phytopathogens either indirectly, by competing for nutrients and space, modifying the environmental conditions, or promoting plant growth and plant defensive mechanisms and antibiosis, or directly, by mechanisms such as mycoparasitism. The commercial success of this fungal antagonist totally depends on effective formulations attributed to higher cfu at the time of application. Due to less cfu in formulations even a very potential *Trichoderma* strain may fail in providing satisfactory results in field. The knowledge of nutritional requirements is the main need in the cultivation of microorganisms using any cultural technique. Bulk production of conidia typically relies on manipulation of nutrients to promote conidiation, of many species of *Trichoderma*. An investigation was undertaken to evaluate the effectiveness of different carbon sources viz., jaggery, honey, sugar, dextrose, peptone; nitrogen sources viz., ammonium sulphate, sodium nitrate, potassium nitrate, urea, ammonium nitrate, calcium nitrate; vitamins sources viz., vitamin c, bicosule, cobadex and amino acids sources viz., glutamic acid, asparagine and leucine on biomass of *Trichoderma harzianum* (Th14). Among the tested different nutrient sources, significantly maximum biomass (mg/ 100ml) was observed in honey (1190mg), ammonium sulphate (1035mg), bicosule (922mg) and asparagine (945mg) in carbon, nitrogen, vitamins and amino acids sources respectively on *Trichoderma harzianum* (Th14). The present result would be helpful in enhancing the conidia and biomass production of local strain and great importance when considering the production of *T. harzianum* for use as a biocontrol agent.

PP 34: Study of Cold Plasma Treatment in Wheat for Sustainable Agriculture

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Wheat (*Triticum aestivum L.*) is the world‘s most widely cultivated food crop. Food grains demand of India will be around 300 million tons per year by 2020and balance mineral nutrition is one of the key factor to achieve this goal. Therefore, Plasma technology is an emerging way to improve nutrient use efficiency and crop productivity in an eco-friendly and cost effective manner. Plasma is a discharge of gas molecules consisting of energetic ions, electrons and neutral species. The plasma treatments provided good fungicidal and bactericidal effects, increased water permeability through surface coat etching and stimulation of germination and seedlings growth. Such morphological changes on seed surfaces are safe and unlikely to have any genetic impact. Plasma treatment of wheat seeds is a new approach that is being proposed to assist germination and survival. A study has been conducted to manage disease, improve germination and growth under biotic and abiotic stresses by cold plasma treatment. Among the four different duration (4, 6, 8, 15minute) respectively, 6minute plasma treatment was found significant and highly effective in inhibiting most of seed borne diseases by sterilization of seed at molecular level and gives almost four times faster growth in 50% water deficit as well as in saturated condition of water over control in laboratory conditions. While least inhibition of diseases and comparatively less growth was found in control.

Session 03:

Disease Management in Medicinal and Horticultural Crops and Post Harvest Diseases

LP 01: Ecofriendly Strategies for Vegetable Disease Management in North Western Himalaya

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India is the second largest producer of vegetables after China. In mid hills, vegetables are generally grown in such a period which is off-season for plains and these are transported to plains where they fetch remunerative prices. During cultivation vegetables are infected with several diseases of fungal, bacterial and viral nature which not only reduce the quantity but also quality of the produce. Chemical fungicides have been used successfully to combat the ravages of these diseases for many years. However, side effects such as ground water pollution, residues on food crops, effect on non-target organisms and the development of resistance to chemicals have drawn attention towards ecofriendly strategies including genetic, cultural and biological control along with minimum use of environment friendly fungicides and resistance inducer chemicals. The cultural practices like sanitation, crop rotation, mulching, soil solarization and soil amendment help in establishing an environment that favours the crop over the pathogen. Reducing plant stress through modification of soil environment promotes good plant health and aides in reducing damage from plant diseases. Cultural practices reduce the initial inoculum of the pathogen (s) in the field besides improving the efficacy of the fungicides applied thus reducing the number of fungicide application. In biological control, bioagents not only reduce the diseases through antagonistic activity but also have plant growth promoting activities like phosphate solublization and siderophore production. Compatibility of antagonists with fungicides further enhances their capability in reducing the disease incidence.

Removal of stalk rot (*Sclerotinia sclerotiorum*) infected leaves at weekly intervals reduces the disease incidence by 50 per cent. Crop rotation i.e. cauliflower –paddy-cauliflower enhances the seed yield of cauliflower by 161 per cent. Pine needle mulch alone and spray applications of copper oxychloride (0.3%) on mulch and foliage was most efficacious in managing buckeye rot of tomato but pine needle mulch impregnated with floor application of copper oxychloride was also quite effective without having residue deposits on fruits with slightly less benefit cost ratio (12.9) compared to foliage application of copper oxychloride (16.7).

In case of Fusarium wilt of pea, soil microflora was isolated for identification of the antagonists. Actinomycete *Streptomyces* sp. (64.17%) and *S. californicus* (59.53%) and fungus *Trichoderma harzianum* (52.53%) showed antagonistic activity under *in vitro* conditions against *Fusarium oxysporum* f.sp. *pisi*. Both actinomycetes were further studied for their plant growth promoting activity (PGPR) and *Streptomyces* sp. was found siderophore producing while *S. californicus* was phosphate solublizing. Besides this *Streptomyces* sp. was also compatible with carbendazim upto 4000 ppm. Under pot culture conditions, seed treatment of pea with carbendazim (0.25) and Streptomyces sp. (0.4%) was found highly effective in reducing the disease incidence to 4 per cent and increasing the nodulation up to 39 per cent as compared to 79 per cent and 14 per cent in control, respectively. When this combination along with soil solarization was evaluated under field conditions, provided maximum disease control and increased the green pod yield. Cold water extracts of *Allium sativum* was found highly effective in the management of pea powdery mildew. For the management of Phytophthora leaf blight and fruit rot of capsicum through induced resistance, two foliar sprays of Acibenzolar-S-methyl (10µM) was most effective in managing the disease followed by DL-β-amino-n- butyric acid (BABA) (1 mM). Similarly, β-aminobutyric acid (2 mM) was found most effective in managing the buckeye fruit rot of tomato with 85.66 per cent disease reduction over control.

IL 01: Potential Use of Microbes for Root-Knot Nematode Management in Medicinal and Aromatic Plants and Improve Production of Plant Secondary Metabolites

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The past few years have witnessed a steep rise in the cultivation and production of medicinal and aromatic crops (MAPs) in restricted area for higher net returns and greater demand. But at the same time the havoc caused by root-knot nematode (Meloidogyne spp.) has increased tremendously in arable soil and this may be due to the continuous cultivation of root-knot nematode susceptible crops. The major MAPs which suffer root-knot nematode infestation are: Menthol mint (*Mentha arvensis*), Davana (*Artemisia pallens*), Geranium (*Pelargonium graveolens*), Patchouli (*Pogostemon patchouli* syn *P. cablin*) Henbanes (*Hyoscyamus* spp.), Basil (*Ocimum* spp.), Opium poppy *(Papaver somniferum*), Ashwagandha (*Withania somnifera*.), Serpagandha (*Rauvolfia serpentina*) Coleus (*Coleus forskohlii*) , Qinghao, (*Artemisia annua*.) Brahmi (*Bacopa monnieri*.) and musli (*Chlorophytum borivillianum*). Scope of chemical pesticide to combat with root-knot nematode showed decreasing trend because of its adverse impact on human and environmental health. Consequently, it has become inevitable to manage these pests through non-chemical methods. The assault on the environment through the use of chemical pesticides as well as unreliable results from cultural methods of nematode management has necessitated the search for sustainable, effective and environmentally acceptable phytonematode management options. Rhizosphere is the site of intensive interaction between plant and diverse rhizospheric microbes possesses immense potential to manage soil and plant health. But this all depends on the density and diversity of microbes. Useful microbes like PGPR, mutualistic fungi, and other nematode antagonists disfavor the multiplication and development of root-knot nematode population in soil, enhancing the growth/yield as well as plant secondary metabolites production in MAPs. As my group deals with rhizospheric and endophytic microbes, most suitable for growth promotion and biocontrol potentials, we started to develop a better understanding of the complex ecologies of soils and agricultural ecosystems, with enhanced strategies for exploitation of various microbes for the management of root-knot nematode and also sustainable production of plant secondary metabolites.

OP 01: Screening of Cucumber Genotypes against Powdery Mildew under Natural Epiphytotic Conditions

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Cucumber (*Cucumis sativus* L.) is one of the oldest cultivated vegetable crops belongs to the family cucurbitaceous with 7 pairs of chromosomes and several distinct morphological features stands apart from other species with 12 pairs of chromosomes which are indigenous to tropical Africa. Now a day's powdery mildew has become a major disease in cucumber, since there is no detailed quantitative information on effective management of the disease resistance genotypes plays an important role to combat against pathogen. This can be used as one of the strategy for the management of the disease. Twenty three genotypes were screened against *E. cichoracearum* under natural epiphytotic conditions in the field to identify the resistance source during late *kharif* 2016 none were found to be immune or and resistant. However, fifteen genotypes *Viz.,* Swathi, BSS-949, JK-special, Mahy Sylvia, Malini, Shirakawa, Yummy, Kareena, Green long,Ajeeth-99, White long, Encounter-962, Shalini, Ranebennur local and Sarpan hybrid were found to be moderately resistant with five grade and five genotypes *Viz.,* Chetak, Gullakai, Khushi, Sribasava and Harini were found to be moderately susceptible with seven grade and Mangalore local, Dharwad green and chitra showed highly susceptible reaction with maximum reaction of nine grade.

OP 02: Substrates Dynamics for Integrated Nutrient Management in Guava

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The experiment was conducted at Horticultural Research Centre (HRC), Patharchatta, Department of Horticulture, G B Pant University of Agriculture and Technology, Pantnagar, Uttarakhand during the year 2006-07 to 2010-11. The experiment was consisted of 11 treatment combinations *viz*., 500g: 200g: 500g NPK/tree (Control) (T_1), T_1 + Zn (0.5%) + B (0.2%) + Mn (1%) as foliar spray twice (August and October) (T_2), T_1 + Organic mulching 10 cm thick (T_3), T_2 + Organic mulching10 cm thick (T_4), ½ T_1 + 50 kg FYM + *Trichoderma* (250g) (T_5), ½ recommended fertilizers + 50 kg FYM + 250g *Azospirillum* (T_6), ½ recommended fertilizers + *Azotobacter* (250g) + 50 kg FYM (T_7), ½ recommended fertilizers + 25 kg FYM + 5 kg Vermicompost (T_8), ½ recommended fertilizers + 50kg FYM + 250g *P.fluorescens* (T_9), ½ recommended fertilizers + 50kg FYM + *Trichoderma* (250g) + *Pseudomonas* (250g) (T_{10}) and ½ recommended fertilizers + 50kg FYM enriched with *Aspergillus niger*(T_{11}). Results revealed that vegetative and quality parameters were influenced by different IPNM substrates. Treatment T_6 (½ dose of recommended fertilizers + 50 kg FYM + 250g *Azospirillium*) gave maximum tree height (4.71 m), trunk girth (40.40 cm) and tree canopy (7.07 m) among vegetative growth. In case of quality characters there were significantly higher yield (51.41 kg/tree), average fruit weight (122.89 g), TSS (10.27° B) and B:C (1.66) observed in case of treatment (T_6)(½ dose of recommended fertilizers + 50 kg FYM + 250g *Azospirillium*). Fruits were also healthy in respect any fungal disease.

OP 03: Major Diseases of Apple and their Management in Arunachal Pradesh, India

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The present investigation was carried out to evaluate the bio-efficacy of new fungicides against Scab; Powdery mildew & Pre mature leaf fall diseases of apple manifested recently in all apple growing states of India. These diseases are favoured by high rainfall and moderate temperature ranging from 20-22^{0}C during the different fruit development stages of apple. The efficacy and phyto-toxicity of fungicides was evaluated during 2015-16 cropping season against all the three diseases. The fungicide, Azoxystrobin 11% + Tebuconazole 18.3% SC @ 1.5 ml/l recorded minimum (2.65%) disease intensity and it was at par with Azoxystrobin 11% + Tebuconazole 18.3% SC @ 1.0 ml/l (2.78%) while, Tebuconazole 25.9% EC @ 1.5 ml/l (4.11%), Azoxystrobin 23% SC @ 1.0 ml/l (4.21%),Hexaconazole 5% EC @ 0.5 ml/l (4.56%) and Azoxystrobin 11% + Tebuconazole 18.3% SC @ 0.5 ml/l (4.95%), untreated control recorded highest disease intensity (18.22%) against scab of apple during both the years. Percent disease reduction was recorded maximum in Azoxystrobin 11% + Tebuconazole 18.3% SC @ 1.5 ml/l (90.09%) followed by Azoxystrobin 11% + Tebuconazole 18.3% SC @ 1.0 ml/l (89.73%) which was recorded the best fungicidal treatment for apple powdery mildew control. Rest of the standard treatment fungicides i.e.Tebuconazole 25.9% EC @ 1.5 ml/l, Azoxystrobin 23% SC @ 1.0 ml/l, Hexaconazole 5% EC @ 0.5 ml/l and Sulphur 80% WP @ 4.0 g/l also gave good control of the diseases but its performance was not comparable with the test fungicide. In, pre mature leaf fall of apple disease, the Azoxystrobin 11% + Tebuconazole 18.3% SC @ 1.5 ml/l recorded minimum (3.38%) disease intensity and it was at par with Azoxystrobin 11% + Tebuconazole 18.3% SC @ 1.0 ml/l (3.46%) while Hexaconazole 5% EC @ 0.5 ml/l, Azoxystrobin 23% SC @ 1.0 ml/l, Azoxystrobin 11% + Tebuconazole 18.3% SC @ 0.5 ml/l and Tebuconazole 25.9% EC @ 1.5 ml/l recorded 4.11, 4.22, 4.23 and 4.55 per cent disease intensity, respectively. Untreated control recorded highest disease intensity (24.94 %). Azoxystrobin 11% + Tebuconazole 18.3% SC @ 1.0-1.5 ml/l was found most efficient and at par in respect to control of scab, powdery mildew and premature leaf fall diseases. Keeping in view the economic benefit, Azoxystrobin 11% + Tebuconazole 18.3% SC @ 1.0 ml/l can be used in apple crop as it expressed the maximum cost benefit ratio. The fungicide was found to be safe to crop as no phytotoxicity symptom was recorded in recommended treatments during both the year of experimental trials in all the respect.

OP 04: Collection and *in vitro* Optimization of Growth Factor of *Ganoderma lucidum*

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Ganoderma lucidum is one of the most popular medicinal mushrooms, cultivated in India but its optimum growth factors are still not established. Mycelial growth of *Ganoderma lucidum* isolates were observed on different media at various temperature (15- 35°C) and pH levels (4- 8). Results indicate that all the five isolates of *G. lucidum* grew well on malt extract agar (MEA) media followed by potato dextrose agar

(PDA) media and isolate GA (*Ganoderma* - Almora) with mycelial growth of 5.37 cm was found to be superior to isolate GP (*Ganoderma* -Pantnagar) on 8th day observation. Mean diametric growth for MEA was maximum (4.60 cm) and that for isolate GA (3.69 cm). Temperature range of 20-25 °C was found to best for isolate GA with mycelial growth of 6.38 cm followed by isolate GP (6.06 cm). Optimal mean mycelial growth (5.05 cm) was exhibited at 25 °C where isolate GA gave maximum mycelial growth (3.70cm). All isolates preferred acidic pH 5-6 for their growth. Isolate GP was found to be superior with maximum mycelial growth (6.79 cm) followed by isolate GA (6.62 cm). pH of 6 with 4.72 cm of mycelial growth was superior for all the isolates and isolate GP (4.38 cm) gave maximum mycelial growth. Different *Ganoderma lucidum* isolates favoured MEA media with a temperature of 20-25°Cand pH of 5-6 for optimum mycelial growth. Isolates GA and GP found to be superior.

OP 05: Foliicolus Fungi on Pineapple from Aizawl, Mizoram

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Pineapple (*Ananas comosus* L.) Merr, DC. Family: Bromeliaceae is one of the most important commercial fruit crop in the world. It is known as the queen of the fruits due to its excellent flavor and taste. It is the third most important tropical fruit in the world after Banana and Citrus. Pineapple are consumed or served fresh, cooked, juiced and can be preserved. The fruit is highly perishable and seasonal. Mature fruit contain 14 per cent sugar, a protein digesting enzyme, bromalin and good amount of citric acid, malic acid, vitamin A&B. The author was in Aizawl during March 13-18, 2016 so as to attend International Symposium on Sustainable Horticulture 2016 organized by Department of Horticulture, Aromatic & Medicinal plants, Mizoram University on March 14-16, 2016. On March 16^{th,} we were acquainted with the nearby area of different valuable sites of multidiscipline. In this route we visited a big pineapple Orchard. The Orchardist provided us the pineapple pieces which were so sweet beyond expectation. With his kind permission I surveyed the field and collected the leaves showing evident symptoms. After preparing the slides of different symptoms and microscopic study, the living leaves were found infected with *Dictyothyrina ananasicola* Kapoor & Munjal, *Leptothyrium indicum* Pavgi & Gupta, Phomacomosa Pavgi & Gupta, and *Dinemasporium microsporum* Sacc.*Geotrichum candidum* Link and *Trichothecium roseum* Link ex Fr where found on harvested crop stored for marketing. The perusal of available related literature reveals that the above mentioned fungi are the first report from Aizawl, Mizoram.

OP 06: Lichenicolous fungi: Hidden Possibility for Novel Organism Discovery

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The immense importance of fungi in our daily life is well recognized. Everyone is well aware about the Penicillin; a globally known antibiotic drug which is till date serving the mankind was extracted from a fungi. The fungi become very important in case of plant pathology, agronomy and many other branches of agriculture. An estimate of occurrence of 1.5 million fungi was made but only 0.1 million fungi have been identified so far. The lichens besides their own fungal partner i.e. mycobiont; provide an underexplored but potential habitat for

other fungal groups. The lichenicolous fungi one of them are highly specialized and successful ecological group of ascomycetes and ascomycetous anamorphic organisms that develop obligatory on lichen thallus. Till date 1800 lichenicolous fungi have been identified, however, there is an estimate of occurrence of about 3000 lichenicolous fungi in world. The present paper describes the lichenicolous fungal biota of Uttarakhand. Lichenicolous fungal wealth of Uttarakhand comprises 64 species of lichenicolous fungi belonging to 40 genera, colonizing 67 different lichen species. *Lichenostigma cosmopolites* showed broad range of distribution i.e. was found growing on 9 different lichen species. Lichen species *Rusavskia elegans* hosted maximum (8) species of different lichenicolous fungi. The hidden potential of a large number of fungi is still unexplored, lichenicolous fungi can provide some new novel organisms to science.

PP 01: Managing Post Harvest Losses of Onion by Pre Harvest Fungicide Application

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Onion is one of the most important commercial crops grown all over the world. It suffers from many post-harvest problems. Storage losses in onion can be as high as 40-50 per cent under ambient conditions. About 10-15 per cent losses are attributed to microbial decay or rotting. Since pre-harvest management is primarily aimed at managing field diseases, therefore its effect on the post-harvest diseases is less studied. Present study was aimed at assessing the effect of pre-harvest sprays of some newer fungicides on the storage losses of onion viz. physiological weight loss, sprouting, black mold (*Aspergillus niger*), soft rot (*Erwinia carotovora* subsp. *carotovora*) and neck rot (*Botrytis allii*). Three sprays were given in the field at 45, 60 and 75 days after transplanting. Bulbs from each treatment were harvested separately, field cured and stored at ambient temperature for three months and weekly observations on percent incidence were recorded. The fungicides were found significantly effective over check in reducing the post-harvest losses. Least physiological weight loss was observed in case of fluopyram + tebuconazole. Black mold incidence was found to be least in propiconazole which provided mean incidence reduction index of 43 per cent. For the management of soft rot, tebuconazolewas found to be most effective with a mean incidence reduction index of 49.31 per cent. For neck rot, highest incidence reduction was offered by azoxystrobin. However, sprouting was not significantly affected.

PP 02: *In vitro* Evaluation of Fungicides, Bioagents and Botanicals against Anthracnose of Pomegranate Caused by *Colletotrichum gloeosporioides*

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Pomegranate (*Punica granatum* L.) is a widely grown fruit of tropical and sub-tropical regions of the world. Anthracnose of pomegranate is one of the limiting factor for low productivity and huge economic losses. Therefore, the integrated disease management of anthracnose is necessary. In this study new fungicide molecules, bioagents and botanicals were evaluated under in vitro condition against the mycelial growth of

Colletotrichum gloeosporioides. In vitro screening of fungicides against C. gloeosporioides showed two combination product Hexaconazole + Zineb, Trifloxystrobin + Tebuconazole and a non-systemic fungicide viz. Captan showed 100 percent inhibition at 100, 250, 500 and 1000 ppm concentration. Likewise, systemic fungicides *viz*. Hexaconazole, Propiconazole, Penconazole, Tebuconazole and Carbendazim showed 100 percent mycelial inhibition at 500, 1000 and 2000 ppm concentrations. Similarly**,** Different bioagents and botanicals evaluated under *in vitro* condition against the mycelial growth of *C. gloeosporioides* revealed that fungal bioagents viz. *Trichoderma viride*, *T. asperellum* and *T. harzianum* showed 87 to 100% mycelial growth inhibition of the fungal pathogen. While, bacterial bioagents *viz*. *Pseudomonas fluorescens* and *Bacillus cereus* showed 47 to 52% mycelial growth inhibition of *C. gloeosporioides*. However, among the tested botanicals, Nagadhale leaf extract showed maximum (68.28%) mycelial growth inhibition of fungus *in vitro*.

PP 03: Sustainable Disease Management of Late Blight of Potato through Plant Extracts

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Indiscriminate use of synthetic pesticides, plant pathogens are gaining resistance against them and also creating environmental and toxicological problems to our ecosystem. In this context, the popularity of botanical pesticides once again increasing and some plant products are being used for sustainable disease management were reported by several workers. The presence of antifungal compounds in higher plants has long been recognized as an important factor for disease control. The pesticidal compounds of plant origin are most effective and have little or no side effects in human beings in comparison to synthetic compounds. Therefore, the study was undertaken on disease management of late blight of potato with plant extracts in the present investigation. Plant extracts viz. *Salix sp., Achyranthus aspera, Solanum nigrum, Parthenium hysterophorus, Datura stramonium, Melilotus albus, Convolvulus arvensis and Lantana camara* as tuber treatment and foliar spray significantly in- creased seed germination from 71 – 86 per cent and plant height with the highest is noted in case of *Lantana camara* treated plant showing 86.34 per cent and 20.2 cm against 71.0 per cent and 10.4 cm, respectively in case of control. Biochemical analysis of treated plant showed that there was increase content of soluble protein and total phenol content. The maximum soluble protein content was found in Lantana camera treated plant showing 32.62 mg/g of fresh leaves against 21.57 mg/g of fresh leaves in case of control. Similarly, high content of phenols was also recorded in *Parthenium hysterophorus* treated plant representing 2.28 mg/g of fresh leaves against 1.52 in control at 15 days of inoculation. The disease severity showed negative correlation with soluble protein (r=-0.5486) and total phenol (r=-0.3225) at 15 days of pathogenic inoculation. Thus, the plant extracts have ability not only to increase seed tuber germination and plant growth promotion but also synthesized defense molecules (Protein & Phenol) in plant resulted decline disease severity from 96.12 – 8.93 per cent.

PP 04: Management of Mango Anthracnose Disease

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The mango (*Mangifera indica*) is an evergreen fruit tree. It suffers from several diseases at all stages of its life. Anthracnose (*Colletotrichum gloeosporioides)* is of widespread occurrence in the field and in storage. The disease produces leaf spot, blossom blight, withered tip, twig blight and fruit rot symptoms. Severe infection destroys the entire inflorescence resulting in failure of fruit setting. Panicle anthracnose or blossom blight can affect both the inflorescence stalk and the individual flowers. Post-harvest anthracnose appears as rounded brown to black lesions with an indefinite border on the fruit surface. Although most or all commercial mango cultivars are susceptible to mango anthracnose, some are less susceptible than others. The cultivar Keitt is less susceptible than Kent, while Kessington Pride is moderately resistant. At present, none of the cultivars under production are significantly resistant to be produced without using some fungicide spray protection in humid environments. Spraying twice with Carbendazirn (Bavistin 0.1%) at 15 days interval during flowering controls blossom infection. Spraying of copper fungicides (0.3%) is recommended for the control of foliar infection. Postharvest disease of mango caused by anthracnose could be controlled by dip treatment of fruits in Carbendazim (0.1%) in hot water at 52 C for 15 minutes.

PP 05: Assessment of Bio-Management Potential of Some Carnivorous Fungi against Root-Knot Disease of Brinjal (*Solanum melongena L.*)

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Root-knot nematode *Meloidogyne incognita*is famous for its highly destructive pathogenic effect that can result in extensive damage of brinjal crop. Chemical nematicides are widely used for the control of plant-parasitic nematodes. However, chemical nematicides are associated with environmental hazard, high costs, and limited availability in many developing countries. Since many nematicides have recently been withdrawn due to their harmful effects on humans and the environment, alternative management strategies are required. Biological management of soil borne plant pathogens have shown to be a potential alternative. In search of the fungal natural enemies of *M. incognita* for the management of the root- knot disease in brinjal, seven species of carnivorous fungi were isolated from agricultural and horticultural soil. Three species of carnivorous fungi namely *Arthrobotrys conoides, Dactylellina gephyropaga* and *Drechslerella brochopaga* were studied in detail with special reference to their adoptability in soil and bio management potential at different doses. *A. conoides* was found fast growing followed by *D. brochopaga* and *D. gephyropaga* on corn meal agar medium. Conidia of all the three carnivorous fungi applied into agricultural soil had good germination ranged from 88.8-96.46%. *D. brochopaga* formed conidial traps whereas *D. gephyropaga* formed adhesive branches on growing hyphae. No trap formation observed in the growing hyphae of *A. conoides*. Three species of carnivorous fungi were studied for their nematophagous ability against second stage juveniles of *M. incognita*under *in vitro* condition. *D. brochopaga* was found more carnivorous by formation of higher number of traps and trapping of *M. incognita* (J_2). Maximum trapping was observed during the nematode interface of *D. brochopaga* and *M. incognita* followed by *D. gephyropaga* and *A. conoides*. Application of 5000 colony forming units per g. of soil in *M. incognita* infested soil caused reduction 69.58 % in number of root- knot by *D. brochopaga* followed by *D. gephyropaga* (58.86%) and *A. conoides* (50.48%). Lowest reduction in number of root knots and number of J_2 was observed by application of 50 CFU of *A. conoides* per g. of soil.

PP 06: Management of Wilt Complex of Geranium using Organic Substrates and Oil Cakes

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All the organic amendments *viz*., neem cake, mustard cake, mushroom spent compost, wheat straw and saw dust tried against soil borne pathogens reduced incidence of root rot/ wilt complex yet application of neem cake and mustard cake was best against wilt complex under glass house and filed conditions. Soil amendments with neem and mustard cakes were showed least disease severity (4.16 and 6.25%) and 93.05 and 86.25% reduction in disease under sterilized soil under glass house conditions while amended soil exhibited the maximum reduction of disease in solarized (92.58 and 85.73%) and un-solarized (74.20 and 58.06%) field conditions. Soil amendment with saw dust (28.60 and 22.52%) was least effective in solarized and un-solarized conditions. It was observed that soil solarization gave satisfactory control of wilt complex in the nursery as well as in the field. The present disease severity reduction over control was the highest (100% in solarized and 91.37% in un-solarized plots) in neem cake. Thus, this technique has potential to be commercially viable for management of root rot/wilt complex.

PP 07: Evaluation of Bio-Control Agents, Bactericides and Antibiotics against Bacterial Wilt of Tomato caused by *Ralstonia solanacearum*

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Tomato (*Solanum lycopersicum*) is the second most important and cultivated vegetable crop, next to potato around the world and belongs to the family *Solanaceae.* Diseases are a major limiting factor for tomato production. Tomato is susceptible to more than 200 diseases. Losses of yield due to diseases may be as high as 70 percent to 95 percent. Bacterial wilt is the most devastating disease of tomato which can cause high yield loss. The characteristic symptom of bacterial wilt in normal grown up tomato plants is the rapid and complete wilting. For the management of soil and seed born bacterial disease chemical and nonchemical methods including biological control agent are used. Because the pathogen invades the inner parts of the plants, the conventional chemical products such as copper may not provide adequate control for the disease. A study was undertaken to evaluate ten chemicals involving biocontrol agents and bactericides and antibiotics against bacterial wilt of tomato caused by *Ralstonia solanacearum*. Treatments were given as three foliar sprays at 30, 40 and 50 days after sowing under *in vivo* conditions (glasshouse and field conditions). In glasshouse and field conditions both, maximum reduction in disease severity was obtained with bleaching powder followed by combination of bio-control agent *T.harzianum+P.fluorescens* with three foliar sprays.

PP 08: Infectivity and Reproduction of *Meloidogyne incognita* on Carrot (*Daucus carota)* Influenced by Organic Additives

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Eco-friendly methods and strategies for nematode management have been recommended due to their non-hazardous impact on environment. A greenhouse experiment was conducted to study the effects of organic additives (chopped leaves) applied in 2 kg soil at different levels (50 g and 100 g/pot) on the infectivity and reproduction of *Meloidogyne incognita* on carrot, *Daucus carota*. All treatments significantly ($P \leq 0.05$) improve the shoot and root height, fresh and dry weight and chlorophyll content compared to untreated inoculated control plants. Plants treated with fresh chopped leaves of *Phyllanthus amarus* (100 g) showed a maximum significant increase in all the growth parameters. As it supported highest vegetative growth and most suppressive effect on the nematode development. Results of this study indicate the fact that local farmers could apply these botanicals as organic fertilizers during cultivation to counteract the effect of root-knot nematode and also to improve the growth of crop plants.

PP 09: Impact of Steroidal Glycoalkaloids on the Physiology of *Phytopthora infestans*

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Steroidal glycoalkaloids are plant secondary metabolites known to be toxic to animals and humans and that have putative roles in defense against pests. The mechanism of glycoalkaloid toxicity are sterol- mediated disruption of membranes and inhibition of choline esterase activity in neurons. Solanidine, the non-glycosylated precursor of α- chaconine and α- solanine have greater physiological impact on inhibiting the mycelial growth of pathogen. These compounds represent up to 95 per cent of the total steroidal glycoalkaloids (SGAs) present in potato. Light exposure,heat, wounding or post-harvest stress can significantly increase tuber glycoalkaloids content with associated increase in the risk to growth of pathogen. It was found that additional interaction between membrane sterols and the glycan moiety of SGAs might lead to loss of ion conductivity of the cells. So,that the pathogen can die within few seconds. The night shade family produces a wide variety ofnitrogencontaining steroidal glycoalkaloids, mostly abundant in potato and tomato. As the glycoalkaloid mostly present in glcosylated form it can be easily degraded by the pathogn. So, mitigation strategies aims at secondary metabolite-based breeding programs mostly in non- glcosylated form of alkaloid to increase plant resistance to infection.

PP 10: Pre-Harvest Fruit Bagging: A Useful Approach for Plant Protection and Improved Post-Harvest Fruit Quality

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Several good agricultural practices (GAP) are becoming popular throughout the World for the production of high quality fruit with less dependence on man-made chemicals. Among such practices, pre-harvest fruit bagging has emerged as an effective method. Bagging is a physical protection method which not only improves the visual quality of fruit by promoting skin colouration and reducing blemishes, but can also change the micro-environment for fruit development, which can have several beneficial effects on internal fruit quality. Pre-harvest bagging of fruit can also reduce the incidence of disease, insect pest and/or mechanical damage, sunburn of the skin, fruit cracking, agrochemical residues on the fruit, and bird damage. Fruit bagging also prevents pathogens from reaching the developing fruit, which protects them from several diseases that can cause major losses. Bagging can protect some fruit from several pathogens. Fruit bagging has been reported to reduce the incidence of anthracnose and stem-end rot in mango, sooty blotch and fly speck in apple, anthracnose and fruit rot in guava as well as in loquat respectively. Phenolic compounds are secondary metabolites which act as anti-oxidants and protect plants (and us) from several diseases. Fruit bagging can also influence the concentrations of phenolic compounds and antioxidant activities in fruit. The concentrations of simple phenolic compounds increased with bagging up to 60 days and then declined in ‗Delicious' apple fruit. Thus, fruit bagging can be a beneficial practice for producing higher quality fruit, without or with less use of chemicals to control diseases.

PP 11: Cultural Practices for the Management of Tomato

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Tomato (*Lycopersicon esculentum*) an important vegetable crop in India. The severity of tomato disease varies with production technology, and with the losses in open field systems that may be absent in greenhouse production. Accompanying of tomato plant with crop like marigolds that attracts syrphids which act as a prey on aphids and also repel flies and is well known for a quality to repel garden pest is probably the most utilized cultural practice for disease control in tomato. This helps in keeping populations of pathogens below than damaging numbers has also been found effective in protecting tomato plant. Early and Late blight, Bacterial wilt, of tomato caused by the previous plant debris introduced through overhead irrigation which can be best minimized by practicing crop rotation. Compost tea which is a concentrated organic liquid fertilizer that is made from steeping biologically active compost in aerated water. Compost tea is nutritionally rich and can help provide plants with beneficial soil bacteria that can be effective at fighting both early and late blight of tomato. Compost tea is made by mixing about one part well-aged compost that is at least 4 months old and 5 to 8 parts of water. Avoiding harvesting of fruit in wet condition also protects the plant from disease.

PP 12: Biochemical and Histochemical Defence of Chilli (*Capsicum annum* L.) to *Colletotrichum capsici* and Colletotrichumine A

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The induction of defence compounds and enzymes involved in the phenylpropanoid pathway were studied in the 21 days old chilliseedlings inoculated with *C. capsici,* Colletotrichumine A and both combined at different concentration. Total phenols and the activity of phenylalanine ammonia lyase (PAL), peroxidase (PO), polyphenol oxidase (PPO) and lignification increased in the inoculated chilliseedlings compared to the corresponding healthy seedlings. Total phenols and the activities of the enzymes were increased after 3-4 days of inoculation. In comparison with *C. capsici* and Colletotrichumine A treated alone, chilli seedlings inoculated with consortia of *C. capsici* and ColletotrichumineA showed higher accumulation of total phenols and higher activities of enzymes. High-performance liquid chromatography (HPLC) analysis showed that the defense enzymes like ferulic acid and catechin also increased after inoculation.

PP13: Effect of Certain Biocontrol Bacteria and Fungi on the Development of Root-Knot Nematode Disease in Tomato

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Effects of soil application of culture suspension and culture filtrate of biocontrol bacteria and fungi viz. *Bacillus subtilis, Pseudomonas fluorescens, Pochonia chlamysporium,T.harzianum* and *T. hamatum* against root-knot nematode, *Meloidogyne incognita* on tomato was examined under pot condition. *In vitro*, different concentrations of cultures of biocontrol agents (BCA) inhibited egg hatching and induced 10-48% mortality to the juvenile of *M. incognita*. Treatments with *Pochonia chlamydosporium* was found to be most effective and caused highest decrease in the hatching and 100% mortality of juveniles at 50% concentration, followed by *T.harzianum, Bacillus subtilis* and *Pseudomonas fluorescens.*The inoculation with 2000 freshly hatched juveniles of *M. incognita* caused characteristic oval and fleshy galls on the roots of tomato cv. K-21, numbering around 95galls/root system. Over 68 egg masses/ root system were also formed. The nematode infection caused significant decrease in the plant growth and yield variables of tomato. The effect of soil application of BCA cultures suppressed the galling, egg mass production, fecundity and soil population *M. incognita,* and improved the growth and yield parameters of the tomato. Treatments with *T. harzianum* provided maximum control of the nematode and increased in the plant growth and yield of tomato followed by *Pochonia chlamydosporium*, *B. subtilis* and *P. fluorescens.* Soil application of *M. incognita* juveniles gradually increased in the control pots, however, it significant decrease in the pot received BCA especially *T. harzianum or Pochonia chlamydosporium.* The soil application of the BCAs increased in both nematode inoculated and un-inoculated pot, being significantly greater in the former.

PP 14: Management of Fusarium Wilt of Cucumber by Antagonistic Fungi and Bacteria

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An experiment was conducted to evaluate the effects of five biocontrol fungi and bacteria viz, *Aspergillus niger, Trichoderma harzianum, T. viride*, *T. hamatum* and *Pseudomonas fluorescens* for the management of Fusarium wilt (*Fusarium oxysporum* f. sp. *cucumerinum*) on cucumber in pots under polyhouse condition. The BCAs were applied through seed treatment (2g/kg seed) and soil application (5g/kg soil) separately. Cucumber seeds were cropped in sterilized soil in earthen pots. The soil was inoculated with *F. oxysporum* @4g/kg soil one day before seedling transplanting. The inoculated plant showed characteristic symptoms of wilt on foliage and darkening of vascular cylinder roots. The infested plants exhibited 20-27% decrease in the plant growth and biomass production. However, application BCAs combated the negative effect of the wilt fungus. Maximum reduction of the disease incidence was observed with the seed treatment with *T. viride* (34%), *T. harzianum* (29%) followed by *T. hamatum* (26%), *A. niger* (21%), and *P. fluorescens* (15%).Whereas, the soil application of these BCAs resulted in 13-25% decrease in the disease incidence. Overall, seed treatment was found to be more effective as compared to soil application. Besides direct suppression, the BCAs also enhanced the plant growth and biomass production of cucumber. Maximum enhancement in plant growth parameters was recorded with seed treatment of *T. viride* (13-22%) as compared to control. Rest of the BCAs showed more or less similar effect.

PP 15: Phenolic Acids in the Fruit Pulp of Some Citrus Varieties and Their Therapeutic Importance in Human Health

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Phenolic compounds play an important role in defence system of the plants and animals against various fungal, bacterial and viral diseases. High performance liquid chromatographic (HPLC) analysis of the pulp of six varieties of citrus fruits showed that they content good amount of phenolic acid. Lemon pulp (*C. lemonum*) had five phenolic acids viz., tannic, gallic, ferulic, o-coumaric and cinnamic acids in which gallic acid (32.18 µg/g) was maximum, followed by tannic (12.49 µg/g), ferulic (1.89 µg/g), ocoumeric (1.34 µg/g) and cinnamic (0.26 µg/g fresh wt) acids. Among other varieties having four phenolic acids, *viz*., tannic, gallic, ferulic and o-coumeric acids were detected. The intake of plant/plant material containing high amount of phenolic acids as well as favonoids enhance resistance due to activation of immune-stimulation and scavenging the SOx radicals the body. Plant polyphenols have attracted much attention recently due to their role in prevention of illnesses such as heart diseases and diseases of cardiovascular system whose causes are in the oxidation of LDL (low density lipoproteins). Phenols and polyphenolic compounds, such as flavonoids, are widely present in the citrus fruits showing significant antioxidant activities. Juice from the pulps of citrus fruits are incorporated in daily dietary food, hence they might be playing a great role in imparting resistance to human body.

PP 16: Prevalence of Guava Decline in Uttarakhand

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Guava (*Psidium guajava* L.) is an important fruit crop of subtropical countries. It is grown almost in all the states of India. It is a very productive and highly profitable fruit crop. It is liked by fruit growers due to its wide adaptability and higher return per unit area. The tarai belt of Uttarakhand provides a relatively favourable production environment for guava cultivation and considered an important fruit crop of Tarai regions. Guava trees bearing flower twice a year, i.e. rainy and winter season and produce about 90 per cent crop in the rainy season. The fruits are rough, insipid and poor in quality during the rainy season while in the winter season, the crop is free from diseases and pests and fetches higher prices in the market. The winter season crop can be harvested by reducing the crop load during rainy season. The successful cultivation of guava is hampered by a number of biotic and abiotic factors. Among the biotic factors, diseases take a heavy toll. Some important guava diseases include guava decline, wilt, anthracnose, *Botryodiplodia* rot, fruit rot, *Phoma* rot, *Rhizopus* rot, collar rot, *Pestalotia* leaf spot, *Cercospora* leaf spot, stem canker and seedling blight. Zinc deficiency is a significant abiotic problem. Among these diseases guava decline is a complex disease syndrome in the Udam Singh Nagar and Haridwar.During the last decade fruit production was adversely affected by a decline problem. The disease starts as early as in the beginning of the month of June or following rainfall but the intensity of infection and spread is accelerated with the on-set of monsoon. The maximum wilting of guava trees is, however, restricted to the months of September and October, beyond which the incidence reduces gradually. Pathogenic fungi survive on dead root material of guava in adverse climatic conditions in summer, while in rainy and winter season they survive around roots. In severe attacks, the trees show significant symptoms of decline. The important symptoms of guava decline are the browning and wilting of leaves, desiccation of twigs and discolouration of stems. Death of branches takes place often from one side of the plant. Affected trees show defoliation and ultimately death of twigs occurs. The roots of such plants are also found rotten. The height and girth of the diseased plant is decreased with an increase in disease severity. Apart from the externally visible symptoms of desiccation of the plants, tissues of the affected stem, extending to the cambium region, display a dark staining. The fungus was soil borne and infected the root system via wounds. Fusarium species is a soil-borne fungal pathogen causing wilt of guava and is difficult to control. The species of *Fusarium* i.e., *F. oxysporum* and *F.solani* are generally the main cause of guava orchards in Uttarakhand and it is identified on the basis of its morphological and cultural characteristics. Both the fungi were found to be capable of inciting wilt either individually or in combination with other pathogenic fungi. Guava growing areas in Uttarakhand such as Udam Singh Nagar, Haridwar, Naintal, Dehradun, Pauri, Champawat, Tehri, and Almora were visited more than once during the year 2012 and 2016. The disease was appeared in all the areas and incidence varied from 12 to 38 percent. The maximum incidence (up to 38%) was evident at US Nagar and Haridwar fruit belt areas, while minimum was at Tehri, and Almora fruit belt.

PP 17: Minimizing Post Harvest Losses in Horticultural Crops

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Harvested fruit and vegetables require adequate and advance technology for minimizing the qualitative as well as quantitative loses after harvesting. Nearly upto 40% horticulture crop are wasted every year due to improper packaging handling and storage on other hand it loss due to microbial pathogen fungi, bacteria, mycoplasma, viruses and viroids. Losses in quantitative and qualitative character in crop are high due to post harvest disease as compared to field crops disease. Growers must begin control procedures in the orchard for fruit diseases which appear long after harvest. The efficiency of different disease management strategies based on cultural methods, physical,chemical and biological method has been shown to depend on the pathogen ecology and population dynamic, host plants species and handling and storage condition. Synthetic fungicides are used to control postharvest decay loss. We also care the temperature in store house should be maintained 30°C because most of the storage fungi can grow well at temperature between 30̊IC and 55̊IC. Insecticides like Methyl bromide and some other fumigant are used to treat the harvested seed and reduce the economic losses. It should be possible to reduce losses substantially but in practice this may be prohibitively expensive.

PP 18: Causes and Management of Peach Leaf Curl Virus

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Peach leaf curl disease is caused by the fungus named *Taphrina deformans*. The fungus is specific to peaches and nectarines and can infect expanding leaves and immature fruit. The fungus is found anywhere peaches are grown but usually goes unnoticed during years in which it is dry and warm during bud swell and leaf expansion. The disease occurs when the weather is wet and cool at the time of leaf emergence and expansion. As long as growers keep up with proper management of the disease every year, it is usually not a problem. However, where spring conditions are often warm and dry, growers frequently relax their management of the disease. The fungus induces cells of infected leaves to multiply rapidly and randomly and enlarge, resulting in deformation and curling. The infected distorted leaf parts are often yellow or red colored. Infected leaves eventually turn brown and fall off. Young infected fruit may also drop prematurely or fruit shows wart like symptoms when mature. The tree leaf out again to replace the fallen leaves which can result in significant yield reduction. There are no management options after infection has occurred. Control can be achieved by a single application of fungicides in the fall after 90 per cent of leaves have fallen to the ground. Thorough coverage of the trees is easier to achieve when most leaves are on the ground and excellent coverage is needed for good control. Chemicals that can be used for control are copper based fungicides or chlorothalonil. Fall fungicide applications should be used in orchards with a history of leaf curl to reduce inoculum. Cultural practices that can be used by homeowners are removal of infected leaves that have fallen to the ground to remove as much inoculum as possible. Resistant varieties against fungus are another option for cultural control which includes Muir and Q-1-8. The variety Redhaven and varieties related to it are tolerant to the disease. Susceptible to highly susceptible varieties include Redskin and its derivatives.

PP 19: Unraveling the Hidden Potential of Defense Inducers in Eliciting Defense Response on Tomato Plants Infected with *Clavibacter michiganensis* subsp. *michiganensis*

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Bacterial canker of tomato caused by the bacterium *Clavibacter michiganensis* subsp. *michiganensis* (Smith.) Davis is a serious and destructive disease worldwide. It is listed as an A2 quarantine pathogen by EPPO and now occurs in many tomato-growing areas worldwide. *Cmm*is considered the most important bacterial disease in tomato and yield losses through it can be severe. The transmission of the pathogen occurs via contaminated seeds and also through stomata, roots, damaged tissue, and other natural openings. After infection *Cmm* invades the xylem vessel, which is followed by a systemic infection of the host. The typical disease symptoms are wilting and at later stage the appearance of canker lesions. One of the potential methods of reducing the severity of disease is an induction of plant resistance which may be viable alternative to traditional pesticides. Assessment of morphological variability within the isolates collected from tomato growing regions of Uttarakhand and Himachal Pradesh was done and defense inducing compounds *viz.,* salicylic acid (SA) and it‘s synthetic analogue 2,6- dichloroisonicotinic acid (INA), Benzothiadizole (BTH) and Lysozyme were tested for their ability to induce resistance against *Cmm*. Levels of three types of defense-related enzymes in tomato leaf tissue, POX, PAL, PPO; phenolic content (TPC) and Pathogenesis related protein-1 (PR-1) were assessed to determine possible relationships between the activation of these enzymes and the protection of seedlings following treatments with defense inducers. Among all the treatments it was observed that BTH played an important role in elevating the concentration of defense inducers in leaf tissue followed by SA, INA and Lysozyme.

PP 20: Post Harvest Treatments for Controlling Crown Rot Disease of Cavendish banana (*Musa acuminata* L.)

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Crown rot of banana is a major cause of losses during storage and marketing of banana and considered as one of the most serious and frequent postharvest and post-packaging diseases. *Fusarium semitectum*, *Colletotrichum musae* and *C. gloeosporioides* were identified as the major crown rot causing fungi around the world. Apart from application of synthetic fungicides, effect of natural plant protectants like commercial essential oils of cinnamon, thyme, bitter and sweet almond activity has been tested against the fungi causing crown rot disease of Cavendish bananas. Complete reduction (100.0%) of crown rot disease incidence of banana fruits was recorded at the concentration of 4.0% of applied cinnamon and thyme oils, followed by sweet almond and bitter almond oils. Stored bananas treated with cinnamon, bitter and sweet almond oils showed no significant differences compared to the control with respect to odour, flavor, taste and overall acceptability. Hence cinnamon, thyme, bitter and sweet almond oils treatment developed during the current study without affecting the organoleptic properties recommended as a safe and cost-effective commercial method for treating bananas to control crown rot disease.

PP 21: Selection of Strains among *Lentinula edodes* on the Basis of Protein Content and Biological Efficiency

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Lentinula edodes (Berk.) Pegler is commonly known as shiitake mushroom. It is the third most important commercially cultivated mushroom native to East Asia, which is cultivated and consumed in many Asian countries and is considered as one of the prominent medicinal mushroom. Present study provides a better insight into the fact that high protein content in edible mushroom and good biological efficiency of the mushroom strains can be used for crop improvement. The research was conducted with the crop of Shiitake (*L. edodes*) mushroom which was cultivated on wheat straw. Investigations were carried on six high temperature strains of mushroom - OE-16, OE-22, OE-28, OE-38, OE-388 and Le (L) and one low temperature strain - Le(O) at Mushroom Research and Training Centre, Pantnagar. Amount of protein per 100 g of dry fruit body was calculated. Highest amount of protein was found in OE-388 (48.07 g), followed by OE-38 (42.85 g), OE-22 (41.35 g), OE-28 (41.29 g), Le (L) (48.07 g), OE-16 (40.69 g). The protein from the mycelium of Le (O) was found to be 39.63 g/100g of dry mycelium. Out of 7 strains tested, OE-388 produced highest 9.8 fresh fruits with 155 g fresh weight/1.5 kg wet substrate followed by 2.7 number, 42.75 g weight in OE-28; 2.4 number, 37.93 g weight in OE-38 and 0.7 number, 11.25 g weight in Le(L), respectively. However, the wild strain Le(O) was unable to produce mushroom fruits. Highest 40% and 39% biological efficiencies were computed with the respective strains OE-388 and OE-28. So the results of this study can be used for the crop improvement programs of shiitake mushroom as we can select that mushroom strain which is estimating highest protein content, number of fruit bodies and biological efficiency.

PP 22: Assessment of Efficacy of Botanicals against Root-Knot Nematode, *Meloidogyne incognita* infecting Okra

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A cage house study was conducted at Department of Nematology to assess the efficacy of plant leaves powder of *Azadirachta indica, Parthenium hysterophorus* and *Lantana camara*as soil application at 2, 4 and 8 g/plant against root-knot nematode, *Meloidogyne incognita* infecting okra. A standard check neem cake at 8 g/plant and untreated check were also taken for comparison. Results indicate that these botanicals were found better over untreated check (control) in improving plant growth characters and reducing nematode reproduction on okra. Among all the treatments application of neem leaves powder at 8 g/plant was found to be the best treatments to improve plant growth character. As regard to nematode reproduction, neem cake at 8/plant was proved best treatment in reducing galls per plant, egg masses per plant, eggs per egg mass, and nematode population/100cc soil of *M. incognita*.

PP 23: Strategies for Disease Management in Fruit Crops under Changing Climatic Scenario

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Agriculture in the past few years has witnessed both direct as well as indirect complex impacts of climate change. The risk factor for perennial fruit crops is higher as compared to the annuals. The production and productivity of fruit crops is being affected by many interacting factors. Change in distribution of pathogens with climate change is an important observation by the scientists all over. Increase in temperature provides congenial conditions for proliferation and multiplication of various fungal and bacterial infections in fruit crops. The microbes are less prone to the adverse effects caused by the increase in CO_2 concentration, O_3 and UV-B than their host plants. Greater fluctuations in the severity and occurrence of a disease from year to year have been observed. Therefore, new management strategies to mitigate the impact of global warming on pests and diseases of fruit crops and to improve the efficacy of defence mechanism are needed. Development and validation of region specific crop based disease risk models have to be run during the season when the disease occurs in the specific crop. Quantitative modelling to study the interacting effects of temperature, moisture and crop growth on disease occurrence is required. Although the cultivars for future cannot be identified at present but development of new cultivars with lower disease susceptibility through molecular breeding and biotechnological tools is required. Transgenic crops will have to be seriously considered in the integrated disease management programmes. Solution will also have to come from development of new production systems including orchard management practices, training systems, irrigation and nutrition, conservation horticulture, greater use of protected structures etc. Regular plant monitoring and determination of trends with the help of experimental data is very important in order to be prepared for the vulnerable effects of climate change. More emphasis has to be given on increasing empirical research linking plant diseases, climate change, crop growth and food security.

Session 04:

Biotic and Abiotic Stress Management Strategies under Changing Climatic Scenario, Disease Dynamics, Epidemiology and Disease Forecasting

LP 01: Keeping Wheat Crop Health Sound over Decades in India- A Success Story

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Wheat (*Triticum aestivum*, *T. durum* and *T. dicoccum*) is most important cereal crop in *rabi* season in India. It is grown in all six agro ecological zones in 18 different states except Kerala, Goa, Telangana and Andhra Pradesh and some North –eastern states. It is second important food crop after rice in India. During 2016-17 record wheat production of 98.38 q/ha was achieved in India from 30.60 million ha with an average productivity of 32.16 q/ha. There had been increase in wheat production by 7 folds since 1964-65 in India and we are placed number two in wheat production globally. It happened due to better varieties, improved agronomic practices, irrigation and mechanization. The assured production and minimum support prices for procurement motivated farmers to prefer wheat and wheat based cropping systems in the states like Punjab, Haryana, UP, Rajasthan, M. P., Bihar, terai of Uttarakhand, Maharashtra and Gujarat. A total of 437 wheat varieties are released and notified in India so far. Out of these few varieties like, Sonalika, HD 2009, WL 711, HD 2329, HD 2285, PBW 343, PBW 373 and HD 2967 became mega varieties. These varieties were gown in large areas (about 10 m ha) in Northern India at one point of time. Further wheat area was extended to non-traditional wheat growing states having warmer and humid climate like Eastern U.P., West Bengal and Assam which are having surplus land after rice harvest. In recent time, changes are witnessed in tillage practices, application of fertilizers, cropping system, irrigation methods, time of sowing and in increased use of conservation agriculture in wheat growing parts of Northern India. All these affected the disease situation in wheat and wide range of pathogenic variability in wheat rusts have resulted disease susceptibility in popular wheat cultivars. The transboundary diseases like stem rust pathotype Ug 99, new pathotypes of stripe rust and news diseases like wheat blast in Bangladesh, posed threats to wheat production in India.

Wheat suffers from yellow (stripe), brown (leaf) and black (stem) rusts besides leaf blight, Karnal bunt, powdery mildew, loose smut and flag smut as well as some minor diseases like hill bunt, foot rot and Fusarium head scab. Rust and powdery mildew are multi cyclic diseases and inoculum of these survives on hills in North and South. Loose smut is completely seedborne disease and transmits through infected seeds whereas flag smut pathogen spreads through seeds and infected soil. However, not all diseases are important in different agro ecological zones. Crop health management strategies are therefore, based on agro ecological approach. The main pillars of crop health management in wheat are strategic survey and surveillance, collection, analysis and use of pathogenic variability in evaluation of yield trial entries, genotypes and breeding population, identification of resistant genetic stocks, sharing of resistant stocks with breeders, strategic deployment of resistant varieties in different agro ecological zones, use of bio-agents and safer fungicides under emergency situations. Any variety released for Northern hills zone and North-western plains zone must be resistant to yellow and brown rust besides moderately resistant to other diseases like Karnal bunt, smuts, powdery mildew and foliar blight. Likewise in case of Peninsular and Central zones, resistance to brown and black rust along with moderate resistance to leaf blight is required for identification and release of varieties. Resistant to brown rust and leaf blight with moderate resistance to yellow rust is must in a variety meant for North-eastern plains zone. The yield trial entries are also tested against three rusts at seedling stage at IIWBR RS Flowedale, Shimla. On an average, 1400 entries of station trial received from major wheat breeding centres are tested against three rusts and leaf blight at hot spot locations and data on their levels of disease resistance are shared with breeders. The entries with resistance and higher yields are promoted in NIVT trials (on an average 375 entries). Likewise, entries of AVT Ist and final years are also tested against rusts, leaf blight, Karnal bunt, powdery mildew, smuts and minor diseases at hot spot locations. Based on yield and quality performance and disease resistance, on an average 5-6 varieties per year are identified and released. The seed of these is distributed in minikits and FLDs are demonstrated thus old and disease susceptible varieties are replaced after 6-7 years of their release since these become susceptible to newly evolved pathotypes of rusts. The breeder seed is produced in sufficient quantity and given to seed producing agencies. On an average 40 resistant genotypes with all passport data on disease resistance are shared with breeders for use in breeding programme since 1999-2000 till date. The survey and surveillance of diseases is done through mobile tours, use of trap plot nurseries, mobile technology etc. using a network of ICAR institutes, SAUs, KVKs and state agriculture departments as well as farmers. The information on occurrence of rust and weather is shared with different agencies through ―Wheat Crop Health Newsletter" and advisories are issued. Post-harvest survey is done for Karnal bunt and black point to facilitate export of wheat. Accordingly state agriculture departments take action on use of foliar fungicides to eliminate rusts right in districts close to foot hills in Punjab and therefore spread to yellow rust is delayed in Punjab, Haryana, UP, Uttarakhand and Rajasthan. Strategy planning meeting for management of wheat crop health are held between DAC & FW, ICAR, SAUs, state seed agencies and state agriculture departments before onset of crop season. The above strategies have averted the epidemics of wheat rusts and other diseases since past five decades in India whereas crop in other countries suffered due to epidemics of rusts and other diseases. It is a unique success story which is achieved through use of science and coordination of different agencies and contributed in record production of wheat and in ensuring food security in India. The use of resistant varieties shaved millions of rupees in terms of minimum use of fungicides. However, to keep it going, we must work to collectively to cope up the effect of climate change, changing cropping system, agronomic practices, conservation agriculture and new pathotypes of rusts and new threats of trans boundary diseases like wheat blast which is present in Bangladesh since 2016.

LP 02: Epidemiology and Prediction Models for the Management of Rapeseed-Mustard Diseases

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The production and productivity of rapeseed-mustard in India is quite low due to several biotic agents, like Alternaria blight [*Alternaria brassicae* (Berk.) Sacc.], White rust [*Albugo candida* (Pers.) ex. Lev.) Kuntze], Downy mildew [*Hyaloperonospora parasitica* (Gaum.) Goker.], Powdery mildew [*Erysiphe cruciferarum* Opiz ex. Junell.] and White stem rot [*Sclerotinia sclerotiorum* (Lib.) de Bary] because of their widespread distribution, severity and resulting yield losses due to epidemic conditions. During the recent past, disease scenario has changed as some diseases earlier rated as minor become major ones owing to intensive cropping, heavy irrigation and fertilization and climate changes. Lot of information has been generated on major diseases relating to geographical distribution, losses incurred, symptoms, diagnostics, disease cycle, epidemiology, resistant sources, physiological specialization and integrated disease management but still much more is required to overcome the annual losses caused by these diseases in the years to come. The control of these diseases through chemicals is readily available but the efficiency of these chemicals depends upon the interaction between pathogen and host as influenced by environmental factors. Studies on epidemiology provide the scientists to prepare a framework on which efficient and workable disease control methods that can be developed. The various weather parameters such as temperature, relative humidity, rainfall, wind velocity and direction, leaf wetness and its duration as well as solar radiation influence the various stages of infection process and disease development. The studies on interaction between these weather parameters (independent variables) and disease development (dependent variables) may pave the way for the development of the prediction models, which can determine the disease situation in advance. Several attempts have been conducted to develop prediction models for efficient management of important diseases of rapeseed-mustard but attempts to interpret the same in the form of disease forecasting models has remained insufficient, except for few other diseases. The control of these diseases through chemicals is readily available but the efficiency of these chemicals depends upon the interaction between pathogen and host which is influenced by environmental factors. The various prediction models developed for the management of important diseases of rapeseed-mustard have been discussed. The prediction model for Alternaria blight revealed that a maximum temperature of 20-25^{O}C, minimum temperature 15^{O}C, RH (mor.) more than 90 per cent and RH (eve.) more than 50 per cent are conducive for disease development. The regression equations developed revealed that amongst various weather factors, RH (eve.) and temp (max.) play crucial role in disease development. White rust, an another important disease, the prediction model revealed that average temperature of more than 15 ^{O}C and RH more than 65 per cent with intermittent rains proved most effective for the development of white rust. Similarly for downy mildew, a temperature range of 15-20^{O} C with high humidity was considered best for its progress. Leaf wetness duration of 4-6 h at 20^{O}C and 6-8 h at 15^{O} C is essential to initiate the downy mildew infection. Stag head due to mixed infection of downy mildew and white rust is favoured by a temperature of 20^{O}C with high humidity. A reduced period of sunshine (2-6 h/day) with rain fall up to 161 mm during flowering favours the stag head formation. Another serious problem in late crop is Powdery mildew. The development of this disease in Haryana is favoured when the mean temperature ranges between 16-28^{O}C, mean RH below 60 per cent and dry weather prevails especially during the months of February and March. The white stem rot or *Sclerotinia* disease of mustard was considered, as minor disease earlier has become a serious problem in Haryana. The epidemiology of *Sclerotinia* disease is dependent on several factors viz., amount of soil inoculum, soil type, soil moisture, rainfall, soil and environmental temperature, host susceptibility, plant density and cultural practices adopted. In this disease, apothecia of *Sclerotinia sclerotiorum* are produced at an optimum temperature of 15^{O}C and about 48-72 h continuous leaf wetness is required for infection by ascospores. Disease progression is favoured by high humidity (>80 %), maximum temperature up to 25^{O}C and minimum temperature of 5-12^{O}C. It has been also observed that in addition to the weather variables, varietal behaviour also plays an important role in disease development. The amount and duration of irrigation also affect the carpogenic germination and severity of the disease. In addition to weather factors, the varieties grown in the particular areas also play an important role in disease development. The rate of Alternaria blight development is faster on *Brassica juncea* and *B. campestris* group of varieties as compared to the *B. carinata*, *B. napus* and *B. alba* group of varieties. Similarly, white rust development is faster on *Brassica juncea* group of varieties as compared to the *B. campestris*, *B. carinata, B. napus* and *B. alba* group of varieties. Similarly, white rust is more serious on *B. juncea* group as compared to *B. campestris* but *vice versa* to Downy mildew. Studies conducted revealed that sometimes, the prediction models developed at one location do not fit for other areas. It indicates that data needs to be generated for quite a long period and model be tested at multiplications. Further, for greater efficiency, disease forecasting models must be developed by taking into account the variety being grown, prevalence of a particular pathotype along with microclimatic factors. Other future priority research areas of *Brassica Pathology* include: standardization of host differentials and nomenclature of pathogenic races; Identification of broad-spectrum sources of resistance, resistant loci and resistant genes in each locus; Identification of slow blighting, slow mildewing, slow rusting genes, tolerant, partial resistant, strong and weak genes with suitable combinations; Genetics of virulence and virulence spectrum; Mapping, cloning, characterization and identification of genes for resistance and virulence; Development of varieties through tissue culture or micro spore culture techniques; Biochemical basis and genetics of *Albugo-Peronospora* association. Besides this, integration of bioagents application; use of organic amendments and systemic acquired resistance (SAR) chemicals would go a long way in devising suitable IPM and IDM modules for economic management of *Brassica* diseases.

IL 01: Wheat Blast: A New Threat in South Asia and Our Preparedness

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Wheat blast caused by *Magnaporthe oryzae* pathotype *Triticum* (*MoT*) is relatively a new disease of wheat that first reported on wheat in Parana State of Brazil and since then spreading throughout many of the important wheat producing areas of Brazil and to neighboring South American countries including Bolivia, Paraguay and Argentina. Wheat blast has now become a serious constraint to wheat production in South America and currently, it affects as much as 3 million hectares causing losses of 10-100% depending on years, genotypes, planting date and environment. In 2011, this disease was reported in Princeton, KY, USA, but later it was confirmed to be caused by *Magnaporthe oryzae* pathotype Lolium (*MoL*). The first outbreak of wheat blast outside the Americas was recorded in Asia, particularly in Bangladesh during Mid-February 2016 that affected a large area (15000 hectares) in eight south-western and southern districts *viz.* Meherpur, Kushtia, Chuadanga, Jheneidah, Jessore, Pabna, Barisal and Bhola, and caused significant crop losses to small scale farmers. Average yield loss in affected field was 25-30%, but in severely infected plot 100% loss was also observed. During 2016-17, wheat blast repapered in Mid-January 2017 with low severity, but additionally spread to four more new districts *viz.* Rajshahi, Faridpur, Magura and Khulna. Overall disease affected 22 ha area with average yield losses of 5-10% which was comparatively less from 2016 incidence. This was due to late infection time and unfavorable weather conditions. This outbreak is particularly worrying as wheat blast pathogen could spread further to major wheat-producing areas in neighbouring South-Asian countries including India, thus threatening food security across the region. However, till now, there was no report of wheat blast from India particularly in West Bengal that is minor wheat producing region of the country and which is very close to the wheat blast infected areas of Bangladesh.

Wheat blast considered a spike disease, can occur on all aerial plant parts. Foliar symptoms include gray-green and water-soaked leaf lesions with dark green borders; these become light tan with necrotic borders, once they have completely expanded. Partly or completely bleached spikes (often confused with symptoms of Fusarium head blight) and blackened rachises are the most notable symptoms of wheat blast. Grains from blast-infected heads are usually small, wrinkled, deformed, and have low test weight. The most severe yield losses occur when head infections start during flowering or early grain formation. *Magnaporthe oryzae* (anamorph *Pyricularia oryzae*) is divided into host-specific sub-groups or pathotypes specialized for infecting rice (*Oryza* pathotype), wheat (*Triticum* pathotype), ryegrass (*Lolium* pathotype), foxtail millet (*Setaria* pathotype), and many other plant species. These crop-specific isolates may occasionally infect plants from other genera. Studies on the host range, sexual fertility, and fingerprinting with repetitive DNA elements have shown that isolates from wheat are distinct from other host-specific subgroups. The *MoT* population has high evolutionary potential after 30 years and is still spreading and evolving. Wheat blast populations exhibit a mixed reproductive system in which sexual reproduction is followed by the local dispersion of clones. A thorough dissection of the fungal biology, including characterization of more isolates and mating types from Bangladesh, is critical to develop durable disease management approaches.

Wheat blast is seed borne in nature besides airborne inoculum from crop residue and secondary hosts. Seed transmission is important for the spread of disease across continents. Disease development is very fast, it appears in patches and then spreading to whole plot by wind and /or rain splash. Heads are severely infected by the diseases while the canopy remains green which mimicking with the physical maturity of crop. Several gramineae and grass weeds may serve as alternative hosts, thus providing shelter in absence of main host. Rains (high RH) followed by warm temperature that coincided with heading and flowering might have played major role for disease outbreaks and spread. Breeding for Wheat Blast resistance is very difficult as genetic base is very narrow. Durable resistance sources against wheat blast are still not found and most of the cultivated wheat varieties are susceptible to blast disease. Pathogen population is very diverse, exhibits many pathotypes that could cross-infect different hosts and overcome resistance. Chemicals are only effective under medium to low disease pressure while not effective at high diseases pressure. Also, control of wheat blast by means of fungicides application is mostly effective for flag leaf but not for ear/head. Pathogen has already showed the ability to develop fungicide resistance to the Strobulirins (QoI) based fungicides (which is most effectively for controlling blast). High risk of spread to other wheat growing areas of Bangladesh and to neighbouring South-Asian countries including India because of the similar climatic conditions in these regions. In the light of probable invasion of wheat blast disease into India, there is a need to have preparedness for better management strategies.

Host resistance is an effective mean for the management of diseases like leaf rust, spot blotch and wheat blast in warmer and humid climate of South Asia. Several cultivars and advanced lines derived from the CIMMYT line ‗Milan' have shown a high level of resistance in South America. Both qualitative and quantitative genetic resistance to wheat blast have been identified in wheat, but the qualitative resistance has been validated only at the seedling stage and further studies are needed at the adult plant stage. In the USA, preliminary screening against *MoT* has identified a few entries with some tolerance to the disease. Using BSL-3 containment inoculations in the US and field tests in South America, the 2NS/2AS translocation from *Aegilops ventricosa* was observed to confer wheat blast resistance in some genetic backgrounds. Genotyping with the diagnostic markers indicated high frequencies of this translocation in most resistant varieties, including Milan. However, the 2NS/2AS-based resistance appears to be breaking down under field infections by more recently-isolated, virulent fungal populations, so additional resistance sources are urgently needed. So far, eight blast resistance genes (*Rmg1* to *Rmg8*) have been identified in wheat, of which only *Rmg2, Rmg3, Rmg7*, and *Rmg8* provide host-plant resistance against *MoT*. Such genes are required to express at seedling as well as heading stages. The corresponding avirulence genes may also be identified. It is postulated that *M. oryzae* fungal/cereal host interactions may be similar to those of the wheat rusts. Further studies on gene-for-gene reactions in rice blast systems and host resistance may provide better opportunities to combat MoT (CIMMYT, 2017).

Besides genetic resistance, optimum seeding and chemical control at heading can help reduce disease severity. Options in short duration wheat cropping seasons are limited and early sowing is required to avoid heat stress and other diseases like spot blotch. Rotation may not be a good control option, since the origin of inoculum is not known and many cereal crops (e.g. triticale, barley, maize, oat, foxtail millet) have been reported to be susceptible to *MoT*. As mentioned, the survival of the pathogen on crop stubble is an issue in Brazil, where conservation agriculture is widespread. Jute after wheat may reduce inoculum in Bangladesh. Deep ploughing and elimination of alternative hosts from the fields, thereby minimizing the presence of the fungus on the soil surface, were also recommended to reduce disease risk in the subsequent crop season, but this practice may not be cost effective nor in line with the widespread use of conservation agriculture. Wheat blast fungus can be transmitted efficiently on wheat seed and remain viable and infectious for up to 22 months. This underlines the need to use healthy seed and, possibly, fungicide treatments on seed, to restrict *MoT* establishment. Fungicides combining triazoles with strobilurins have proven effective at heading, especially in moderately resistant wheat varieties under low-to-moderate disease pressure. Fungicides have been ineffective when applied to susceptible varieties or under high disease pressure. Improper use of fungicides is costly, contaminates the environment, and may lead to fungicidal resistance in the pathogen. Increased resistance of wheat blast to strobilurin fungicides is being observed in endemic regions of South America. There have been reports on agronomic management and biological control of rice blast having potential implications for integrated management of wheat blast. Sowing date significantly affected disease incidence and yield of 14 wheat varieties in Brazil. The strain F0142 of *Chaetomium globosum* isolated from barnyard grass showed potent disease control efficacy against *M. grisea* and also wheat leaf rust. The methanol extract from stems of a tree of Chinese origin, *Catalpa ovata* exhibited potent antifungal activity against several fungal pathogens including *M. grisea.* The fungus, *Trichoderma harzianum* and bacteria *viz. Pseudomonas* spp. and *Bacillus* spp. were also observed to control rice blast. The results hold promise and warrant further investigations to integrate agents of biological origin in a wheat blast management strategy.

IL 02: Cotton Leaf Curl Multan Virus-Rajasthan Strain is Dominant Causing Outbreak of Cotton Leaf Curl Disease in Northwest India

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Cotton leaf curl disease (CLCuD) caused by whitefly (*Bemisia tabaci*) transmitted monopartite begomoviruses associated with satellite molecules is a serious constraint in cultivation of cotton in cotton growing areas in Haryana, Punjab and Rajasthan in Northwest (NW) India. The CLCuD incidence was studied for three successive years of 2013 to 2015. High CLCuD incidence of 54.1-77.5% in 2013 and 36.4-69.5% in 2015 was recorded. But in 2014, the incidence was low as low (8.9-57.8%). The year 2013 was the epidemic year in Haryana causing about 35-40% crop losses with disease incidence of 77.5-100%. Punjab was severely

(57.8%) infected but Rajasthan was less (8.9%) affected. In 2015, the highest incidence was recorded in Punjab (69.5%), but Haryana and Rajasthan had moderate incidence of 36.4 and 39.6%, respectively.

The 18 CLCuD-begomovirus isolates collected during this period from different areas of NW India were amplified by rolling circle amplification (RCA), cloned, sequenced and analysed. Eleven CLCuD isolates (Faz-14, Si-17, Rh-4, SG-14, S-9, Uf-1, Ma-14-3, Sa-3, IARI-34, IARI-42 and IARI-50) were found to be member of Cotton leaf curl Multan virus (CLCuMuV)-Rajasthan strain; one isolate S-11 was member of CLCuMuV-Faisalabad and another isolate Hi-3 was a member of CLCuMuV-Pakistan strain. Five isolates, Hi-14, Hmg-14, Si-14-1, IARI-30 and IARI-45 were members of Cotton leaf curl Multan virus (CLCuKoV)-Burewala strain. The present CLCuMuV isolates have genome lengths from 2739 to 2753nt, and CLCuKoV isolates have a genome length of 2759-2762 nt. The ORF C4 of all the CLCuMuV isolates showed similar lengths (303 nt) positioned at ~2142-2444 nt, but CLCuKoV isolates had different lengths ranges from 303 to 441 nt. Thirteen present CLCuD-begomovirus isolates were recombinant and five (SG14, Uf-1, Ma-14-3, IARI-34 and Hi-3) were non-recombinant. Eight betasatellite molecules were obtained from CLCuD-affected cotton plants were members of Cotton leaf curl Multan betasatellite (CLCuMB; AY083590) and all of them were recombinants. Nine alphasatellites were obtained in the present study, of them six were members of Cotton leaf curl Burewala-Pakistan alphasatellite (CLCuBuA-Pak; FR772090), two were *Gossypium darwinii* symptomless alphasatellites (GDSA; FJ218493) and one was Croton yellow vein mosaic alphasatellite (CrYVMoA; KC577541). Most of the alphasatellite molecules were recombinant. Our study established that recent CLCuD outbreaks in NW India predominantly associated with CLCuMuV-Rajasthan strain or mixed with CLCuKoV-Burewala, CLCuMuV-Pakistan and CLCuMuV-Faisalabad or Hisar strains with association of recombinant betasatellite CLCuMB.

OP 01: Yellow Rust Monitoring in Wheat using Remote Sensing Based Innovative Tools

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A study based on remote sensing derived indices and modelling techniques has been conducted in *tarai* region of Uttarakhand to monitor yellow rust disease in wheat. Severity estimation of yellow rust disease in wheat demands identification of the yellow rust infested crop as well as recognizing the depressions/dips in the growth profile and correlating them with the congenial weather conditions. The inter-annual deviation in mean NDVI from the normal value was used to develop spectro-meteorological model. Wheat crop was discriminated via land use and land cover map generated using ENVI-4.8 image processing software. This was achieved by means of multi-year (2005-06 to 2014-15) wheat season image of LANDSAT-TM/ETM+/OLI. For monitoring wheat field and yellow rust severity, ground truth had been conducted in the months of February and March (2013-2015). The daily weather data during the overall crop cycle was collected and converted into decadal weather data by taking decadal average for the defined parameters. The mean NDVI of wheat (the value of NDVI from 1st November to 30th April) were calculated. A remote sensing (NDVI) based spectro-meteorological model was developed using SPSS software in order to estimate/foretell the possibility of yellow rust and its possible impacts on wheat. In order to develop the integrated spectro-meteorological model, remote sensing derived decadal mean NDVI prior to dip and decadal meteorological data was correlated so as to find out a relationship with DSI (Disease Severity Index) in per cent. The spectro-meteorological models illustrates that the dependent variable (disease severity for different years) are related with the independent spectral (NDVI mean) as well as the weather variables. A total of three spectro-meteorological models have been developed for estimating DSI (%).The measured disease index ranged between -0.49% to -14.52% and the disease severity estimated from model-1 ranged from 0.36% to -13.44%. Out of the entire model, the performance of the third model was found to be the best. Model 3 uses Mean NDVI of January 3rd decade, Mean NDVI of January 2nd decade and Maximum temperature (^{0}C) of 1st decade of January. The estimated values by model 3 were found very close to the observed disease impact. The very high value of coefficient of determination (CD=0.91) suggests that spectro-meteorological model could prove to be very accurate in estimating the losses due to the disease in a very precise and timely manner.

OP 02: Population Structure of *Rhizoctonia solani* AG1IA causing Sheath Blight of Rice

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One hundred and twelve isolates of *Rhizoctonia solani* AG1IA collected from North India were studied for their morphological and molecular variability. Morphological characterization revealed considerable diversity among *R. solani* AG1IAisolates. Isolates of *R. solani* AG1IA were classified into five groups according to colonies morphological characters *viz.,* Group-1, Group-2, Group-3, Group-4 and Group-5 which contains 28, 35, 44, 3 and 2 isolates, respectively. Principal component analysis (PCA) of growth rate and number of sclerotia of *R. solani* AG1IA using XLSTAT software showed 100.00 and 86.84 per cent variation, respectively. In molecular characterization 8249 alleles were identified from the 112 isolates of *R. solani* AG1IA through analysis of the ten inter simple sequence repeat markers (ISSR1, ISSR2, ISSR5, ISSR05, ISSR6, ISSR14, ISSR15, ISSR18, ISSR19 and ISSR25). All the ten ISSR markers were polymorphic. The average number of bands per primer was 7.3 which ranged in size from 250 to 1500 bp. The primer ISSR14 produced the maximum number of polymorphic loci (1024) followed by ISSR18 (935). The Principal Component Analysis (PCA) was done using similarity indices. The first two components accounted for 67.48 per cent of the variability. There were nine clearly defined groups, while six clades (II, IV, VII, X, XIII and XV) contained single isolate only. Genetic structure of the isolates using inter simple sequence repeat primers showed high degree of polymorphism (PIC value ranging from 0.81 to 0.90).The analysis of molecular variance (AMOVA) based on ΦPT (fixation indices) values indicated that most of the genetic diversity occurred within populations (60%), while the variability among populations and among regions contributed 25 per cent and15 per cent, respectively. All the ten loci showed significant deviation from HWE in all populations. A chi-square analysis of the eight sites demonstrated that *R. solani* AG1IA frequency was significantly higher in Varanasi (chi-square=576.8, n=31, p<1.0), while least in Jaunpur (chi-square =2.0, n=2, p<0.6).

OP 03: Status and Management of European Mistletoe (*Viscum album*) Infesting Walnut (*Juglans regia*) in Kashmir valley

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In valley of Kashmir walnut is an important horticultural cash crop of farmers. Walnut trees are currently having moderate to heavy mistletoe infestation in walnut growing belts of Kashmir. Across the valley during assessment of per cent infestation, it was found 50 to 85 per cent trees are infested with the mistletoe. The botanical characters of the parasitic weed are suggestive to *Viscum album* (European mistletoe). A four year study was conducted to work out an effective management strategy. Simple removing of mistletoe spikes were not effective as they re-grow from the embedded root system from the host tissue. The spraying of weed bunches with chemicals at and around label recommended concentrations were not much effective. Pruning followed by polythene covering was effective but resulted in localized rotting of host tissue. Application of chemicals to cut stubs of mistletoe at most of the tested concentrations with ethaphan @ 10, 15, 20 and 39 percent and glyphosate at 10 % were very effective. No host injury was observed with any of the given treatments. To facilitate both cutting/removing of mistletoe spikes and simultaneous application of the effective chemical on cut stumps to prevent regrowth of mistletoe on small and large walnut trees a device Mistletoe Eradicator was designed and invented. The device Mistletoe Eradicator gave a control of 93.81 percent and 88.61 percent control as recorded after nine months of weed removal, when used along with ethaphan and glyphosate @10 percent respectively.

OP 04: Effect of SCYLV on Growth of Sugarcane (*Saccharum officinarum Linn.)* Growth

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In India four states including Uttar Pradesh SCYLV was very first reported in 2000. A field experiment has been done to assess the impact of SCYLV on agronomic characteristics of sugarcane. The characteristics of SCYLV-infected plants were compared to those of virus-free plants collected from the various zones of Uttar Pradesh; on various growth parameters of sugarcane viz. juice quality, cane yield and cane quality for varieties CoS 08272, Co 0238, CoS 8436 and CoS 767. Significant reduction in stalk weight were detected for cultivar CoS 8436 and CoS 767 (28%, and 22% respectively but not for either of the two other cultivars. In the first ratoon crop the reduction in stalk weight were recorded CoS 8436 (32 %), CoS 767 (27 %) and also for CoS 08272 (7.5%) and Co 0238 (6%). There is also significant reduction in amount and quality of cane juice was observed in CoS 8436 (11 %) and CoS 767 (9 %). There is no significant reduction in the observed parameters were observed in CoS 08272 and Co 0238, although reduction in stalk height and diameter were recorded in infected canes of these cultivars in the first ratoon.

OP 05: Effect of Elevated Levels of CO_2 on the Plant Growth and Powdery Mildew Disease of Cucumber

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A study was conducted to investigate the effect of elevated level of carbon dioxide on the plant growth, physiology, biomass production and powdery mildew disease development on cucumber. Three weeks old plants were inoculated with the powdery mildew fungus, *Sphaerotheca fuliginea* by leaf rolling method and the uninoculated plants served as control. Two days after inoculation the plants were exposed to 400, 450 and 500 ppb CO_2 for 6 hrs on alternate day during day time for 60 days of monitoring. The cucumber plants exposed to CO_2 had relatively higher photosynthetic rate, stomatal conductance, trichome length, number of leaves per plant, plant growth, biomass production and yield as compared to the ambient plants exposed to air (380 ppb CO_2). The cucumber var. Khira-3 (parthenocarpic) was found susceptible to the powdery mildew fungus and developed characteristic symptoms on leaves and stem. The fungal disease became severe on the plants exposed to 500 ppb CO_2. The elevated level of CO_2 (500 ppb) significantly enhanced the severity of the disease. The population of *S. fuliginea* in terms of CFU was also higher on the plants exposed to CO_2.

OP 06: Impact of Climate Change on the Development of Nematode Diseases in Agricultural Crops

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During the burning of fossil fuels various environmental contaminants, especially air pollutants such as CO_2, SO_2, NO_2, O_3 etc. are produced or formed later. The CO_2 is generally produced at much higher concentrations during the fossil fuel combustion. The elevated levels of CO_2 are a major cause of the global problem of climate change. By 1950s, the global mean concentration of CO_2 was around 340-350 ppm, but since 2013, ambient CO_2 level has exceeded 400 ppm concentration. Plants are the product of the environment in which they grow. Development of plant diseases also depends on the environment prevailing around the host and pathogen, and a change in the constituents may influence host susceptibility and consequently the host-parasite relationship. Nematodes, which parasitize plants, may be influenced by the environmental contaminants and climate change directly or indirectly depending on the mode of parasitism. Generally, CO_2 is non phytotoxic, rather its higher concentration may directly enhance plant biomass by reducing the photorespiration, especially in C3 plants. But enhancement in the plant biomass production, the host-parasite relationship involving nematodes may also be influenced. Research has shown that elevated level of CO_2 at 500-600ppm may promote the parasitism of ectoparasitic as well as endoparasitic nematodes. Indirectly, the climatic change may greatly influence survival, development and build-up of phytonematodes because of their obligate nature and dependence on moisture for survival.

OP 07: Relationship between Plant Height and Pod Infection of Alternaria Blight of Some Exotic and Indigenous Oleiferous *Brassica* Crop Species

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Ten cultivars of five *Brassica* crop species *viz. B. alba, B. campestis,* var. yellow sarson, *B. carinata, B. juncea* and *B. napus* were grown over a period of four years under field conditions to establish the relationship between plant height and infection of *Alternaria* blight (AB) on pods. The results revealed that there was a negative correlation between height of the plants and development of the disease on pods. For every unit increase in plant height there was a unit decrease in AB infection on pods and the regression equation was being; Y = 123.176 - 0.386X. Where Y = percent AB index on pods and X = height of plants (cm). For example *B. campestis,* var. yellow sarson cv. YST 151 which had lower height (139cm) showed higher AB index (85%) as against less AB index (10 - 23%) on *B. alba, B. carinata,* and *B. juncea* cv. Exotic which showed the height in the range of 240 - 265cm. The height of *B. napus* cv. EA was 153cm and showed AB index to the extent of 44 per cent.

OP 08: Ascospore maturity of *Venturia inaequalis* in Uttarakhand Himalayas

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In Gangotri valley of Distt. Uttarakashi defoliation in apple trees from August 15 to continued around 65 days. The leaves which is fell earliest in the season showed maximum reduction in leaf weight, leaf areas and pseusdothecial productivity. The long time survival of the leaves fallen in September, October and November was linked with the maximum production of pseudothecia though the leaves fallen in September were more conductive for the early maturity of pseudothecia and better production of ascospore then being from leaves of other two months. Host cultivar did not influence the overwintering of *V. inaequalis*, which not only affected pseudothecial productivity but also result in variable patterns of their maturity and level of ascospore emission. During the consecutive year pseudothecia matured before pink bud stage. Pseudothecia estimated to develop to stage four and five during pink bud to petal fall stage during first week of May to last week of June. The scab lesion on leaves were first (Primary infection) observed during second week of May. The secondary scab infection started from first week of June and thus overlapped with the primary infection period. Quantitative production of primary inoculums of *V. inaequalis* was affected by the orchard height, being the maximum heighest elevation from 2675 msl (Jochira), and in declining trend at 2675 msl. (Bagori) 2600 msl. (Purali) 2527 msl. (Jashpur) 2515 msl. (Shukhi) 2430 msl. and (Raithal) 1930 msl. Such as influence of orchard height on the primary inoculums was infact the outcome of weather conditions prevalent in these place during overwintering

periods. Pseudothecia matured at Jochira , Dharali and Auli at full bloom to petal fall stage , (first week of May) and Purola Naugaon, Koti-Kanasar, Tuni, Tal and Talwadi at early pink to full bloom stage (first week of March) respectively. Not only the orchard height, but also the locations (shade and sunny) within the same orchard affected the development of primary inoculums. Shady portion in orchard fevoured to better pseudothecial productivity, early maturity and higher percentage of ascospore emission. The ascospore discharged directly dependent on the prevailing atmospheric temperature and continues wetting of the infected leaves for swelling of the pseudothecia. A good soaking rain is, therefore, pre-requisite to wet the leaves. Short interval intermittent rain or even heavy dew influencing the wetting and drying of the fallen leaves also increase the rate of maturity os ascospores and their discharge. Maturity rate further increases as the temperature increase from 0 to 20^{0}C, but its development is showed down at temperature above 24^{0}C. Continue directly sunshine is lethal to spores. Ascospores releases continued till the fruit development stage (Last week of June at Harsil), Auli and second week of May at Purola-Naugaon, Tuni, Koti-kanasar and Gwaldam fruit belt) and generally took 43 to 85 days resulting in 827 to 1137^0 accumulated degree days.

OP 09: *Trichoderma harzianum* Mediated Alleviation of Drought Stress in *Oryza sativa* L. DRR-44

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Drought stress in India is major problem in around94 million hectare area causing annual loss of approximately Rs. 650,000 crore. For management of drought, the only viable alternative is to develop drought tolerant variety which is time taking process. Drought tolerant rhizospheric microorganisms play a partial role in the management of oxidative stress caused in plants due to drought. Hence, this study focuses on the isolation, screening and characterisation of *Trichoderma* spp. for management of drought. 50 *Trichoderma* isolates were isolated on *Trichoderma* selective medium from Banda, Bundelkhand (25.4530^{0}N, 78.6098^{0}E), Mirzapur (25.1337^{0}N, 82.5644^{0}E) and Chandauli (25.1794^{0}N, 83.2934^{0}E) during the months of May –June, 2016. Out of which 3 isolates showed high *in vitro* drought tolerance up to (1%) PEG. *Trichoderma* BHU-1 was identified as *T. harzianum* while *Trichoderma* BHU-23 and *Trichoderma* BHU-47 were identified as *T. bravicompactum* based on TEF-1 and 4 primers. Since, *T. bravicompactum* is a potential human pathogen and hence BHU-23and BHU-45 isolates were discarded. *Trichoderma* BHU-1 showed significant increase in plant dry weight, root length, flag leaf length and panicle length in green house trials in comparison to untreated control. Moreover, it showed significant decrease in biochemical parameters for oxidative stress caused due to drought *viz*. peroxidase, catalase, superoxide dismutase, total phenol content and free L-Proline content. Hence, this paper presents exciting possibilities of management of drought stress in plants by applications of drought tolerant plant beneficial rhizospheric microorganisms.

PP 01: Evaluation of Fluorescent *Pseudomonas* on Root Exudation Patterns in Pigeon Pea during Interactions with Biotic and Abiotic Stresses

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Plant growth-promoting rhizobacteria (PGPR) helps in plant growth and development and also protect plants from various biotic (pathogens) and abiotic stresses. A study was conducted to evaluate how *Pseudomonas* strain (AKC-O11) help plants to protect from biotic (*Fusarium udum, Macrophomina phaseolina*) as well as abiotic (NaCl) stresses. The *Pseudomonas* strain (AKC-O11) was used individually and in combination with the stresses and applied as seed bacterization in pigeonpea (variety MA-3) to see the impact on total phenol content in plant root exudates. The bacterized seeds were grown under *in vitro* conditions and after three days of germination the seedlings were exposed to biotic stresses by inoculation of the pathogens (*F. udum, M. phaseolina*) and abiotic stress (100 mM NaCl solution). Root exudates were collected at 48, 96 and 144 h after the application of stresses (biotic and abiotic). The collected root exudates were processed for qualitative and quantitative phenolic acid contents. It was observed that total phenol content was low in seeds bacterized with *Pseudomonas* strain but the concentration increased when the plants were challenged with the pathogen particularly *M. phaseolina.* A similar trend was also observed in gallic acid accumulation. The above results indicates that *Pseudomonas* strain (AKC-O11) have potential to be used as biocontrol agent that can help pigeonpea plants to combat attack of *M. phaseolina* and *F. udum* as well as the threat of salinity.

PP 02: Evaluation of Stress Tolerant Capability of *Azotobacter* Isolates

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Adversities always bring the best out of anything and in our current experiment also we crave to accomplish this feat by following the scientific instinct burning within our mind and heart. The present global scenario revolves around big fat issues like climate change, global warming, population explosion and shrinking agricultural productivity which indicate towards a stressful environment in near future. Mainly abiotic stresses like rise in temperature, pH, and salinity among others are the major ones we need to deal with. In our experiment, we tried to pursue this objective and isolated some novel *Azotobacter* strains which were tolerant to the above stresses. Screening and evaluation of 51 *Azotobacter* isolates was done for pH, high temperature and salinity tolerance capability out of which four isolates (Azo-48,Azo-137,Azo-144 and Azo-160) showed their prowess. A large number of isolates (20 isolates) showed tolerance for pH (5.0) while around 75 per cent showed temperature tolerance ability. Further analysis was carried out for studying colony characteristics, biochemical properties, nitrogen fixing capacity and phytohormones production of 15 selected isolates. Conclusively, four isolates were finally sorted out and one of them (Azo-144) exhibited high degree of salinity stress tolerance ability.

PP 03: *In vitro* Evaluation of Fungicides against Curvularia Leaf Spot of Maize

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Maize (*Zea mays* L.) is one of the most important cereal crops of the world and contributes to food security in most of the developing countries. The crop is cultivated under diverse environmental conditions spread over various agro- ecological zones and agro- climatic conditions. Therefore, the crop is prone to ubiquitous pathogens at every stage of growth.Curvularia causes significant damage to maize up to 60 per cent due to great loss of photosynthetic area of the crop. This disease is an important seed and soil borne disease prevalent mostly in subtropical and tropical regions. The fungus, *Curvularia lunata* produced small necrotic and chlorotic spots surrounded with light colored yellow halo on the leaves. Morphological macroscopic features of *C. lunatus* include brown to black colour, hairy,velvety or woolly texture, and loosely arranged and rapidly growing colonies on potato dextrose agar medium.A study has been conducted to manage the disease *in vitro* conditions by using poison food technique to observe the effect of both systemic and non-systemic fungicides on growth of *C.lunata*. Among the four systemic fungicides tested at different concentrations (5,10,20,30 and 50 ppm) respectively. Propiconazole was found highly effective in inhibiting the growth (100%) of the test fungus followed by Tebuconazole (93.33%) and Difenconazole (84.44%) while least inhibition was found in Hexaconazole (75.55%) at 50 ppm each. Among the four non-systemic fungicides tested at different concentrations (50,100,200,500 and1000 ppm), respectively, (Zineb 68% + Hexaconazole 4%) was was found highly effective in inhibiting the growth of the test fungus (100%) in laboratory conditions followed by Captan (89.53%) and Curzate M-8 (80.88%) while least inhibition was found in Zineb (59.88%) at concentration 1000 ppm each.The growth in control was 90mm.

PP 04: Use of Microbes in Disease Management and their Response under Drought Stress Condition

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Sheath blight of rice caused by *Rhizoctonia* spp. is one of the most important rice diseases worldwide including India. Depending upon the severity of the disease, it may cause 25-100 per cent yield losses. Native biocontrol agents were isolated from rice rhizospheric soil of different region and NADEP compost. Fourteen strains of *Trichoderma* were isolated and screened in vitro against *R. solani* causing sheath blight of rice through dual culture technique. Among all tested isolates under in vitro conditions *Trichoderma* RT-4, DT-11 and DT-8 showed the maximum inhibition for *R. solani* (71.48%, 67.28% and 63.89 % respectively). These strains of *Trichoderma* were also taken for checking drought tolerance in rice crop. *Trichoderma* strains when applied as seed + root dip treatment showed reduction of disease incidence. It also acted as plant growth promoter and increased the number of tillers/hill, plant height and also the yield of the crop. They also show a significant response under drought stress condition. *Trichoderma* alter the drought response including drought avoidance through morphological adaptations, drought tolerance through physiological and biochemical adaptations, and enhanced drought recovery. The root colonization by *Trichoderma* increases the growth of roots and of the entire plant, thereby increasing plant productivity. Biochemical tests for estimation of chlorophyll, phenol and proline content showed the ability of *Trichoderma* RT-4, DT-11 and DT-8 to produce high level of chlorophyll and phenol content and decreases level of proline content in *Trichoderma* treated rice crop.

PP 05: Influence of Global Solar Radiation and Related Air Temperature on the Yield of Mango

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An experiment was conducted at the Horticulture Research Station, Department of Fruit Science and Horticulture Technology, OUAT, Bhubaneswar, aiming at analyzing the relationship between the global solar radiation-related air temperature and the mango tree yield, variety Tommy Atkins, taken as reference the exhibition areas NW, SW, SE, and NE of the canopy. For production analysis five plants were considered, one chosen for installation of the temperature sensor. Portion SE of the canopy yield the highest production (59.11 kg/tree), followed by SW (55.82 kg/tree), NE (50.59 kg/tree), and NW (45.41 kg/tree). The most productive areas were the ones that received larger incidence of solar radiation and higher temperatures. Forty-one percent of the fruits presented export conditions. The average weight of the fruits varied from 0.38 to 0.44 kg for sides SE and SW, respectively. The air temperature around the fruits presented an average of 30.7°C and 24.7°C for daily and night values respectively for all portions on the canopy. Maximum values of 39.3°C and minimum values of 18.8 °C in the sides SW and NW were registered.

PP 06: Induction, Selection and Histological Studies of Iron Tolerant Callus in Peach (*Prunus persica* L. Batsch)

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The present investigation was firstly started, with callus formation in three different seasons by using leaf disc and internodal segment as an explant; secondly, to standardize different combinations and concentrations of auxin and cytokinin in MS media for fast callus initiation; thirdly, to evaluate various low chill peach varieties for their callusing ability and finally, evaluating and selecting the iron tolerant callus for further scanning electron microscopic studies. The best sterilization treatment for culture establishment and callus induction in peach was sequential exposure of explants to ethanol (70 %) 30 sec + $HgCl_2$ (0.1 %) 3 min + NaOCl (1.0 %) 3 min resulting 63.34 per cent aseptic culture with 80.00 per cent survival of explants in both leaf disc and internodal segment explant. The explants taken during spring season responded better in the terms of maximum per cent callus induction (94.44%), minimum time taken to callus initiation (13.17 days), minimum fungal (28.15 %) and bacterial (19.26 %) contamination with maximum callus culture survival (86.67 %) as compared to explants taken during summer and winter. The explants type differed in their responses for callus induction as well as callus culture survival due to their dependency upon the composition of medium, different hormonal combinations and concentration levels and culture conditions. The MS basal medium supplemented with BAP (0.5 mg/L) +2,4-D (2.0 mg/L) responded better in the terms of maximum callus induction (100 % within 33 to 34 days) with (97.78 %) survival in internodal segment explants as compared to other hormonal combinations. The various concentrations of auxin (2,4-D) and explants collected from different low chill peach varieties differed in their ability to callus induction, survival and morphology. Explants taken from variety Early Grande performed well when cultured on MS medium supplemented with BAP (0.5 mg/L) + 2,4-D (2.0 mg/L). This combination produced very good amount of compact and yellowish green or light green callus in both the explants. The different concentrations of iron in the media were effective in screening as well as selection of the tolerant type callus. Elemental analysis of iron tolerant and non-tolerant callus using Energy Dispersive Spectroscopy (EDS) revealed the mineral element composition in tolerant and non-tolerant callus. SEM studies were able to clearly demonstrate that somatic cells from Peach leaf explants/ internodal segment could develop into fully differentiated somatic embryos through the characteristic embryological patterns of differentiation.

PP 07: Bio-prospecting Fluorescent *Pseudomonas* spp. Enhance Seed Performance, Manage diseases and Ameliorate Drought Stress with Respect to their Plant Growth Promotion and Bio-control Activities in Finger Millet [*Eleusine coracana* (L.) Gaertn.]

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Due to increasing incidence of climate change, the time is opportune for identifying such crops that are able to tolerate adverse environmental conditions, without having a significant effect on their growth and development. Finger millet (*Eleusine coracana* L.) is one of them, being a hardy crop it is relatively easy to grow under stressful regimes, without hampering the net productivity. The crop finger millet is being cultivated in the Himalayan region by the traditional hill farmers as life support plant species from time immemorial. Finger millet characteristically adapt to unfavorable ecological conditions including biotic and abiotic stresses. Diseases and insects pests‘ problems have been negligible in such hardy crops. However, with changing climate, it is now known to be affected by several diseases and their lives are exposed to numerous abiotic stresses viz., drought, uncertainty in rains, flood *etc*. In view of this, a repository of 42 fluorescent *Pseudomonas* isolates was established with a particular reference for improving seed performance, management of diseases and delay in drought response of finger millet. All the isolates were morphologically and biochemically characterized. Many fluorescent pseudomonads from the repository were identified as good HCN producers, siderophore producers and P-solubilizers. *In vitro* dual culture assay revealed that out of 42 bacterial isolates, 27 isolates were antagonistic to *Sclerotium rolfsi* (ranged from 22.5 % to 83.5 %), 30 to *Rhizoctonia solani* (ranged from 21.2 % to 85.0 %), 26 to *Pyricularia grisea* (18.46 % to 80.0 %) and 25 isolates were antagonistic to *Helminthosporium nodulosum* (ranged from 36.2 % to 78.5 %), the four major pathogens causing foot rot, sheath/banded blight, blast and leaf spot diseases in finger millet respectively. In present study, fluorescent pseudomonads viz., UUHF *Psf*-4, 11, 12, 15 and 41when applied through seed bio-priming performed best in enhancing seed quality parameters *viz.,* first count, standard germination, root length, shoot length, plant height, seedling fresh weight, seedling dry weight and vigour index-I and II of finger millet plants when compared to untreated control under both *in vitro* and *in vivo* conditions. Among all the tested isolates UUHF *Psf*-4 was found to have maximum potential with respect to biocontrol and plant growth promotion activities. The present study also investigated the role of *Pseudomonas* inoculation through seed bio-priming method in alleviating deleterious effects of drought stress in finger millet. Green house study was conducted with an aim to explore the mechanism underlying plant water stress resilience in response to *Pseudomonas* inoculation. One factor was six treatments (five best isolates of *Pseudomonas viz*., UUHF *Psf*-4, 11, 12, 15 and 41 , selected on the basis of conducted different preliminary screenings and one untreated control) and other factor was five levels of drought stress viz., no stress, 6 DDS, 9 DDS, 12 DDS and 15 DDS. Measurements on membrane stability index, proline content, malondialdehyde (MDA) and phenolics content were carried out. With or without exposure to drought, seed bio-priming with *Pseudomonas* isolates promoted seedling growth, the most consistent effect being an increase in shoot and root growth. The primary direct effect of colonization was promotion of root growth, regardless of water status, and an increase in water content, which it is proposed, caused a delay in many aspects of the drought response of finger millet. Drought stress from 6 to 15 days of withholding water induced an increase in the concentration of many stress induced metabolites in finger millet leaves. *Pseudomonas* colonization caused a decrease in malondialdehyde content and an increase in phenolics concentration, proline and membrane stability index. Whereas maximum accumulation of malondialdehyde content was noticed in untreated control. Evidences presented in this research indicate that drought stress resistance in finger millet was alleviated through osmoregulation, amelioration of damage caused by ROS (Reactive Oxygen Species) and accumulation of phenolics compounds along with increased root and shoot growth. It is concluded that seed bio-priming with selected fluorescent *Pseudomonas* isolates reduced the severity of the effects of drought stress though the amelioration was better in UUHF *Psf*-4 for most of the parameters studied under present materials and conditions. This research merits attention as it additionally opens the avenues for the use of application through seed bio-priming in finger millet plants for enhanced biotic and abiotic stress tolerance.

PP 08: Epidemiology and Management of Rhizoctonia Aerial Blight of Soybean (*Glycine max* L. Merrill)

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Rhizoctonia aerial blight caused by *Rhizoctonia solani Kuhn* (teleomorph: *Thanatephorus cucumeris (Frank*) Donk is one of the most important disease of soybean in sub tropical low and foot hill regions of

Uttarakhand causing heavy yield losses. The disease was found prevalent in moderate to severe form under favourable environmental conditions in soybean growing areas. RAB under field conditions with its qualitative and ecological implications and biochemical induction of host defense. Periodic surveys were conducted during 2013 to 2015 at farmer‘s fields. The incidence of RAB ranged from 2.67 to 57.67 per cent while the severity was 3.70 to 59.66 per cent. The disease was more severe in tarai regions with maximum in Udham Singh Nagar (43.00%). Pantnagar was observed as the hot spot for RAB having maximum disease incidence and severity of 57.67 and 59.66 per cent, respectively. Out of the 16 popular cultivars screened against *R. solani* under epiphytotic conditions, only Pk-472 (Disease severity index= 13.65%; r= 0.061 unit/day; AUDPC= 133.67) and PK-262 (Disease severity index= 15.52%; r= 0.044 unit/day; AUDPC= 147.81) exhibited moderate resistance while JS-7244, JS-72-220, JS-7105, Bragg and Monetta cultivars were found moderately susceptible. Weather conditions during September and October were most favourable for the disease development. Disease progression on RAB was recorded during the 1st week of Sept on susceptible cultivars which gradually progressed up to the end of Oct but slowly declined later on. Maximum progression was observed from pod initiation to full pod stage (60-74 days) of crop. The PDI on all varieties exhibited negative correlation with temperature and humidity during 2013 to 2015, whereas it showed a positive correlation with rainfall and sunshine under field conditions. The data on disease progression in relation to corresponding weather variables was subjected to step-wise multiple regression analysis with max temperature, morning relative humidity, rainfall and sunshine being significant contributors in prediction of disease index. Using these prediction equations for different cultivars, it is now possible to predict the disease index in advance, providing sufficient time for contingency plan with plant protection inputs to restrict and manage RAB growth and development. Pencycuron, Tebuconazole, Hexaconazole and Pyraclostrobin were found effective in completely inhibiting mycelial growth of *R. solani* at 10 ppm and 50 ppm while antagonists *T. harzianum* caused maximum 64.9 per cent inhibition. In field experiments, two sprays of Pyraclostrobin, Fluopyram and Pencycuron significantly reduced the disease with 53.35, 48.72 and 49.47 per cent reduction in disease and 43.56, 43.12 and 42.87 per cent increase in soybean seed yield. Commercial formulations of antagonists were not so effective in managing RAB. For pooled data of both years the observed per cent yield loss varied from 2.32 to 31.98 per cent. Linear and multiple regression crop yield loss model were also developed. The models explained more accurately the yield loss with disease index in 1:1 relationship. Cost benefit ratio of the treatment Pencycuron (0.07:1) was superior followed by Hexaconazole (0.08:1), Pyraclostrobin (0.12:1) and Chlorothalonil (0.13:1). Maximum oil content was recorded in soybean plants treated with Azoxystrobin (21.60%) followed by Pyraclostrobin (21.39%) and Difenoconazole (21.06%). Oil content increase in treatments may be attributed to enhanced seed health due to reduced disease pressure. Fungicides and antagonists sprays have no significante in soybean protein content which varied between 37.37-37.95 per cent, highest being in Pyraclostrobin (37.95%) and Myclobutanil (37.95%). Seed samples treated with Myclobutanil were found to have 0.21ppm residue while Axozystrobin treated had 0.0071 ppm residue and rest of the fungicides were below detection limit. All fungicides tested were found to be below the permissible MRL prescribed for soybean seeds. Elicitor compounds including chemicals, hormones and bioagents increased the content of defense compounds such as H_2O_2, APX, POD, PPO, SOD and PAL while the endogenous enzyme content decreased post pathogen inoculation. Elicitor compounds were effective in controlling RAB under glass house conditions. Bioagents were more responsive to elicitors compared to other treatments. Above information will have wider practical applicability in an integrated disease management programme. The future thrust and follow-up research efforts may aim to study the effect of weather changes and need based chemicals on plant disease control under field conditions. This will provide an opportunity for eco-friendly disease management in soybean.

PP 09: Disease Assessment of Mango Anthracnose

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Anthracnose is caused by *Colletotrichum gloeosporioides* is a serious disease of mango. Phytopathometry is the quantitive study of the suffering plant and a major tool for developing resistant varieties. The objective is to evaluate the disease incidence and per cent disease index (PDI) for developing the resistant cultivars in mango breeding programmers. The field trials will be laid out in twenty cultivars with three replications in a randomized block design at Horticulture Research Centre (HRC), Pattharchatta, G.B. Pant University of Agriculture and Technology, Pantnagar for consecutive two years. The study will be carried out to find incidence and severity of disease development within the selected 20 varieties of mango. The incidence of disease was more in the commercially successful variety like Dashehari (11.22%) and was minimum in local variety Redtotapuri (4.35%) in both the years. The maximum PDI was found in cultivar Dashehari (1.77%), while minimum PDI was observed in cultivar Redtotapuri (0.99%) in both the years. The conclusion was that the cultivar Dashehari was found to be more susceptible, however the local cultivar Redtotapuri is found to be least susceptible which indicated the role of local cultivar like Redtotapuri in incorporating anthracnose resistance in the development of improved mango cultivars/ varieties in future.

PP 10: Enhancing Drought Tolerance in Wheat through Seed Biopriming with *Trichoderma harzianum* isolates

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Wheat (*Triticum aestivum*) crop is very sensitive to water deficit at any crop growth stage. Studies were conducted to investigate whether seed biopriming through some of the drought tolerant isolates of *Trichoderma harzianum* induces drought tolerance in wheat variety DBW-17or not. Direct effect of seed bioprimingin wheat, which was apparently noticed, was promotion of root growth and an increase in water content, which probably manifested in a delay in many aspects of the drought response of wheat. Biopriming with *Trichoderma*, delayed drought response through several changes like stomatal conductance, net photosynthesis, chlorophyll content and greenness of plants. Findings clearly indicated that treating wheat seed with *T. harzianum* strains like SV-21, SV-28, SV-26, IRRI-1, SV-03 and SV-30, enhances speed of wheat seed germination as the seed treated with SV-21 germinated faster and more uniformly as compared to those which remained untreated. Also, seedling growth was quite faster due to all isolates with a maximum by isolate SV-21.This isolate was best performer in stimulating germination and also increasing plant height of wheat after sowing. Treated seeds germinated at 5 days after sowing whereas untreated (control) seeds could germinate at 7 days after showing. Similarly, shoot lenght of wheat was found maximum due to above mentioned treatment *i.e.* biopriming with SV-21. Value of shoot lenght due to biopriming with all isolates was 29.16, 28.33, 28.13, 27.33, 26.96 and

26.73 cm as compared to25.54 cm in untreated in 42 days old plants. These isolates have also been found effective in increasing root length. Biochemical analysis of plants has revealed that all the treatments significantly increased the chlorophyll content in the treated plants as compared to (control). Chlorophyll of wheat was found highest due to. SV-21.Value of chlorophyll content due to various isolates was 39.03, 37.73, 35.8, 35.13, 35.03, and 31.06 as compared to22.56 in untreated plants at 42 days of age.

PP 11: Influence of Weather Factors on Development of Wilt (*Fusarium oxysporum* f.sp. *psidii*) of Guava in Tarai Regions of Uttarakhand

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Wilt is one of soil borne disease and has spread widely to different parts of India. The disease is attaining an alarming situation and may become a limiting factor for guava cultivation in Tarai region of Uttarakhand, U.P. and Bihar. Only one prominent fungi, *Fusarium oxysporum* (sheld.) Snyd. and Hans. f.sp. *psidii* has been consistently isolated from the orchards of Pantnagar. Periodic surveys were conducted during 2014 in the farmers orchards of Tarai region of Uttarakhand. During 2014, 112 orchards were surveyed in the two district viz., Udham Singh Nagar and Nainital. The wilt complex was observed to be present in partial to complete wilting. The average disease incidence and index were ranged between 4 to 31 per cent and 1.2 to 31.0 per cent. Pathogenicity tests were performed in pot experiments to confirm the causal agent of the disease. Progressive natural wilting of guava plants in three popular cultivars viz., Pant Prabhat, Lalita and Shweta at HRC, Pantnagar, throughout the year at regular weekly intervals indicated that chlorosis, partial and complete wilting starts from last week of June, August which increases during September and maximum wilting takes place during the months of October – November. Higher relative humidity (58-92%), soil temperature (16.38-39.83 ΊC), atmospheric temperature (21.3-33.9 ΊC) with 2-6 rainy days were conducive for the development of wilt in guava plants. Simple correlation coefficients between disease severity and RH (0.653, 0.675, 0.713) was found to be highly significant and positive while average soil temperature (-0.705, -0.624, -0.664), total rainfall (-0.368,-0.357,-0.360) as well as no. of rainy days (-0.379,-0.299,-0.355) also showed significant negative correlation. Regression equation between disease severity and environmental factors explained 90.95, 94.03 and 92.79 per cent change in the disease severity to be due to above mentioned environmental factors.

PP 12: Evaluation of Systemic and Non Systemic Fungicide against *Rhizoctonia solani* causing Web Blight in Urdbean [*Vigna mungo* (L.) Hepper]

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Pulses are important source of dietary protein, and have unique property of maintaining and restoring soil fertility through biological nitrogen fixation. Among the pulse crops urdbean [*Vigna mungo*

(L.) Hepper] is one of the most important pulse of the *'vigna'* group which is used for various purposes. Web blight caused by *Rhizoctonia solani* Kóhn is one of the most important fungal disease of urdbean causing heavy yield losses up to 20-30 %.The fungus infects all above ground parts of the plant i.e. leaves, petioles, stem and pods but most destructive symptom is on foliage. Considering the importance of the disease in the *'Tarai* region, present investigations were carried out to find out the best possible fungicide for management of web blight of urdbean. Field experiment was carried out to find the most efficient systemic and non systemic fungicide for management of web blight of urdbean. Five systemic fungicides *viz*., propiconazole, hexaconazole, carboxin, ridomil and carbendazim were screened at 5.0, 10.0, 15.0 and 20.0ppm concentrations whereas five non-systemic fungicides *viz*., captan, thiram, propineb, mancozeb and zineb were screened at 25.0, 50.0, 100.0 and 400.0 ppm concentrations against *R. solani* for their antifungal activity. Among systemic fungicides Carbendazim and propiconazole were found highly effective in reducing the radial growth of *R. Solani* 93.33% where as ridomil was found less effective. Mancozeb and propineb were found highly effective as non systemic fungicides in reducing the radial growth of *R. Solani* 91.47% and 90.47% respectively at 400ppm. Based on effectiveness of fungicides in vitro, they were further tested under *in vivo* conditions. Foliar spray of carbendazim was observed superior over other treatments giving 85.77% reduction in disease severity, maximum grain yield (1590.45 kg/ha) and test weight (25.65 g) followed by propiconazole.

PP 13: Impact of Growth Media on Enhancement of Sporulation and Determination of Virulence of *Alternaria solani* isolates Infecting Tomato

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To study the effect media, incubation condition and calcium carbonate ($CaCO_3$) amendment on mycelia growth and sporulation of *A. solani* 13 different media were examined under three different incubation conditions. Potato dextrose agar, phytone agar and Czapeck Dox agar supported maximum mycelial growth after 10 days of incubation at 25±1°C temperature. Incubation condition T_2 (One week continuous florescent light at 25±1°C followed by one week period dark at 21±1°C) supported sporulation in all isolates of *A. solani*. Moreover, pearl millet-$CaCO_3$ agar media supported sporulation in all *A. solani* isolates and found to be the best medium supporting sporulation in *A. solani*. However, all the $CaCO_3$ supplemented media (HPDA+$CaCO_3$, $CaCO_3$ agar and pearl millet-$CaCO_3$) supported sporulation in *A. solani.* Further a random isolate As-4 cultured under two growth condition *viz.,* (i) pearl millet+ $CaCO_3$ media and incubated under T_2 incubation condition-designated as isolate As-P and (ii) PDA and incubated for 14 days under alternate light and dark condition at 25°C-designated as isolate As-Q. Effect of these growth conditions on virulence of *A. solani* were evaluated by inoculating both the isolate As-P and As-Q on different tomato germplasm/cultivar under glasshouse condition. EC-519795 and Pant Bahar were highly susceptible and moderately susceptible to As-P and As-Q respectively. Tomato entries Shalimar 2, Palam Pink and Arka Saurabh showed susceptible reaction against As-P while moderately susceptible reaction against As-Q. Roma, Arka Vikas, EC-519770, Palam Pride and Arka Samrat appeared same against both the isolates. Results of glasshouse experiment indicated that *A.solani* isolate As-P more virulent than isolate As-Q.

PP 14: Effect of Temperature Levels on Conidial Germination of *Erysiphae cichoracearum* an Incitant of Powdery Mildew in Cucumber

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The effect of different temperature levels on conidial germination of *E. cichoracearum* was studied and results revealed that effect of different temperature regimes on the conidial germination of fungus was significant. Maximum per cent conidial germination of 48.52 per cent was observed at 25^0C, and at 30^0C observed 46.12 per cent which are on par with each other from temperature levels tested. This was followed by 35^0C and 20^0C at which the conidial germination was 29.30 per cent and 21.15 per cent, respectively.

PP 15: Survey of Powdery Mildew in Major Cucumber Growing Areas of Northern Karnataka

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Powdery mildew is very important foliar disease of cucumber among the major cucurbits growing areas of Karnataka which results in huge economic loss. Disease first appear on the leaves thirty days after sowing and continue to produce white mycelia growth on various aerial plant parts up to the harvest. Survey results revealed that the disease severity of powdery mildew in all the cucumber growing areas of northern Karnataka is low to severe (10.25 to 63.08 %). The disease severity was varied among different stage of the crop and varieties grown but there was no significant difference among the cultivation practices. Maximum mean disease severity was recorded in Dharwad district 33.06 per cent, whereas minimum disease severity was recorded in Belagavi with 27.21 per cent.

PP 16: Effect of Different Relative Humidity Levels on Conidial Germination of *Erysiphae cichoracearum* an Incitant of Powdery Mildew of Cucumber

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The effect of different relative humidity levels on spore germination of *E. cichoracearum* was studied and results revealed that effect of different relative humidity regimes on theconidial germination of fungus was significant. Maximum conidial germination 46.72 per cent was observed at 85 per cent relative humidity, which was significantly superior to other treatments. Relative humidity of 90 percent was the next best treatment with 41.86 per cent conidial germination. The conidial germination of 41.61 per cent and 31.62 per cent was observed at 80 per cent and 95 per cent relative humidity, respectively which varied significantly among the treatments. However conidial germination was least of 16.31 per cent was at 65 per cent relative humidity.

PP 17: Evaluation of Inoculation Methods and Standardization of Cell Concentration in Inoculum of *Erwinia Chrysanthemi* for Creating Artificial Epidemic in Stalk Rot of Sorghum.

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Stalk rot caused by *Erwinia chrysanthemi* (*Ech.*) is one of the most destructive diseases of sorghum crop. The bacterium was isolated from infected sorghum plants collected from livestock research centre, G.B. Pant University of Agriculture and Technology, Pantnagar, India. Experiments were conducted in glasshouse and field using healthy seeds of susceptible sorghum cultivar SPV 2128. Bacterial cell suspension was prepared from 24 h old culture of *Ech* and adjusted to $1X10^6$ cfu/ml, $1X10^7$ cfu/ml and $1X10^8$ cfu/ml by adding sterilized distilled water and 0.7% (v/v) of tween-40 (surfactant). Twenty one days old plants were inoculated with this bacterial suspension between 5-7 pm, by four different methods *viz.* leaf whorl inoculation, stem injection, tooth-pick and root tip cut and dip. For control only sterilized water was used. Of the above four methods tested in glasshouse; leaf whorl inoculation, stem injection and root tip cut and dip which showed significant result, was further used for field experimentation. Leaf whorl inoculated plants showed curling, yellowing and wilting of leaves, apical leaves gives ashy appearance and brown necrotic leaf spots after 7 days of inoculation. In stem injection, the rotting started at point of injection of bacterial suspension usually 5 days after inoculation and it expand in both the direction. In root tip cut and dip method the symptom appeared usually 3-5 days of inoculation as rotting of basal portion of stem with sudden collapse of entire plant. Tooth-pick method showed symptoms about 10 days after inoculation. Maximum disease severity was observed in root tip cut and dip method at 1×10^8 cfu/ml followed by leaf whorl inoculation method at 1×10^8 cfu/ml and stem injection at 1×10^8 cfu/ml. Among inoculation methods root tip cut and dip method was found best and stem injection method least effective in creating artificial epidemic in field while in glasshouse tooth-pick method was least effective. Within concentration 1×10^8 cfu/ml developed maximum disease severity for each inoculation method whereas 1×10^6 cfu/ml developed minimum disease severity. The increase in disease severity was more when concentration was increased from 1×10^6 to 1×10^7 cfu/ml as compared to those from 1×10^7 to 1×10^8 cfu/ml. The glasshouse and field experimentation both showed root tip cut dip method to be best of all four methods and the optimum infection was reported at $1X10^7$ cfu/ml.

PP 18: Beneficial Microorganisms Alleviate Abiotic Stress Conditions

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Abiotic stresses are the foremost limiting factors in agriculture. It is affects plants in different ways and which causes reduction in crop productivity. In order to increase crop productivity it becomes necessary to evolve efficient technologies for abiotic stress management. Microorganisms could play a significant role in this respect, if we can exploit their unique properties of tolerance to extremities, their ubiquity, genetic diversity, their interaction with crop plants. Soil microorganisms, if exploited can serve in agriculture for increasing and maintaining crop productivity. Beneficial soil microorganisms can promote growth and increase productivity through mechanisms such as nutrient mobilization, hormone secretion and disease suppression. Besides influencing the physico-chemical properties of rhizospheric soil through production of exopolysaccharides and formation of biofilm, microorganisms can also influence higher plants response to abiotic stresses like drought, chilling injury, salinity, metal toxicity and high temperature, through different mechanisms like induction of osmo-protectants and heat shock proteins etc. in plant cells. Many soil microorganisms such as *Trichoderma harzianum, Pseudomonas syringae P. fluorescens* and *Bacillus* sp. (tolerance to salinity and drought), *B. polymyxa*, *P. alacaligenes* (tolerance to nutrient deficiency), Arbuscular mycorrhizal fungi *i.e. Glomus mosseae*, *G. etunicatum*, *G. intraradices*, *G. fasciculatum*, *G. macrocarpum*, *G.coronatum etc.,* (enhancing nutrient uptake) help in alleviating abiotic stresses.

PP 19: Studies on Incidence and Epidemiology of Viral Diseases of Potato in Madhya Pradesh

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Potato (*Solanum tuberosum* L.) is staple vegetable food crop in world as well as in India. Potato suffered from many pathogens such as fungal, bacterial, and viral etc. but at present scenario the viral diseases became a major problem for the potato seed growers. The survey has been made among the 8 districts, 14 villages and 64 fields of Madhya Pradesh during the Rabi 2015-16. Incidence was recorded at Seoni, Chhindwara, Indore, Ujjain, Ratlam and Shajapur for the viral diseases *i.e.* common mosaic, leaf roll, stem necrosis. Common mosaic was more prevalent at Indore (5-19%), leaf roll incidence more at Seoni (2-22%) and stem necrosis highest at Chhindwara (5-39%). Study also made on the epidemiology of these viral diseases during Rabi 2015-16 at seed production unit Jabalpur. As both common mosaic and leaf roll shows highest incidence at second fortnight of November 2015 with 15% incidence each observed at seed production unit, Jabalpur. During this time period average temperature was 21.6^{o}C and relative humidity was 73.8% recorded. Due to this congenial environment conditions virus shows more vigorously expressed at surveyed places.

PP 20: Plant Growth Promoting Bio-Inoculants for Enhancing Drought Stress Tolerance in Rice (*Oryza sativa* L.)

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Water stress frequently encountered by rice crop at different stages of its life cycle which results a huge loss of productivity. Although the roles of PGPR in plant growth promotion, nutrient management, and disease control are well known, their roles in the management of abiotic stress such as drought has only recently gained importance. The present research was undertaken in order to study a microbial based approach to enhance water deficit stress tolerance in rice. Two microbial isolates *Gluconacetobacter diazotrophicus and Bacillus subtilis* were characterized by *in vitro* biochemical tests, Polyethylene glycol induced water stress, root colonization ability by hydroponic technique. Simultaneously pot experiment was also conducted to enhance the effect of single and combined inoculation of bio-inoculants to determine water stress tolerance and yield of rice under stress and non-stress condition. Both the inoculants were found to produce IAA, ACC and Exopolysaccharide. The root colonizing ability of both the bacterial cultures were assessed by Scanning Electron Microscopy and found to colonize the surface and interior regions of the rice root. Present finding clearly indicates that application of *G. diazotrophicus* and *B. subtilis* significantly improves plant growth parameters in both stress and non-stress condition.

PP 21: Germplasm Screening for Heat Tolerance under Different Sowing Conditions in Bread Wheat (*Triticum aestivum* L. Em. Thell.)

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The present investigation was carried out with 32 diverse genotypes of bread wheat in completely randomized block design with three replications at NEBCRC, GBPUAT Pantnagar for the screening of wheat genotypes for heat tolerance under three environments viz. timely sown (stress free), late sown (stress) & very late sown (stress) conditions. Analysis of variance indicated the significant variation among the treatments for different characters in all the sowings. Among the morphological characters, plot yield exhibited highest range of variation while among physiological traits, relative water content exhibited the highest range of variation. On the basis of heat susceptibility index under late sown condition, the nineteen genotypes were found heat tolerant & rest genotypes were found moderately heat tolerant. Under very late sown condition, the five genotypes were found heat tolerant while rest genotypes were found to be moderately heat tolerant &moderately heat susceptible. The five genotypes HD-2967, IC-118737, CHIRYA-3,CUS/79/PRULLA & BWL-0814were found tolerant to heat stress under both stress conditions. These five genotypes performed very well in all the three sowing conditions. These findings may be helpful in exploiting these heat stress tolerant genotypes in the future breeding programme for developing the stable genotypes for heat tolerance as donor parents.

PP 22: Management of Sheath Blight of Rice caused by *Rhizoctonia solani* through Novel Fungicide Combination CCP- 333 SC

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India has maximum area under rice cultivation at world level but productivity is low which is attributed to several factors like drought, lack of inputs, unfavorable weather conditions, lack of world standards suitable

varieties, poor seed quality, less availability of agro-chemicals and socio-economic problems, non-adoption of modern production technologies and the most important are the losses caused by weeds, insect-pests and diseases. The rice crop suffers from many diseases caused by fungi, bacteria, nematodes, viruses and nutritional deficiencies. Among these, sheath blight caused by *Rhizoctonia solani* is one of the most important disease prevailing all across the paddy cultivation areas of India. This disease cause yield loss up to 69% and appears at maximum tillering stage. The disease is soil-borne in nature. The sclerotia produced by the fungus is the main source of survival of this pathogen. Once infection occurs, secondary spread take place through direct contact. For the management of this disease KRDC scientist have evaluated novel pre mix combination fungicide coded as CCP-333 in Suspension concentrate (SC). CCP-333 is the mixture of 2 different groups of fungicide, one belonging to trizole group and second component of this mixture belongs to strobilurins each with different nature of mode of action. Recommended as foliar sprays under field conditions. This pre mix fungicide was found to be effective in reducing Sheath blight intensity and resulted in highest grain yield as compared to recommended fungicides. The recommended dose for the disease management is 200-250 ml per acre. This novel fungicide mixture with good and stable suspension concentrate (SC) formulation has become excellent alternatives to the currently available chemical tools for field level inhibition of this severe biotic threat of rice.

PP 23: Investigation on Temporal Variation in Population of *Lipaphis erysimi* (Kalt.) for its Judicious Management on *Brassica rapa*

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Lipaphis erysimi (Kalt.) has gained the status of key pest causing significant yield loss to the range of 9 to 99%. A proper combination of environment and host can go a long way in minimizing the attack of *L. erysimi* by escaping it through alternation in date of sowing of the crop. The present investigation was undertaken for study the seasonal incidence of mustard aphid on *Brassica rapa* cv. BSH-1 with respect to sowing dates so as to manage the aphid at lower cost and help farmers in achieving good harvest. The general trend showed that the mustard aphid was quite active during December, January and February infesting the flowering stage with respect to different sowing dates, but later decreased significantly due to gradual increment the temperature. The aphid population on *B. rapa* cv. BSH-1 in 3rd Oct, 18th Oct, 3rd Nov,18th Nov, and 3rd Dec sowing dates were observed as 137.3 185.8, 186.5 261.8, 300.5 and 163.3, 164.5, 163.8, 184.0 and 256.3, respectively during 2015-16 and 2016-17. The gradual increment in the aphid population was recorded with the delaying in sowing date. Thus it was concluded that mustard crop sown in first fortnight of October may escape from the damage of the mustard aphid.

PP 24: Comparative Efficacy of Commercial Fungicides on Cercospora Leaf Spot of Chilli (*Capsicum annuum* L.) incited by *Cercospora capsici*

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Chilli (*Capsicum annuum* L.) is an indispensable condiment as well as vegetable in every household in India. It belongs to nightshade family Solanaceae. India is meeting approximately 25%of the world's chilli requirement and considered to be leader in chilli export followed by China with 24%. In India, Andhra Pradesh leads in both the land used for cultivation (20%) and production (55%). Beside different pests; various fungal, bacterial and viral disease pathogens are serious threat for chilli. Generally, fungal diseases cause more damage than diseases caused by other pathogens. Cercospora leaf spot, an important disease of chilli (*Capsicum annuum*), is caused by the fungus *Cercospora capsici* Heald & F. A. Wolf. It affects the entire plant canopy, especially the leaves. An extensive research was conducted during 2015-16 at the Vegetable section, Kalyanpur, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. The highly susceptible variety of chilli (G-4) was taken with 10 treatments and three replications. Chlorothalonil (0.2%), Topsin-M (0.2%) and Captafol (0.2%) were found most effective against the pathogen. Treatment one, three subsequent foliar sprays of Chlorothalonil @ (0.2%) at an interval of 12 days from 45 days after transplanting gave an average minimum disease intensity (8.40%) and maximum ripe fruit yield (29.25q/ha) in crop season year 2015-16.

PP 25: Distribution and Incidence of Rhizoctonia Aerial Blight in a Mixed Cultivar of Soybean and Relationship to Disease Severity

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Soybean (*Glycine max* L. Merrill) is one of the most important oilseed crops in Tarai region of Uttarakhand. Severe attack of *Rhizoctonia* aerial blight (*Rhizoctonia solani* Kóhn) is responsible for huge yield losses every year. *Rhizoctonia* aerial blight epidemics can be readily described in terms of the disease triangle. The role of different environmental factors, viz., temperature, relative humidity, leaf wetness, sunshine and rainfall were studied in relation to disease development. The present experiment was conducted during the season 2017 to determine a simplified assessment procedure by which Rhizoctonia aerial blight severity/ index could be predicted from incidence data and develop incidence-severity relationship in soybean cultivars under Pantnagar conditions. The observations on incidence of disease on the foliage were recorded using 0-9 scale. The initial pathogen population is a key primary determinant in the development of aerial blight epidemic. The development of aerial blight on sixteen popular cultivars of soybean, viz., JS-7244, JS-7546, JS-7105, JS-72-280, PK-262, PK-472, MACS-58, JS-93-05, Pb-1, Bragg, Monetta, KHSb-2, NRC-7, VLS-58, JS-335 and Shivalik were studied to determine incidence-severity relationship. The disease was confined primarily to the lower leaves early in the season and progressed to the other leaves later and it has covered whole plant. The use of percentage scales and keys of visual disease severity, and disease incidence are considered valid approaches for disease assessment. The relationship between increase in incidence of Rhizoctonia aerial blight in relation to severity can be established either by making sequential records in one more than ten plants/ cultivar during the progress of an epidemic or by assessing many plants with different amounts of disease at one point of time. Disease incidence started in 2nd week of September with maximum temperature of 35°*C* and highest incidence was recorded in 3rd week of October with temperature 33.5°*C*. Highest incidence was observed in Shivalik and minimum in MACS-58. Thus, from the above analysis, it is evident that a combination of several factors like the presence of susceptible host, virulent pathogen, and congenial environment for disease development during receptive stage of soybean, was responsible for the incidence of the Rhizoctonia aerial blight on soybean in Pantnagar during 2017crop seasons.

PP 26: Effect of Temperature on Mycelial Growth and Sclerotia Formation in *Sclerotium oryzae*

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Sclerotia are important resting bodies of *Sclerotium oryzae* in rice crop. Temperature plays a very important role in the formation of sclerotial bodies. Therefore, we studied the effect of temperatures starting from 20ΊC, 25ΊC, 30ΊC,35ΊC, 40ΊC and 45ΊC to better understand the wide range of temperature that exist during different seasons and localities on sclerotial formation. The maximum radial growth during the study period was recorded in 30Ί C and 35Ί C followed by 25, 40, 20 and 45Ί C. Temperatures 30Ί C and 35Ί C were highly favorable for the growth of the fungus.

PP 27: Effect of Initial Population Densities of Root-Knot Nematode (*Meloidogyne Javanica*), on Different Growth Parameters of Mung Bean (*Vigna radiata* L.)

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The two experiments have been conducted in steam-sterilized soil in one kg capacity plastic pots in glasshouse, the pathogenicity of *M. javanica* on two mung bean (*Vigna radiate* L.) cultivars Pant mung-5 and Pant mung-8 was investigated in Department of Plant Pathology, College of Agriculture, Pantnagar. 10 days after seedling emergence, the second stage larvae of *Meloidogyne javanica* were inoculated @ 100, 250, 500, 1000, 2000, 4000 and 8000 larvae per kg soil by removing upper soil. Un-inoculated pots were treated as control. Each treatment was replicated three times. 65 days after of nematode inoculation, the observations were recorded on root length, shoot length, fresh root weight, fresh shoot weight, dry weight of root and shoot, number of knots and final population of nematodes. Results showed that an inoculum level of 500 J2 per kg soil and above significantly reduced the various plant growth parameters (shoot length, root length, fresh shoot weight, fresh root weight, dry shoot weight, dry root weight and number of gall formation) over uninoculated control and the maximum reduction was obtained at the inoculums level of 8000 larvae of nematode per kg soil. Increase in the inoculum levels i.e. 100, 250, 500, 1000, 2000, 4000, and 8000 larvae of nematode per kg soil decrease the growth parameter of mung bean, respectively.

PP 28: Virulence and Cross Infectivity of *Rhizoctonia Solani* in Rice and Maize

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Rice (*Oryza sativa* L.) and Maize *(Zea mays)* is a graminaceous crop and they are one of the most important staple food for Asian and Europian countries. Sheath Blight of rice and Banded leaf and sheath blight of maize caused by *Rhizoctonia solani* (teleomorph: *Thanatephorus cucumeris*), is a complex pathogen and worldwide in distribution, a very destructive disease under favorable weather conditions causes substantial yield losses. Yield losses due to this disease are estimated to range from 1.2 to 69 per cent in rice and 23.9 to 31.9 per cent in maize. Virulence and cross infectivity of the pathogen was studied in rice and maize crops under glasshouse condition at GBPUAT, Pantnagar, Uttarakhand, India. It was found that *Rhizoctonia solani* isolate of maize was more aggressive and virulent and causes disease severity of about 30.56 per cent than the *Rhizoctonia solani* isolates of rice.

PP 29: Aphid: A Potential Vector of Plant Viruses

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Insects are being considered as the most efficient vector for the transmission of plant viruses, besides economic damage to the crops. Among the insects, Homopterans are most promising vector of plant viruses. However, Aphids transmitted up to 275 known viruses till date and about 150 potential vectors of Aphids transmit some genera of viruses in non-persistent/stylet borne, semi persistent or persistent mode. Aphids feeding mechanism and virus transmission patterns are studied only in few general species like *Myzus persicae* on major crops like tobacco and legumes and thus limit the underlying unexplored part of the vector-pathogen relationship. Semipersistence and Bimodal transmission of the virion by the insect, and how Tobacco Mosaic Virus that are easily available in sap at high concentration cannot be transmitted through Aphid‘s probing are left with no adequate explanation. Several hypotheses prove that transmission of viruses can be reduced by reducing transmission rate such as treatment of formalin made failure in probing. Incorporation of several genes showing antibiosis against aphid reduces the transmission rate. Arabidopsis MPL1 (MYZUS PERSICAE-INDUCED LIPASE1) gene are reported to show defence against the green peach aphid (*Myzus persicae* Sulzer) by restricting reproduction.

Session 05:

Integrated Management of Phytopathogens, Plant Clinics and Extension Plant Pathology

LP 01: Plant Quarantine for Regulating Transboundary Movement of | Plant Genetic Resources

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Plant quarantine is a legislative measure to regulate the introduction of planting material, plant products, soil and living organisms, etc. in order to prevent inadvertent introduction of pests. With the advent of WTO in 1995 and to comply with the obligations under its Agreement on Application of Sanitary and Phytosanitary Measures, the national regulatory mechanism has been revised as the Plant Quarantine (Regulation of Import into India) Order 2003 to meet the challenges of liberalized trade. Under this Order, for import of commodities, the additional declarations for freedom from quarantine pests is based on a standardised pest risk analysis. Additional declarations have been specified for import of >100 agricultural commodities with specific lists of >600 quarantine pests and 31 weed species. Several amendments of the PQ Order 2003 have been notifies to the WTO revising quarantine pest lists; recognition of irradiation and cold treatments; pest fee areas; revising the lists of crops under Schedule VI and VII to include 820 and 248 crops/ commodities, respectively. Under the PQ Order, ICAR-National Bureau of Plant Genetic Resources (ICAR-NBPGR) has been authorised to issue Import Permit and to undertake quarantine processing of all imported plant genetic resources (PGR) including transgenics and for issue of Phytosanitary Certificate for material meant for export. The Division of Plant Quarantine at ICAR-NBPGR has developed procedures for systematic and step-wise quarantine processing for pest diagnostics, salvaging and containment to ensure pest-free exchange of planting material and transparency in international exchange. Critical quarantine examination of PGR have resulted in interception of several seed-borne fungi, bacteria, viruses, insect pests, nematodes and weeds. Some of these are not yet reported from India, if reported have a limited distribution; have a wide host range and/or cause great economic losses or have more virulent/ large number of physiological races, etc. Presently, since exchange of germplasm has become more difficult under the Convention on Biological Diversity, all attempts are made to salvage the germplasm. All infested/ infected/ contaminated samples are either salvaged prior to release or incinerated depending on the category of pest intercepted. Over the past forty years, a total of 64 exotic pests including fungi (5), viruses (17), insects/ mites (24) and weeds (16) of great quarantine significance to the country have been intercepted. If any of these pests were not intercepted and escaped, they could have been introduced into the country and established, as favourable environmental conditions are available in India and could have caused significant losses to our agriculture. Although, ICAR-NBPGR has facilities to take up this task properly, more comprehensive efforts are needed to develop and customize the modern detection and eco-friendly salvaging techniques to minimize the risk of escape in quarantine processing.

LP 02: Potential Uses of Beneficial Microorganisms in Crop Protection and Entrepreneurship Development

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Plant growth promoting fungi and plant growth promoting rhizobacteria isolated from forest and agricultural field soil from Darjeeling hills were identified by rDNA technology, screened for their beneficial traits and utilized for developing management strategies of cereal, pulses, horticultural plant and plantation crop. *In vitro* antagonistic activities of selected PGPR (*Bacillus pumilus, B. altitudinis*, *B. megaterium*, *B. aerophilus*, *B. methylotrophicus*, *Paenibacillus polymyxa*, *Pseudomonas fulva, Streptomyces griseolus* and *S. griseus*) against phytopathogens were confirmed prior to their application in nursery and field grown plants. All these isolates could enhance plant growth when evaluated in terms of increased root and shoot length and leaf biomass which were significantly higher when dual application of PGPR were made. Suppression of sclerotial blight of green gram and tea, root rot of chickpea, soybean and mandarin, charcoal rot of soybean, sheath blight of rice, brown rot and charcoal stump rot of tea were evident either by single or dual applications of these potential PGPR. Decrease in the disease incidence was brought about by a significant increase in the key defense enzymes such as chitinase, β-1, 3-glucanase, peroxidase, phenylalanine ammonia lyase in roots. Polyclonal antibody(PAb) based immunological assays (dot immunobinding assay and plate trapped enzyme linked immunosorbent assay) using PAb of pathogen(s) showed that its population was greatly reduced in the PGPR treated rhizosphere soil. Dual application with PGPR enhance plant growth through cumulative mechanisms like phosphate solubilization, IAA, HCN, ACC deaminase and siderophore production and induction of resistance in plants against fungal pathogen(s) as evidenced by immunolocalization of chitinase using PAb of chtinase and labeled with FITC in leaf tissues following PGPR treatment. Induction of PR-2 and PR-3 and their cellular localization was further confirmed by indirect immunofluorescence followed by immunogold labelling. Enhance accumulation of phytoalexins following induction of resistance in plants were noticed. Disease suppression and health improvement in these plants can lead to development of bioformulations using such potential microbial resources.

OP 01: Management of Wilt Complex of Geranium using Organic Substrates and Oil Cakes

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All the organic amendments *viz.,* neem cake, mustard cake, mushroom spent compost, wheat straw and saw dust tried against soil borne pathogens reduced incidence of root rot/ wilt complex yet application of neem cake and mustard cake was best against wilt complex under glass house and filed conditions. Soil amendments with neem and mustard cakes were showed least disease severity (4.16 and 6.25%) and 93.05 and 86.25 per cent reduction in disease under sterilized soil under glass house conditions while amended soil exhibited the maximum reduction of disease in solarized (92.58 and 85.73%) and unsolarized (74.20 and 58.06%) field conditions. Soil amendment with saw dust (28.60 and 22.52%) was least effective in solarized and unsolarized conditions. It was observed that soil solarization gave satisfactory control of wilt complex in the nursery as well as in the field. The present disease severity reduction over control was the highest (100% in solarized and 91.37% in unsolarized plots) in neem cake. Thus, this technique has potential to be commercially viable for management of root rot/wilt complex.

OP 02: Tolerant *Trichoderma* Strain and Copper Synergy for Efficient Management of Late Blight (*Phytophthora infestans)* in Potato

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An experiment was conducted involving copper tolerant *Trichoderma* strains and copper fungicide for effective and safe management of *Phytophthora infestans* in potato. Based on copper tolerance activity, potential *Trichoderma* (*viz.,* TCMS-36, SBIT-32 and TCMS-71) were selected. Microscopic studies revealed that the tolerant isolates (SBIT-32 and TCMS 36) accumulated copper on the cell wall, while the sensitive isolate (TCMS 71) was inhibited due to ultra-structural changes such as shrinking of cytoplasmic material, destruction of mycelia due to penetration of copper into the cell wall. The results were further validated by AAS method. TCMS-36 recorded maximum copper accumulation (0.3506 mg/g) of dry biomass of copper in living mycelia while, SBIT-32 recorded highest accumulation (0.2368 mg/g) in dead mycelia. Field experiment on effectiveness of Cu tolerant isolates of *T. asperellum* in combination with Cu- based fungicides viz., COC (Blitox-50), COH (Kocide) and alone was carried under field conditions**.** Tuber treatment followed by foliar application was found most effective as it delayed the progress of disease to the maximum extent. Dual combination involving lower doses of Cu as COC@500ppm and *Trichoderma* was found more effective than COC alone @1000ppm. The results suggest that copper tolerant *Trichoderma* with lower doses Cu- based fungicides could be employed for developing combination products for safe and effective management of late blight disease.

OP 03: Effect of Antibiotic Treatment on Phytoplasma causing White Leaf Disease in Sugarcane

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Phytoplasma are widespread prokaryotic microorganisms that infect several plant species in India. Outbreaks of phytoplasma disease epidemics can be controlled either by controlling the vectors, or by eliminating the pathogens from infected plants through meristem tip culture using antibiotics or by other chemicals. Elimination of sugarcane white leaf disease (WLD) caused by phytolasma through apical meristem Culture along with chemical treatment for producing clean planting material of sugarcane has been attempted in the present investigation. As a first step to eradicate phytoplasma from infected tissues, the efficacy of tetracycline was tested at various concentrations (20, 40, 60, 80 and 100 mg/L). Twenty proliferating shoot cultures were transferred on MS medium supplemented with tetracycline at each concentration. A set of cultures without antibiotic compound served as control. Cultures were incubated as previously mentioned, allowed to grow for next two weeks and then transferred to antibiotic-free medium. Newly emerged and apparently healthy looking shoots, obtained from the most effective concentration of tetracycline, were transferred to half-strength

MS liquid medium containing α-naphthalene acetic acid, NAA (5.0 mg/L) and sucrose (50 g/L) for 2-3 weeks for development of roots. The elimination frequency of phytoplasma in micropropagated population was confirmed by nested PCR analysis which was calculated as 80 and 70% for the plantlets treated with 80 and 60 mg/L of tetracycline treatments, respectively, at the first multiplication stage. Absence of phytoplasma in regenerated plantlets (tested by PCR assays) at monthly intervals up to 2 months revealed phytoplasma eradication from the infected mother shoots. The results showed that the optimum frequency of elimination of phytoplasma was achieved with treatment of 80 mg/L. which may further utilize for the eradication of WLD of sugarcane.

OP 04: Large Scale Implementation of Bio-Intensive Disease Management Technologies at Farmer's Field

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With growing concern about environmental safety, biological control has emerged as the promising alternative for plant disease management. It could easily be integrated with other pest management practices. Biocontrol Laboratory at G.B. Pant University of Agriculture & Technology, Pantnagar, has developed four commercial formulations of bio-agents *viz.*, Pant Bio-control Agent -1 (*Trichoderma harzianum*), Pant Bio-control Agent 2 (*Pseudomonas fluorescens*), Pant Bio-control Agent -3 (*T. harzianum* + *P. fluorescens*) and Pant Bio-control Agent -4 (consortium of two strains of *P. fluorescens*). In order to create awareness amongst farming community, large scale demonstrations on bio-intensive technologies viz., soil solarization, use of bio agents for seed treatment, seedling treatment, soil treatment and foliar spray, bio-composting including vermi composting and use of value-added vermin compost or FYM were conducted at farmers' fields in Uttarakhand. These technologies were carried out for various field and vegetable crops viz., rice, pea, tomato, capsicum, cauliflower and brinjal. Capacity building and awareness creation amongst the farmers was done by demonstrating the method of application of bio-pesticides in crops, distribution of inputs, organizing trainings and gosthies, and regular visits at farmers' fields. During the last five years, biocontrol technology has been extended to 1907 farmers covering an area of about 1895 ha in distt. U.S.Nagar. For popularizing the benefits of biocontrol agents, almost 250 quintals of quality biocontrol agents mass produced in Biocontrol Lab was distributed amongst practicing farmers. The average yield of rice using bio-intensive technologies was 60q/ha as compared to conventional farmers practices (53q/ha) with an yield increase of 13.5 per cent; the yield obtained in pea was 72q/ha as compared to farmers practices (58q/ha) with an yield increase of 23.5 per cent; In tomato it was 209q/ha as compared to farmers practices (167q/ha) with an yield increase of 24.7 per cent. Through the adoption of biocontrol technologies farmers were able to reduce their cost of production substantially and minimized losses due to pests and diseases resulting in increased benefit-cost ratio and a healthy crop. Depending on the extent of damage to the soil ecology through indiscriminate use of chemicals, varying degree of success has been achieved. However, with continuous adoption of Biocontrol technologies achievement rate could be quite high.

OP 05: AIMDb: Database for Agriculturally Important microorganisms

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Agriculturally important microorganisms (AIMs) have huge potential to provide nutrient to the crop plants. Agricultural process have utilized microorganism for many centuries. AIMs also regulates the interactions between plants and pathogens. Microorganism play pivotal role in agriculture and related fields. Here we developed a dynamic database "AIMDb"for easy and simple retrieval of informationabout the various agriculturally important microorganisms. AIMDb reflects the result of a wide literature survey, database searches, and the data curation.Present form of this database contains information about 130 AIMs along with details for each. We have taken it as a starting point and gradually the no. of AIM will increase. The AIMDb will be helpful for researchers working on agriculturally important microorganism as they can have all the information at a single plateform.

OP 06: Performance of Organic Matters for Sustainable Management of *Meloidogyne incognita* Infesting *Lens culinaris* Medik

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Root-knot nematode, *Meloidogyne incognita*, is one of the most disastrous soil pathogen causing severe damage in many crops. Nematicides are one of the most effective means but are costly and environmentally hazardous. This has lead to search out an eco-friendly means of management. Therefore, a pot experiment was carried out to manage the root-knot nematode, *Meloidogyne incognita* on *Lens culinaris* using some organic matters *viz.,* cow, poultry, horse, buffalo, goat and pigeon manure @ 35g/pot and 70g/pot. Three weeks old seedlings of lentil were inoculated with 2000 second stage juveniles of *M. incognita*. Data were collected in terms of plant length, plant dry weight, number of pods/plant, number of egg masses/root and root-knot index. All animal manures at both doses significantly ($p \leq 0.05$) enhanced the growth of plants and reduced nematode multiplication and root damage compared with control. However, application of poultry manure (@ 70g/pot) showed most significant exaggeration in plant growth characters and thereby suppression in nematode multiplication. On the other hand, horse manure (@ 35g) was found to be least effective. It is, therefore, recommended that the utilization of poultry manure be employed in combination with other management strategies to achieve sustainable, economic and environment-friendly nematode management.

PP 01: Studies on Bacterial Panicle Blight of Paddy and its Management

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Bacterial panicle blight caused by *Burkholderia glumae* is one of the most severe seed-borne bacterial diseases of paddy in the world which can induce 75% yield loss in severely infested fields. Currently, this disease has affected many countries of Asia, Africa, South and North America. The pathogen favors warm night and high humidity conditions which always occur during the rice-growing season. BPB appears during the rice heading stage when it has high night temperature and frequent rainfalls which are the important environmental conditions predisposing rice to disease outbreak. Under appropriate environmental conditions, the serious epidemics of BPB spread and increase rapidly. BPB is a severe disease not only due to the diversity of pathogens, but also because of the lack of effective methods to manage the disease. Different chemicals and biocontrol agents were screened for anticipating a short-term disease management strategy of planting cleaner seed to prevent the introduction of bacteria to a field. For this purpose *B. glumae* was frequently isolated from symptomatic panicles and infected seeds were cultured in specific medium. Maximum inhibition of the pathogen was found in the consortium of copper oxy chloride (500ppm) and streptomycin sulphate (200ppm) and in case of biocontol agents, PBAT-2 was found effective showing maximum inhibition of the pathogen during *in-vitro* screening.

PP 02: Comparison of Efficacy of Different Copper Compounds in the Triple Combination of Copper-Chitosan-*Trichoderma* for the Management of Potato Late Blight

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Potato late blight disease signifies the official beginning of the science of plant pathology. The disease was responsible for triggering Irish famine that resulted in mass mortality and emigration. Managing the late blight pathogen under field conditions is a challenge. Keeping in view the above mentioned challenge, a ‗triple combination' comprising of low dose of fungicide (CuOH), bio-control agent (*Trichoderma*) and plant defense activator compound (chitosan) was developed at Biocontrol laboratory, G.B.P.U.A&T., Pantnagar. It was field tested over years and was found effective against late blight of potato. The present study was conducted to check the efficacy of different copper compounds in the triple combination. Different variants of triple combination were tested under field conditions. Among different variants, CuOH(Technical Grade, 500 ppm) + Chitosan (500ppm) + *Trichoderma* (1%) showed least disease severity of 1.66% at 80DAS and produced yield of 308 q/ha as compared to control in which 100% severity at 80DAS and 164.33 q/ha yield was recorded. This was followed by Kocide (500 ppm) +Chitosan (500ppm) +*Trichoderma* (1%) showing disease severity of 26.66% at 80 DAS and yield of 257.66 q/ha. Least effective variant was $CuSO_4$ (500ppm) + chitosan (500ppm)

+*Trichoderma* (1%) in which 51.66% severity and yield of 178.66 q/ha was recorded at 80 DAS. So, it could be concluded that among different copper compounds used in the study, CuOH (Technical Grade) was more effective in triple combination as compare to Kocide and $CuSO_4$.

PP 03: Evaluation of Different Animal Products and Bioagents to Manage Wilt of Lentil caused by *Fusarium oxysporum* f.sp. *lentis*

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Lentil is an important pulse crop in India which is suffered from several fungal and bacterial diseases during its growth period. Wilt of lentil is of paramount importance in lentil diseases which sometimes leads to complete crop failure. It is caused by the fungus *Fusarium oxysporum* f.sp. *lentis.* The present investigation was done to test whether the bioagents and the animal products can be used as the management tool for the disease and should we integrate them in an IDM program. By keeping all this in mind studies on *in vitro* evaluation of bioagents (*Trichoderma harzianum* and *Pseudomonas fluorescens*) was done by employing ―dual culture technique"; moreover ―Poisoned Food Technique" was employed to test animal products like maththa, cow urine and cow dung. The findings from present investigation reveals that among the different animal products cow urine is best to control the radial growth of pathogen in medium, it showed 100 percent inhibition of the pathogen growth followed by cow dung (50.67%), maththa (25%) and among the bioagents *Trichoderma harzianum* showed maximum radial growth inhibition i.e. 77.3 per cent of the pathogen followed by *Pseudomonas fluorescens* showing inhibition of 63.53 per cent. From the present investigation it can be concluded that the bioagents and some of the animal products have the potential to inhibit the pathogen growth and can be used as the management tool for the disease in field. These products are eco-friendly too and can be a component of IDM module of the of lentil crop.

PP 04: Integrated Management of Banded Leaf and Sheath Blight of Maize using Fungicides, Bio-Control Agents and Cultural Practices

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Banded leaf and sheath blight (BLSB) caused by *Rhizoctonia solani* f. sp. *sasakii* (Kuhn) Exner has become an increasingly severe and economically important disease of maize in several countries of Asia. The pathogen is capable of attacking a wide range of host plants, causing seed decay, damping off, stem canker, root rot, aerial blight and seed/cob decay. It is the combination of its competitive saprophytic ability and high pathogenic potential that makes *R. solani*, a persistent and destructive plant pathogen. The sources for resistance to BLSB have been found to be limited which has prompted development of alternative methodologies to arrest its proliferation. In view of this, field experiments were conducted at Norman E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar to study the effect of fungicides, application methods of bio-control agents and cultural practices (intercropping and leaf stripping) on incidence and severity of banded leaf and sheath blight of maize during Kharif 2009 and 2010. Foliar spray of Tilt 25 EC was found superior over all other fungicides giving lowest disease severity, highest grain yield and maximum 1000 grain weight followed by Contaf and Bavistin while check plots gave lowest yield. Among the bio-agents evaluated, plots treated with seed+spray of T-43 exhibited minimum disease severity followed by (seed+spray) with a mixture of T-43 and Ps-27 and seed treatment by mixture of T-43 and Ps-27. Intercropping of maize with soybean had advantage over other cultural practices.

PP 05: Seed Treatment and Foliar Spray of Bioagents and Fungicides on the Disease Severity of Ascochyta Blight of Chickpea Incited by *Ascochyta rabiei*

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Ascochyta blight (*Ascochyta rabiei*) of chickpea (*Cicer arietinum L.*) is an economically important disease transmitted through the seed and stubble. The experiment was conducted during *Rabi* season of 2015-2016 in *Tarai* region of Uttarakhand to determine the efficacy of combined action of seed treatment along with foliar spray in preventing the disease. Seed treatment with carbendazim+thiram (1:2) and 3 foliar sprays of pyraclostrobin + metiram was found the best among all in terms of reducing the maximum disease severity of Ascochyta blight to 82.63 per cent. Least per cent disease control over the check was recorded in seed treatment with *T. harzianum* + *P. flourescens* and 3 sprays of chlorothalonil (65.29%).

PP 06: Early Detection of White Rust Disease (*Albugo candida*) in Rapeseed Mustard

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White rust caused by *Albugo candida* is considered as one of the most important disease due to its destructive nature, wide distribution and grain yield losses of 17-34 per cent. The pathogen has to cause potential yield loss of up to 89.9 per cent due to foliar and floral infection**.** It is very essential to recognize the infection as early as possible before appearance of white rust symptoms. Early detection could be helpful in the decision making of preventive foliar applications an appropriate time i.e. before development of pathogen in the host for the cost effective management. The early detection of *A. candida* was done by PCR-based assay and light microscopy. In PCR based assay the primers ITS1 (3‘-GAGGGACTTTTGGGTAATCA-5‘) and Short ITS JV34 (3‘-CGCCATTTAGAGGAAGGTGA-5‘) and JV37 (3‘-GTCAAGCAAAACAT-5‘) were used to amplify the ITS region of *A. candida* and *Alternaria brassicae*. PCR amplification of *A. candida* from inoculated symptomatic and asymptomatic leaves yielded PCR products of 1200 bp and 600 bp of ITS1 and Short ITS primers, respectively whereas no bands were amplified in *A. brassicae*. This confirmed the presence of *A. candida* in asymptomatic inoculated leaves at early stage i.e. 1, 2, 3, 4, 5 and 6 DAI. In light microscopy the presence of pathogen structures were observed from inoculated symptomatic and asymptomatic inoculated leaves. This presence of pathogen structure viz. mycelium and sporangia was observed in asymptomatic leaves at early stage at 6,7,8 and 9 days after inoculation and from symptomatic leaves at 10 and 11 days after inoculation whereas no fungal structure in healthy mustard leaves after staining with 1 percent cotton blue in lacto phenol and 0.4% trypan blue.

PP 07: *In vitro* Evaluation of Antibiotics, Chemicals and Bioagents against *Xanthomons axonopodis.* pv. *glycines*

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The bacterial pustule of soybean caused by pathogen *Xanthomonas axonopodis* pv. *glycines* can be effectively controlled by antibiotics, chemicals and bioagents. The effect of different antibiotics, chemicals and bio-agents was assessed *in vitro* by paper disc method and the antibiotics revealed that streptocycline (750 ppm) with the inhibition of 2.69 cm was more effective and bactrinashak was least effective. Among chemicals Bordeaux mixture at 1 per cent recorded maximum inhibitory zone. Among the combination COC (0.3%) + streptocycline (750 ppm) was found significantly very effective than rest of the treatments with maximum inhibition zone of 3.41 cm. Among the seven bio-agents evaluated, *P. fluorescens* recorded highest inhibitory zone (2.63 cm) against *X.axonopodis* pv. *glycines* which were followed by *Bacillus amyloliquifaciens* (0.93 cm). PPFM-20 (0.89 cm) and PPFM-71 (0.88 cm) which are on par with each other.

PP 08: Management of Yellow Mosaic Virus Disease in Soybean

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Soybean is popularly known as ―Golden bean" or ―Miracle crop" of 20th century because of its oil and protein, and its use in food, feed and other industrial purposes. The yellow mosaic virus disease (YMD) accounts to 30-70 per cent yield loss and increases up to 80 per cent during severe incidence of disease in soybean. The YMD is transmitted by whitefly, *Bemisia tabaci*. A single whitefly would be able to transmit the virus. In view of existing situation and importance of soybean in Indian economy, different integrated pest management modules with border crops and insecticides were tested against YMD and its vector whitefly at Norman E. Borlaug crop research centre, G. B. Pant University of Agriculture and Technology, Pantnagar during *Kharif*, 2015 and 2016 on soybean variety JS 335. The results indicated that the module with two rows of maize as border crop and seed treatment with thiamethoxam 30FS @ 10ml/kg followed by foliar application of imidacloprid 17.8SL @ 500ml/ha at 30-35 DAS and triazophos 40EC @ 800 ml/ha at 45-50 DAS was found effective and economically feasible for the management of YMD and its vector whitefly in soybean.

PP 09: Eco Friendly Management of *Alternaria solani* (Ellis and Mart.) Jones and Grout Causing Fruit Rot of Tomato under *in vivo* Condition

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Under *in vivo* condition effect of three plant extracts namely garlic, sweet flag and chaste tree and two biocontrol agents *i.e Trichoderma harzianum* and *Penicillium citrinum* along with a check fungicide (mancozeb) were tested against *Alternaria solani* causing fruit rot of tomato. Amitabh cultivar was selected for the present study. The plot size was 2X3m with spacing of 60X45 cm and seven numbers of treatments. The first foliar spray was given on 10 day old fruits followed by second spray at 10 day interval after the first spray during March and April of 2016. The plots sprayed with only water served as control. Each treatment was replicated thrice. From the study it was observed that among all the treatments mancozeb (0.2%) was found most effective in reducing the disease intensity to more than 50% followed by garlic (42.84%) at 3%, Sweet flag (41.52%) at 10%, *P. citrinum* (33.09%) at $2X10^8$cfu/ml, Chaste tree (23.91%) at 10% and *T. harzianum* (16.60%) over the control. Mancozeb (21.32 t/ha) also recorded the highest yield followed by garlic (16.65t/ha), sweet flag (15.92 t/ha), *P. citrinum* (13.62 t/ha), chaste tree (13.06 t/ha) and *T. harzianum* (11.95 t/ha). Number of fruits per plant and weight of fruit per plant were also highest in mancozeb followed by garlic, sweet lag. Highest Benefit cost ratio was observed in mancozeb (3.04) followed by garlic (2.33) lowest by *T. harzianum* (1.45) and control (1.2) treated plots. Although spraying mancozeb was found very effective, prolong use of chemical may cause harmful to human health and environment. So from this study it has been suggested that garlic and sweet flag can be used to manage the *A. solani.*

PP 10: Efficacy of Fungicides, Botanicals and Biocontrol Agents for the Management of Sheath Blight of Rice

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Sheath Blight of rice caused by *Rhizoctonia solani* (teleomorph: *Thanatephorus cucumeris*), is a complex pathogen and has a wide host range with worldwide distribution, a very destructive disease under favorable weather conditions in rice growing areas of the world which ultimately causes substantial yield losses. Field experiment were laid out during the *kharif* season 2016-17 at N.E. Borlaug Crop Research Centre, Pantnagar (29^0 N latitude, 79.3^0 E longitude), Uttarakhand on rice cultivar Pant Dhan- 4 to evaluate the effect of different fungicides, Botanicals and Biocontrol agents in controlling sheath blight of rice. Seven fungicides viz;

Validamycin 3% L, Propiconazole 25% EC, Tricyclazole, 75%WP Tebuconazole 16% L, Hexaconazole 5% EC, Carbendazim 50% WP, and Azoxystobin 23% SC, four botanicals Neem, Turmeric, Tulsi and Bhang as well as three biocontrol agents PBAT-01, PBAT-02 and PBAT-03 were evaluated for the control of the pathogen at different stages of the plant growth while the control plots were left un-treated. Among these Azoxystrbin 23% SC, PBAT-03 and Neem was found superior over all fungicides, botanicals and biocontrol agents.

PP 11: Field Evaluation of Fungicides, Botanicals and Bioagents for the Management of Brown Leaf Spot of Rice

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Rice (*Oryza sativa* L.) has been regarded as one of the most important cereal crops and a major food grain contributor to the total world food grain basket. Brown leaf spot of rice caused by *Bipolaris oryzae* causes 67 per cent yield reduction. The disease becomes more severe under stress conditions, causes seed discoloration, reduced seedling vigour and the yield loss. Present study was undertaken to evaluate the relative efficacy of different fungicides, botanicals and bioagent for the management of brown leaf spot of rice during *kharif* 2016 at Agricultural Research Station, Mugad. Totally two sprays were given at an interval of 15 days from the onset of disease. The maximum PDI was recorded in untreated control (46.80 %) and significantly minimum in plots treated with Propiconazole at 0.1 per cent (13.03 %) and Tricyclazole (18 %) + Mancozeb (62 %) (14.58 %) at 0.2 per cent followed by Mancozeb (20.07 %) at 0.2 per cent concentration. Similarly plots treated with Carbendazim (24.36 %) and *Trichoderma harzianum* (26.22 %) were on par with each other. This was followed by Propineb (25.27 %) and Neem gold (32.69 %) and control (46.80 %) which different significantly with each other. Further, per cent disease control over untreated check was calculated for all the treatments. Among eight treatments highest PDC of 65.80 per cent was found in Propiconazole at 0.1 per cent and 61.74 in Tricyclazole (18 %) + Mancozeb (62 %) at 0.2 per cent. Similarly minimum PDC was observed in control.

PP 12: *In vitro* Evaluation of Fungicides against *Bipolaris oryzae* an Incitant of Brown Leaf Spot of Rice

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Efficacy of twelve fungicides (non-systemic, systemic and combo products) were evaluated at three different concentrations by following poison food technique. The results revealed that, among the non- systemic fungicides, maximum per cent of mycelia inhibition was observed in Propineb 70 % WP (78.21 %) which was significantly superior to all other fungicides followed by Copper oxy chloride 50 % WP (72.59 %) and Chlorothalonil 75 % WP (66.43 %). The least per cent of inhibition of fungus was recorded in Captan 50 % WP (66.36 %). Among four systemic fungicides tested Propiconazole 25 % EC (96.22 %), Hexaconazole 25 % EC

(90.64 %) gave maximum mean per cent inhibition of mycelia growth which were significantly superior to other treatment followed by Difenconazole 25 % EC (73.81 %). The least per cent of inhibition of mycelia was recorded in Azoxystrobin 25 % EC (65.27 %). In combiproducts maximum per cent inhibition (82.47 %) of the fungus was recorded in Tricyclazole (18 %) + Mancozeb (62 %) which was significantly superior over all other fungicides followed by Hexaconazole (4 %) + Zineb (68 %) (81.69 %), Hexaconazole (5 %) + Captan (70 %) (73.36 %) and least per cent of inhibition (72.26 %) was shown in Carbendazim (12 %) + Mancozeb (63 %).

PP 13: Field Evaluation of Fungicides, Botanicals and Bio Agents for the Management of Powdery Mildew in Cucumber

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Cucumber (*Cucumis sativus* L.) is a popular vegetable used for various dishes and other recipes. Cucumber powdery mildew disease is attributed to two fungal species, *Sphaerotheca fuliginea* and *Erysiphe cichoracearum*, which belongs to two different genera's in the same family Erysiphaceae. Yield loss due to powdery mildew and downy mildew diseases is estimated to be 50-70 per cent. Cucumber is often consumed as a raw vegetable and being short duration crop toxic effect of pesticides are more prevalent so present investigation was carried out to find best alternative means of management practices compatible with the chemical fungicides. The results revealed of the present study that maximum disease reduction was found in T_4 with two sprays of Nativo (Tebuconazole 50% + Trifloxystrobin 25% 75 WG) followed by T_3 with two sprays of Amistar 25SC (Azoxystrobin) with lower PDI of 6.73 and 14.66 compared to control (56.77) and higher yield of 11.42 and 10.16 tones/ha) and there is no much difference in B: C ratio of these two treatments 3.60 and 3.22 respectively. Among the botanicals and their combinations one spray of Nativo along with leaf extract of Giant knot weed (*Reynoutriu sachhalensis* 20%) has reduced the disease significantly with 16.02 PDI with an yield of 9.4 tonnes/ha.

PP 14: Role of Silicon in the Management of Blast Disease of Rice

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Rice blast disease is caused by *Magnaporthe grisea* is one of the most destructive disease of rice (*Oryza sativa* L.). The pathogen infects all above ground parts of the plant, mostly on leaves in vegetative stage causing leaf blast and on neck nodes during reproductive stage causing neck blast. Silicon even not being an essential plant nutrient, plays a significant role in controlling rice blast. An experiment was conducted taking three rice cultivars (CL-151, CL-152 & CL-142 that are susceptible, moderately resistant and resistant to rice blast disease respectively) in nutrient culture. With about 2 mol m^{-3} Si in solution the RIE (Relative Infection Efficiency) values of all the cultivars reduced by more than 90% than the control with no Si added in solution. Lession length and the rate of lesion expansion were reduced by approximately 40% and 50% respectively. Sporulation per lesion was lowered by about 45% to 47%.Environmental scanning electron microscope observations revealed that Si application resulted in higher Si deposition. Percentage of Si in leaf tissue is increased by 60%.The number of spores per lesion, lesion length, rate of expansion were reduced significantly with silicon application regardless of cultivar.

PP 15: Farmers Perception on Disease Diagnosis and Pesticide Use: A Survey

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Diseases are major problems of crop cultivation and responsible for reducing the yield, increasing the production cost and having direct impact to the farmers and society. A survey was conducted on farmers from Uttarakhand and Uttar Pradesh visited to kisan mela organized by G B Pant University of Agriculture and Technology, Pantnagar to study their perception on plant disease diagnosis and pesticide use for their management. The farmers studied were from marginal to very large land holders following mainly rice wheat cropping system. Most of the farmers diagnose the pest and disease problems by themselves without taking any external support. Advisory services for diagnosis and pest management adopted by the farmers of all categories were mostly from the local dealers and less approaches to KVKs, help lines and other Government agencies for diagnosis of field problems and their solutions. Chemical methods for pest and disease management were preferred more. As source for supply of pesticides, private companies and organizations were leading as 89 per cent respondents persuade towards private sources. Majority of the farmers were unaware about the side effects of pesticides without knowing the toxic categories of pesticides. Only 25 per cent of the total surveyed farmers were aware about the benefits of using biopesticides however, application is very limited. As far the precautions during using the pesticides is concern, 33 per cent farmers do not take any precaution during application of the pesticides, they also do not read the information given on packaging material but they ask the another farmers about how to use of pesticides. The huge investment on pesticides was found to be due to improper diagnosis of the problem basically done by the pesticide dealers and use of a cocktail of fungicides, insecticides, antibiotics and other synthetic chemicals which sometimes force to increase both the dosage and number of pesticide application.

PP 16: Management of Whitefly Using Newer Insecticides and their Role in Controlling Yellow Mosaic Virus (YMV)

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Soybean is an important legume crop, providing protein (43%) and oil (23%) its productivity is affected by many insect pests of which whitefly is major pest of soybean. The management of whiteflies and its effect on transmission of Yellow Mosaic Virus using newer insecticides was carried out during *kharif*2016 in Crop Research Centre, GBPUA & T, Pantnagar. It was found that seed treatment with Thiamethoxam 30 FS @ 10 ml/kg seed + spray of Imidacloprid 17.8 SL @ 600 ml/ha was more effective in controlling the YMV infesetation11.42% and followed by Imidacloprid 48 FS @ 1.25 ml/kg seed + spray of Thiamethoxam 25 WG @ 100 g/ha and Thiacloprid 21.7 SC @ 750 ml/ha with(11.57%) and (12.58%) respectively. Effect of treatments and YMV infection also affected the yield. We found that highest yield was recorded in Thiamethoxam 30 FS @ 10 ml/kg seed + spray of Imidacloprid 17.8 SL @ 600 ml/ha 1675.00Kg/ha, 1588.43 Kg/ha in Imidacloprid 48 FS @ 1.25 ml/kg seed + spray of Thiamethoxam 25 WG @ 100 g/ha and 1544.91 kg/haSpiromesifen 22.9 SC @ 600 ml/ha.

PP 17: Integrated Management of Web Blight Disease of Mungbean

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Web blight disease *caused by Rhizoctonia solani* Kóhn [*Thanatephorus cucumeris* (Frank) Donk] is one of the major serious constraints in mungbean production causing heavy yield losses. Two pot experiments were carried out under glasshouse conditions to develop suitable management strategy against this disease. In the first experiment, seed was treated with Thiram + Carbendazim (2:1) @ 3 g/kg seed for all the treatments whereas in the second experiment seed was treated with *Trichoderma harzianum* @ 4 g/kg seed except check. There were 14 treatments as foliar sprays in each experiment including Carbendazim (0.1%), Propiconazole (0.1%), Hexaconazole (0.1%), Mancozeb (0.25 %), Difenoconazole (0.05%), Azoxystrobin (0.05%), Thiophanate methyl (0.05%), Zineb (0.2%), calotropis @ 35%, ocimum @ 35%, PBAT-1 (*T. harzianum*) @ 0.4%, PBAT- 2 (*Pseudomonas fluorescens*) @ 1%, PBAT-3 (*T. harzianum* + *P. fluorescens*) @ 1% and check. The results revealed that seed treatment with Thiram+Carbendazim (2:1) @ 3 g/kg seeds followed by three foliar sprays of Propiconazole @ 0.1 per cent at 15 days interval gave maximum reduction in web blight disease severity *i.e.* 70.47 per cent.

PP 18: Integrated Practices for the Management of Soil-Borne Diseases under Organic Farming System

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Soil-borne diseases lead to significant yield loss in all over the world. Pesticides are frequently used for the management of plant diseases, there are not so much pesticides known for controlling soil borne diseases, and the pesticides which are available can be used as fumigants and drenching. Pesticides are known as poison because of their harmful effects due to their poisonous residue consumed as food by human beings and animals which results to effect the humans and animal health as well as to pollute the water and air. Due its harmful consequences demand for healthy food and environment farmer‘s have switched over to the organic farming. It involves use of compost, green manures, bone meal, bio-control and mixed cropping and crop rotation.

Approaches to crop protection in organic agriculture differ widely among growers globally and regionally. So, organic farming benefits in the long term subsistence of agriculture by improving the soil health which results in sustainable crop production, bio-diversity conservation and environmental protection. This review deals with the importance of integrated methods in organic farming system for management of soil-borne diseases, so that we can save our food and health for the next generation and for ourselves.

PP 19: Importance of Antifungal Resistance Strategies in Integrated Disease Management

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Fungicidal resistance is the resistance of the pathogen, towards the fungicide, for which it was susceptible earlier. This not only becomes a hindrance towards management of the disease, but also poses a threat for sudden increase in pathogen population, which ultimately causes a huge loss, as the earlier used pesticide becomes waste and there is not much time to deal with the new strain. The resistance of pathogen against fungicide is caused due to genetic changes in them, that is a new strain emerges in the scenario. Very recent example of fungicide resistance is resistance of wheat powdery mildew against strobilurin in Australia. Some pathogens like *Alternaria alternata, Botrytis cinerea* are at high risk of developing resistance towards fungicides. This calls for the need to implement antiresistance strategies in integrated management. This constitutes of management strategies which include, resistance risk assessment of fungicides, use of combination fungicide, avoidance of regular and intensive use of same fungicide, use of fungicide only when in strict need and in optimum dose only. Proper combination of fungicides needs to be chalked out, based upon their risk of resistance, which in turn is based upon their mode of action and efficiency. Ultimately, we have to reduce the selection pressure of the pathogen, through cultural practices and resistant cultivars and reduce the time of exposure to the fungicide at risk.

PP 20: Copper Fungicide Tolerance of *Trichoderma* spp. for their Potential Synergy in Plant Disease Management

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The incorporation of bio-control agents (BCA) in Integrated Disease Management (IDM) package provides a feasible solution to the environmental problems due to excessive pesticide usage on one hand, while on the other, these antagonists are suspected on grounds of their efficacy since decades and for that matter the tolerance to chemicals and heavy metals may offer a cutting edge to BCAs. Therefore, tolerance against Copper fungicide was examined in *Trichoderma sp.* to test the possibility of consortial application with enhanced

efficacy. Besides measurement of radial mycelial growth on culture plates amended with variable concentrations of Cu fungicide (500, 800 and 1000 ppm), the Scanning Electron Microscopy (SEM) and Energy-Dispersive X-ray Spectroscopy (EDX) analysis were employed to study the interaction of the two agents (Cu fungicide and BCA). Observations revealed that 500 ppm fungicidal Cu was inhibitory to the sensitive isolate, whereas, tolerant isolate sustained concentration up to 1000 ppm. SEM results showed high extent of mycelial shrinkage in Cu sensitive isolate and no or very less mycelial shrinkage in Cu tolerant isolate. The EDX analysis of mycelial matrix of the BCA cultured on media supplemented with and without Cu fungicide spotted no Cu in mycelia from control culture, whereas, Cu was found within fungal beads of mycelial matrix of tolerant *Trichoderma* isolate, as was evident from the two distinct peaks of copper obtained at Kα 8.040 keV and Lα 0.930 keV, respectively, which were absent in control. EDX mapping of the fungal beads showed even distribution of Cu throughout the mycelial matrix of tolerant isolate thereby suggesting bio-sorption of Cu in mycelial matrix of the fungus. This may eventually results into slower release of Cu on degradation of fungal mycelium offering prolonged protection with reduced fungicide dosages thus, devising an efficient tool for IDM package. Therefore, the Copper tolerance trait of *Trichoderma* sp. could be utilized to use this BCA and reduced dosage of Cu fungicide in consortia for synergistic and eco-friendly management of plant diseases.

PP 21: Integrated Disease Management for Sustainable Development

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Integrated disease management should be understood as an ideal combination of various methods of plant protection against the entire complex of pests, diseases and weeds in a specified farming ecosystem in a way that minimizes economic health and environmental risks.Combination of biological, cultural, physical and chemical control techniques rather than using a single control measure prove to be more efficient and reduce ecological harms.The development of IDM systems depend on thorough knowledge of the cropping systems as well as of the pathogen and can only be achieved by interdisciplinary research.The success and sustainability of IDM strategy depends on involvement in generating local specific techniques and solutions for their particular farming systems and integrating control components that are readily available to them. Entomologists initiated the work on the concept of IPM following the problems faced with pest resistance to insecticides and the ecological damage with the widespread use of insecticides in the late 1950s and early 1960s.Plant pathologists embraced IDM by applying fundamental information on loss potential and pathogen biology, ecology and epidemiology, and applying the basic concepts of plant disease management. Success requires appropriate policies such as plant protection, private sector investment, trade and export, food safety, land use, education and awareness, and agriculture extension. Experience over the last few decades clearly showed that adoption and support for using participatory approaches help farmers improve their overall field management, including disease management, reducing cost and improving production efficacy.

PP 22: Evaluation of Three *Trichoderma* spp. from three District with Local Strain

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Tomato is the most important vegetable crop but its productivity is very low due to several fungal diseases. One of them, wilt of tomato is a major problem in U.P. *Fusarium oxysporum* f. sp.*lycopersici* is responsible for wilt disease of tomato which results in extensive to the crop. In this experiment, the three isolates *Trchoderma* spp. from different districts of U.P. were compared to *Fusarium oxysporum* f. sp.*lycopersici* isolate. Antagonistic behavior of bioagent was evaluated against *Fusarium oxysporum* f. sp. *lycopersici* by dual culture techniques. All three spp. of *Trichoderma* were also evaluated under field condition and data of disease incidence were recorded at 30, 60 and 90 DAT (Days after Transplanting). Among all treatments the *Trichoderma* spp. Of Allahabad was found very effective under *in vitro* and field both condition. In the present study, the local strain of Trichoderma spp. from same field gave very good results against *Fusarium oxysporum* f. sp. *lycopersici*.

PP 23: Eco-Friendly Management of Chickpea Wilt Buttoned up with Intercropping of Three Crops in Distinguished Patterns

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Chickpea (*Cicer arietinum* L.) is one of the premier pulse consumed primarily as pulses being rich in protein. The production of chickpea (825 kg hec^{-1}) is obstacled by various pest causing different diseases worldwide among which Wilt caused by *Fusarium oxysporum* f.sp. *ciceri* (Padwick) is most threatening and serious disease where annual losses range from 10 to 90 %. Various fungicidal treatments have been recommended but harsh effects due to use of chemicals in environment has fuelled human interest to find alternative eco-friendly management of the disease. Hence, a field study was carried out by incorporating crops viz., Lentil, mustard and wheat in seven different patterns. Results revealed that the wilt incidence was reduced and growth parameters such as plant height, plant population were improved in the pattern where chickpea was intercropped with wheat followed by a pattern of mustard, chickpea, lentil and wheat.

Session: 04

Azoxystrobin 18.2 % + Difenoconazole 11.4 % W/W SC: A New generation Fungicide for the Management of Major Sugarcane Diseases

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Sugarcane is a huge potential crop but its cultivation all over the world is hindered by biotic and abiotic stresses, of which diseases are the most important. Red rot disease is caused by fungus *Colletotricumfalcatum* Went as it has become major constraints in the profitable cultivation of sugarcane. Smut caused by fungus *Sporisoriumscitamineum*, the sett borne pathogens responsible for considerable loss to sugarcane productivity. Rust is caused by fungus *Pucciniamelanocephela* H. & P. Syd. which is responsible for both quantitative as well as quantitative losses in the cane yield. So a field experiment was conducted during *spring* 2013-14 and 2014-15 to the study the response of Azoxystrobin 18.2 % + Difenoconazole 11.4 % w/w SC against sugarcane diseases. The treatments includes Azoxystrobin 18.2 % + Difenoconazole 11.4 % w/w SC @ 0.75 ml/l, Azoxystrobin 18.2 % + Difenoconazole 11.4 % w/w SC @ 1.00 ml/l, Azoxystrobin 18.2 % + Difenoconazole 11.4 % w/w SC @ 1.25 ml/l, Azoxystrobin 23 % w/w SC @ 1.00 ml/l, Difenoconazole 25 % EC @ 0.50 ml/l along with control. Among the various treatments, Azoxystrobin 18.2 % + Difenoconazole 11.4 % w/w SC @ 1.25 ml/l were found significantly at par with Azoxystrobin 18.2 % + Difenoconazole 11.4 % w/w SC @ 1.00 ml/l in controlling red rot, smut and rust disease of sugarcane. Among the various treatments, Azoxystrobin 18.2 % + Difenoconazole 11.4 % w/w SC @ 1.00 ml/l recorded 6.06 PDI and 5.12 PDI against red rot, 5.28 % and 5.00 % disease incidence against smut, 6.12 PDI and 5.05 PDI against rust of sugarcane in 2013-14 and 2014-15 respectively. It showed the lowest disease intensity and highest cane yield.

Session: 01

Balanced Use of Available Resources for Sustainable Agriculture Production

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After impressive gain in production due to various inputs used and adoption of improved agronomic practices during green revolution, now the sustainability of the system is questionable in the context of deteriorating soil health, to overcome this major problem conservation agriculture production is best option. Applying conservation agriculture essentially means altering literally generations of traditional farming practices and implement use. As such, the movement towards conservation agriculture-based technologies normally is comprised of a sequence of step-wise changes in cropping system management to improve productivity and sustainability. The principles of marked tillage reductions are initially applied in combination with the retention of sufficient amounts of crop residue on the soil surface, with the assumption that appropriate crop rotations can be maintained or incorporated into the system later to achieve an integrated, sustainable production system. In conservation agriculture system Residue retention helps to maintain good soil structure, increase in biological activity in soil and supply important nutrient elements. In general, rice residue after grain harvest has been used for animal feed, a valuable animal feed and wheat straw has been burned for the facilitation of summer ploughing. The exploration of conservation agriculture is must needed for to conserve the soil for long term production.

Session: 02

Elimination of Yellow Leaf Disease of Sugarcane Caused by Phytoplasma through Apical Meristem Culture

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Yellow leaf syndrome (YLS) of sugarcane is a widely distributed disease found in almost all sugarcane growing country. YLS is caused by two types of pathogen either Polerovirus or Phytoplasma or by both the agents causing more than 50% loses. There is none single approach which can provide effective and long lasting management of sugarcane phytoplasma. Thermotherapy or chemotherapy of setts cuttings or chemical control of vector could be used for phytoplasmal control but the effective method to control the spreading of disease is yet to be evolved. Our aim of this study was to develop YLS phytoplasma free seeds through *in vitro* technique. Apical meristem of the plant having phytopasma infection was selected as an explant and it was inoculated on the semi-solid MS media containing Kinetin and BAP (0.5mg/l each). The cultures established from the apical meristems were multiplied in MS liquid media and further transferred to half strength MS media for root development. Genome of the plantlet propagated through apical meristems was analyzed to detect the presence of Phytoplasma with universal primer R16F2/R16R2. The result showed the apical meristems culture is very effective in elimination of phytoplasma from the seeds used for cultivation of sugarcane.

Session: 02

Molecular Characterization of ERF Transcription Factor in *Fusarium udum* Challenged Pigeonpea

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Ethylene responsive factor (ERF) is one of the important plant specific transcription factors which play vital role in defense mechanism. Among pulses pigeonpea (*Cajanus cajan*) is the most consumed pulse in India and encountered by the wilt pathogen *Fusarium udum*. In this study, ERF genes have been identified from pigeonpea by *in silico* analysis. The ERF sequences of pigeonpea and *Arabidopsis* is retrieved from database. This finding is further strengthened by phylogenetic relationship. The gene structure has been studied and motifs of these sequences are also analyzed. The identity match percentage of each sequence with other sequences and also with *Arabidopsis* is observed. Further expression pattern of pigeonpea ERF's responsive to wilt pathogen *F. udum* is checked. Different primers were designed for all pathogen responsive ERFs, and thus, each band in the gel electrophoresis following RT-PCR reflects the expression pattern of a particular ERF gene. Total 40 pathogen responsive genes had been identified from phylogenetic study. Out of them 36 ERFs were positively regulated during *Fusarium udum* challenge, 3 were negatively regulated and one had no effect as there was no change in gene expression in both control and inoculated plants. Thus, it can be concluded that ERF genes are involved in various defense mechanism in pigeonpea against *Fusarium udum.*

Session: 02

Suppression of Diseases by PGPR as Induced Systemic Resistance (ISR)

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Plants possess a range of active defense apparatuses that can be actively expressed in response to biotic stresses (pathogens and parasites) of various scales (ranging from microscopic viruses to phytophagous insect). Selected strains of plant growth-promoting rhizobacteria (PGPR) suppress diseases by antagonism between the bacteria and soil-borne pathogens as well as by inducing a systemic resistance in plant against both root and foliar pathogens. Rhizobacteria mediated ISR resembles that of pathogen induced SAR in that both types of induced resistance render uninfected plant parts more resistant towards a broad spectrum of plant pathogens. Several rhizobacteria trigger the salicylic acid (SA)-dependent SAR pathway by producing SA at the root surface whereas other rhizobacteria trigger different signaling pathway independent of SA. The existence of SA-independent ISR pathway has been studied in Arabidopsis thaliana, which is dependent on jasmonic acid (JA) and ethylene signaling. Specific Pseudomonas strains induce systemic resistance in viz., carnation, cucumber, radish, tobacco, and Arabidopsis, as evidenced by an enhanced defensive capacity upon challenge inoculation. Combination of ISR and SAR can increase protection against pathogens that are resisted through both pathways besides extended protection to a broader spectrum of pathogens than ISR/SAR alone. Beside Pseudomonas strains, ISR is conducted by Bacillus spp. wherein published results show that several specific strains of species *B. amyloliquifaciens*, *B. subtilis*, *B. pasteurii*, *B. cereus*, *B. pumilus*, *B. mycoides*, and *B. sphaericus* elicit significant reduction in the incidence or severity of various diseases on a diversity of hosts.

Session: 03

Foliicolus Fungi on Sugarbeet at Mukteshwar, Uttarakhand

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The beet root is the taproot protein of the beet plant usually known as the beet, table beet, garden beet, red beet or golden beet. It is one of several of the cultivated varieties of *Beta vulgaris* grown for their edible taproots and their leaves called as beet greens. Other than as a food, beet have use as a food coloring and as a medicinal plant. Beet can also be used to make alcohol/wine. Raw beet root has 88% water, 10% carbohydrate, 2% protein and less than 1% fat. In 100 gm amount it provides 43 calories; raw beet root is a rich source of folate and moderate source of manganese. It has amazing health benefits. During 1970s and 1980s Indian Institute of Sugarcane Research, Lucknow identified for seed crop in hills above an altitude of 16,000ft. At present IISR is actively involved in maintenance of 78 germplasm and limited seed production at its breeding outpost at ICAR-Indian Veterinary Research Institute Mukteshwar Nainital, Uttarakhand. The site is at 7km on Shital road from PG Hostel cum Delegate House (Adward House) in a protected forest area under charge of IVRI, Mukteshwar. The author has visited the site at Mukteshwar on 22nd June 2017. During the survey of germplasm protected site we found an open site of germ plasm LS-06 in open and a hut of Russian germplasm R-06 which can be opened from top. The leaves of Russian germ plasm were quite small as compared to Lucknow germplasm. The leaves size of LS-06 was three times more than Russian germplasm R-06. We found both the germplasm with foliar infection. With permission, we collected the samples and after careful microscopic examination it has been found that the Russian germplasm R-06 was infected with *Alternaria brassicae* (Berk.) Sacc. and *Phomabetae* (Oudem) Frank. Whereas Lucknow germplasm has been found to be infected with *Cercosporabeticola*Sacc. and Erysiphebetae (Vanha) Wetzier. On dead branches of both germplasm of *Beta vulgaris* were found to be infected with *Fusarium solani*.

Session: 04

Evaluating the Effect of Different Nitrogen Levels on Morpho-Physiological Responses in Different Genotypes of Rice (*Oryza sativa* L.)

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Rice is one of the supreme cereal crops of the world, cultivated in varied range of climatic zones and is known to be the pivotal food crop. Imbalanced and inefficient uses of fertilizer have led to increased deficiencies of secondary and micronutrient which is turn have adversely affected the crop response to applied NPK. Low fertilizer use efficiency has resulted in declined productivity and farmer‘s profitability but also increased the threat to the environment. The experiment was conducted at College of agriculture, Indira Gandhi Krishi Vishwavidylaya, Raipur (C.G.) during *Kharif* 2016-17 and 2017-18 season under field conditions in split plot design. Twenty rice genotypes treated with varying nitrogen doses *viz.* N 40, N 80 and N 120 in two replications each with an objective to identify the physiological attributes associated with high nitrogen use efficiency (NUE) in rice genotypes. The observation were recorded at tillering and flowering stage. The observations indicate significant interaction between N level and growth of all rice genotypes. As found the result, higher rate of morphological parameters such as plant height, tiller number hill^{-1} and TDM were increased with the increasing nitrogen levels and also found that reduction % of all rice genotypes is 5.13 (average) in N 40.

Session: 04

Effect of Different Media on Growth and Sporulation of *Magnaporthe oryzae*

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Rice blast caused by *Magnaporthe oryzae* (Anamorph: *Pyricularia oryzae*) is one of the most destructive pathogens and well established in rice, wheat, finger millet and other grasses causing severe loss in production of food grains. It infect rice in all growth stages from seedling to maturity and cause various symptoms viz., leaf blast, nodal blast, neck blast and white head formation, etc. In the present study we report suitable media for growth and sporulation of *M. oryzae*. Six different media i.e. PDA, OMA (5 % oat), V8 (pH 6.0), V8 pH 4.5), YEMA and YEMA (Synthetic) were tested for sporulation of eight isolates of *M. oryzae* isolated from different parts of the country. All isolates were incubated at 28^0C with 16 h light and 8 h darkness. Mycelium growth was measured after 7 days of incubation and observed for sporulation. The isolate M6 and RB observed highest growth in OMA media, isolates ITCC and NGR in PDA medium, isolates RW and GLR showed highest growth in V8 (pH 6.0), isolate TN1 in YEMA and isolate MDY in V8 (pH 4.5), respectively. Sporulation was observed highest only in TN1 isolate in YEMA medium. We concluded that, PDA medium is better for vegetative growth (73.06 mm) compared to other medium. Isolate M6 (84.16 mm) produced best mycelial growth compared to the other isolates.

Session: 04

Purpureocillium lilacinum against Root-Knot Nematode, *Meloidogyne incognita* infesting *Cicer arietinum* L.

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A pot experiment was conducted to determine the nematicidal potential of biocontrol agent, *Purpureocillium lilacinum* for the sustainable management of root-knot nematode, *Meloidogyne incognita* on chickpea cv. ‗Avarodhi' under glasshouse conditions. All the treatments significantly improved the growth and yield of the chickpea as compared to untreated inoculated control. Results showed that highest improvement in plant growth parameters *viz*., plant length (cm), fresh weight (g), dry weight (g), number of flower and pods, chlorophyll content (mg/g), nitrate reductase activity (µm $g^{-1}h^{-1}$) and highest reduction in pathological parameters *viz*., number of galls and number of eggmasses was found when *P. lilacinum* was applied alone. Least was found in those plants inoculated with 1500 second stage juveniles of *M. incognita* alone. Concomitant and sequential application of *P. lilacinum* with *M. incognita* also improved growth and yield of chickpea. Hence, it may be concluded that biocontrol agent, *P. lilacinum* is better substitute against chemical nematicide for the sustainable management of root-knot nematode, *M. incognita* and will be an asset in the clean and pollution free environment.

Session 04:

Reducing Cotton Leaf Curl Disease Incidence under Changing Climate in North-Western India

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Cotton occupies the most prominent position in the agriculture scenario of the country, as well as Haryana owing to its importance as a cash crop. Among the diseases, *Cotton leaf curl disease* (CLCuD) is the most important, causing enormous losses to the crop. Diseases are however not independent entities but the result of a complex interaction among host plants, pathogens and the environment. Climate change is altering temperature and Relative Humidity resulting in the shift of some insect/pest from small population to large population thus effecting crops yield. The study was carried out in order to manage the disease in the field by controlling only agronomic practices. Three different dates of sowing were used as different sowing environment and the result which was found was of immense important to the farmers of North India. Minimum loss occurred in the early sown crop irrespective of varieties whether resistant or susceptible. In the late sown crop losses were more in susceptible cultivars in terms of different yield attributes. Effect of various weather parameters were also studied in order to study the role of climate change on disease development and it was concluded the rainfall as well as temperature were highly correlated to disease development.

Session: 05

Impact of Chemicals and Bioagents for the Management of Red Rot Disease of Sugarcane

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Sugarcane is one of the major commercial crop playing principal roles in agriculture and industrial economy of India. Globally sugarcane is affected by about 240 diseases caused by various plant pathogenic organisms and in India, sugarcane being affected by approximately more than 55 diseases which are mainly due to fungi, bacteria, viruses, phytoplasma and nematode. Among all the diseases of sugarcane, red rot is one of the most important frightful diseases of sugarcane caused by *Colletotricum falcatum*. Keeping in view the importance of the crop and yield losses caused by the red rot, the present investigation has been carried out with the objective of evaluation of different chemicals and bio-agents for the management of red rot disease of sugarcane. For the experiment, sett were treated with different doses of chemicals alone and in combination viz., carbendazim 50WP @0.1% as standard check, tebuconazole 29.5 EC and propiconazole 25EC @ 0.05, 0.1 and 0.15 per cent propiconazole (0.05%) + carbendazim (0.05%), propiconazole (0.05%) + carbendazim (0.1%), propiconazole (0.1%) + carbendazim (0.05), propiconazole (0.1%) + carbendazim (0.1%), tebuconazole (0.05%) + carbendazim (0.05%), tebuconazole (0.05%) + carbendazim (0.1%), tebuconazole (0.1%) + carbendazim (0.05%) and tebuconazole (0.1%) + carbendazim (0.1%). In another set of experiment setts were treated with pant bio agents i.e. PBAT1, PBAT2, PBAT 3 @ 10, 20 and30 g/20l in water) and setts without any treatments were sown as check. The data observes showed that minimum disease score 4.08 was recorded in carbendazim (0.1%) treated plots followed by 4.43 from tebuconazole (0.15%), these setts were remarked as moderately resistant for the pathogen, whereas the maximum disease score was observed in tebuconazole 0.05% (6.30) followed by tebuconazole 0.05% + carbendazim 0.05% (6.03), these treated setts were remarked as susceptible. Likewise bio control agents were also tested under field condition at different concentration against red rot pathogen. With the help of disease rating scale PBAT3 (@30g/20L of water) showed minimum disease score (4.43) found the best in disease suppression of red rot disease followed by PBAT1 and PBAT2 showed disease score i.e. 4.43 and 4.73, respectively.

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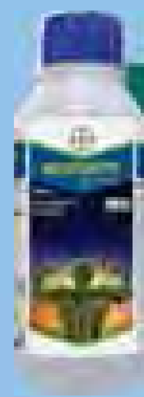

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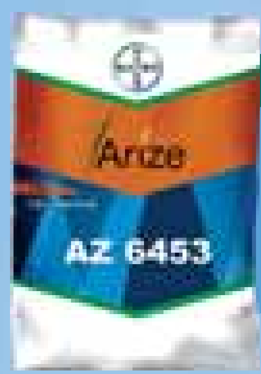

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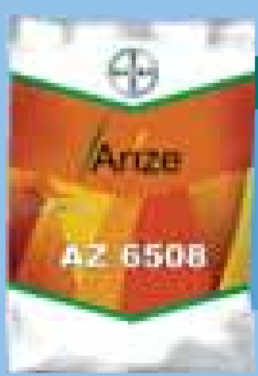

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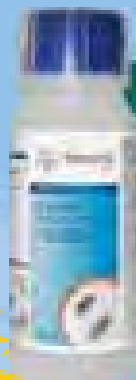

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