PREFACE

The science of Plant Pathology has an important role in the future success of programmes and policies designed to increase and sustain food production. In order to combat the losses caused by plant diseases, it is necessary to define the problem and seek remedies. At the biological level, the requirements are for the speedy and accurate identification of the causal organism, accurate estimates of the severity of disease and its effect on yield, and identification of its virulence mechanisms. Disease may then be minimized by the reduction of the pathogen’s inoculum, inhibition of its virulence mechanisms, and promotion of genetic diversity in the crop. Conventional plant breeding for resistance has an important role to play that can now be facilitated by marker-assisted selection. There is also a role for transgenic modification with genes that confer resistance. At the governance level, there is a need to acknowledge that plant diseases threaten our food supplies and to devote adequate resources to their control.

Plant Pathology is thus challenging, interesting and an important science that aims at averting the food loss due to the impact of plant diseases and thus contributes directly to the food basket of hungry millions. However, society, consumers and growers will only be able to continue to benefit from plant pathology if the discipline can evolve appropriate disease management schemes that can respond to the significant changes in agricultural practices; the ultimate goal is to produce more and safer food in sustainable agricultural systems that conserve natural resources and the environment. Information technology, communication and the integration of conventional and new technologies are all essential elements that must be integrated by the modern practitioners of plant pathology into effective disease management schemes that can be implemented at the farm level. Developing appropriate schemes for large farmers and subsistence farmers presents different challenges, but joint action in their development can be of mutual benefit to all.

The 21-day training under Center of Advanced Faculty Training in Plant Pathology envisaged to address certain core issues that unravel, address or supplement strategies that are either in demand or are in vogue for sustaining food productivity in the country taking into account the newer threats posed by changing productions systems and climatic aberrations. It was also intended to address proactive and responsive communication strategies to enable effective implementation of both the technologies already on the shelf, and those that will flow from future research. Excellent response was received from all over India for participation in this training. Twenty two participants representing nine states, who actively participated in the programme, were exposed to the recent advances made towards Plant Pathology in Practice through series of lectures, practical and field visits. Thematic area entailed series of lectures covering various aspects of technological advancements with respect to the identification, characterization, multiplication, validation and delivery of bioagents and their integration in disease management strategies.

We are grateful to the ICAR for sponsoring this 23rd advanced training programme in series, and the 1st under the banner of the newly created Centre of Advanced Faculty Training in Plant Pathology at Pantnagar. We are highly grateful to Prof. B.S. Bisht, Vice-Chancellor for his constant support, guidance and encouragement in making the training a great success. We like to put on record the help and guidance received from Dr. J.P. Tiwari, Dean Agriculture and Dr. S.K. Saini, Director, Experiment Station in the successful conduct of training programme. We sincerely acknowledge the services of our guest speakers Dr. S. Gangopadhyay, RAU, Bikaner; Dr. Suresh Pandey, ICRISAT; Dr. J.P. Upadhyay, RAU, Pusa; Dr. S.C. Dubey, IARI, New Delhi; Dr. N.K. Dubey, BHU, Varanasi; Dr. Akhtar Haseeb, AMU, Aligarh; Dr. Y.P. Singh, FRI, Dehradun; Dr. Yogesh Negi, Dehradun and Dr. S.L. Chaudhary, MPUAT, Udaipur. We would like to place on record the help and logistic support received from Dr. M.C. Nautiyal, Dean, Hill Campus, Ranichauri and his team of scientists for delivering lectures during exposure visit of participants. Several scientists from various departments such as Agronomy, Soil Science, Entomology, Genetics and Plant Breeding, Agriculture Communication, Agricultural Economics, Agrometeorology, Vegetable Science, Biological Science, Microbiology, Molecular Biology & Genetic Engineering, Vet. Anatomy and the University library in addition to the Plant Pathology rendered all possible help and delivered scientific lectures and designed practical exposure to the participants. We acknowledge their contributions with utmost gratitude and sincerity.

Dr. H.S. Tripathi
Course Coordinator
Pantnagar
April 11, 2010

Dr. J. Kumar
Director, CAFT
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Good morning everybody. On behalf of the faculty of Plant Pathology and on my own behalf, I welcome you all in this inaugural function of XXIII training under Centre of Advanced Faculty Training on “Plant Pathology in Practice”.

Hon’ble Chief Guest, Dean, College of Agriculture, Dr. J. P. Tewari ji, Head cum Director CAFT in Plant Pathology, Registrar, and Act. V.C, and Chairman of today’s function, Dr J. Kumar, Director Experiment Station, Dr. S. K. Saini, Deans, Directors, Officers, Faculty Members, Distinguished Participants, Press and Media persons, Staff, Dear Students, Ladies and Gentleman.

It is a great pleasure in welcoming Dr. J. P. Tiwari the Dean, College of Agriculture and Chief Guest of today’s function. Dr. Tiwari is highly experienced and has been on several important positions such as Head, Department of Horticulture, Registrar, and Dean, P.G.S. in this university. Dr. Tiwari has held college of agriculture in high esteem. We all members of Plant Pathology faculty welcome you sir.

I am also pleased to welcome Dr. J. Kumar, acting V.C., and Head cum Director CAFT in Plant Pathology, Registrar, Coordinator Bio-control programme and chairman of to days function. I heartily welcome you sir.

I am also pleased to welcome Dr. S. K. Saini, Director Experiment Station and a well known Agronomist, Dr. Saini has also holding various other important positions such as Head cum Director CAFT in Agronomy, Coordinator, Sugarcane programme. I welcome you to this function, sir.

I again welcome all the Deans, Directors, Heads and Faculty members of various departments who are present here in the hall. They have very kindly responded to our request and spared their time to grace this occasion.

The trainees may be aware that this University is the 1st Agriculture University established in 1960 by none other than late Pt. Jawahar Lal Nehru, the first prime Minister of India. Ladies and Gentlemen, the department of Plant Pathology was created and accredited by ICAR in 1961 and ever since the Department has had a strong commitment to, the history of, sound education, research and extension in Plant Pathology. Dr. Y.L. Nene was the first Head of the Department. Under his capable
leadership, the department expanded to include many dedicated and extraordinary faculty members including Dr. R.S. Singh and Dr. A.N. Mukhopadhyay whose programmes made the Department the recognized leader in the country. The next generation of faculty members like the first responded to the changing needs presented by the modern agriculture. At present the Department includes 9 professors, one Emeritus professor one honorary professor from INRA, France, four Associate Professors and three Assistant Professors with 14 technical and 11 supporting staffs. We have well equipped 12 labs including a molecular research lab, Plant Diseases Clinic, Mushroom research Centre and two large glasshouses. There are more than 22 Research Projects funded by national and International agencies.

The participants of the training from different universities have traveled a long distance to reach Pantnagar. At Pantnagar you may miss the comfort and attractions of big cities but the warmth of academic that exists at this place and a very exhaustive work that awaits you should keep you engrossed and compensate for any logistic inadequacies. I welcome you all and assure you a comfortable stay within our means.

In the last, but not the least, I welcome all our students and staff, press and media persons and others who are present in the hall and made the arrangements for this inaugural session.

The Department has a well-knit under graduate (U.G.) and post graduate (P.G.) programme with updated and modern course curricula. It offers six U.G. and 20 P.G. courses. A broad range of carefully designed courses complimented by lectures in other Departments appropriately address the academic needs of the students. The great diversity of areas of expertise and interests present in the Department leads to diversity in thesis titles. So far about 310 M.Sc. and 165 Ph.D. students have earned degrees from the Department.

The Department is actively engaged in the research work on both fundamental and applied aspects in the domains of ecology of soil borne plant pathogens, epidemiology and forecasting, biological control and IPM including small farms technologies, molecular diagnostics, pathogen population biology, seed pathology, fungicides, nematology, phytovirology, phytobacteriology and biology & technology of mushroom production.

The distinguished faculty of the Department has brought in a number of national and international research grants besides a series of AICRPs. For a number of AICRPs such as those of Wheat, Oilseeds, Potato, chickpea, pegeion pea, MuLLaRP, Mushroom, Bio-control, Rice and Seeds. The faculty members of the Department render services as the Project Coordinators also.

Over the years, the trained and accomplished faculty members as well as students in addressing current issues in Plant Pathology have won over 40 national and international awards. Individual staff members with in the department have long been recognized for their leadership role in the
science of Plant Pathology. By way of their contributions many faculty members of the Department have earned International positions. Also a number of faculty members have served as president, vice presidents, and zonal president of several professional societies.

The Department has a unique distinction of producing 35 books published by not only Indian but also reputed international publishers. This is besides a series of technical bulletins, lab manuals, compendia and extension literature that have also been prepared.

The Department, besides other fields, has a strong set up in IPM and biocontrol and has given a number of technologies both plains and hills. The biocontrol lab in the Department has been recognized as the referral lab by DBT. Lately, Government of India has declared the Bio-control Lab in the Department to perform the functions of the 'Central Insecticide Lab' for biopesticides. Similarly the Department also holds big strength in mushroom research and trainings.

In view of quality of teaching, research and extension work being carried out by the department, ICAR upgraded the department to the status of CAS in Plant Pathology in the year 1995 and later CAFT in Plant Pathology in the year 2010, with the major mandate to train scientific faculty from all over the country in important and innovative areas of Plant Pathology. So far 22 trainings have been conducted wherein 437 scientists from 24 states have participated.

The topic of the present training under CAFT is 'Plant Pathology in Practice'.

Plant diseases are known to cause huge losses to crops, vegetables, fruits, Medicinal plants etc.

Plant diseases need to be controlled to maintain the quality and abundance of food, feed, and fiber produced by growers around the world. Different approaches may be used to prevent, mitigate or control plant diseases. Uses of pesticides have contributed significantly to the spectacular improvements in crop productivity and quality over the past 100 years.

At the biological level, the requirements are for the speedy and accurate identification of the causal organism, accurate estimates of the severity of disease and its effect on yield, and identification of its virulence mechanisms. Disease may then be minimized by the reduction of the pathogen’s inoculums, inhibition of its virulence mechanisms, and promotion of genetic diversity in the crop. Conventional plant breeding of resistance has an important role to play that can now be facilitated by marker-assisted selection. There is also a role for transgenic modification with genes that confer resistance.

Once again, I would like to extend all the participants the warm welcome and best wishes that the Training Programme will be pleasant and professionally profitable to them.

Thanks you all.

* * * * * * * *
INAUGURAL ADDRESS

by

Dr. J.P. Tiwari
Dean Agriculture

G.B. Pant University of Agriculture & Technology, Pantnagar- 263 145
on
March 22, 2010

I consider it a great privilege and honour to be called upon to inaugurate the training course “Plant Pathology in Practice” being organized by the Centre of Advanced Faculty training (CAFT) in Plant Pathology. I am delighted to know that as many as 22 scientists from different SAUs from various parts of the country are participating in the training course. I extend my warm welcome to you all.

I hope all of you know that Pantnagar University has a distinguished record of producing outstanding Plant Pathologists. The accomplishments of this Department have all become self-evident as the faculty members and their students have won nearly 40 national/international awards from different recognized bodies like FAO, ICAR, Indian Phytopathological Society, Society of Mycology and Plant Pathology, Indian Society of Oilseeds Research, Asian Agri-History Foundations and many others. On this occasion, I would further like to make a mention of two great plant pathologists, Dr. Y.L. Nene and Dr. R.S. Singh, who gave inspiring leadership to the Department of Plant Pathology soon after the establishment of the University on November 17, 1960. You may well be aware that discovery of Khaira diseases of rice due to zinc deficiency and its control turned this Tarai into rice bowl of the country. Thus the goal of establishment of first Agriculture University in India at Pantnagar was full-filled. It was this single most important and simple factor in 1967 that earned a name for the university as well as the department by way of the coveted FAO award conferred upon Dr. Nene. It is widely acknowledged as one of the most important plant pathological discovery not only in India but at the global level that had maximum impact on farmers. You may also be aware that Dr. R.S. Singh worked out basic mechanisms for obtaining the disease control of soil-borne plant diseases through organic amendments, which is now becoming a reality and way of organic farming. His books are considered to be the milestones for being handy text books both for under graduate and post graduate students in Plant Pathology. This department has to its credits considerable number of research publications and many books that have been published by some of the most reputed national and international publishers from the USA and Europe.

The Science of Plant Pathology has an important role in the future success of programmes and policies designed to increase and sustain food production. In order to
combat the losses caused by plant diseases. It is necessary to define the problem and seek remedies. At the biological level, the requirements are for the speedy and accurate identification of the causal organism, accurate estimates of the severity of disease and its effect on yield, and identification of its virulence mechanisms. Disease may then be minimized by the reduction of the pathogen’s inoculums, inhibition of its virulence mechanisms, and promotion of genetic diversity in the crop. Conventional plant breeding of resistance has an important role to play that can now be facilitated by marker-assisted selection. There is also a role for transgenic modification with genes that confer resistance. At the governance level, there is a need to acknowledge that plant diseases threaten our food supplies and to devote adequate resources to their control. Success in pest management, as in most walks of life, depends on having the right tools and the confidence to apply them.

Plant pathology is challenging, interesting and an important science that deals with science of disease development (causes & mechanism) and art of managing diseases (minimizing the crop losses). The amount of food loss averted is a direct contribution in the food basket of hungry millions. Society, consumers and growers will only be able to continue to benefit from plant pathology if the discipline can evolve appropriate disease management schemes that can respond to the significant agricultural practices; the ultimate goal is to produce more and safer food in sustainable agricultural systems that conserve natural resources and the environment. Information technology, communication and the integration of conventional and new technologies are all essential elements that must be integrated by the modern practitioners of plant pathology into effective disease management schemes that can be implemented at the farm level. Developing appropriate schemes for large farmers and subsistence farmers presents different challenges, but joint action in their development can be of mutual benefit to all.

Plant diseases need to be controlled to maintain the quality and abundance of food, feed, and fiber produced by growers around the world. Different approaches may be used to prevent, mitigate or control plant diseases. Use of pesticides have contributed significantly to the spectacular improvements in crop productivity and quality over the past 100 years. However, the environmental pollution caused by excessive use and misuse of agrochemicals has led to considerable changes in people’s attitudes towards the use of pesticides in agriculture.

If we consider the WHO estimates, approximately 7,50,000 people are taken ill every year with pesticide poisoning and up to 14,000 of those die in agony. Although the Third World uses one-sixth of the total pesticides produced globally, at least 37, 500 people are poisoned yearly, 10, 000 of them fatally. In the USA, some 3,00,000 farm workers are affected by pesticide-related illness such as dizziness, vomiting, pinpoint
pupils and severe skin rashes. Accordingly, there is considerable public pressure as well as pressure from environmentalists to decrease emphasis on chemical control. The holocaust of ‘Bhopal Tragedy’ in India is still fresh in our memory. Pesticides are necessary, but may not be the long term solution to soil and crop health. Besides their non-target effects and hazardous nature, petroleum-based pesticides will become more expensive, and some are now losing their effectiveness because of development of resistant pest strains. Unfortunately, breeding for resistance, which continues to be the most economical and practical method of controlling plant diseases, has not kept pace with the development of more virulent and aggressive pathogen strains.

Over the past one hundred years, research has repeatedly demonstrated that diverse microorganisms can act as natural antagonists of various plant pathogens. Intensive screenings have yielded numerous candidate organisms for commercial development. Some of the microbial taxa that have been successfully commercialized and are currently marketed as EPA-registered biopesticides include bacteria belonging to the genera *Agrobacterium*, *Bacillus*, *Pseudomonas*, and *Streptomyces* and fungi belonging to the genera *Ampelomyces*, *Candida*, *Coniothyrium*, and *Trichoderma*. However, a variety of research questions remain to be fully answered about the nature of biological control and the means to most effectively manage it under production conditions. Advanced molecular techniques are now being used to characterize the diversity, abundance, and activities of microbes that live in and around plants, including those that significantly impact plant health. Still, much remains to be learned about the microbial ecology of both plant pathogens and their microbial antagonists in different agricultural systems. More studies on the practical aspects of mass-production and formulation need to be undertaken to make new biocontrol products stable, effective, safer and more cost-effective. The field of plant pathology will contribute substantially to making the 21st century the age of biotechnology by the development of innovative biocontrol strategies.

It is a matter of great pleasure that the Centre of Advanced Faculty Training in Plant Pathology with its accomplishments in the area of *Plant Pathology in Practice* is suitably organizing this advanced training. It is hoped that the scientists participating in this course would effectively utilize the knowledge earned not only in doing research and teaching but also to find out ways and means of transferring the technology to the farmers who are the sole judge of our R&D efforts.

I have thus pleasure in the declaring the training course "*Plant Pathology in Practice* " open and I wish the training course, discussions and deliberations a grand success.

‘Jai Hind’

* * * * * * * * * *
Establishment of University – 1960
Department created and Accredited – 1961
M. Sc. (Ag) Programme – 1963
Ph. D. Programme – 1965

Ist course – Introductory Plant Pathology
Ist Instructor – Dr. Y. L. Nene
Ist HOD – Dr. Y. L. Nene

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<td>Honorary Professor</td>
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<td>2</td>
<td>Dr. J. Kumar</td>
<td>Professor &amp; Head</td>
<td>Plant disease management on small farm, IPM, Biological control, Molecular characterization of Plant Pathogens</td>
</tr>
<tr>
<td>3</td>
<td>Dr. A.P. Sinha</td>
<td>Professor</td>
<td>Rice disease &amp; fungicides</td>
</tr>
<tr>
<td>4</td>
<td>Dr. H.S. Tripathi</td>
<td>Professor</td>
<td>Pulse diseases &amp; virology</td>
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<td>5</td>
<td>Dr. R.P. Awasthi</td>
<td>Professor</td>
<td>Oilseed crop disease</td>
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<td>6</td>
<td>Dr. K.S. Dubey</td>
<td>Professor</td>
<td>Soybean diseases</td>
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The G.B. Pant University of Agriculture & Technology (earlier known as U.P. Agriculture University) was established in 1960. Department of Plant pathology was created and accredited by ICAR in 1961. The postgraduate degree programme leading to M.Sc. (Ag.) Plant Pathology and Ph.D. Plant Pathology were started in 1963 and 1965, respectively.

Faculty of Plant Pathology is highly qualified and includes 10 professors, 1 Honorary Professor, 01 Emeritus Scientist, 4 Associate Professors and 3 Assistant Professor with 13 technical staff and 10 supporting staffs.
TEACHING

The department of plant pathology has made immense contribution in the area of teaching, research and extension. A well-knit UG and PG programme with updated and modern syllabi is already in operation in the department. The department offers 6 courses for undergraduate students. There are 20 postgraduate courses leading to M.Sc. (Ag.) and Ph.D. degrees in Plant Pathology. Since the inception of the department 313 M.Sc. (Ag.) and 176 Ph.D. students have been awarded degrees.

Under graduate courses:

1961’s Introductory Plant Pathology

Present

APP-312 Introductory Plant Pathology (2)          APA/APP/APE-319 Organic Farming (2)
APP-314 Crop disease & their management (2)       APP/APP-321 Integrated Pest Management (2)
APP-321 Mushroom cultivation (1)                  APP-316 Disease of Vegetable & Horticulture Crop

Post graduate courses:

Core courses

APP-500 Principles of Plant Pathology (2)          APP-520 Diagnosis of Plant Diseases (2)
APP-505 Phytopathological Techniques (2)          APP-600 Seminar (1)
APP-515 Phytobacteriology (2)                     APP-690 Thesis Research (15)
APP-530 Phytovirology (2)

Basic Supporting Courses

BBB-625 Mycology I (3)                             BBB-626 Mycology II (3);
BPS-661 Experimental Statistics (4)               BPM-502 Computer (2)

Optional courses – 6 Cr. Hr.
APP-610 Principle of Plant Disease Control (3)
APP-615 Seed Pathology (2)
APP-640 Fungicides (3)
APP-604 Diseases Resistance in Plants (2)
APP-612 Introduction to Edible Fungi (3)
APP-624 Cultural and Chemical Control of Plant Parasitic Nematodes (2)
APP-630 Phytonematology (2)
APP-602 Diseases of Ornamental and Medicinal Plants (2)

Deficiency Courses

For B. Sc. (Ag):

APP-410 Disease of Field Crops (3)
APP-430 Diseases of Horticultural Crops (3)

For ZBC:

APP-401 Introductory Plant Pathology (3)
APA-401 Elements of Crop Production (3)
APH-401 Introduction to Horticulture (3)
APP-410 Disease of Field Crops (3)
APP-430 Diseases of Horticultural Crops (3)

Ph.D. Courses:

APP-600 Seminar (1-2)
APP-604 Disease Resistance in Plants (2)
APP-700 Epidemiology of Plant Diseases (2)
APP-710 Biochemistry of Plant Infection (2)
APP-720 Ecology of Soil Borne Plant Pathogens (3)
APP-790 Thesis Research (30)
Minor: 10 Cr.hr.

Books Published

The department has unique distinction of producing 33 books published by not only Indian but also reputed international publishers like Elsevier Science (UK), Gordon and Beach (UK), Prentice Hall (USA), CRC Press (USA), Science Publisher (USA), Lewis Publishers (USA) etc. It has also produced 13 technical bulletins. A number of text books in Hindi for U.G. students have been published. The faculty members have written/prepared several laboratory manuals, reference books, working sheets on diseases, bulletins, extension pamphlets, etc. for the benefit of U.G. and P.G. students of plant pathology as well as for the farmers.

(A) Hindi – (10) (B) English– (33)

- Plant Disease 8th Edition by Dr. R.S. Singh
- An Introduction to Principles of Plant Pathology 4th Edition by Dr. R.S. Singh
- Plant Pathogens: The Fungi by Dr. R.S. Singh
- Plant Pathogens: The Viruses & Viroids by Dr. R.S. Singh
- Plant Pathogens: The Prokaryotes by Dr. R.S. Singh
- Integrated Disease Management by Dr. R.S. Singh
- Diseases of Fruit Crops by Dr. R.S. Singh
- Fungicides in Plant Disease Control by Drs. P.N. Thapliyal and Y.L. Nene
- Diseases of Annual Edible Oilseed Crops Vol. I by Dr. S.J. Kolte
- Diseases of Annual Edible Oilseed Crops Vol. II by Dr. S.J. Kolte
- Diseases of Annual Edible Oilseed Crops Vol. III by Dr. S.J. Kolte
- Diseases of Linseed & Fibre Flex by Dr. S.J. Kolte
- Castor Diseases & Crop Improvement by Dr. S.J. Kolte
- Plant Diseases of International Importance Vol. II: Diseases of Vegetables & Oil Seed Crops by Drs. H.S. Chaube, U.S. Singh, A. N. Mukhopadhyay & J. Kumar
- Plant Diseases of International Importance Vol. III: Diseases of Fruit Crops by Drs. J. Kumar, H.S. Chaube, U. S. Singh & A. N. Mukhopadhyay
- Plant Diseases of International Importance Vol. IV: Diseases of Sugar, Forest & Plantation Crops by Drs. A. N. Mukhopadhyay, J. Kumar, H.S. Chaube & U.S. Singh
- Pathogenesis & Host Specificity in Plant Diseases Vol. I: Prokaryotes by Drs. U. S. Singh, Dr. Keisuke Kohmoto and R. P. Singh
- Aromatic Rices by Drs. R.K. Singh, U.S. Singh and G. S. Khush
- A Treatise on the Scented Rices of India by Drs. R.K. Singh and U.S. Singh
- Scented Rices of Uttar Pradesh & Uttarakhand by Drs. R. K. Singh and U.S. Singh
- Plant Disease Management: Principles & practices by Drs. H.S. Chaube and U.S. Singh
- Molecular Methods in Plant Pathology by Drs. R. P. Singh and U.S. Singh
- Soil Fungicides Vol. I by Drs. A.P. Sinha and Kishan Singh
- Soil Fungicides Vol. II by Drs. A.P. Sinha and Kishan Singh
Singh, W.M. Hess & D.J. Weber

- **Seed Pathology**, 2 volumes by Dr. V.K. Agarwal
- **Phytopathological Techniques** by Dr. K. Vishunavat and S.J. Kolte
- **Crop Diseases & Their Management** by H.S. Chaube & V.S. Pundhir

**Laboratory Manuals published:**

- **Introductory Plant Path (UG)**: H. S. Chaube, V. S. Pundhir, S. N. Vishwakarma
- **Crop Diseases & Their Management**: A. N. Tewari
- **Diagnosis of Plant Diseases**: A. N. Tewari
- **Identification of Plant Disease & their control**: A. N. Tewari
- **Phytovirology**: Y.P.S. Rathi, H. S. Tripathi & P. Kumar
- **Introductory Plant Pathology (UG)**: YPS Rathi, P. Kumar & H. S. Tripathi

**RESEARCH**

Research work in the department began since the inception of the University. With the addition of new programme and staff strength, the research activities got diversified encompassing, Ecology of soil borne plant pathogens, Epidemiology and Forecasting, Biological control and IPM, Molecular Biology and Population Biology, Seed Pathology, Fungicides, Nematology, Phytovirology, Phytobacteriology and Biology & Technology of Mushroom Production. The department has several research projects funded by national and international funding agencies. The department is guiding the research work at the regional station such as Bharsar, Kashipur, Lohaghat, Majhera and Ranichauri on pathological aspects. The scientists of the department have won many national and international awards.

The department is actively engaged in the research work on both fundamental and applied aspects in frontier areas of plant pathology. The plant protection technology developed by the department is being effectively communicated to the farming community of state of Uttaranchal. The department has to cater the needs of not only farmers of the plain but also of hills located at different altitudes. In hills crops, diseases and cropping practices vary a lot depending on altitudes and they are quite different from plain. This offers a big challenge to the Centre of Advanced Studies in Plant Pathology.

**Significant Contribution**

- Cause and control of Khaira disease of rice
- Development of selective media for isolation and enumeration of *Pythium* and *Fusarium*
- Mechanism of biological control in soil amended with organic matters
- Biology and characterization of legume viruses
- Ecology of soil–borne pathogens (*Fusarium, Pythium, Rhizoctonia solani, Sclerotium rofsii*)
- Mechanism of absorption, translocation and distribution of fungicides in plants
- Methods for quantitative estimation of fungicides like metalaxyl, organotin compounds, carbendazim etc.
- Hormonal action of fungicides
- Phenolics in Plant disease resistance
- Biological control with introduced antagonists
- Etiology & management of mango malformation
- Etiology and management of shisham wilt.
- Epidemiology and Genetics of Karnal bunt fungus
- Population biology of rice blast fungus, *Magnaporthe grisea*
- Mechanism of intra-field variability in *Rhizoctonia solani*
- Soil solarization
- Mushrooms – Development of strains, and production technologies
- Role of *Ps. fluorescens* in sporophores development of *A. bisporus*
- Compost formulation with Sugarcane baggase + Wheat Straw, 2:1 developed to reduce cost of cultivation of *Agaricus bisporus*.
- Developed chemical treatment (Formalin 15ml + Bavistin 0.5g/10kg compost) of long method compost to avoid the moulds in cultivation of *A. bisporus*.
- Recommended supplementation of substrate with 2% mixture of Neem cake + Wheat straw + Rice bran + Soybean meal for *Pleurotus* spp. cultivation.
- Standardized cultivation of *Auricularia polytricha* using sterilized wheat straw supplemented with wheat bran (5%).
- Standardized cultivation of *Lentinula edodes* with substrate popular sawdust.
- Systemic induced resistance in brassicae.
- Use of siderophore producing *Pseudomonads* for early fruiting and enhanced yield of *Agaricus bisporus*.
- Use of *Pseudomonas fluorescens* for control of mushroom diseases caused by *Verticillium, Sepedonium, Trichoderma* and *Fusarium*.
- *Pleurotus sajor-caju* and *P. florida* recommended for commercial cultivation using soybean straw / Paddy straw / Wheat straw / Mustard straw.
- Standardized cultivation technology for *Hypsizygus almarius* using wheat straw supplemented with wheat bran.
- Standardized cultivation of *Calocybe indica* using wheat straw as a substrate with casing of FYM + Spent Compost + Sand (2:1:1).
- A relay cropping schedule developed for Tarai region of *Lentinula edodes* and *Calocybe indica*.
Uttaranchal: two crops *Agaricus bisporus* (Sept. - March), four crops *Pleurotus spp.* (Sept.- Nov. and Feb.- April) and three crops of *Calocybe indica* (March-October).

- Developed two strains of *Agaricus bisporus*, Pant 31 and Pant 52, now included in multilocational testing under coordinated trials.
- Development and commercialization of seven hybrids of oyster mushroom.
- Associated with multilocal testing and release of the strains NCS-100, NCS-102, NCH-102 of *A. bisporus*.
- 120 mushroom species from different locations in Uttaranchal have been collected and preserved in the museum of the centre.
- Of the collected mushrooms five *Auricularia*, four species of *Pleurotus* and two species of *Ganoderma* have been brought under cultivation.
- Isolated a high value caterpillar mushroom *Cordyceps sinensis* from high altitudes of Uttaranchal and analysed for antioxidative properties.

**MAJOR ACHIEVEMENTS**

- Twenty seven wheat lines, combining better agronomic characteristics and resistance to diseases including Karnal bunt have been identified (Shanghai-4, BW 1052, HUW 318, Lira/Hyan’S’ VUI’S’, CUMPAS 88, BOBWHITE, SPRW 15/BB/Sn 64/KLRE/3/CHA/4/GB(K)/16/VEE/ GOV/AZ/MU, NI9947, Raj 3666, UP 1170, HS 265, HD 2590, HS317, PH 130, PH 131, PH 147, PH 148, PH 168, HW 2004, GW 188, MACS 2496, CPAN 3004, K8804, K8806, ISWYN-29 (Veery"S") and Annapurna).
- Foliar blight of wheat has now been assumed as a problem in Tarai areas of U.P and foothills of Uttaranchal. *Bipolaris sorokiniana - Dreschlera sorokiniana*, was found associated with the disease in this area. Karnal bunt of wheat caused by *Tilletia indica* Mitra, is widely distributed in various Western and Eastern districts of U.P while the North hills and Southern dry areas are free from the disease.
- Multiple disease control in wheat has been obtained by seed treatment with Raxil 2DS @ 1.5g/Kg seed + one foliar spray fungicide Folicur 250 EW (Tebuconazole) @ 500ml/ha, which controls loose smut, brown rust, yellow rust, powdery mildew and leaf blight disease very effectively.
- The mixture of HD 2329 + WH 542 + UP 2338 produced highest yield recording 11.67 per cent
higher as compared to average yield of their components.

- Among new fungicides Raxil 2DS (Tebuconazole) @ 1.0, 1.5, 2.0 and 2.5g/kg seed, Flutriafol and Dividend @ 2.5g/Kg seed were found highly effective in controlling the disease. Raxil 2DS @ 1.5g/Kg seed as slurry treatment gave complete control of loose smut.

- New techniques for embryo count and seedling count for loose smut, modified partial vacuum inoculation method of loose smut, creation of artificial epiphytotics of Karnal bunt, NaOH seed soaked method for Karnal bunt detection and detached leaf technique for screening against leaf blight using pathogen toxin developed.

- The major emphasis has been on the screening of maize germplasms to various diseases with special reference to brown stripe downy mildew, banded leaf and sheath blight and Erwinia stalk rot. A sick-plot has been developed to ensure natural source of inoculum. Efficient techniques for mass multiplication of inoculum and screening of germplasms have been developed to create epiphytotic conditions. The selected genotypes have been utilized for evolving agronomically adaptable varieties. Several promising hybrids and composites have developed and released following interdisciplinary approach.

- Studies on estimation of yield losses, epidemiological parameters on various economically important diseases of maize have been worked out to evolve suitable control measures and have been recommended to farmers in the region.

- Based on the survey and surveillance studies the information on the occurrence of various diseases in UP and Uttaranchal, a disease map has been prepared and monitored to finalize the out breaks of one or more diseases in a given area based on weather parameters. It will help the growers to be prepared to save the crop from recommended plant protection measures.

- An repository of >600 isolates of biocontrol agents developed at Pantnagar & Ranichauri. These isolates are suited for different crops & agro-ecological conditions.

- Standard methods developed for testing hyphal and sclerotial colonization.

- Isolate of T. virens capable of colonizing sclerotia of Rhizoctonia, Sclerotium and Sclerotinia isolated for the first time. It may have great potential.

- 16 new technologies related with mass multiplication and formulation of microbial bio-agents developed and are in the process of being patented.

- Several genotypes including SPV 462, SPV 475, SPV 1685, SPH 1375, SPH 1420, CSV 13, CSV 15, CSH 14, CSH 16, CSH 18, G-01-03, G-09-03, GMRP 91, RS 629, UTFS 45, UTMC 523 and AKR 150 have been identified with high level of resistance to anthracnose and zonate leaf spot diseases.

- Biocontrol agents T. harzianum and P. fluorescens have been found effective in increasing the growth of plants and reducing the severity of zonate leaf spot. G. virens and T. viride have been found most effective against anthracnose pathogen.

- The cause of Khaira as zinc deficiency was established for the first time and zinc sulphate +slacked lime application schedule was developed for the control of the disease.
Inoculation technique was developed to create “Kresek” phase in rice seedlings. Pre-planting root exposure technique in a suspension of $10^8$ cells/ml for 24 hrs gave the maximum “Kresek”. Root inoculation, in general was found better for development of wilt symptoms than shoot inoculation.

A simple technique has been developed to detect the pathogen in and/or on seeds. The presence of viable pathogen has been demonstrated from infected seeds stored at room temperature up to 11 months after harvest.

The disease is sporadic in occurrence often becomes serious in nature. Chemical control trials showed that the disease can effectively be controlled by giving 2-3 foliar sprays of streptocycline @ 15 g/ha.

A number of new fungicides along with recommended ones and botanicals were tested against sheath blight. Foliar sprays with Anvil, Contaf, Opus, Swing and RIL F004 @ 2 ml/l and Tilt @ 1 ml/l were found highly effective in controlling sheath blight. Foliar sprays with Neem gold @ 20 ml/lit. or Neem azal @ 3ml/lit. was found significantly effective in reducing sheath blight and increasing grain yield.

Foliar sprays with talc based formulations of the bioagents (Trichoderma harzianum, or Pseudomonas fluorescence, rice leaf isolates) were found effective in reducing sheath blight and increasing grain yield. Foliar sprays with the bioagents (T.harzianum) or (P. fluorescence) given 7 days before inoculation with R. solani was highly effective against the disease.

Seed or soil treatment with T. harzianum or P. fluorescence @ 2, 4 or 8 g/kg enhanced root and shoot growth and fresh and dry weight of rice seedlings.

Seed treatment with fungorene followed by one spray of carbendazim (@ 0.05% at tillering at diseases appearance) and two sprays of Hinosan @ 0.1% at panicle initiation and 50% flowering was most effective and economical treatment in reducing the disease intensity and increasing the yield.

For the first time, true sclerotia were observed in Kumaon and Garhwal regions at an altitude of 900 m above. True sclerotia have a dormancy period of approximately six months. Exposure of sclerotia to near ultraviolet radiation for an hour breaks the dormancy and increased germination.

Trichoderma may reduce population of earthworm in vermicomposting during early days

An repository of >600 isolates of biocontrol agents developed at Pantnagar & Ranichauri. These isolates are suited for different crops & agro-ecological conditions.

Isolates of T. virens capable of colonizing sclerotia of Rhizoctonia, Sclerotium and Sclerotinia isolated for the first time. It may have great potential.

Standard methods developed for testing hyphal and sclerotial colonization.

16 new technologies related with mass multiplication and formulation of microbial bioagents developed and are in the process of being patented.
Effect of different physical factors and extracts on the germination of true sclerotia was studied. Maximum germination was observed at 25°C and at pH 6.0, in fluorescent light. Among the substratum, maximum germination occurred on moist sand. Soil extract was more favourable than other extracts. The number of stipes and mature head formation was directly correlated with the size and weight of the sclerotia.

The viability of the 3 propagules namely; conidia, pseudo and true sclerotia stored under different conditions showed that conidia remain viable from 2-3 months, pseudo- sclerotia from 4-6 months and true sclerotia up to 11 months at room temperature and under field conditions. True sclerotia buried at different depth (2.5 to 10 cm) in soil germinated well, but sclerota buried at 15 cm depth did not germinate and rotted.

Discoloured grains of various types were grouped according to their symptoms. The fungi responsible for each type of symptoms were identified. Ash grey discolouration of glumes separated by dark brown band was caused by Alternaria alternata and Nigrospora oryzae. Spots with dark brown margin and ash grey centre by Curvularia lunata and Alternaria alternata, light yellow to light brown spots by C. pallescens, Fusarium equiseti and N. oryzae, Brown to black dot by Phyllosticta oryzae Dark brown to black spot and specks by Drechslera victoriae, D. rostratum and D. oryzae, light to dark brown glumes by Sarocladium oryzae and D. oryzae, and light to dark brown spots by D. Austra lienese.

Rice varieties Manhar, Narendra 80, Saket 7, Ajaya, Bansmati, 385 showed higher incidence (34.1 to 41.8%) whereas Sarju 52, UPR 1561-6-3, Pusa 44, Jaya, Pant Dhan 10 and improved Sharbati exhibited lower (18.4-22.3%) incidence of seed discolouration. Bipolaris oryzae caused highest seed discolouration which is followed by Fusarium moniliforme, curvularia lunata and Fusarium graminium in all the test varieties.

On the basis of the symptoms pattern and transmissibility of the pathogen through grafting and eriophyied mite (Aceria cajani), presence of foreign ribonucleic protein and nuclear inclusion like bodies in the phloem cell indicated the viral (RNA virus) nature of the pathogen of sterility mosaic of pigeon pea. The vector mite of the pathogen was found on lower surface of leaves of Canavis sativus and Oxalis circulata weeds in this area. Mild mosaic, ring spot and severe mosaic symptoms were observed in different as well as same cultivar. This observation reveals the presence of variation in the pathogen.

Germplasm lines/ cultivars screened viz; ICP 14290, ICP 92059,ICP 8093, KPBR 80-2-2, PL 366, ICPL 371, Bahar, NP (WR) 15.were found resistant against Phytophthora stem blight.

Seed treatment with carbendazim (0.1%) followed by two prophylactic sprays of carbendazim (0, 05%) or Dithane M-45 @ 0.25% was found most effective in reducing disease severity of anthracnose disease. In early sown crop high disease severity was observed while in late sown crop low disease severity was recorded. Inter cropping with cereals or pulses have no effect on anthracnose severity.

Propiconazol 0.1%, carbendazim 0.1%, hexaconazol 0.1%, mancozeb 0.25% sprayed plots have low disease severity and high grain yield against Cercospora leaf spot.

Studies on integrated management of wilt/root rot/collar rot showed that Seed treatment with fungicide alone or in combination with other fungicides/ bio agents were found effective. Among the fungicides seed treatment with Bavistin + Thiram (1:2), vitavax + Thiram (1:2), vitavax, Bavistin, Bayleton, Bio agent *Gliocladium virens* + Vitavax and *Pseudomonas fluorescence* decreased the seedling mortality, improved germ inabilty, plant stand and yield.

Eleven thousand germplasm lines/ breeding populations \( F_2 \), \( F_3 \), \( F_4 \) and \( F_5 \) generations were screened. Many germplasm/ accessions were found resistant/ tolerant to Botrytis grey mould viz; ICC 1069, ICC 10302, ICCL 87322, ICC 1599, - 15980, - 8529, ICCV 88510, E100Y (M) BG 256, BG261, H86-73, IGCP 6 and GNG 146.

Lentil entries evaluated under sick plot for wilt/root rot/ collar rot diseases. The following lines were found promising viz; LL 383, PL 81-17, LH 54-8, DPL-58, DPL 14, Jawahar Massor- 3, DPL 112, IPL-114, L 4147 and Pant L 639.

The promising germplasm lines/ cultivars are as follows: DPL 62, PL-406, L 4076, TL 717, E 153, IPL 101, IPL 105, PL- 639, LH 84-8, and Precoz.

The field pea lines were found promising JP 141, Pant P-5, KFPD 24 (swati), HUDP 15, KFPD-2, HFP-4, P1361, EC-1, P-632, P 108-1, KPMR 444, KF 9412, DPR 48, T-10, KPMRD348, DDR13, IM9102, KFP 141 and KPMR 467 against powdery mildew and JP 141, Pant P-5, P 10, FP 141, KDMRD 384, HUDP-9, HUP-2 and T-10 were found promising against rust disease.

Mid-September planting or early October planting of rapeseed-mustard has been found to escape from Alternaria blight (*Alternaria brassicae*) downy mildew (*Peronospora parasitica*) and white rust (*Albugo candida*) diseases as against mid and late October planting. In general high occurrence of the floral infection (staghead phase) of white rust and downy mildew during flowering period has been found to be associated with reduced period, i.e. 2-6 hours, of bright sunshine/day concomitant with the mean maximum temperature of 21-25°C, the mean minimum temperature of 6-10°C and higher total rainfall up to 166 mm. Bright sunshine hours /day has a significant negative correlation whereas total rainfall has a significant positive correlation with staghead development.
All the three important foliar diseases of rapeseed-mustard could be effectively controlled by following integrated package of balanced N_{100} P_{40} K_{40} application, early October sowing and treating the seed with Apron 35 SD @ 6g kg^{-1} seed followed by spray of mixture of metalaxyl + mancozeb (i.e Ridomil MZ 72 WP @ 0.25%) at flowering stage and by spray of mancozeb or iprodione @ 0.2% at pod formation stage. In situations where Sclerotinia stem rot and / or powdery mildew appeared to be important in a particular crop season, a spray of mixture of carbendazim (0.05%) + mancozeb (0.2%) was found to give excellent cost effective control of the diseases with significant increase in seed yield of the crop.

Among the botanicals, leaf extracts of Eucalyptus globosus (5%) and Azadirchta indica (5%) have been proved to exhibit greater antifungal activity against A. brassicae and Albugo candida and showed significant reduction in the severity of Alternaria blight and white rust diseases which was rated to be at par with mancozeb fungicide spray.

Some abiotic chemical nutrient salts such as calcium sulphate (1%), zinc sulphate(0.1%) and borax (0.5%) and biocontrol agents such as Trichoderma harzianum and non-aggressive D pathotype of A.brassicae have been shown to induce systemic host resistance in mustard against aggressive “A” pathotype of A. brassicae and virulent race(s) of A. candida.

The staghead phase in B. juncea has been investigated to be due to A. candida and not due P. parasitica. Tissues at the staghead phase become more susceptible to P. parasitica than normal tissues of the same plant.

B. juncea genotypes (EC 399296, EC 399299, EC 399301, EC 399313, PAB-9535, Divya Selection-2 and PAB 9511), B. napus genotypes (EC 338997, BNS-4) and B. carinata (PBC-9221) have been shown to possess resistance to white rust coupled with high degree of tolerance to Alternaria blight. Reduced sporulation is identified to be the major component for slow blighting.

B. juncea (RESJ 836), B. rapa (RESR 219) and B. napus (EC 339000) have been selected for resistance to downy mildew and for high yield performance. Total 52 genotypes of mustard representing at least 12 differential resistance sources, 23 lines of yellow sarson representing 6 differential resistance sources and 54 lines of B. napus representing 3 differential resistance sources to downy mildew have been identified.

A new short duration (95-100 days) short statured (85-96 cm) plant type of mustard strain ‘DIVYA’ possessing high degree of tolerance to Alternaria blight suitable for intercropping with autumn sown sugarcane and potato yielding with an average of 15-22 q ha^{-1} has been developed. This ‘Mustard DIVYA’ plant type is now recommended as a source for breeding more and more improved varieties of mustard as it has been proved to have good general combining ability for short stature characteristics.

Seed treatment with mancozeb @ 0.2% + thiram @ 0.2% has been found to control seed, seedling and root rot diseases of groundnut. However seed treatment with thiram @ 0.2% + vitavax @ 0.2% has been found to control collar rot (Sclerotium rolfsii) of groundnut. Two
sprays of carbendazim @ 0.05% have been found to give excellent control of early and late leaf spot (tikka disease) of groundnut.

- Mid September planting of sunflower was found to escape the occurrence of major diseases like Sclerotinia wilt and rot, Sclerotium wilt, charcoal rot and toxemia. Severity of Alternaria blight was found to be negligible and did not cause any reduction in yield. The crop could be harvested by 15th December. The yield obtained was 16 q/ha.

- The average percent loss has been noted in the range of 50.6 to 80.7 percent due to Alternaria blight disease under Kharif conditions. However, the percent loss in oil has been shown in the range of 21.6 to 32.3. To control the disease, total 4 sprays of mancozeb @ 0.3% at 10 day interval have been found effective.

- A repository of about 5000 rice blast isolates was made from 30 locations in Indian Himalayas at Hill Campus, Ranichauri. Blast pathogen population from the region was analyzed using molecular markers and phenotypic assays. Most locations sampled and analyzed had distinct populations with some containing one or a few lineages and others were very diverse. Within an agroecological region migration appeared to be high. The structure of some populations could be affected to some extent by sexual recombination.

- Magnaporthe grisea isolates derived from Eleusine coracana, Setaria italica and Echinochloa frumentaceum collected from a disease screening nursery were cross compatible. The chromosome number of each isolate was found to be six or seven. Similarity of karyotypes was found among isolates within a lineage though between lineages some variability was noticed. A remarkable similarity between karyotypes of Eleusine coracana and Setaria italica was observed. All of these isolates were fertile and mated with each other to produce productive perithecia. The existing data however showed no evidence of genetic exchange among host-limited M. grisea populations in Indian Himalayas.

- No strong relationship appeared between the number of virulences in a pathotype and its frequency of detection. The frequency of virulent phenotype to a cultivar and susceptibility of that cultivar in the field did not correspond. The number of virulences per isolate was in general less than the number of virulences per pathotype, which indicated predominance of isolates from pathotypes with fewer virulences. There was a tendency for the pathotypes to have fewer virulences. The frequency of virulence among rare pathotypes was higher than common pathotypes against all the differential NILs, including two-gene pyramids. These rare pathotypes could be the potential source of resistance breakdown of the novel resistance genes.

- Blast resistant gene Pi-2(t) appeared to have the broadest and Pi-1(t) the narrowest resistant spectra. Compatibility to Pi-2 (t) gene did not appear to limit compatibilities with other resistant genes. Loss of avirulence to all the five major gene tested may carry a serious fitness penalty. Major gene Pi-2 and gene combination Pi-1,2 showed least compatibilities and hold promise in managing blast in the region. In the overall Himalayan population, gene combinations in
general were effective at most locations. Combination of $Pi-1+2$ genes was effective at most locations until the year tested. However, three gene pyramid [$Pi-1(t) + Pi-2(t)+Pi-4(t)$] resisted infection at all locations.

- It was inferred that the pathotype composition of the blast pathogen composition in the Indian Himalayas was very complex and diversifying the resistance genes in various rice breeding programmes should prove to be a useful strategy for disease management.

- A common minimum programme under bio-intensive IPM in vegetables in Uttaranchal hills was designed that is extended to over 2000 farmers from 20 villages in district Tehri Garhwal.

- Epidemiological considerations in the apple scab disease management led to the development of disease prediction models. Relation of degree-day accumulations to maturation of ascospores, and potential ascospore dose (PAD) were found to be useful for predicting the total amount of inoculum in an orchard thereby effectively improving apple scab management.

- Out of 71 genotypes tested against red rot caused by *Colletotrichum falcatum*, four genotypes viz; Co Pant 92226, Co Pant 96216, Co Pant 97222 and CoJ 83 were found resistant and another 24 exhibited fairly good tolerance.

- Seed treatment with Thiram + Carbendazim (2:1) @ 3g/kg seed or Vitavax 0.2% controlled the seed and seedling rots and improved the seedling emergence without any adverse effect on the nodulation and invariably yield were increased. Seed treatment with *Trichoderma harzianum*, *T. viride* or *Pseudomonas fluorescens* @ 10g/kg controlled seed and seedling rots and increased plant emergence.

- Purple seed stain disease can be effectively controlled by seed treatment with thiram + carbendazim (2:1) @ 3 g/kg seed followed by two sprays of benomyl or Carbendazim @ 0.5 kg/ha.

- Rhizoctonia aerial blight can be effectively controlled by two sprays of carbendazim @ 0.5 kg/ha. Seed treatment with *T. harzianum* or *Pseudomonas fluorescens* 10g/kg seed + soil treatment with pant Bioagent-3 mixed with FYM @50q/ha followed by two sprays of *T. harzianum* @ 0.25% reduced the disease severity of RAB.

- Pod blight and foliar diseases caused by *Colletrotichum dematium var truncatum* could be effectively controlled by the use of carbendazim 0.05%, Mancozeb 0.25%, Copperoxychloride 0.3%, Thiophanate methyl 0.05%, Chlorothalonil 0.25%, Hexaconazole 0.1% and Propiconazole 0.1%. First spray should be given as soon as disease appear and second spray after 15 days of first spray.

- Rust disease could be effectively controlled with three sprays of Benomyl 0.05%, Mancozeb 0.25% or Zineb 0.25%, at 50, 60 and 70 days after sowing. Varieties Ankur, PK-7139, PK-
Charcoal rot disease can be effectively controlled by seed treatment with *Trichoderma harzianum* @ 0.2% + vitavax @ 0.1%. 

Pre-mature drying problem Soybean can be minimized by seed treatment with carbendazim + Thiram (2:1) @ 3g/kg seed followed by two sprays with carbendazim, mancozeb and Aureofungin. Varieties PSS-1, PS-1042, PK-1162, PK-1242 and PK-1250 were found to be superior for premature drying problem.

Integrated disease management (IDM) modules based on combined use of cultural practices, fungicides for fungal disease, insecticide for virus disease and host resistance were evaluated against RAB and Soybean yellow Mosaic virus diseases.

Bacterial pustules can be successfully controlled by two sprays at 45 and 55 days after planting with a mixture of Blitox-50 (1.5 kg/ha) + Agrimycin-100 (150g/ha) or streptocycline (150 g/ha) + copper sulphate (1kg/ha).

Soybean yellow Mosaic can be very effectively controlled by four sprays with oxymethyl demoton @ 1/l/1000 lit/ha at 20, 30, 40 and 50 days after planting. Soil application with Phorate 10G @ 10 kg/ha and Furadan 3G @ 17.5 kg/ha controlled the disease. Varieties PK-1284, 1251, 1259, 1043, 1225, 1303, 1314, 1343, 1347, PS-1042 PS-564, 1364 were identified as resistant to Soybean yellow Mosaic virus.

**EXTENSION**

The scientists also participate in the farmers contact programme as well as practical trainings at different levels including those of IAS and PCS officers, Extension workers, Agricultural officers, Farmers, Defense Personnels etc. The Scientists of the department also actively participate in the trainings organized under the T&V programme for the benefit of farmers/State level Agricultural Officers. Two Professors (Extension Pathology) and crop disease specialists are deputed to “Help Line Service” started recently by the University under Agriculture Technology Information Centre (ATIC). The telephone number of help line services is 05944-234810 and 1551. Technology developed by the centre is regularly communicated to the farmers of the 13 districts of Uttaranchal State through the extension staff (Plant Protection) of both university and state agriculture and horticulture departments posted in all districts of the state. The radio talks and TV programme are delivered. Popular articles and disease circulars are published regularly for the benefit of the farmers.

**UP-GRADATION TO CENTRE OF ADVANCED STUDIES**

In view of the outstanding quality of teaching, research and extension work being carried out by the department, ICAR vide letter No. 1-2/93 (CAS)UNDP dated Feb.02, 1995 upgraded the department.
Major mandate of the CAS was to train scientific faculty from all over the country in important and innovative areas of plant pathology. So far under CAS, 16 trainings have been conducted and 336 scientists from all over the country have been trained in different areas. Centre of Advanced Studies in Plant Pathology at Pantnagar was awarded a certificate of Appreciation in commemoration of Golden Jubilee year of independence (1998) for organizing the programmes for human resource development and developing excellent instructional material by the education division, ICAR on August 14, 1998. The progress report CAS in Plant Pathology during X plan is as follows:

**Trainings Held**

1. Recent advances in biology, epidemiology and management of diseases of major kharif crops (Sept. 19 - Oct. 12, 1996)
2. Recent advances in biology, epidemiology and management of diseases of major rabi crops (Feb. 25 –March 17, 1997)
4. Advanced techniques in plant pathology (Oct. 12 – Nov. 02, 1998)
5. Recent advances in detection and management of seed-borne pathogens (March 10-30, 1999)
8. Recent advances in research on major diseases of horticultural crops (March 01-30, 2001)
9. Recent advances in plant protection technology for sustainable agriculture (Nov. 19 –Dec. 09, 2001)


15. Regulatory and cultural practices in plant disease management (Dec. 03-21, 2005)

16. Crop disease management: needs and outlook for transgenics, microbial antagonists and botanicals (March 21 – April 10, 2006)

17. Soil Health and Crop Disease Management (December 02-22, 2007)

18. Role of Mineral Nutrients and Innovative Eco-friendly Measures in Crop Disease Management (March 22- April 11, 2007)

19. Plant Disease Management on Small Farms (January 03-23, 2008)

20. Seed Health Management for Better Productivity (March 28 to April 17, 2008)

21. Recent Advances in Plant Disease Management (Dec. 13, 08 to Jan. 02, 09)

22. Recent Advances in Biological Control of Plant Diseases (March 20 - April 09, 2009)

23. Plant Pathology in Practice (March 22 to April 11, 2010)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>State</th>
<th>Total</th>
<th>Sl. No.</th>
<th>State</th>
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<td>13.</td>
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<td>22.</td>
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<td>11.</td>
<td>Kerla</td>
<td>05</td>
<td>23.</td>
<td>Uttaranchal</td>
<td>69</td>
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<tr>
<td>12.</td>
<td>Madhya Pradesh</td>
<td>25</td>
<td>24.</td>
<td>West Bengal</td>
<td>18</td>
</tr>
</tbody>
</table>

**Total = 478**
INFRASTRUCTURE

- Wheat Pathology Lab. – General Path, Epidemiology, Toxin, Tissue Culture
- Maize Pathology Lab. – General Plant Pathology, Bacteriology
- Rice Pathology Lab. – General Plant Pathology
- Ecology and Vegetable Pathology Lab. – Ecology, Histopathology, Biocontrol, Nematodes
- Soybean Path. Lab.– General Plant Pathology, Fungicides
- Oil Seed Path. Lab.– General Pl. Path., Tissue, Culture, Histopathology, Toxins
- Pulse Path. Lab. – General Pl. Path., Phytovirology
- Seed Path. Lab. – General Path, Seed Borne diseases
- Biocontrol Lab. – Biocontrol & IPM
- Molecular Pl. Path Lab. – Population biology & host-pathogen interaction
- Mushroom Research – Research & training
- Glass houses – 3
- Polyhouses – 3
- UG Practical Lab – 1
- PG Lab – 1
- Training Hall – 1
- Conference Hall – 1
- Office – 1

Huts for Mushroom Production
Research Project (on going)

- Large Scale Demonstration of IPM technology through KVKs in Network Mode (HTMM-I)
- Promoting IPM through a Common Minimum Programme in Vegetable Cultivation in Uttarakhand Hills (RKVY, Govt. of India)
- Programme Mode Support in Agrobiotechnology (DBT)
- Translational Research Centre on Biopesticides (DBT)
- AICRP on Biological Control (ICAR)
- All India Coordinated Wheat and Barley Improvement Project-Plant Pathology component (ICAR)
- AIC Chickpea Improvement Project (ICAR)
- AIC Pigeonpea Improvement Project (ICAR)
- AIC MullaRP Improvement Project (ICAR)
- Screening of chickpea germplasms/lines against BGM disease-(NBPG)
- All India Coordinated Soybean Improvement Project (ICAR)
- All India Coordinator Research Project on Rapeseed & Mustard (ICAR)
- All India Coordinated Rice Improvement Project (ICAR)
- Cereal Systems Initiative for South ASIA (CSISA) Objective 3 (IRRI)
- AICRP on (NSP) Seed Technology Research (ICAR)
- DUS Test Centre for Implementation of PVP-legislation for forage sorghum at Pantnagar (ICAR)
- Seed Production in agriculture crops and fisheries (Mega Seed Project) in Seed Technology Research (ICAR)
- All India Coordinator Potato Improvement Project (ICAR)
- All India Coordinated Vegetable Improvement Project (ICAR)
- All India coordinated Maize Improvement Project (ICAR)
- All India Coordinated Sugarcane Improvement Project (ICAR)
- All India Coordinated Sorghum Improvement Project (ICAR)
- All India Coordinated Mushroom Improvement Project (ICAR)

Consultancy Project

- Evaluation of BAYER fungicides against wheat diseases
- Evaluation of SYNGENTA fungicides against wheat diseases
- Evaluation of UPL fungicides against wheat diseases
- Bio-efficacy of copper hydroxide 46% DF against bacterial leaf blight and false smut diseases of rice
- Phytotoxicity studies on meptyldinocap 35% EC for powdery mildew in pea funded by Dow Agro Sciences India Pvt. Ltd.
- Bio-efficacy of fungicides against blister blight of tea
- Bio-efficacy of fungicide Tebuconazole 250 EC (Folicur EC 250) against anthracnose in Soybean funded by Bayer Crop Science

Total Budget Outlay – > 1000 lakhs

Research Areas – Biological Control, IPM, Shisham wilt, Soil solarization, Population Biology, Seed pathology, Mushroom etc.

Publication:

1. Books - 33
2. Research Bulletins - 20
3. Research Papers - >1200
4. Conceptual / Review articles - >130
5. Chapters contributed to book - >150
6. Extension literature - over (200)

(Hindi – English)
Annual Review of Phytopathology - 02

Recognition and Awards:
- UNO (Rome) – Dr. Y. L. Nene
- Prof. M. J. Narisimhan Academic Award (IPS) 5
- Jawahar Lal Nehru Award (ICAR) 2
- Pesticide India Award (ISMPP) 7
- P. R. Verma Award for best Ph. D. Thesis (ISMPP) 2
- Other (Hexamar, MS Pavgi, Rajendra Prasad etc.) >20
- Uttarakhand Ratana 2
- Education Award 2004-05” for his book “फलों के रोग” 01

by the Ministry of Human Resource Development, GOI

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 Soc. Seed Technology**
- Vice Presidents - 3

**Science Congress**
- President (Agriculture Chapter) - 1

**National Academy of Agricultural Sciences**
- Fellows - 3

Future Strategies:

**Teaching:** Introduction of new courses
- Methods in Biological Control
- Plant disease and national importance
- Integrated plant disease management
- Molecular plant pathology
- Advances in mushroom production
Research thrust:
- Biological control & ICM (IPM + INM) in different crops/cropping systems
- Disease management under organic farming
- Microbial ecology
- Green chemicals
- Population biology of pathogens (including use of molecular tools)
- Induced resistance
- Exploitation of indigenous edible and medicinal mushrooms

Human Resource Development

Degree awarded

<table>
<thead>
<tr>
<th>Degree</th>
<th>No.</th>
</tr>
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<tbody>
<tr>
<td>M.Sc.</td>
<td>365</td>
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<tr>
<td>PhD</td>
<td>215</td>
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</table>

Trainings organized

<table>
<thead>
<tr>
<th>Training Type</th>
<th>No.</th>
<th>Persons trained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer schools (ICAR)</td>
<td>5</td>
<td>136</td>
</tr>
<tr>
<td>Summer training (DBT)</td>
<td>1</td>
<td>24</td>
</tr>
<tr>
<td>International training (IRRI)</td>
<td>1</td>
<td>11 (8 countries)</td>
</tr>
<tr>
<td>Under CAS</td>
<td>23</td>
<td>478</td>
</tr>
</tbody>
</table>

Persons training under SGSY on Mushroom Production 1785

Out of above > 750 persons have started mushroom cultivation

Future Goal:
Ecologically sustainable management of plant diseases to ensure both food security & safety through education, research & extension
Plant Disease: A Threat to Global Food Security

H.S. Tripathi
Department of Plant Pathology, G.B.P.U.A. & T., Pantnagar - 263 145 (Uttarakhand)

The world population by the year 2000 was 6.2 billion and by 2010, population may go up to 7.1 billion while 800 million population do not have adequate food moreover 1.3 billion population live on less then 1$/day. Fourteen food crop plants provide the bulk food for human consumption throughout the world. At least 10% crop loss is estimated by plant diseases.

(Supply: Richard and Peter, 2005)

<table>
<thead>
<tr>
<th>Region</th>
<th>US$ in billion</th>
<th>Percent of potential production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia</td>
<td>43.8</td>
<td>14.2</td>
</tr>
<tr>
<td>Former Soviet Union</td>
<td>8.2</td>
<td>15.2</td>
</tr>
<tr>
<td>North America</td>
<td>7.1</td>
<td>9.7</td>
</tr>
<tr>
<td>Latin America</td>
<td>7.1</td>
<td>13.5</td>
</tr>
<tr>
<td>Europe</td>
<td>5.8</td>
<td>9.8</td>
</tr>
<tr>
<td>Africa</td>
<td>4.1</td>
<td>15.7</td>
</tr>
</tbody>
</table>

Main reasons of threat in developing country:

The main reasons are high rate of population growth, poverty amongst masses, masses depend on locally staple food, poor transfer of production technology to the farmer, poorly resourced R&D, less land holdings with farmers, improper identification and quantification of plant diseases, misleading feedback to government and policy maker regarding diseases in particular areas.
What are major threats?

- Causal agents:
  - Fungi
  - Bacteria
  - Viruses
  - Nematodes

Late blight of potato. In 1844 – late blight appears in U.S; in 1845, epidemic sweeps Ireland like a storm. Not only did many starve and die, but many were evicted from their homes. Millions die from starvation and more than a million immigrate to U.S. Immigrants treated as second class citizens and take low paying, dangerous jobs as policemen, firemen and miners.

Great Bengal Famine: The disease appears in Epidemic form during the year 1942-43, two million people died of starvation (*Bipolaris oryzae*), heavy rain fall at the time of ear formation and three rice season per year.

SOUTHERN CORN BLIGHT: In 1970, epidemic of corn blight by new race specific for plants with Texas male sterile cytoplasm found in southern US, 15% of US corn supply loss in 1970 (enough to feed sufficient cattle to make 30 billion Big Macs, USDA projections were for 90-100% loss in 1971

Stem rust of cereals: Widespread epidemics have been documented for Australia. Losses in North Dakota, during the severe epidemics of 1935 and 1954, were estimated at US $356 million and US $260 million, respectively, based on wheat prices in late 1995.

Red rot of sugarcane (*Glomerella tucumanensis*): Important disease, particularly in sub-tropical countries. Reductions of over 30% have been recorded in India, but may reach 50% or more, In Bangladesh, 10-15%, In Pakistan 29-75% reduction in cane weight, 30-87% loss in cane juice yield and 30-74% loss in recoverable sugar.

Bacterial soft rot: *E. carotovora* subsp. *carotovora* affects a wide range of plants causing soft rot of potatoes and many fruits and vegetables. The mean incidence of soft rot ranged from 10 to 100%

Bacterial wilt of solanaceous crops: Serious obstacle to the cultivation of many solanaceous plants in both tropical and temperate regions, cutting potato seed seriously increases the risk of high losses. When seed potatoes are cut disease incidence was found to increase by 250% and yield was reduced by 40%. In tomato, In India, a yield loss study with one cultivar showed 10-100% mortality of plants and 10-91% yield loss, respectively, at different stages of infection (0-90 days).

Nematodes as a potential threat: Potato cyst nematodes cause extensive damage, crop losses can be as high as 80%. *G. rostochiensis* reduced the yield by 76%; the marketable yield of 13.75 t/ha on treated areas was reduced (by 85%) to 1.96 t/ha. In Germany, As populations of 500 larvae/100 cmn are regularly reached, losses on affected areas were estimated at 10-15%.

Root knot nematode: In the field, crops including lucerne, groundnut, potato, carrot, sugarbeet, strawberry, pyrethrum and onion may be severely affected. Losses may range from 30-60% in severely affected areas.
New Emerging plant diseases

<table>
<thead>
<tr>
<th>Diseases</th>
<th>Distribution and crop losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat Rust- “Ug99” Threat</td>
<td>Most serious threat to wheat and barley crop in 50 years and most of the world wheat is vulnerable.</td>
</tr>
<tr>
<td>Scab of wheat and barley</td>
<td>Major threat in America. Yield losses were estimated at 95 million bushels in North Dakota.</td>
</tr>
<tr>
<td>Reemergence of potato and tomato late blight in US</td>
<td>An epidemic of late blight, lineage US-8, in July and August 1994. One grower with approximately 200 ha of potatoes suffered an 80 to 85% crop loss in 1994 and subsequently was forced out of business.</td>
</tr>
<tr>
<td>Sudden death syndrome of soybean</td>
<td>In the north central United States, estimated average annual yield losses of 175,619 t occurred during 1989 to 1991.</td>
</tr>
<tr>
<td>Potato Early Dying</td>
<td>In North America, yield reduction in moderately diseased fields can easily be 10 to 15%, and in severely diseased fields it can be as high as 30 to 50%.</td>
</tr>
<tr>
<td>Gray leaf spot of Maize</td>
<td>One of the most significant yield limiting diseases of maize (corn) worldwide. Yield losses due to gray leaf spot as high as 50% in some U.S. maize fields.</td>
</tr>
<tr>
<td>Soybean Rust</td>
<td>Disease that causes serious crop losses in many parts of the world, long known to occur in Asia. Yield losses in other parts of the world due to soybean rust have been reported to range from 10 to 90 percent.</td>
</tr>
<tr>
<td>Karnal Bunt of Wheat</td>
<td>The disease is endemic in Gurdaspur, Hoshiarpur, Jalandhar and Ropar districts (the sub-mountainous tracts) of Punjab. Brennan et al (1990) estimated the economic losses from Karnal bunt of wheat in Mexico, was US $ 7.02 million per year.</td>
</tr>
</tbody>
</table>


1. **Pathogen identification**: By Visual observation (symptoms) and by CABI Crop protection compendium.

**ELISA**
- M.F.Clark and A.N.Adam (1976)

**Principle**
- An enzyme conjugated with an antibody react with a colorless substrate to generate a colored reaction product.

**Enzymes**
- Alkaline phosphatase (ALP)
- Horseradish peroxidase (HRP)
- β-galactosidase

**Polymerase chain reaction**
- Kerry Mullis (1993)
- The PCR is a primer mediated enzymatic amplification of a DNA segment lying between two regions of known sequences.
STEPS IN PCR

[I] Melting of target DNA (denaturation).

[II] Annealing of primers to denatured DNA.

[III] Primer extension by DNA polymerase.

**Plant pathogen characterized by molecular markers**

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Disease</th>
<th>Marker</th>
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<tbody>
<tr>
<td><em>Alternaria brassicae</em></td>
<td>Leaf spot of crucifers</td>
<td>RAPD</td>
</tr>
<tr>
<td><em>Xanthomonas campestris pv. Vesicatoria</em></td>
<td>Bacterial leaf spot of pepper and tomato</td>
<td>REP PCR</td>
</tr>
<tr>
<td><em>Verticillium dahliae</em></td>
<td>Wide host range</td>
<td>RAPD</td>
</tr>
<tr>
<td><em>Verticillium dahliae</em> V. <em>Albotrum</em></td>
<td>Leaf spot of crucifers</td>
<td>RAPD</td>
</tr>
<tr>
<td><em>Ascochyta rabie</em></td>
<td>Chickpea blight</td>
<td>RAPD</td>
</tr>
<tr>
<td><em>Pseudomonas syringae pv. Syringae</em></td>
<td>Bacterial blight of peas</td>
<td>REP PCR</td>
</tr>
<tr>
<td><em>Leotospheeria maculans</em></td>
<td>Black leg of crucifers</td>
<td>AFLP</td>
</tr>
<tr>
<td><em>Rhynchosporium secalis</em></td>
<td>Barley scald</td>
<td>RAPD</td>
</tr>
<tr>
<td><em>Xanthomonas campastris pv. Oryzae</em></td>
<td>Bacterial blight of rice</td>
<td>RAPD</td>
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<tr>
<td><em>Magnaporthe grisea</em></td>
<td>Rice blast</td>
<td>RFLP</td>
</tr>
<tr>
<td><em>Leotospheeria maculans</em></td>
<td>Black leg of crucifers</td>
<td>RAPD</td>
</tr>
<tr>
<td><em>Phaeasariopsis griseola</em></td>
<td>Angular leaf spot of beans</td>
<td>RAPD</td>
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<tr>
<td><em>Phyoophthora infestans</em></td>
<td>Late blight of potato</td>
<td>AFLP/RFLP</td>
</tr>
<tr>
<td><em>Venturia inaequalis</em></td>
<td>Apple scab</td>
<td>MICROsATELLITES</td>
</tr>
<tr>
<td><em>Tilletia indica</em></td>
<td>Karnal bunt</td>
<td>ITS</td>
</tr>
<tr>
<td><em>Magnaporthe grisea</em></td>
<td>Rice blast</td>
<td>RAPD</td>
</tr>
<tr>
<td><em>Phomopsis helianthi</em></td>
<td>Brown stem canker of sun flower</td>
<td>AFLP</td>
</tr>
</tbody>
</table>

**Crop Yield Loss Estimation**

- **Critical point model**: The disease severity at a “critical point” is used to establish relation with crop yield loss. These models generally use linear regressions where disease is taken as independent variable. eg. rice blast, wheat stem rust and potato cyst nematode (*Globodera rotochiensis*)

  \[ Y = a + bx \]

- **Multiple Point Model**: This is a modified approach over first model as disease is scored at different times, during disease progress, and crop yield losses is computed as sum of disease ratings and regression coefficients. Multiple regression analysis is employed, where \(Y\) (% yield loss; dependent variable) depends upon disease increments (\(X_1\), \(X_2\) and \(X_n\), independent variables, observed periodically.

  \[ Y = b_1X_1 + b_2X_2 + b_3X_3 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots b_n X_n \]

**Area under Disease Progress Curve (AUDPC)**

- Disease progress curves are highly sensitive to fluctuations in epidemiological factors.
during disease development. The AUDPC accounts for all these factors. Since the crop damage / yield loss depends upon severity as well as duration of disease

**How can the threats be minimized?**
- Exclusion, Elimination or reduction of inoculums.
- Use of genetically resistant varieties.
- Maintain the genetic diversity of crop plants
- Exploiting the knowledge of biochemistry and molecular biology.
- The GM option

**Plant Quarantine**
- Exclusion of the pathogen through plant quarantine is the first line of defense. Quarantine is manmade barriers for the disease spread and operates through various legislative measures.
- Federal plant quarantine act, 1982 (USA)
- Destructive insect pest act, 1914 (India)
- Quarantine laws are of two types.
  1. Domestic or local quarantine (within the political boundary of country)
  2. International quarantine (between the boundary of two country)

**Plant disease introduced in India before and after quarantine laws**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Disease</th>
<th>Year</th>
<th>Introduce from</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Leaf rust of coffee</td>
<td>1879</td>
<td>Ceylon</td>
</tr>
<tr>
<td>2.</td>
<td>Late blight of potato</td>
<td>1883</td>
<td>Europe</td>
</tr>
<tr>
<td>3.</td>
<td>Flag smut of wheat</td>
<td>1906</td>
<td>Australia</td>
</tr>
<tr>
<td>4.</td>
<td>Downy mildew of grapes</td>
<td>1910</td>
<td>Europe</td>
</tr>
<tr>
<td>5.</td>
<td>Downy mildew of cucurbits</td>
<td>1910</td>
<td>Ceylon</td>
</tr>
<tr>
<td>6.</td>
<td>Downy mildew of maize</td>
<td>1912</td>
<td>Java</td>
</tr>
<tr>
<td>7.</td>
<td>Powdery mildew of rubber</td>
<td>1938</td>
<td>Malaya</td>
</tr>
<tr>
<td>8.</td>
<td>Fire blight of pear and apple</td>
<td>1940</td>
<td>England</td>
</tr>
<tr>
<td>10.</td>
<td>Bunchy top of banana</td>
<td>1953</td>
<td>Ceylon</td>
</tr>
<tr>
<td>11.</td>
<td>Wart disease of potato</td>
<td>1953</td>
<td>Netherlands</td>
</tr>
</tbody>
</table>

**Eradication**
- It is defined as the control of plant diseases by eliminating the pathogen after it is established or by eliminating the agent that carry the pathogen.

**Methods of Eradication**
1. Removal and destruction of main foci of inoculums
2. Breaking of the infection chain
3. Starvation of the pathogen
4. Modification of environmental conditions
### Eradication methods | Disease controlled
--- | ---
Field sanitation | Powdery mildew of wheat, barley, peas, downy mildew of maize, red rot of sugarcane
Crop rotation and land fallowing | Wilt diseases, bacterial ring of potato, black rot and black leg of cabbage, powdery scab of potato
Rouging | Loose smut of wheat, covered smut of barley and Wilt disease of Arhar
Alternate and collateral host destruction | Cereal rust, rust of apple and pine
Seed selection | Bunchy top of banana, loose smut of wheat, foot rot of ginger, red rot of sugarcane
Change in planting time | Rust diseases
Mixed cropping | Root rot of cotton and blight of pulse
Heat treat and chemical treatment | Loose smut of wheat, red rot of sugarcane
Eradication of insect vectors | Mostly viral diseases

### Use of genetically resistant plant
- Resistant varieties can be the most simple, practical, effective and economical method of plant management. The use of resistant varieties can not only ensure protection against the diseases but can also save the time, energy and money spent on other measure of control.

### Use of resistant varieties

<table>
<thead>
<tr>
<th>Diseases</th>
<th>Resistant varieties uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loose smut of wheat</td>
<td>PBW-181,HW888,HD4502 etc.</td>
</tr>
<tr>
<td>Karnal bunt of wheat</td>
<td>HD -29, &amp; HD-30.</td>
</tr>
<tr>
<td>Stem rust of wheat</td>
<td>NP-4, BR-319.</td>
</tr>
<tr>
<td>Brown leaf spot of rice</td>
<td>Ch-13,CH-45,T-141,T-998</td>
</tr>
<tr>
<td>Blast of rice</td>
<td>Alkulu, Kukulu,Suchi,BJ-1.</td>
</tr>
<tr>
<td>Wilt of Cotton</td>
<td>Verun, BDS, Jarila, Vijay.</td>
</tr>
<tr>
<td>Ascochyta blight of chickpea</td>
<td>GG-715,ICC-76</td>
</tr>
<tr>
<td>Downy mildew of maize</td>
<td>DMR-1</td>
</tr>
</tbody>
</table>

### Exploiting the knowledge of the Biochemistry & Molecular biology
- *Xanthomonas albilineans*, causal agent of sugarcane leaf scaled, produces a family of toxins and antibiotics known as the albicidins, which selectively block DNA replication in bacteria and chloroplast. In consequences sugarcane infected by the bacterium is chlorotic. During a screening programm , an albicidin resistant isolate of *Pantoea Dispersa* was found that efficiently detoxified albicidin and was effective as a biocontrol agent.
- The secretion of two protiens,ECP1 and ECP2, by *Cladosporium fulvum* was required for
full expression of virulence of this tomato pathogen. When a construct of gene encoding ECP2 was made with potato virus(PVX::ECP2) and used to infect a range of tomato genotypes, four were found that responded with a systemic hyper sensitive response. This reaction was encoded by a single dominant gene, designated CF-ECP2, that recognizes the protein ECP2. Since this factor is required for virulence, the resistance conferred by CF-ECP2 is expected to be durable. (LAUGE et al.,1997)

The GM option

- Genetic engineering can involve moving genes both within or between species. Organisms modified in this way, are referred to as being transgenic or genetically modified or genetically engineered or simply as GMO’s. GM technology thus gives the ability to add, subtract, alter or exchange an individual gene or a group of genes, which are known to influence an individual characteristic.

The GM option

- Apple has been transformed with stilbene synthase gene from grapevine and a polygalacturonase inhibiting protein (PGIP) from Kiwi.
- Transformation of rice with the AFP gene of Aspergillus giganteus, which encodes the antifungal AFP protein, showed varying levels of resistance to rice blast caused by Mangaporthe grisea.
- Farming of papaya (Carica papaya) in Hawaii was threatened by papaya ringspot virus. Initial control was obtained by cross protection with a mild strain.

We should all remember that we need HEALTHY PLANTS in order to have HEALTHY AND HAPPY PEOPLE
Strategies to Mitigate the Threat to Wheat Production from the Ug99 (TTKS) Race of Stem Rust

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Introduction

Stem or black rust of wheat, caused by fungus *Puccinia graminis* Pers. F. sp. *tritici* Eriks. & E. Henn., was at one time the most feared disease of wheat worldwide. It was not until the beginning of the 20th century and soon after the rediscovery of Mendel's laws, that Biffen in 1905 demonstrated that inheritance of resistance to wheat yellow rust, caused by *Puccinia striiformis*, followed Mendel's laws. After two devastating stem rust epidemics in North America in 1904 and 1916, another important finding came from the work of Stakman and Piemeisel 1917 who showed that stem rust pathogen had various forms or races. These races varied in their ability to infect different wheat varieties which later were found to carry distinct resistance genes or combinations thereof. Strong emphases to identify resistance to stem rust and breed resistant wheat cultivars were given in the USA, Canada, Australia and Europe. A simultaneous effort was also made to understand rust epidemiology and evolution, which led to the barberry eradication programme in North America and Europe and formulation of genetic control strategies. Efforts to find a solution to stem rust also initiated global collaboration among wheat scientists who grew and evaluated wheat germplasm for resistance to stem rust.

**Table 1.** Originating genus and species and usefulness of designated Sr genes in conferring seedling and/or adult plant resistance to Ug99 race of stem rust pathogen *P. graminis* f. sp. *tritici*

<table>
<thead>
<tr>
<th>Origin of Sr genes</th>
<th>Stem rust resistant (Sr) genes</th>
<th>Infective</th>
<th>Effective</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Triticum aestivum</em></td>
<td>5, 6, 7a, 7b, 8a, 8b, 9a, 9b, 9f, 10, 15, 16, 18, 19, 20, 23, 30, 41, 42, Wld-1</td>
<td>281, 291, Tmp</td>
<td></td>
</tr>
<tr>
<td><em>Triticum turgidum</em></td>
<td>9d, 9e, 9g, 11, 12, 17</td>
<td>21c, 1312, 141</td>
<td></td>
</tr>
<tr>
<td><em>Triticum monococcum</em></td>
<td>21</td>
<td>22, 35</td>
<td></td>
</tr>
<tr>
<td><em>Triticum timopheevi</em></td>
<td>361, 37</td>
<td>38, 39</td>
<td></td>
</tr>
<tr>
<td><em>Triticum speltaeoides</em></td>
<td>32</td>
<td>33c, 45</td>
<td></td>
</tr>
<tr>
<td><em>Triticum tauschii</em></td>
<td>34</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Triticum comosum</em></td>
<td>34</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Triticum ventricosum</em></td>
<td>38</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Triticum araraticum</em></td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Thinopyrum elongatum</em></td>
<td>241, 25, 26, 43</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Thinopyrum intermedium</em></td>
<td>44</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Secale cereale</em></td>
<td>31</td>
<td>271, 1A, 1R</td>
<td></td>
</tr>
</tbody>
</table>

Almost 50 different stem resistance genes are now catalogued (5), several of which are incorporated in wheat from alien relatives of wheat (Table 1). All but one of 50 resistance genes are race-specific, and are expressed in both seedling and adult plants. Race specificity derives from the gene-for-gene relationship between the host plant resistance gene and corresponding virulence genes in the pathogen. Gene Sr2, transferred to wheat from ‘Yaroslav emmer’ by
McFadden 1930, is the only catalogued gene that is not race-specific. Sr2 can confer slow rusting resistance of adult-plant nature. Resistance gene Sr2, in addition to other unknown minor genes derived from cultivar Hope and commonly known as ‘Sr2-Complex’, provided the foundation for durable resistance to stem rust in germplasm from university of Minnesota in the USA, Sydney University in Australia, and the spring wheat germplasm developed by Dr. N.E. Borlaug as part of a programme sponsored by the Mexican Government and the Rockefeller Foundation.

The importance of stem rust declined worldwide with the deployment of various other alien resistance genes such as Sr 24, Sr 26, Sr 31 and more recently Sr 38. Translocations carrying these genes, except that with Sr 26, also carried additional genes that conferred resistance to some other important diseases such as leaf rust, yellow rust or powdery mildew.

**Susceptibility of Global Wheat Germplasm to *P. graminis tritici* Race Ug 99 Present in East Africa**

Race Ug 99, first identified in Uganda during 1999, is the only known race of *P. graminis tritici* that has virulence for gene Sr 31 from rye (*Secale cereale*). Later this race was designated as TTKS by Wanyera et al. (2006) using the North American nomenclature system. Unfortunately, race Ug 99 not only carries virulence to gene Sr 31 but also this unique virulence is present together with virulences for most of the genes of wheat origin and virulence for gene Sr 38 introduced in wheat from *Triticum ventricosum* that is present in several European and Australian cultivars and a small portion of new CIMMYT germplasm (Table 1).

Predicted patterns of movement of airborne pathogens are filled with uncertainty, although advances in air-borne modeling and prediction are offering some interesting new insights. Typically, most spores will be deposited close to the source, however long-distance dispersal is well documented, with three principal modes of dispersal known to occur. The first mode of dispersal is single event, extremely long-distance (typically cross-continent) dispersal that results in pathogen colonization of new regions. Dispersion of this type is rare under natural conditions and by nature inherently unpredictable.

Assisted long-distance dispersal, typically on traveller’s clothing or infected plant material, is another increasingly important is another increasingly important element in the colonization of new areas by pathogens. Despite strict phytosanitary regulations, increasing globalization and air travel both increase the risk of pathogen spread.

The second major mode of dispersal for pathogens like rusts is step-wise range expansion. This typically occurs over shorter distances, within country or region, and has a much higher probability than the first described dispersal mode. This probably represents the most common or normal mode of dispersal for rust pathogens. A good example of this type of dispersal mechanism would include the spread of yellow rust by a Yr9-virulent race of *P. striiformis* that evolved in eastern Africa and migrated to South Asia through the Middle East and West Asia in a step-wise manner over about 10 years, and caused severe epidemics in its path.

The third mode of dispersal, extinction and re-colonization, could perhaps be considered a
sub-mechanism of step-wise range expansion. This mechanism occurs in areas that have unsuitable conditions of year round survival.

Race Ug99 was first detected in Uganda in 1999. Following its detection, investigations in neighbouring countries in East Africa revealed that the same race may have migrated to sites in the Rift Valley province of central Kenya by 1998/1999, with subsequent advancement to site in Eastern Kenya by 2001. In 2003, race Ug 99 was detected in Ethiopia with 2005 reports from at least six dispersed site locations. Available evidence suggests that Ug99 is now established in the eastern African highlands and spreading.

The East African highlands are a known ‘hot-spot’ for the evolution of new rust races. The favourable environmental conditions, plus the presence of host plants year-round all favour the buildup of pathogen populations. Available evidence emerging from the East African countries indicates that Ug99 has exhibited a gradual step-wise range expansion, following the predominant west-east airflows.

A major concern is that a significant proportion of global wheat germplasm is potentially at risk from race Ug99. Reynolds and Borlaug estimated that this area might amount to 50 million ha of wheat grown globally i.e., about 25% of the world’s wheat area. Germplasm with resistance to Ug 99 is available, but for many parts of the world, material of this type is not present in varieties grown in farmers’ fields. Major questions that now arise are: how likely is it that Ug 99 might spread, where Ug99 might spread to, and what the likely consequences of any movement are.

**Potential Migration Paths for Race Ug99**

Most evidence, albeit circumstantial, indicate that Ug 99 is likely to spread beyond the borders of the three East African countries in which it is currently present. The sheer mobility of rust spores led an international panel of rust experts to conclude that it is only a matter of time until Ug99 reaches across the Saudi Arabian Peninsula and into the Middle East, South Asia, and eventually, East Asia and the Americas’. In addition, there is documented evidence connecting East Africa with West and South Asia for migration of rust races of East African origin.

**Strategies to Mitigate the Risks of Losses From Epidemics Caused by Race Ug 99**

The best control strategy is to identify resistant wheat genotypes that can adapt to the prevalent environments in these countries, and release them after proper testing while simultaneously producing the seed. An aggressive strategy to promote these resistant cultivars in farmer’s fields is the only viable option as resource-poor farmers in most of East Africa, except some commercial farmers in Kenya, can not afford to use chemical control. A reduction in disease pressure in East Africa will also reduce chances of migration beyond the region.

Reducing the area planted to susceptible cultivars in the Arabian Peninsula, North Africa, Middle East and West and South Asia is also the best strategy if major losses are to be avoided when race Ug99 migrates to these areas. The ‘Global Rust Initiative’, launched during 2005 and led by CIMMYT in partnership with ICARDA and various National and Advanced Research Institutions, is using the following strategies to reduce the possibilities of major epidemics:
1) monitoring the spread of race Ug 99 beyond eastern Africa
2) screening of released cultivars and germplasm for resistance
3) distributing sources of resistance worldwide for either direct use as cultivars or for breeding, and
4) targeted breeding to incorporate diverse resistance genes and adult plant resistance into high-yielding adapted cultivars and germplasm (www.globalrust.org).

Table 2: Frequency of wheat cultivars and advanced breeding lines of different origins for their field response to Ug99 race of the stem rust pathogen at Njoro, Kenya during 2006

<table>
<thead>
<tr>
<th>Country/Institution</th>
<th>Response and frequency</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Resistant</td>
<td>Moderately resistant</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>China</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Egypt</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>India</td>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td>Iran</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Nepal</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pakistan</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Russia</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Turkey</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>CIMMYT-Irrigated*</td>
<td>94</td>
<td>56</td>
</tr>
<tr>
<td>CIMMYT-Semiarid*</td>
<td>50</td>
<td>9</td>
</tr>
<tr>
<td>CIMMYT-High Rainfall*</td>
<td>11</td>
<td>6</td>
</tr>
</tbody>
</table>

Race-specific Resistance Genes

A large portion of the highly resistant germplasm from South America, Australia and CIMMYT possess Sr 24. There are three distinct Sr24-carrying translocations: the original one linked to a gene for re grain colour, the shorter segment with white grain, and a third segment where a very small segment has been retranslocated onto chromosome 1BS. In all three segments both Sr24 and Lr 24 are present together. Therefore, selection for Lr24 with avirulent leaf rust isolates can be used as an indirect selection strategy. This gene would look like an attractive candidate for future breeding efforts; however it must be used in combination with other effective resistance genes because virulence to Sr 24 is already known in South Africa and India.

Gene Sr 36 derived from Triticum timopheevi, exhibits an immunity (no symptoms) to race Ug99 at both seedling and adult plant stages. The gene occurs in a high frequency in US soft winter wheat. Although races with virulence for Sr 36 are common, it could be used effectively as a component for Ug99 resistance breeding.

Breeding strategies for resistance to P. graminis tritici Race Ug99

The fastest way to reduce the susceptibility of important wheat cultivars and the best new germplasm is to systematically incorporate diverse sources of resistance into them through limited or repeated backcrossing. To transfer two or more effective resistance genes into an adapted cultivar the better crossing strategy would be to first cross the resistance sources and then cross
the F<sub>1</sub> plants with the adapted cultivar. Molecular markers can then be used to select top-cross plants that have desirable agronomic features and carry the targeted resistance genes.

The strategy adopted at CIMMYT is to transfer the adult-plant resistance from Pavon 76, and a few other wheats identified so far, to a range of important CIMMYT wheat germplasm by using the ‘single-backcross selected-bulk’ breeding approach. In this strategy the resistance sources are crossed with the adapted high-yielding wheats and then a single backcross is made with the recurrent parent to obtain about 400 BC<sub>1</sub> seeds. BC<sub>1</sub> plants were then selected for desired agronomic features and resistance to leaf and yellow rusts, and harvested as bulk. Large F<sub>2</sub> populations of about 2500 plants will be grown and plants will be selected in Mexico for agronomic traits and resistance to other diseases and harvested as bulk. A similar selection will be practiced in the F<sub>3</sub> generation to obtain F<sub>4</sub> populations. At this stage we will try to select for adult-plant resistance by growing densely sown F<sub>4</sub>-buld population is Kenya or Ethiopia, under high stem rust pressure created by inoculating with Ug99 race. Populations will be bulk harvested and plumper grains selected to grow F<sub>5</sub> generation in Mexico. Because stem rust affects grain filling, we expect that plants with insufficient resistance will have shriveled grains. Moreover, by F<sub>4</sub> generation enough homozygosity is achieved for the selection of additive resistance genes. Individual plants with desired agronomic features and resistance to other diseases will be selected in the F<sub>5</sub> generation and those with good grain characteristics will be grown in F<sub>6</sub> as hill plots or short rows in Kenya or Ethiopia as well as small plots in Mexico for final selection. Finally, the resistant F<sub>6</sub> plots will be harvested for conducting yield trials in the following crop season. The same methodology is also proposed to transfer resistance from old, tall Kenyan cultivars into adapted semidwarf wheats. The proposed approach is expected to rebuild the durable resistance in modern wheat germplasm. Genetic analyses will be necessary to understand the number and type of resistance genes involved in sources contributing the adult plant resistance. Genomic locations of minor, additive resistance genes will be determined through molecular mapping. Such information will be useful to establish and enhance genetic diversity for minor genes.

**Rapid Seed Multiplication**

Once UG99 resistant wheat varieties are nationally or regionally registered and ready for release, a national strategy should be in place for the seed multiplication and distribution of quality seed of rust resistant varieties to replace rust susceptible varieties in high areas or hot spots. As a stating point, the initial target for rapid seed multiplication is 10% of the wheat production area. In most countries this can be accomplished in 3-4 generations (see Table 2). The actual targets for rapid seed multiplication will depend on the actual and potential threat of UG99 that will be elaborated as part of the contingency planning and surveillance system.

**Table 1: Planting rate of 100kg/ha with varying yields (3T/ha, 4T/ha and 6T/ha)**

<table>
<thead>
<tr>
<th>Generation</th>
<th>Qty of seed produced in Tons with different Seed Multiplication Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1:30</td>
</tr>
<tr>
<td>Initial seed Qty</td>
<td>0.05</td>
</tr>
<tr>
<td>First</td>
<td>1.5 (0.5 ha)</td>
</tr>
<tr>
<td>Second</td>
<td>45 (15 ha)</td>
</tr>
</tbody>
</table>
To provide an idea of the number of generations, area needed for seed multiplication and area the seed can cover at various multiplication factors, the above tables will provide some basic information of a seed multiplication system starting with 50kg of nucleus seed.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Country</th>
<th>Area under Wheat cultivation 2007</th>
<th>10% of the wheat area</th>
<th>% Area that will be covered after 4 generations with following Multiplication Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1:30</td>
</tr>
<tr>
<td>1.</td>
<td>Afghanistan</td>
<td>2,190,000</td>
<td>219,000</td>
<td>18.4</td>
</tr>
<tr>
<td>2.</td>
<td>Algeria</td>
<td>1,785,000</td>
<td>178,500</td>
<td>22.6</td>
</tr>
<tr>
<td>3.</td>
<td>Armenia</td>
<td>113,300</td>
<td>11,330</td>
<td>100</td>
</tr>
<tr>
<td>4.</td>
<td>Azerbaijan</td>
<td>486,990</td>
<td>48,699</td>
<td>83.4</td>
</tr>
<tr>
<td>5.</td>
<td>Bangladesh</td>
<td>805,000</td>
<td>80,500</td>
<td>50.3</td>
</tr>
<tr>
<td>6.</td>
<td>China</td>
<td>30,000,000</td>
<td>3,000,000</td>
<td>1.4</td>
</tr>
<tr>
<td>7.</td>
<td>Egypt</td>
<td>1,139,000</td>
<td>113,900</td>
<td>35.6</td>
</tr>
<tr>
<td>8.</td>
<td>Ethiopia</td>
<td>1,351,000</td>
<td>135,100</td>
<td>29.9</td>
</tr>
<tr>
<td>9.</td>
<td>Georgia</td>
<td>61,000</td>
<td>6,100</td>
<td>100</td>
</tr>
<tr>
<td>10.</td>
<td>India</td>
<td>28,035,000</td>
<td>2,803,500</td>
<td>1.4</td>
</tr>
<tr>
<td>11.</td>
<td>Iran</td>
<td>6,400,000</td>
<td>640,000</td>
<td>6.3</td>
</tr>
<tr>
<td>12.</td>
<td>Iraq</td>
<td>531,210</td>
<td>53,121</td>
<td>76.2</td>
</tr>
<tr>
<td>13.</td>
<td>Jordan</td>
<td>30,000</td>
<td>3,000</td>
<td>100</td>
</tr>
<tr>
<td>14.</td>
<td>Kenya</td>
<td>150,000</td>
<td>15,000</td>
<td>100</td>
</tr>
<tr>
<td>15.</td>
<td>Kyrgyzstan</td>
<td>354,500</td>
<td>35,450</td>
<td>100</td>
</tr>
<tr>
<td>16.</td>
<td>Lebanon</td>
<td>48,000</td>
<td>4,800</td>
<td>100</td>
</tr>
<tr>
<td>17.</td>
<td>Libya</td>
<td>257,000</td>
<td>25,700</td>
<td>100</td>
</tr>
<tr>
<td>18.</td>
<td>Morocco</td>
<td>1,500,000</td>
<td>150,000</td>
<td>27.0</td>
</tr>
<tr>
<td>19.</td>
<td>Nepal</td>
<td>472,000</td>
<td>47,200</td>
<td>85.8</td>
</tr>
<tr>
<td>20.</td>
<td>Oman</td>
<td>275</td>
<td>27.5</td>
<td>100</td>
</tr>
<tr>
<td>21.</td>
<td>Pakistan</td>
<td>8,494,000</td>
<td>849,400</td>
<td>4.8</td>
</tr>
<tr>
<td>22.</td>
<td>Saudi Arabia</td>
<td>462,000</td>
<td>46,200</td>
<td>87.7</td>
</tr>
<tr>
<td>23.</td>
<td>Sudan</td>
<td>250,000</td>
<td>25,000</td>
<td>100</td>
</tr>
<tr>
<td>24.</td>
<td>Syria</td>
<td>1,850,000</td>
<td>185,000</td>
<td>21.9</td>
</tr>
<tr>
<td>25.</td>
<td>Tajikistan</td>
<td>330,000</td>
<td>33,000</td>
<td>100</td>
</tr>
<tr>
<td>26.</td>
<td>Tunisia</td>
<td>974,000</td>
<td>97,400</td>
<td>41.6</td>
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<tr>
<td>27.</td>
<td>Turkey</td>
<td>8,600,000</td>
<td>860,000</td>
<td>4.7</td>
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<tr>
<td>28.</td>
<td>Uganda</td>
<td>11,000</td>
<td>1,100</td>
<td>100</td>
</tr>
<tr>
<td>29.</td>
<td>Uzbekistan</td>
<td>140,000</td>
<td>14,000</td>
<td>28.9</td>
</tr>
<tr>
<td>30.</td>
<td>Yemen</td>
<td>114,030</td>
<td>11,403</td>
<td>100</td>
</tr>
</tbody>
</table>

This second table focuses on providing an idea of indicative quantities of seed that may be needed in each country. A tentative target of seed to cover 10% of the total area in wheat is included. In addition the percentage of the area that can be covered by 4 generation of seed production a multiplication factor of 30, 40 and 60 demonstrates the need to undertaken intensive
wheat seed production in order to reduce the time to reach the target quantities.

**Gene Deployment: Indian Experience**

Gene deployment is the strategic usage of resistance genes over a large area to reduce the threat of epidemics.

Gene deployment schemes with aim to prevent large-scale build up of wheat rusts were also proposed in India.

In order for the gene deployment to be effective, information on some of key areas
- Pathogenicity survey in the country,
- Information on virulence of exogenous pathotypes
- Epidemiological studies must be acquired and made available.

In order for the gene deployment to be effective, it is very essential that role of exogenous inoculum is ascertained. Breakdown of Kalyansona, Sonalika and Yr9 resistance against stripe rust was traced to Eastern Africa, Turkey, Syria, Iran and Pakistan. Another challenge now is that similar route of migration has also been predicted for Ug99.

A successful, though unintentional, deployment for stem rust resistance is the large scale cultivation of HD2189 in Peninsular India. Presently, this cultivar is resistant to Indian stem rust pathogen. Another Sr31- cultivar (DWR162) being cultivated in Karnataka or Nilgiris is not able to multiply as it lands on the resistant gene. Consequently, three popular cultivars of Central Zone namely Lok-1, Sujata and WH147, though susceptible but are protected against any transported inoculum.

**Chemical and Cultural Management of TTSK (Ug99) of Wheat Stem Rust Pathogen in Kenya**

While resistant is the most effective method of controlling stem rust, there are no commercial varieties in Kenya with adequate resistance. Therefore, fungicides as foliar or seed treatments will play a role in the integrated management of the disease until new varieties with improved resistance are released.

Stem rust epidemics are causing grain losses of up to 70% in experimental plots and over 70% in farmer’s fields. This is yield of sprayed vs. unsprayed wheat crop. Spraying only reduces but does not eliminate the disease. It is therefore possible to get yield losses higher than this when relative to a clean crop. In the year 2007, farmers who never controlled the disease at all, lost 100% of their crop regardless of the variety.

Short term control of stem rust can be achieved with standard application of fungicides, provided the infection is not severe. Some of the foliar fungicides recommended for the control of yellow and leaf rusts can also be used to reduce/suppress the stem rust disease. Because most farmers are not able to identify the rust, it is recommended to apply two sprays, 60 days and 75-78 days respectively, after planting.
REFERENCES


2. Ravi P. Singh et al. Current status, likely migration and strategies to mitigate the threat to wheat production from Race Ug 99 of stem rust. CAB Rev. 2006, 1, no. 054.


Plant Healthcare for Resource Poor Farmers

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Since recorded history, the impact of pests on different crops has been important as a result of which many practices of “traditional” and “modern” agriculture have evolved. During the last century high input based intensification of agricultural production and less diversified farming systems has caused crop protection problems to multiply. As a result an impressive array of crop protection technologies such as pest-resistant plants, cultural controls, biological controls, pesticides, behavior-modifying substances, quarantine laws, and pest eradication programs have evolved. Ancient farmers developed sustainable agriculture practices, which allowed them to produce food and fibre for thousand of years with few outside inputs. Most of such practices were developed empirically through millennia of trial and errors, natural selection, and keen observations. Some of these practices which often conserve energy, maintain natural resources and reduce chemical use, deserve examination. Today, perhaps over half the world’s arable land is farmed by traditional farmers. Many of their techniques are unknown or poorly understood, but have allowed them to produce crops and animals with minimal or no purchased inputs. The striking diversity existing in the traditional farming systems gives them a high degree of stability, resilience and efficiency especially on marginal lands.

Efforts to intensify agriculture production will continue as a result of the need for food security among rapidly growing population. But changes in agricultural systems and in the intensity of land use have impacts on pest problems. Growing food demand must be met primarily by increasing production on land already under cultivation (productive and marginal lands) and by reducing losses due to diseases and pests. Attention, therefore, must go to small and marginal farmers, who till nearly 65% of world’s arable land, to increase farm productivity. Crop protection aspects must accordingly be incorporated as an integral part of sustainable efforts to intensify production.

Plant protection in hill agriculture

Rainfed farming and intensive cultivation on small and fragmented lands is characteristic of hill agriculture. Less land per person requires more high yielding agriculture and often the response is high levels of chemical inputs, reduced rotations and extensive monocultures. The search for greater and ever-cheaper production with increased intensification reduces the biodiversity of the system itself and makes it vulnerable (Box 1).
Decreased biodiversity tends to result in agroecosystems that are unstable and prone to recurrent pest outbreaks and many other problems. In a recent study (Singh and Singh, 2005) carried out in four hill districts of Uttarakhand, viz., Bageshwar (Kumaon), Nainital (Kumaon), Uttarkashi (Garhwal) and Pauri Garhwal (Garhwal), it was found that the per hectare agrochemical usage in the vegetable crops was quite high as compared to cereal crops. The highest per ha consumption was recorded in tomato, which stood at 406 kg/ha of fertilizers and an average five sprays of pesticides. Similarly in other vegetables, the agrochemical (including pesticides) consumption has dramatically increased and will continue in future as well.

High pesticide use does not guarantee pest control. Unaware of the problems arising from pesticide resistance and the destruction of natural enemies, farmers often respond to pest outbreaks by applying more pesticide, which merely aggravate the problem, a situation known as ‘the pesticide treadmill’. Once on the treadmill, the farmers find himself or herself facing spiraling pesticide input costs, potentially increased pest problems and lower yields, leading to increasingly smaller returns on investment. To increase yield from existing land requires good crop protection against losses before and after harvesting, which, must be achieved within the framework of Integrated Pest Management (IPM). However, the underlying, well taken theme--that an IPM approach can lead to reduced reliance on pesticides--has to compete with constraints such as intensive agriculture on small and scattered holdings, poor risk bearing capacity of the farmers, inherent susceptibility of vegetable varieties in use to a spectrum of diseases and pests and natural calamities (like draught or incessant rains).
Integrated Pest Management

Integrated pest management (IPM) is a concept of crop production incorporating effective, stable, long-lasting crop protection components that minimize the negative side effects of current pest control actions. IPM recognizes that farmers' knowledge - and not just the technology - is the key to success. It thus takes its place in a broad school of sustainable approaches, ranging from organic agriculture to low external-input practices. In the traditional sense, IPM has been thought of to be the use of multiple tactics to optimize control, but slowly that vision has changed to accommodate the integration of all pest management tactics for a crop (Box 2). Pesticides are the option of last resort in IPM programs because of their potential negative impacts on the environment. If chemical pesticides must be used, it is to the grower's advantage to choose the least-toxic pesticide that will control the pest but not harm non-target organisms such as birds, fish, and mammals. Pesticides that are short-lived or act on one or a few specific organisms are included in this category. More recently, a larger portion of strategies utilized in agriculture have been biological control practices progressing towards biointensive IPM (Box 3). The goal is to increase farmers' income and to ensure that it can be sustained over time, and to reduce environmental and health risks.

IPM Interventions

- Pesticides
- Biological control
- Physical/mechanical control
- Cultural/sanitation practices

IPM Continuum

- Biointensive
  - Biologically based control
  - Prevention
  - Reduced risk pesticides
  - Economic thresholds
  - Monitoring
- Chemically intensive

IPM is especially well suited to small scale farming because it makes use of on-farm labour and farmers' knowledge instead of purchased inputs. If deliberate attempts are made to strengthen the natural defenses of the ecosystem, it is likely that there will be little or no need of chemical inputs to manage pests. Promoting improved and promising IPM strategies that can be easily understood and implemented by small scale farmers thus remains the major objective under two situations: one involving traditional cultivation system and subsistence crops where pests regularly cause considerable crop losses and the other involving pesticide induced crises caused by high-input biased intensification, where farmers are continually forced to increase the amount of pesticides they use in order to maintain yield levels. Both the situations need to be targeted in order to implement an IPM programme in Uttarakhand hills.

A Common Minimum Programme under IPM: a case study in Uttarakhand hills

Off-season vegetable cultivation plays a unique role in the hill farming system in
Uttarakhand. Being low volume and high value crops they are rated to be potential cash earners. Unfortunately, however, all these cash crops suffer recurrent chronic losses due to a variety of seed and soil borne diseases and impact of insects like, white grub and cutworm. Farmers suffer from limited choice of improved cultivars and have poor access to healthy seeds and propagation material. These problems result in an injudicious use of pesticides to solve pest problems causing a number of problems related to heavy use of pesticides, like residues in soil, ground water and harvested produce, intoxication of farmers and development of pesticide resistance.

The problems faced by the farmers in the region are consistent with mandate of IPM. The challenge is to apply research to issues that lead to insecurity amongst small and marginal farmers as regards crop management and protection. While threats with regard to biotic and abiotic causes vary from region to region, there is a range of common challenges such as recurrent losses (over 70%) to vegetable cultivation due to seed and soil borne pathogens and pests that warrant a regional approach of integrated management (Box 4).

**COMMON THREATS TO VEGETABLES IN UTTARAKHAND HILLS**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Threat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato</td>
<td>Late blight, bacterial wilt, brown rot, cut worm, white grub</td>
</tr>
<tr>
<td>Pea</td>
<td>Seed rot, Root rot complex, Ascochyta blight, cut worm</td>
</tr>
<tr>
<td>Bean</td>
<td>Seed rot, Root rot complex, anthracnose, angular leaf spot</td>
</tr>
<tr>
<td>Cabbage</td>
<td>Seed rot, Root rot complex, collar rot, black rot, head rot</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>Root rot complex, collar rot, black rot, head rot</td>
</tr>
<tr>
<td>Capsicum</td>
<td>Root rot complex, fruit rot, Cercospora leaf spot, dieback</td>
</tr>
<tr>
<td>Tomato</td>
<td>Seed rot, Root rot complex, early blight, fruit rot, wilt, fruit borer</td>
</tr>
<tr>
<td>Cucumber</td>
<td>Root rot complex, Bacterial wilt</td>
</tr>
</tbody>
</table>

- Common threats indicated in *italics* are those that either seed or soil borne in nature and cause over 70% losses to crops each season in mid and high hills.
- Common crops in **bold** are those that are raised through nurseries and harbour severe damage due to pre- and post emergence damping off and root rot complex in the nursery itself causing severe losses to the farmers due to high seed costs.
- Strategies that can mitigate losses (of over 70%) due to seed and soil borne causative can enhance production by the same proportion

The cost of soil borne pathogens and pests to society and the environment far exceeds the direct costs to growers and consumers. Long term chemical applications may permanently alter the microbial community structure to an extent that sustainable agriculture may be impossible. The opportunity therefore exists to address the issues relating to IPM across ecosystems through a Common Minimum Programme. Other specific problems could be addressed through supplementary intervention(s).

The key elements of the Common Minimum Programme that provide the frame work for a regional approach include **soil solarization**, **vermicomposting**, **use of bioagents**, and **value addition of vermicompost**. Each element has a strong ecological base and operates through
maintaining and increasing biological diversity in the soil.

1. Soil solarization

The use of clear polythene film to cover moistened soil and trap lethal amounts of heat from solar radiation, termed as soil solarization. The pesticidal activity of soil solarization has been found to stem from a combination of physical, chemical and biological effects. For most vegetables, nursery is raised from the seeds and transplanted in the field. In the nursery, the seed and the emerging seedlings encounter a plethora of soil pathogens and insects. As a result, substantial portion of the nursery is lost due to seed rot, damping off, root rot, collar rot, stem rot and insect damage. The left over seedlings are usually infected and poor in growth, and carry infection to the field. Soil solarization is a low-cost technique to reduce losses due to insect pests and diseases. Under the technique, nursery beds are prepared 5-8 weeks in advance of seed sowing and are irrigated. Subsequently, they are covered with a transparent polythene sheet (50-100 μ thick) in such a manner that there is no leakage of air from any point in the nursery. Polythene sheet is removed 3-4 days ahead of the seed sowing time. The polythene sheet gives a green-house effect whereby sun rays are trapped underneath. As a result, temperature of the soil increases to a level that it becomes injurious to the soil microorganisms. Besides, it reduces weed population, improved physical and chemical properties of the soil and increases population of useful (friendly) micro flora in the soil. Since, plant pathogens are weakened through the effect of solarization; they are over powered by the bioagents. In order to get maximum benefit from soil solarization, it is necessary to perform the practice for about 5-8 weeks during hottest months of the year using a transparent polythene sheet. Nursery beds must be irrigated before being covered by polythene sheet and organic compost must be incorporated.

2. Preparation and use of vermicompost

Traditionally farmers use undecomposed farm yard manure, which is deficient in nutrients and does more harm than good to the crop. Undecomposed FYM promotes diseases, insects and pests and weed populations in the soil. On the other hand, vermicompost is more nutritious and gets ready in lesser time. For its preparation, dung, crop residue, green manure and other wastes are used by the earthworms to convert these to nutritious compost. Vermicompost is balanced natural compost for vegetables, fruits and cereal crops. Use of vermicompost reduces the cost of production, increases plant’s health and resistance against biotic and abiotic causes and fertility and water holding capacity of the soil. Since the waste material consumed by the earthworms passes through their guts, where it is acted upon by enzymes and hence becomes nutritious for the crops. Of other species of earthworms, *Eisenia fetida* has been found to be efficient in compost making.

3. Use of bioagents

Biological control is the sum total of harmful activities, which an organism (biological control agent, abbreviated synonym “bioagent”) inflicts on the other. The term biological control has been used in different fields of biology, more commonly in entomology and plant pathology. In
entomology, it has been used to describe the live predatory insects, entomopathogenic nematodes, or microbial pathogens to suppress populations of different pest insects. In plant pathology, the term applies to the use of microbial antagonists to suppress diseases as well as the use of host specific pathogens to control weed populations. Continuous use of pesticide results into the development of resistance in the pests, therefore use of bioagents is a better alternative. More so because they are environment friendly and improve soil ecology and health. During last two decades many bioagents have become commercially available in the market of which *Trichoderma* and *Pseudomonas* spp. are quite popular for management of plant diseases. Bioagents (microbial antagonists) could be used as seed treatment, rhizome treatment, seedling treatment, compost treatment, spray or drench.

Use of bioagents offers several advantages: (i) it reduces cost of cultivation, (ii) it is ecofriendly and does not affect the health of humans and animals, (iii) through its use pathogens do not develop resistance and (iv) use of bioagents promotes seed germination and plant growth.

**4. Value addition of vermi compost/ biocompost**

Vermicompost/ biocompost should be supplemented with bioagents (@ 250 g/q). This increases the nutritive value of the compost as well as provides opportunity to the bioagent to grow faster on the compost so that it can compete well with plant pathogens in the soil. Further, it facilitates rapid spread of bioagent in the soil. Bioagent colonized compost acts as both biofertilizer and biopesticide because of its nutritional superiority. Bioagent application through colonized compost is least expensive and the best delivery system for biocontrol agents. Colonized compost also serves as inoculum for fresh compost.

Through adoption CMP losses through seed and soil borne diseases could be severely minimized. The ultimate aim is to raise healthy plant, which can resist/withstand attacks of biotic and abiotic agents. This is achieved through maintaining microbial diversity in the soil, creating conditions suitable for their growth and development through providing habitats for their growth. The CMP tends to fulfill these objectives. Through the adoption of CMP farmers can reduce cost of production, minimize losses due to pests and diseases, increase benefit-cost ratio and raise value added crop. CMP has been extended to over 3500 farmers from over 95 villages in Uttarakhand hills through 124 trainings (farmers’ field schools).

Field observations revealed marked differences between the farmers who were adopting IPM practices and conventional practices. This was a yardstick, showing how far the ‘older’ farmers have come. Importantly, they are applying the results to the bulk of their crops. Management was a crucial element in producing healthy crops. For instance, crops failed where farmers were busy with off-farm work. By comparison, committed farmers in disease prone areas were visiting their crops weekly – in some places daily despite heavy rains – checking for disease, roguing plants, and applying suggested measures. Diligence was seen to be a crucial factor in pest and disease control. Seed quality and vagaries of weather were crucial to the implementation of technology.
Experience of farmers adopting CMP nevertheless revealed that intensive vegetable cultivation without complete reliance on pesticides and synthetic fertilizers is perfectly possible. The low-cost technology while on one hand offers a solution to recurrent disease and pest problems, on the other falls within the framework of organic farming, which is the state policy. CMP has a sound basis. The enthusiasm amongst people suggested that it would have wide acceptability.

Although there is still a long way to go for local vegetable farmers to implement IPM perfectly, the programme has contributed a lot to local vegetable production and to the upward changes of farmers’ idea, habits and practice in pest management activities. However, certain guidelines, such as the following, may lead the future course of action in sustaining vegetable cultivation in the region through adoption of IPM: i). Initiating the establishment of a regional network for the development and application of IPM in vegetables, ii). Establishing a databank on IPM practices of vegetable cultivation and to make the information widely available, iii). Strengthening the capacity for extension and training in IPM in vegetables and to develop strategies to support IPM activities at various levels of the agricultural society, iv). Extending and multiplying the pilot-stage training of lead farmers in vegetable IPM down to village/farmer level as widely as possible, v). Strengthening and encouraging adaptive research for the development of farmers' adoptable IPM packages, vi). Promoting supply of certified seeds of high yielding and pest tolerant/resistant vegetable cultivars, vii). Minimizing pesticide use and promote safe and judicious use of chemical pest control methods, viii). Developing a monitoring and surveillance program for major pests of vegetables, ix). Ensuring sustained supply of quality bioagents and biopesticides and x). Strengthening quality control units.

IPM techniques still are used by only a small number of farmers, primarily in pilot initiatives. Government adoption of IPM as a part of its agriculture policy will move IPM from the level of individual projects to increase the take-up, and bring benefits to the State. Farmers are largely unaware of the benefits of adopting IPM practices but use cultural mechanical and crude botanical pesticides, as well as indigenous and traditional knowledge for pest control. Encouraging farmers to expand and adopt these pest management strategies, creating greater awareness of the environmental benefits of IPM practices through education and training of extension agents and farmers, and establishing mechanisms for recognition for farmers, who successfully adopt IPM practices would not only facilitate the implementation of the IPM programme but also significantly minimize the identified risks associated with pesticide dependent pest control strategies.

Certification of crops raised according to IPM or some other ecology-based standards may give growers a marketing advantage as public concerns about health and environmental safety increase. One goal of the program, in addition to being a marketing vehicle, would be to educate consumers about agriculture and the food system. While the other goal would be to keep all growers moving along the “IPM Continuum.”
Climate Change and Plant Diseases

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Worldwide concerns have been rising about climatic change and potential changes in crop yields and production systems. Such concerns include the ability to accommodate these uncertainties in order to ensure an adequate food supply for ever increasing population. Crop yields and changes in productivity due to climate change will vary considerably across regions and among localities, thus changing the patterns of production in general, productivity is projected to increase in middle to high latitudes, depending on crop type, growing season, changes in temperature regime, and seasonality of precipitation. Most researchers believe that higher temperatures and droughts caused by climate change will depress crop yields in many places in the coming decades.

Impact of Climate Change on Crop Production

In the coming decades, global agriculture faces the prospect of a changing climate as well as the challenge to feed the world's population, projected to be double its present level by about the year 2060. The prospective climate change is global warming (with associated changes in hydrological regimes and other climatic variables) induced by the increasing concentration of active greenhouse gases. Despite of technological advances such as improved crop varieties and irrigation systems, weather and climate are still key factors in agricultural productivity. For example, weak monsoon rains in 1987 caused large shortfalls in crop production in India, Bangladesh, and Pakistan, contributing to reverting to wheat imports by India and Pakistan (World Food Institute, 1988). The 1980s also saw the continuing deterioration of food production in Africa, caused in part by persistent drought and low production potential, and international relief efforts to prevent widespread famine. The effects of climate on agriculture in individual countries cannot be considered in isolation. Agricultural trade has grown dramatically in recent decades and now provides significant increments of national food supplies to major importing nations and substantial income for major exporting nations. These examples emphasize the close links between agriculture and climate, the international nature of food trade and food security, and the need to consider the impacts of climate change in a global context.

Climate change induced by increasing greenhouse gases is likely to affect crop yields differently from region to region across the globe.

The greenhouse gases CH₄, N₂O and chlorofluorocarbons (CFCs) have no known direct effects on plant physiological processes. They only change global temperature and are therefore not discussed further. Instead, concentration should be on the effects of increased CO₂, tropospheric O₃, increased UV-B through depleted stratospheric ozone, increased temperatures and the associated intensification of the hydrological cycle.

In general, higher temperatures are associated with higher radiation and higher water use.
It is relatively difficult to separate the physiological effects (at the level of plants and plant organs) of temperatures from the ecological ones. There are both positive and negative impacts at two levels, and only crop- and site-specific simulation can assess the global 'net' effect of temperature increases. It is generally agreed that: rising temperatures - now estimated to be 0.2°C per decade, or 1 °C by 2040 with smallest increase in tropics would diminish the yields of some crops, especially if night temperatures are increased. Higher cold-season temperatures may lead to earlier ripening of annual crops, diminishing yield per crop, but would allow for more crops per year due to lengthening of the growing season.

**Effect of increasing temperature: Indian Scenario**

Agriculture represents a core part of the Indian economy and provides food and livelihood activities to much of the Indian population. The agricultural sector represents 35% of India’s Gross National Product (GNP) and as such plays a crucial role in the country’s development. Food grain production quadrupled during the post-independence era; this growth is projected to continue. The impact of climate change on agriculture could result in problems with food security and may threaten the livelihood activities. Climate change can affect crop yields (both positively and negatively), as well as the types of crops that can be grown in certain areas, by impacting agricultural inputs such as water for irrigation, amounts of solar radiation that affect plant growth, as well as the prevalence of pests. While the magnitude of impact varies greatly by region, climate change is expected to impact on agricultural productivity and shifting crop patterns. The policy implications are wide-reaching, as changes in agriculture could affect food security, trade policy, livelihood activities and water conservation issues, impacting large portions of the population.

According to a recent report of IPCC (2007) Crop productivity will fall, especially in non-irrigated lands, as temperatures rise for all of South Asia by as much as 1.2 degrees C on average. Food and Agriculture Organization (FAO) said India could lose as much as 125 million tones of its rainfed cereal production. In contrast, the industrialized countries are likely to gain in production potential. On the contrary, at lower latitudes, especially in the seasonally dry tropics, crop yield potential is likely to decline for even small global temperature rises, which would increase the risk of hunger. Greater frequency of droughts and floods would affect local production negatively, especially in subsistence sectors at low latitudes. Rising temperature, due to global warming, will affect the amount of rainfall and the pattern of monsoon season. Because India’s economy is heavily based on agriculture, the importance of accurately predicting the timing and severity of monsoons is extremely important. For example, if monsoon rains do not arrive on time, farmers will be forced to wait and run the risk of planting their crops late.. If monsoon rains are too severe, seedlings that were planted could be damaged. A number of recent scientific studies have acknowledged this risk and have examined the factors which create and influence monsoons in an attempt to better predict future monsoon seasons.

**Effect on Plant diseases:**

Coakley et al. concluded that the effects of climate change on plant disease management
may be less important than changes in land-use patterns, transgenic technologies, and availability of chemical pesticides. Another general conclusion was that the effects of climate change will tend to be different for different pathosystems in different locations, so that generalization is a challenge.

The direct effects of climate change on individual plants and plant communities may occur in the absence of pathogens, but may also bring about changes in plants that will affect their interactions with pathogens. Changes in plant architecture may affect microclimate and thus risks of infection. In general, increased plant density will tend to increase leaf surface wetness and leaf surface wetness duration, and so make infection by foliar pathogens more likely. Elevated CO₂ levels tend to result in changed plant structure. At multiple scales, plant organs may increase in size: Increased leaf area, increased leaf thickness, higher numbers of leaves, higher total leaf area per plant, and stems and branches with greater diameter have been observed under elevated CO₂. Enhanced photosynthesis, increased water use efficiency, and reduced damage from ozone are also reported under elevated CO₂. Since many foliar pathogens benefit from denser plant growth and the resulting humid microclimate, there is the potential for these changes in plant architecture to increase infection rates.

Also, different populations of the same species may differ in both their genetic structure and the extent to which climate change will push the species to its physiological limits. As a result of climate change, the abundance of particular species may change rapidly, as species may lose their ability to recover from other perturbations such as diseases, insect herbivores, and climatic extremes within a background of climate changes. Novel plant communities may result with the increased potential for new patterns of host-sharing by pathogens. The range of many pathogens is limited by climatic requirements for overwintering or oversummering of the pathogen or vector. For example, higher winter temperatures of −6°C versus −10°C increase survivorship of overwintering rust fungi (*Puccinia graminis*) and increase subsequent disease on *Festuca* and *Lolium*. In the case of *Phytophthora infestans*, the introduction of multiple mating types, allowing sexual reproduction, increases the ability of the pathogen to overwinter. For pathogens subject to an Allee effect, or destabilizing density-dependent reproduction at low population levels, release from overwintering restrictions may have a much stronger effect than expected. Temperature requirements for infection differ among pathogen species. For example, wheat rust fungi differ in their requirements from 2°–15°C for stripe rust, 10°–30°C for leaf rust, and 15°–35°C for stem rust. In a review of the effect of climate change on insect herbivory, Bale et al. make many points relevant to plant pathogens, whether insect-vectored or not. They concluded that temperature was the dominant climate factor in terms of direct effects through effects on overwintering and the potentially important combination of photoperiod and temperature. In many cases, temperature increases are predicted to lead to the geographic expansion of pathogen and vector distributions, bringing pathogens into contact with more potential hosts and providing new opportunities for pathogen hybridization. Increased
transportation and human movement may act synergistically with temperature changes.

Temperature governs the rate of reproduction for many pathogens; for example, spore germination of the rust fungus *Puccinia substriata* increases with increasing temperature over a range of temperatures, and the root rot pathogen *Monosporascus cannonballus* reproduces more quickly at higher temperatures. Under climate change, pathogens, like plants, may potentially be unable to migrate or adapt as rapidly as environmental conditions change. But most pathogens will have the advantage over plants because of their shorter generation times and, in many cases, the ability to move readily through wind dispersal.

Disease management strategies may require adjustment under climate change. Strategies such as delaying planting to avoid a pathogen may become less reliable. And one of the major problems with applications of biological control for plant disease management in the field has been the vulnerability of biocontrol agent populations to environmental variation. Simulation models are based on theoretical relationships and can be used to predict outcomes under a range of scenarios. Because climate change occurs slowly and variably, it is difficult to study its effects directly. Temporal variability in climate can be used to draw inference about the potential effects of climate change through the argument that temporary effects of a year with unusual climatic features are likely to represent the effects of longer-term changes.

Models of plant disease have now been developed to incorporate more sophisticated climate predictions from General Circulation Models.

In the population level, the adaptive potential of plant and pathogen populations may prove to be one of the most important predictors of the magnitude of climate change effects on plant disease, since, for many species, populations will not be able to migrate quickly enough to keep pace with climate change.

**Needs for further research**

Due to the complex interaction of climate impacts, combined with varying irrigation techniques, regional factors, and differences in crops, the detailed impacts of these factors need to be investigated further. Specific recommendations for further research include:

- Precision in climate change prediction with higher resolution on spatial and temporal scales;
- Linking of predictions with agricultural production systems to suggest suitable options for sustaining agricultural production;
- Preparation of a database on climate change impacts on agriculture; and
- Development of models for pest /diseases population dynamics.

**Conclusions**

It is evident that the relationship between climate change and agriculture is still very much a matter of concern with many uncertainties. Predicted changes in average values of global climate variables (increased temperatures, altered precipitation patterns, increased concentrations of atmospheric CO2) and changes in the frequency, duration, and degree of extremes (such as frost, heat, drought, hail, storms, floods) will affect agricultural crops, agroecosystems, and
agricultural productivity. Forecasts of regional climate changes are still not precise. Overall, shortage of water will be the predominant factor affecting plant growth. As higher temperatures are known to enhance plant development and especially the grain-filling duration of cereals, grain yield losses are possible in a warmer climate. On the other hand, elevated atmospheric CO2 concentrations are known to stimulate photosynthesis and enhance growth and yield ("CO2 fertilization"); concomitantly, leaf transpiration is reduced, resulting in improved water use efficiency. Elucidating the interactions between positive and negative effects of climate change is of crucial importance for any prediction of future crop yields. The prediction of the response of crops to climate on both seasonal and decadal timescales shows promise. The potential benefit of increasingly accurate prediction is clear: for the season, the mobilization of resources; for the adaptive measures to minimise the adverse impacts of climate change.

REFERENCES

8. Kalra Naveen and Sharma K Subodh,2007. Report on Climate change impact on Agriculture in India. Indian Agricultural Research Institute, Delhi
Farmers Participatory Integrated Diseases Management (IDM) in Legumes at ICRISAT

S. Pande
International Crops Research Institute for the Semi Arid Tropics, Patancheru, 502324 (Andhra Pradesh)

1. Introduction: Disease is the outcome of interaction between host, pathogen and environment. Pathogen is a biological organism and includes fungi, bacteria, and viruses etc. and can cause disease epidemic and economic damage to its host in the favorable environment. Diseases in ICRISAT mandated crops cause severe economic losses in Asia and Africa (Table 1). A successful disease control refers to a situation where a crop has been protected from the yield-reducing effects of the pathogen rendering the later to economic insignificance. Integrated Disease Management (IDM) involves a total systems approach to the suppression of pathogen populations to a level where higher yields can be obtained which provide the framer with maximum economic return. In general the “Integrated disease management is holistic multidisciplinary management system that integrates the ecological and economic components of disease management to combat with the pathogens that coexist in an agro-ecosystem”. In the IDM system, the individual components of diseases management such as host plant resistance (HPR), agronomic practices, judicious use of fungicides, bio-pesticides etc. need to be compatible. It is impractical and impossible to reduce pathogen population levels to zero. Economic threshold levels, which signal control actions, are determined on the basis of a quantified pathogen forms and host growth stage, maximizes the difference between the cost of control and gross income. No control measures are normally implemented until this level is reached.

2. Approach and Components of IDM: Our approach to manage diseases through IDM is holistic and multidisciplinary. It is primarily based on HPR, additionally we also identify other components of diseases management and depending upon the need, scope and affordability by the end users, we combine more than one component in to a location specific IDM package for the effective and economical management of host diseases. Finally these IDM packages are refined and validated in partnership with stakeholders: the farmers (Figure 1). Components of IDM either used alone or in combination to combat diseases of the ICRISAT mandated crops are as follows:

- Host plant resistance (HPR)
- Epidemiology (disease modeling) and its use in IDM
- Effective, efficient and economical fungicides
- Additional components / alternatives to fungicides (botanical/ biological)
- Integration and evaluation of different combinations of IDM components
- Use of new approaches (use of biotechnological tools in enhancing HPR)

3. Rationale: Despite good intentions, the distance between scientists and farmers is great. It is greater in developing countries than in developed countries. There is a need to narrow down the distance between the technologies generated in the field of IDM, their refinement, validation,
transfer and adoption. It is with this hypothesis we followed “the optimization of disease control measures in an economically, and ecologically sound manner, accomplished by coordinated use of multiple tactics to assure stable crop production and to maintain disease damage below the economic injury level whilst minimizing hazards to humans, animals plants and environment” at ICRISAT in the three legumes chickpea, pigeonpea and groundnut.

**Status of IDM at ICRISAT:** Several management practices have been developed and tested in farmers’ fields. Farmers both in Africa and Asia have adopted components of IDM packages. Major successes, for example, have been reported in management of groundnut and chickpea foliar diseases. Many farmers have tested management options to control groundnut rosette in southern and eastern Africa and western and central Africa, and achieved significant increases in yield. These technologies are currently being scaled up in Malawi. A combination of HPR and weather-based minimal fungicidal protection has led to the rehabilitation of chickpea in BGM-prone areas in Nepal, Bangladesh and India. IDM of BGM, which also includes management strategies for wilt and pod borer control, has been adopted by several thousand farmers in Nepal and Bangladesh. Integrated management of groundnut foliar diseases - combining HPR in high-yielding varieties (both short- and medium-duration) and economical use of fungicides (based on critical growth stage of the host and weather conditions) - has been validated with over 8000 farmers in the states of Andhra Pradesh, Karnataka and Tamil Nadu in India. The status of IDM of major diseases of ICRISAT mandated legumes crops (chickpea, pigeonpea and groundnut) is summarized in the Table 2.

**Transfer of IDM Technology to NARS and Farmers:** IDM promotion and capacity building are significant component of ICRISAT’s research and development and have been very well encapsulated in its vision, mission, goal and strategy where it mobilizes with partners for poverty alleviation, food security, and environment protection for poor rural families in SAT. Sharing of HPR with NARS for the management of wilt, Ascochyta blight, and Botrytis gray mold diseases of chickpea, foliar diseases of groundnut and, wilt and sterility mosaic diseases of pigeonpea was one of our major activities related to transfer of IDM technology. Few examples of successful transfer of IDM technologies in participation with farmers are:

- Promotion of IDM of foliar diseases in groundnut in India and Asia
- Reviving of chickpea through IDM of Botrytis gray mold in Nepal, and Bangladesh
- Reintroduction of pigeonpea through IPM/IDM in India

**Future Thrust.** Considerable progress has been made in the past in developing the disease resistance screening techniques, identifying sources of resistance and transferring resistance genes into high-yielding, improved and agronomically superior genetic backgrounds. However, HPR, fungicides, natural plant products, bio-fungicides, botanicals and agronomic practices will remain the potentially viable options for integrated disease management (IDM). They are relatively safe for non-target pathogens and human beings. Biotechnological tools such as marker-assisted
selection, genetic engineering, and wide hybridization to develop crop cultivars with resistance to diseases will play a key role in future disease management programs. Disease modeling, decision support systems, and remote sensing could contribute to up-scaling and dissemination of IDM technologies. Disease resistance in a background of terminal drought resistance is of immense useful. Our future activities need to be focused on the expansion of IDM technology by increasing the awareness of farmers on the importance of quality of crop residues of ICRISAT mandated legume crops as affected by diseases and an essential component of the prevailing mixed crop livestock system in the SAT countries in Asia and Africa.

Table 1. Important diseases of ICRISAT mandate legume crops distribution and yield losses

<table>
<thead>
<tr>
<th>Crop</th>
<th>Disease</th>
<th>Causal organism</th>
<th>Distribution</th>
<th>Yield loss (Million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chickpea</td>
<td>Wilt</td>
<td><em>Fusarium oxysporum f.sp. ciceri</em></td>
<td>Asia, Africa</td>
<td>218</td>
</tr>
<tr>
<td></td>
<td>Ascochyta blight</td>
<td><em>Ascochyta rabiei (Pass.) Labr.</em></td>
<td>Asia, Africa</td>
<td>248</td>
</tr>
<tr>
<td></td>
<td>Botrytis gray mold</td>
<td><em>Botrytis cinerea Pres. Ex Fr.</em></td>
<td>Asia</td>
<td>33</td>
</tr>
<tr>
<td>Pigeonpea</td>
<td>Fusarium wilt</td>
<td><em>Fusarium udum</em></td>
<td>Asia, Africa</td>
<td>193</td>
</tr>
<tr>
<td>Sterility mosaic</td>
<td>Sterility mosaic virus</td>
<td></td>
<td>Asia</td>
<td>290</td>
</tr>
<tr>
<td>Groundnut</td>
<td>Foliar diseases</td>
<td><em>Cercospora arachidicola Hori</em></td>
<td>Asia, Africa</td>
<td>1392</td>
</tr>
<tr>
<td></td>
<td>Early leaf spot</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Late leaf spot</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rust</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aflatoxin</td>
<td><em>Aspergillus Species</em></td>
<td>Asia, Africa</td>
<td>371</td>
</tr>
<tr>
<td></td>
<td>Rosette/clump virus</td>
<td></td>
<td>Africa</td>
<td>194</td>
</tr>
<tr>
<td></td>
<td>Bud necrosis virus</td>
<td></td>
<td>Asia</td>
<td>89</td>
</tr>
</tbody>
</table>

Table 2. Important diseases of ICRISAT mandate legumes crops and their components of integrated disease management

<table>
<thead>
<tr>
<th>Crop</th>
<th>Disease</th>
<th>Components of integrated disease management (IDM)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Host Plant Resistance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PB</td>
</tr>
<tr>
<td>Chickpea</td>
<td>Wilt</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>Ascochyta blight</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>Botrytis gray mold</td>
<td>**</td>
</tr>
<tr>
<td>Pigeonpea</td>
<td>Fusarium wilt</td>
<td>***</td>
</tr>
<tr>
<td>Sterility mosaic</td>
<td>Sterility mosaic virus</td>
<td></td>
</tr>
<tr>
<td>Groundnut</td>
<td>Foliar diseases</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>Aflatoxin</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Rosette/clump virus</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>Bud necrosis virus</td>
<td>**</td>
</tr>
</tbody>
</table>

PB = Plant breeding. WH = Wide hybridization. MAS = Marker-assisted selection. GE = genetic engineering. X = Not in common use. *, **, *** = Low, medium, and high potential, respectively.

Source: ICRISAT medium term plan 1992 and publications
Identification of individual components

On station evaluation

Multi-location evaluation

On farm participatory evaluation

On station integration & evaluation

On-farm validation & correction

Expansion

Impact assessment

**Figure 1.** Thematic structure for development of integrated disease management (IDM) technology.

**REFERENCES**


Criticality of Emerging Trends in Indian Agriculture

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A. Production Environment in Agriculture

Av. holding size consistently declining (down from 1.87 ha. in 85-86 to 1.69 ha. in 1990-91 to 1.55 ha in 2000-01)
- Net sown area declining (down from 46.9% in 1990-91 to 46.1 percent in 2000-01 of total reported area)
- Area under Non-agricultural uses is increasing (up from 6.9% in 1990-91 to 7.7% in 2000-01 of total reported area)
- Water table going down (in Punjab, out of 138 locks, 84 blocks have become Dark, 16 grey and only 38 remain white)
- Soil health deteriorating due to intensive cultivation coupled with imbalanced use of fertilizers
- Stagnation/deceleration in yields of major food grain crops.
- Wide technology and yield gaps (15-30% yield gaps)

Implications?

B. Economic environment of Agriculture sector

- Share of agriculture in GDP declining (down from 28% in 1999-00 to 22.6% in 2004-05 and 19.6% in 2005-06)
- Share of agricultural employment in total employment declining but at a slower rate (down from 58.54% in 1999-00 to 54.19% in 2004-05)
- 60% of population still dependent for its livelihood on agriculture
- Consistent decline in Growth Rate of Ag.

<table>
<thead>
<tr>
<th>Year</th>
<th>Growth Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1951-52 to 67-68</td>
<td>2.5</td>
</tr>
<tr>
<td>68-69 to 80-81</td>
<td>2.4</td>
</tr>
<tr>
<td>81-82 to 90-91</td>
<td>3.5</td>
</tr>
<tr>
<td>91-92 to 96-97</td>
<td>3.7</td>
</tr>
</tbody>
</table>

IX & X (Pre-green rev. pd) (green rev. pd)(wider tech.des.pd)(Early reforms pd) (FYPs)

Ag. & allied 2.5 2.4 3.5 3.7 2.5
Crops &Livestock 2.7 2.7 3.7 3.7 2.5

- Considerable **Inter-regional variations in agricultural growth** across the country

<table>
<thead>
<tr>
<th>Year</th>
<th>Growth Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993-2003</td>
<td>(-) 19% to (+) 28% (at 1993-94 prices)</td>
</tr>
</tbody>
</table>

Implications?

C. Policy and Institutions

- Investment in Ag. (Capital formation) declining (down from 2.2% of Net Domestic Product in 1999-00 to 1.9% in 2005-06 at 1999-00 prices)
- Input-supply mechanism weak
- Credit delivery system inadequate despite innovations Infrastructure inadequate to meet
the emerging needs of diversification and modernization of Ag.

Implications?

D. Trade Environment in Agriculture

- SPS and TBT
- Domestic Support (Subsidy issues)
- Price volatility increasing
- Non-trade concerns (Environment and labour related issues)
- Energy (via biofuels due to rising petroleum prices) becoming an integrated part of the agriculture. Ethanol made from maize and sugarcane is being mixed with petrol. Also, edible oils from soybeans, mustard and sunflower are being mixed with diesel. So diversion of crops form human consumption to fuel production affecting food supply and prices

Implications?

E. Agriculture becoming vulnerable

- Falling productivity
- Rising costs
- Rising volatility in prices
- Increases in net farm business income not matching with growing inflation
- Re-emergence of weather risks as a result of global warming
- Farming becoming unremunerative and risky.

F. Relevant Options

- Technology upgradation and Precision farming
- Soil health care
- Strengthening of technology transfer mechanism
- Strengthening of input supply system
- Adequate insurance cover and farm credit
- Strengthening infrastructure for cutting down post harvest losses and value addition to support diversification
- Rational pricing of water
- Better Restructuring and targeting of price and subsidy support to make it more efficient and effective
- Establishing Special Agricultural Zones(SAZs) for holistic and internationally competitive support to agriculture.
Seed Treatment as Innovative Crop Protection Strategies

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Department of Plant Pathology, G.B.P.U.A.&T., Pantnagar- 263 145 (Uttarakhand)

Seed Treatment
Seed treatment can be defined as “The application of bioactive chemicals or antagonistic or symbiotic microorganisms to the seed prior to sowing to reduce, control, or repel disease organisms, insects or other pest that attack seed or seedling grown from treated seed .

Need for Seed Treatment
Seed will continue to increase and become the delivery vehicle for new traits and functional attributes for improving germination and seedling development. Genetic modification will not impact disease control by 2007-2012 so seed treatment ( chemical) will have to be relied upon to provide the required protection.

Seed treatment may:
• Improve stand quality
• Protect seed from seed and soil borne pathogens
• Improve seed shape for planting
• Increase yields
• Increase return on investment
• Improve seed storability or performance.
• Help in fixing nitrogen and enhance uptake of nutrients

When to go for seed treatments?
• Field is for seed production.
• Low test weight or older seed.
• Planting in unfavorable germination conditions (dry soil or cold soil).
• Planting into fields with a history of stand establishment problems.
• Planting to precise populations.
• Replanting will not be feasible if first planting fails.
• Seed is expensive.
• Seed is infected or infested
• Yield potential of field is high.

Mode of Action of Seed Treatments
• Chemical seed treatment
• Physical seed treatment
• Biological seed treatment
• Natural products and
• Biodynamics preparations for seed treatment
Purpose of seed treatments
In seed health point of view

<table>
<thead>
<tr>
<th>Seed disinfestation</th>
<th>killing of spores, mycelia, or propagules of microorganisms on seed surface.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed disinfection</td>
<td>elimination of pathogen that has penetrated into living cells of seed (e.g. smut or bunt).</td>
</tr>
<tr>
<td>Seed protection</td>
<td>application to protect seed from pathogens in the soil (damping-off). A systemic fungicide may provide post-emergence protection (powdery mildew).</td>
</tr>
</tbody>
</table>

Chemical Seed Treatment is defined as
Given an application of a pesticide or subjected to a process designed to reduce, control, repel disease organisms, insects, or other pests that attack seed or seedlings. This includes control of pests while seed is in storage and after planting. Reduces Active ingredient

loading into the environment
Using a seed treatment reduces the area in contact with a crop protection product from 10,000m² for foliar application or 500m² for furrow application to only 50m²

Example
Seed rate 100,000 seeds /ha in corn
Foliar application rate 1350g a.i./ha
Furrow application 600 g a.i./ha
Seed treatment rate 50a.i./ha

<table>
<thead>
<tr>
<th>Common name</th>
<th>Activity</th>
<th>Disease management</th>
<th>Group name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Captan</td>
<td>broad spectrum protective activity</td>
<td>Controls seed rots and damping-off</td>
<td>Heterocyclic compound</td>
</tr>
<tr>
<td>Thiram (Tetramethylthiuram disulphide)</td>
<td>broad spectrum protective activity</td>
<td>seed rots, damping-off, covered smut of wheat, Helminthosporium stripe rust of barley</td>
<td>Dithiocarbamate compound</td>
</tr>
<tr>
<td>Apron or Allegiance (metalaxyl) and Apron XL (mefenoxam)</td>
<td>systemic specific</td>
<td>for seed rot and damping-off by water molds (Pythium and Phytophthora sp.)</td>
<td>Acylalanine compounds</td>
</tr>
<tr>
<td>Petachloronitrobenzene (PCNB)</td>
<td>broad spectrum protective activity</td>
<td>seed rots and damping-off caused by (Rhizoctonia spp). No activity on Pythium spp.</td>
<td>Aromatic compound</td>
</tr>
<tr>
<td>(Difenonazole (Dividend) Tebuconazole (Raxil))</td>
<td>systemic and curative activity</td>
<td>Controls smuts, certain seedborne and soilborne pathogens in cereal grains Weak suppressive activity on powdery mildew</td>
<td>Triazole compounds</td>
</tr>
<tr>
<td>Carboxin (vitavax)</td>
<td>protective contact-systemic fungicide</td>
<td>controls embryo-borne loose smut of wheat and barley, seed rotting and seedling blight fungi (Rhizoctonia solani, Helminthosporium spp)</td>
<td>Oxanthiin compound</td>
</tr>
<tr>
<td>Triadimenol (Baytan)</td>
<td>systemic and curative activity</td>
<td>Controls smuts, certain seedborne and soilborne pathogens in cereal grains</td>
<td>Triazole compound</td>
</tr>
<tr>
<td>Fludioxonil Maxim.</td>
<td>Contact fungicide</td>
<td>Active against Fusarium, Rhizoctonia, Helminthosporium, Aspergillus, and Penicillium spp. on corn sweet corn and sorghum</td>
<td>Triazole compound</td>
</tr>
</tbody>
</table>
Benefits of using the new Seed Treatments

Required in lower dose and and thus reduces environmental exposure to the user.

New seed treatment fungicides contain several active ingredients with different modes of action and higher efficacies and a broader range of disease control.

Most of the new seed treatments are water based and are in ready to apply or RTA formulations. Required in lower dose and and thus reduces environmental exposure to the user.

New seed treatment fungicides contain several active ingredients with different modes of action and higher efficacies and a broader range of disease control.

Most of the new seed treatments are water based and are in ready to apply or RTA formulations.

<table>
<thead>
<tr>
<th>Trade Name</th>
<th>Common name of fungicide/insecticide (% active)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitavax +thiram RTU</td>
<td>carboxin + thiram (10+10)</td>
</tr>
<tr>
<td>Baytan+Thiram</td>
<td>triadimenol + thiram (5.0+15.3)</td>
</tr>
<tr>
<td>Gaucho XT</td>
<td>imidacloprid + tebuconazole + metalaxyl (12.7+0.62+0.82)</td>
</tr>
<tr>
<td>Raxil MD</td>
<td>tebuconazole + metalaxyl (0.48+0.64)</td>
</tr>
<tr>
<td>Raxil MD Extra</td>
<td>tebuconazole + metalaxyl + imazalil (0.43+0.58+1.0)</td>
</tr>
<tr>
<td>Vitavax Extra – RTU</td>
<td>carboxin + imazalil + thiabendazole (16.7+1.2+1.5)</td>
</tr>
<tr>
<td>Vitavax – Thiram - RTU</td>
<td>carboxin + thiram (10+10)</td>
</tr>
<tr>
<td>Vitavax – PCNB</td>
<td>carboxin + PCNB (17+17)</td>
</tr>
<tr>
<td>Vitavax – Thiram – Lindane</td>
<td>carboxin + thiram + lindane (14+12+8)</td>
</tr>
<tr>
<td>Vitavax 200</td>
<td>carboxin + thiram (17+17)</td>
</tr>
<tr>
<td>Vitavax M</td>
<td>carboxin + molybdenum.</td>
</tr>
<tr>
<td>System 3</td>
<td>metalaxyl + PCNB + Bacillus subtilis</td>
</tr>
<tr>
<td>Dividend XL RTA</td>
<td>Difenoconazole /metalaxyl (3.21+0.27)</td>
</tr>
<tr>
<td>Maxim XL fludioxonil (21.0)</td>
<td></td>
</tr>
<tr>
<td>Trace Enhance</td>
<td>captan + carboxin (19.1+20)</td>
</tr>
</tbody>
</table>

Labeling of Treated Seed

- Special labeling for treated seed
- Proper handling and storage
- Ensure that "leftover" seed is not used for any unintended purpose
- Information for workers safety
- Seed regulations require

Seed act requires:

- Statement that seed is treated with a pesticide
- Name of pesticide(s); common and trade names
- Labeling must include health hazards of the pesticide(s) and if it is a skin irritant, a carcinogen, or able to cause eye damage
- Name, address, phone number of pesticide manufacturer and seed treater

Application equipment

- Are designed to **apply precisely measured quantities** of pesticide to a given volume of seed
- Coating chambers are designed to **handle seed gently while uniformly coating** with
pesticide formulation

- **Precision application is essential** (check calibration regularly)

**Physical Seed Treatment**
- Dry heat treatment
- Hot water treatment
- Aerated steam treatment
- Radio-frequency heat treatment
- Radiations

**Dry heat for control of Seed-borne bacteria**

<table>
<thead>
<tr>
<th>Crop and pathogen</th>
<th>Treatment</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley (<strong>Xanthomonas campestris pv. translucens</strong>)</td>
<td>4 days at 72°C</td>
<td>Fourest et al., 1990</td>
</tr>
<tr>
<td></td>
<td>7 days at 72°C</td>
<td>Fourest et al., 1990</td>
</tr>
<tr>
<td>Bean (<strong>Pseudomonas syringae pv. phaseolicola</strong>)</td>
<td>1 day at 60°C</td>
<td>Naumann and Karl, 1988</td>
</tr>
<tr>
<td></td>
<td>3 day at 50°C</td>
<td>Naumann and Karl, 1988</td>
</tr>
<tr>
<td>Bean (<strong>Pseudomonas syringae pv. phaseolicola</strong>)</td>
<td>3 h at 50°C</td>
<td>Tamietti &amp; Garabaldi, 1984</td>
</tr>
<tr>
<td></td>
<td>2 h at 70°C</td>
<td>Belletti &amp; Tamietti, 1982</td>
</tr>
<tr>
<td>Cucumber (<strong>Pseudomonas syringae pv. lachrymans</strong>)</td>
<td>3 days at 70°C</td>
<td>Umekawa and Watanabe, 1978; Umekawa, 1987</td>
</tr>
<tr>
<td>Pea (<strong>Pseudomonas syringae pv. pisi</strong>)</td>
<td>1 day at 65°C</td>
<td>Grondeau et al., 1992</td>
</tr>
<tr>
<td>Rice (<strong>Pseudomonas gluinae</strong>)</td>
<td>2 days at 65°C</td>
<td>Ziegler and Alvarez, 1989</td>
</tr>
<tr>
<td>Tomato (<strong>Clavibacter michiganense subsp. michiganese</strong>)</td>
<td>1 h at 80°C</td>
<td>Marinescu, 1975</td>
</tr>
</tbody>
</table>

**Hot water in the treatment of seed-borne fungal diseases.**

<table>
<thead>
<tr>
<th>Crop, disease and pathogen</th>
<th>Treatment</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fungi</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brassica Cancer (<strong>Leptospheria maculans</strong>)</td>
<td>30 min at 500°C</td>
<td>Walker, 1969</td>
</tr>
<tr>
<td>Brassica Cancer (<strong>Leptospheria maculans</strong>)</td>
<td>25 min at 500°C</td>
<td>Millard, 1945</td>
</tr>
<tr>
<td>Brassica dark leaf spot (<strong>Alternaria brassicaceae</strong>)</td>
<td>20 min at 500°C</td>
<td>Randhawa and Aulakh, 1984</td>
</tr>
<tr>
<td>Brassica dark leaf spot (<strong>Alternaria brassicicola</strong>)</td>
<td>18 min at 500°C</td>
<td>Schimmer, 1953</td>
</tr>
<tr>
<td>Cereley leaf blight (<strong>Septoria apicalola</strong>)</td>
<td>30 min at 48-490°C</td>
<td>Krout, 1921</td>
</tr>
<tr>
<td>Cereley leaf blight (<strong>Septoria apicalola</strong>)</td>
<td>25 min at 500°C</td>
<td>Bant and Storey, 1952</td>
</tr>
<tr>
<td>Cereal loose smut (<strong>Ustilago segetum var. tritici</strong>)</td>
<td>5 min at 25.80°C</td>
<td>Jensen, 1888</td>
</tr>
<tr>
<td>Cereley loose smut (<strong>Ustilago segetum var. tritici</strong>)</td>
<td>1.5 – 2 h at 490°C or 5-6 h at 410°C</td>
<td>Doling, 1965b</td>
</tr>
<tr>
<td>Cereley loose smut (<strong>Ustilago segetum var. tritici</strong>)</td>
<td>5h at 210°C presoak+ 1min at 490°C + 11min at 520°C</td>
<td>Walker, 1969</td>
</tr>
<tr>
<td>Millet downy mildew (<strong>sclerospora graminicola</strong>)</td>
<td>10 min at 550°C</td>
<td>Thakur and Kanwar, 1977</td>
</tr>
<tr>
<td>Riceblast (<strong>Magnaporthe grisea</strong>)</td>
<td>6-12h in cool water +1-2 min at 500°C</td>
<td>Nakamura, 1986</td>
</tr>
</tbody>
</table>
Rice leaf spot (Cochliobolus miyabeanus) 7min at 510°C  Nakamura, 1986
Safflower leaf spot (Alternaria alternate, A. carthamii) 30min at 500°C  Zazzerini et al. 1985

Radiations

Ultrasonic radiations: eg. In case of soybean bacterial infection (15 min of 21.3Kc/sec).

ultrasonic radiations against A. besseyi.

Trichoconis padwickii Fusarium sp., Curvularia lunata, and Bipolaris oryzae in paddy (radio frequency treatment)

Biological Seed Treatment

Biological control agents used in seed treatment are microorganisms that protect seed and seedlings from various pathogens.

Commercial Formulations

Biocontrol organisms include the bacteria Bacillus subtilis (trade name Kodiak) and Streptomyces griseoviridis (trade names Mycostop, Subtilex, System3), and the fungus Trichoderma harzianum (trade names T-22, Bio-Trek). Biological fungicides are a relatively new tool available. Biological Plant Protectant Granules™, registered as an in-furrow soil treatment on tomatoes and other vegetables, contains Trichoderma harzianum, strain KRL-AG2 (T-22G). Trichoderma viride sensu. (trade name F-Stop™,) is a registered product for seed treatment in tomatoes

Bio-fertilizers

CB-QGG is a liquid biological seed treatment and root growth promoter formulated with beneficial microbes, macro and micro nutrients, amino acids, organic acids, root growth stimulants, enzymes, proteins, vitamins and minerals. It promotes nitrogen fixation, root development and quick emergence.

RHIZOBIUM

Leguminous seeds treated with right type of Rhizobium biofertilizer show adequate nodulation on roots with higher plant weight

AZOTOBACTER / AZOSPIRILLUM

Non legume, seeds (such as maize) treated with Azotobacter or Azospirillium biofertilizer, improves plant vigour, texture, colour and plant weight

Some Important issues to focus

Bioagents have different modes of action. Each mode of action has its own advantages and disadvantages. Single mode of action has limited activity against a very narrow spectrum of pathogens. To date majority of biological products are focused on one disease. The need is that the mixture of organisms with different mode of action or combination might enhance the spectrum activity but the knowledge is limited.
Latest trends in seed treatment

Coating technologies, pelleting, encrusting and film-coating, are used increasingly to ease seed sowing by altering seed shape, surface properties and weight. Polymer seed coating, colourants and inoculants are more widely used. A range of beneficial additives including micronutrients and plant protection agents; (high dose systemic pesticides) to improve the value addition. Seed vigour or physiological status can be manipulated by hydration treatments such as by priming and steeping. Eradication of fungal and bacterial seed infections can be achieved through heat or biocide treatments although there are challenges in operating these processes at an industrial scale without jeopardising viability, vigour and shelf life.
Integrated Management of Soil-borne Diseases

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Soil-borne plant pathogens cause significant yield losses in field and horticultural crops. These pathogens can survive in soil for many years through resistant structures. Besides, these diseases are difficult to predict. Soil factors like soil type, texture, pH, moisture, temperature, level of organic matter and nutrient content influence the activity of soil-borne pathogens and disease. In order to survive successfully, these pathogens compete with other microbes for nutrition, space and other requirements. Understanding of the dynamics of these pathogens and other microbial population in soil in relation to environmental condition is essential for successful management of these diseases.

The science of plant pathology has an important role in the future success programme and policies designed to increase the food production. The world market continues to be highly competitive and supply of superior quality and disease free produce with acceptable shelf life is required. Disease management is an important consideration both under conventional and organic farming systems. The widespread use of pesticides has created public concern over human health and human safety. In fact, the agricultural sector is concerned about increasing resistance of pests and pathogens to pesticides including fungicides and bactericides and shifts of pests and disease complex in food production system. Biological interaction in the complete food production system needs to be better visualized in order to reduce the crop losses due to pests and diseases. The integration of disease management practices with insect and weed control and general crop production practices is desirable for sustained food production system. Integrated disease management (IDM) involves the selection and application of harmonious range of disease control strategies that minimize losses while maximizing the return. IDM strategy effectively prevents the epidemic progression of the disease and minimize the impact on crop growth and productivity.

Cultural practices

Cultural practices are considered as first line of defense. There are a number of practices which growers should consider for integrated management of disease.

Reducing the level of inoculum

Practices which reduce the initial level of inoculum include selecting appropriate planting material, destruction of crop residues, elimination of living plants that carry pathogen and crop rotation.

Crop rotation refers successive planting of different crops in the same area. The pathogen inocula is reduced or eliminated due to absence of susceptible hosts. Crop rotation favours to develop diverse microflora in soil. Certain crop plants besides revenue generating have suppressive effects on disease development. For example, root exudates of sorghum contain hydrocyanic acid which is detrimental to soil pathogens. Similarly, residues of crucifer crops
release toxic substances which inhibit soil borne pathogens. Hence, these residues can be used for biofumigation of soil.

Tillage practices have indirect effect on the spread of the pathogen. Tillage can bury pathogens in the top soil in deeper layer and hence less likely to cause disease. Summer ploughing is a common practice adopted in traditional farming and is effective in destroying pathogen propagules like sclerotia. Sowing practices such as time of sowing, depth of sowing influence disease severity.

Use of resistant cultivars

Selection, improvement and cultivation of varieties resistant to one or more pathogens is the most important component in an integrated disease management programme. The term resistance is commonly understood as the hosts ability to suppress or retard the activity and progress of a pathogenic agent which results in the absence or reduction of symptom development. The term tolerance is often used interchangeably with resistance although it has different meaning. Tolerant plants can endure severe disease without suffering significant losses in quality or yield. Use of disease resistant cultivars have distinct advantages. The growers may stop the use of chemical pesticides for controlling pests and diseases through use of resistant cultivars. In most of the cases resistant varieties are harmless and completely non-disruptive to the environment. There are some disadvantages of using resistant cultivars. The greatest short coming is that, resistance is not available for all the diseases in many crops. In some cases resistant cultivars fail to provide resistance after a certain period. The failure of resistance may be due to development of new strains of the target pathogen that overcome the resistance genes.

Irrigation management is clearly an important factor. Overhead sprinkler irrigation enhances pathogen dispersal specially bacterial pathogens. However, a brief overhead watering can wash spores without causing long periods of leaf wetness. In case of drip irrigation, water is delivered directly to root zones and thus the dispersal of pathogen is not favoured. It also reduces soil saturation hence lowers the risk of soil-borne diseases.

Plant nutrition

Plant nutrition is an important consideration in increasing the crop productivity. A well balance supply of soil nutrients will result in healthy vigorous plants which usually withstand the attack by the pathogens. However, many pathogens like biotrophs and viruses thrive well under ideal growth conditions. The excess use of nitrogen fertilizers can result in leaf growth which is more succulent and hence more susceptible to some diseases. In certain cases nitrate forms of nitrogen suppresses Fusarium wilt while ammonium form enhances it. Potassium generally inhibit disease development and counteracts some of the disadvantages of nitrogen fertilizers. The phosphorus fertilizers influence the diseases in different ways to different crops/diseases. The mechanism through which phosphorus influence plant disease are not well understood. Calcium is a necessary nutrient for the composition of cell walls. An adequate supply of calcium makes cell wall more resistant to penetration of facultative pathogens. Potato scab is more severe in soils
having pH above 5.2. The disease is generally suppressed if sulphur and ammonium sources of nitrogen is used. While, club root of crucifers is inhibited in neutral to slightly alkaline soil. More studies are required to understand the effect of interacting nutritional factors on growth and survival of pathogens in soil and the influence on host responses to pathogens.

**Use of compost**

Addition of compost into soils is a fundamental cultural practice specially in organic productions. Compost improves the soil fertility and other physical conditions. The crop yield enhanced considerably in most of the crops. Application of stable and good quality compost results in enhanced population of beneficial and antagonistic microbes which inhibit the pathogen population in soil. Systemic resistance is also induced in responses to compost treatments. Well decomposed compost is more suppressive to soil-borne diseases. Readily available carbon compounds from low quality immature composites support soil pathogens like *Pythium* and *Rhizoctonia*. The comparative competitive saprophytic ability of pathogen and antagonists will determine the survival and population of microbes and pathogens in soil.

**Use of antagonists**

Crop losses due to diseases could be reduced by the use of biocontrol agents *viz.*, *Trichoderma* spp., *Pseudomonas fluorescens*, *Bacillus subtilis* etc. Commercial formulations of the bioagents are being sold in India and abroad. The talc based bioagent formulations are mostly used as dry seed dressings for controlling soil-borne diseases. The mode of antagonisms are mycoparasitism, antibiosis, competition for nutrient and space, induction of host resistance, psiderophore formation etc. The antagonists should be able to survive in soil so that these can compete effectively against microbial pathogens in soil. There is great potential of using these biocontrol agents in place of toxic and hazardous chemicals in integrated disease management strategies. The disease control efficacy of bioagents can be enhanced using organic substrates. The combined use of bioagents with fungicides also improves the disease control potentiality of bioagents. The locally isolated bioagents with high CFU is essential for suppressing the pathogens.

**Use of botanicals**

Plant preparations have been used for centuries in medicine and pest control. Neem products are used for medical, cosmetic and pesticidal purposes. Neem seed extracts contain azadiractin which is chemically similar to ecdysonoids, the hormone having anti-feedant property and may cause insect to stop feeding. Efficacy of neem oil products against powdery mildews of cucurbits and grapes has been demonstrated. Other herbal products like clove, garlic etc. have antimicrobial properties. The use of botanicals in disease management strategies are considered important specially in organic farming.

**Soil solarization and biodisinfestation**

Soil solarization is a non-chemical method of soil disinfection that is based on the exploitation of trapped soil energy with transparent polyethylene sheets, under suitable climatic conditions.
conditions. It is relatively cheap, simple, non-hazardous and the solarized soils are less receptive to pathogen reinfestation. Soil solarization has been developed mainly in regions where temperature and solar radiation during the summer months are high.

Soil disinfestation with fumigants like methyl bromide or steam prior to the establishment of the plants although almost completely eliminate the pathogen from soil, but creates a biological vacuum which enables the quick reestablishment of the pathogens. Hence non-chemical disinfestations or biodisinfestation methods are desired. Biodisinfestation involves the incorporation of green plant material, followed by irrigation and application of an impermeable plastic tarp, for 12-15 weeks. Anaerobic soil conditions develop quickly when soil metabolic activity is stimulated by incorporation of decomposable organic matter and diffusion of oxygen from the atmosphere into the soil is prevented. Biodisinfestation can be applied to areas or periods of low sunlight, thus a growing season is not lost.

Less toxic chemicals like copper and sulfur fungicides are preferred in disease management. Certain newer salts like sodium bicarbonate, potassium phosphate salts etc. are being tested for their potential antimicrobial and antipathogen activities.

Scouting of fields to identify infection foci and hot spots of the diseases is essential. Considerable efforts have been made on developing disease forecasting models. These models use the weather and biological data to predict disease incidence. Various kinds of models like empirical models, mathematical models, computer models etc. are used in forecasting plant diseases. These forecasting models are useful in taking decisions regarding timely application of pesticides for effective control measures. However, not much work has been done for soil-borne diseases. Standardization of techniques for enumeration of pathogen in soil is the most important step for determining the population dynamics of the pathogen in soil.

Disease diagnosis

Accurate and timely diagnosis of plant disease is an essential component of integrated disease control in organic and conventional systems. Various molecular techniques are being used in diagnosis of pathogen. There is a need for comprehensive diagnostic kit that can detect the presence of more than one pathogen in a single host.

REFERENCES


Integrated Management of Important Foliar Diseases

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The Indian economy continues to be dependant upon agriculture. Seventy-two per cent of India’s population lives in rural areas, while 58 percent earn the livelihood from agriculture. The Indian population is growing at 1.8 percent per year and if this trend continues the population will be around 1.3 billion by 2020 A.D. The contribution of agriculture and the allied sector to country’s GDP has fallen considerably during last few decades. Per capita availability of agricultural resources shall be decreased due to demographic pressure and land diversion to non-agricultural purpose. Due to rise in population, the demand for food grains, fruits, vegetables, milk and other food materials shall be considerably increased. An annual increase of more than six million tonnes of food grains, around 4.2 million tonnes of fruits and 2.5 million tonnes of vegetables and substantial increase in milk and fish production will be required to meet the food demand of rising population in the country. In order to achieve sustained food production, the crop production system has to be intensified. The changes in cropping pattern, cultural practices, over use of irrigation have resulted in high incidence and severity of diseases of crop plants. The losses caused by insects pests, microbial pathogen, nematodes and weeds needs to be minimized. The continuous use of pesticide may cause bioaccumulation of the toxic residues besides giving rise to pesticide resistant strains. The integrated disease management strategies include the selection and application of cultural, genetic, biological, chemical and novel approaches which minimizes losses due to pathogen attack and maximizes the return. The disease management strategies in some important crops will be discussed.

Management in rapeseed-mustard Disease

Rapeseed-mustard crops suffer from various fungal, bacterial and phytoplasmal diseases. White rust (Albugo cruciferaum), downy mildew, Alternaria blight (Alternaria brassicae) and Sclerotinia stem rot are most important and causes considerable yield losses in India. Alternaria blight infects leaves stems and siliqua of plants. The pathogen survives in infected plant debris and in soil. White rust is another foliar disease in these crops which cause upto 30 per cent losses under natural field conditions. This pathogen also infects most of the above ground parts. The infected plant debris left over in soil constitutes major source of primary infecton. Downy mildew is commonly associated with white rust. Sclerotinia stem rot, a soil-borne disease has become a serious problem in some mustard growing region of the country.

Integrated disease management strategies are suggested to prevent yield losses in these crops. The white rust and downy mildew intensity is significantly reduced if the crop is sown during first fortnight of October. The severity of these diseases can be reduced by using balanced fertilizer. Fungicidal management of various diseases are advocated to check the further progression of diseases. The spray schedule should be based on appearance and progression of
diseases and prevailing weather conditions

Management of groundnut diseases

Groundnut or peanut suffers from some serious diseases like early and late leaf spots, rusts, collar rot, charcoal rot, peg and pod rots, bud necrosis and clump. Early and late leaf spots may cause 15 to 50 percent losses in yield. The yield losses due to rust varies from 10 to 29 percent. Losses to the extent of 28 to 50 percent due to collar rot has been reported. Severity of most of the diseases of groundnut can be reduced by one to two years crop rotation. Continuous cultivation of the crop encourages the population build up of soil-borne pathogens specially Aspergillus spp. The intercropping of groundnut and pearl millet results in low severity of bud necrosis.

Management of cotton diseases

Cotton based cropping sequence is one of the important cropping system existing in different parts of the country. Bacterial blight, root rot, wilt, leaf curl, and leaf spots are serious diseases and causes substantial yield losses in this crop. The leaf curl appeared in severe form American cotton varieties in 1993 crop season at Sriganganagar district of Rajasthan. Leaf curl is caused by Gemini virus and transmitted by white fly. The bacterial blight is less in timely sown crop as compared to late sown crops. Use of bioagents like Trichoderma seed treatment has proved useful in checking root rots. Cultivation of desi cotton is advocated in leaf curl prone belt of cotton growing areas in Rajasthan and adjoining states.

Management of diseases in pulse/legume crops

Chickpea, mothbean, mungbean, cowpea ad clusterbean are major legume crops grown in arid zone in India. Most of these crops are prone to various diseases viz., foliar diseases like blight, yellow mosaic virus and soil-borne diseases like root rots, wilts etc. The severity of yellow mosaic can be checked by sowing the crops at appropriate time and using resistant /tolerant varieties i.e. RMO 40 (moth bean), RMG 62 and MUM 2 (mung bean). Bioagents i.e. Trichoderma spp are used as seed treatment provides satisfactory control. Based on incidence and severity of various diseases, prevailing weather and soil conditions, integrated management strategies be developed in order to check the crop losses.

REFERENCES

Host Plant Resistance in Chickpea: Innovation to Impact

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Introduction

Chickpea is the third most important legume worldwide cultivated in 11.67 million ha producing 9.31 million tons of seed. India accounts for approximately 64% of the world chickpea production. Despite the large area under chickpea cultivation, total production and productivity is quite low and there is wide gap between potential yield (5 t ha⁻¹) and actual yield (0.8 ha⁻¹). The primary cause of low yields in chickpea is its susceptibility to a number of biotic and abiotic stresses. Among biotic stresses, Fusarium wilt (F. oxysporum, f.sp ciceris), Dry root rot (Rhizoctonia bataticola), collar rot (Sclerotium rolfsii), Ascochyta blight (Ascochyta rabiei) and botrytis grey mold (Botrytis cinerea) are widespread soil-borne and foliar diseases that cause 30-90% yield losses annually. Since fungicidal management of these diseases is not economical and environmentally safe, therefore, host plant resistance (HPR) is the most sustainable, economical and durable disease management option to combat these diseases. Development of reliable and repeatable resistance screening techniques is most important for exploitation of HPR i) to identify genetic resistance ii) for utilizing HPR in disease management alone and iii) for using HPR as a major component of integrated disease management (IDM). In this presentation, attempts have been made to review the historical development, improvement and location specific modifications of screening techniques and their utilization in identifying resistance sources, culling out ultra susceptible breeding lines and finally identifying and deploying high yielding disease resistant varieties to farmers for increasing chickpea production.

HPR at ICRISAT

Research on HPR in pulses began in ICRISAT during 1976-1977, four years after its establishment in 1972. In early 1970’s ICRISAT focused their attention on occurrence and severity of diseases in chickpea. Considerable efforts have been by ICRISAT towards understanding the biology of the pathogen, epidemiology of the disease and understanding the effect of temperature, relative humidity and photoperiod required for the penetration, infection and colonization of the disease. In late 1970’s, in collaboration with NARS partners ICRISAT initiated studies on managing the diseases through HPR involving identifying reliable, repeatable components of screening techniques such as identification of indicator/infector rows, susceptible/resistant checks, inoculum concentration, optimum environmental conditions and disease rating scales for identifying the resistant sources and utilizing these in resistance breeding program.

Between 1972 and 2006, several screening techniques have been developed, standardized and modified to screen chickpea germplasm and breeding material effectively and efficiently against soil-borne (wilt and root rots) and foliar diseases (Ascochyta blight and Botrytis gray mold) (Reddy and Nene, 1978, 1979; Nene and Haware, 1980; Singh et al., 1981, Pande et
al., 2005 and 2006). The procedural details of these techniques were described by Nene et al., 1981. Since then the screening procedures including inoculum concentration, inoculation methods, standardization of temperature, relative humidity, light and their duration along with disease scoring procedures have been refined/modified over the period of time by ICRISA T as well as different research institutes for screening against wilt, dry root rot, collar rot, Ascochyta blight and Botrytis grey mold in the field, greenhouse and controlled environment (Pande et al., 2009).

**Screening techniques**

ICRISA T in partnership with NARS scientists have developed, modified and transferred the following screening techniques for identifying resistant sources against chickpea diseases.

**Fusarium wilt (FW):**
- Field - Sick plot
- Greenhouse - Sick plot
- Root-dip screening technique

**Dry root rot (DRR):**
- Field - Sick plot
- Greenhouse - Sick pot
- Laboratory - Paper towel screening technique

**Collar rot (CR):**
- Field - Sick plot
- Greenhouse - Sick soil

**Ascochyta blight (AB)**
- Controlled environment (ICRISAT): Whole plant screening technique
- Cut-twig screening technique using water
- Cut-twig screening technique using sand
- Field (hot spots) - Hisar, Dhaulakuan and Ludhiana

**Botrytis gray mold (BGM)**
- Controlled environment (ICRISA T): Whole plant screening technique
- Cut-twig screening technique using water
- Cut-twig screening technique using sand
- Field (hot spots) - Pantnagar (India), Tarhara (Nepal), Ishrudi (Bangladesh)

Results of field and greenhouse/controlled environment screening techniques were found highly correlated (r>0.8, p<0.0001) for all the diseases.

**Resistant sources**

At ICRISA T, using field, greenhouse, laboratory and controlled environment screening techniques, several thousand germplasm and breeding lines have been screened for FW, DRR, CR, AB and BGM. These resistant sources were shared with NARS and were used in developing and releasing multiple disease resistant cultivars. Several FW resistant lines were released in the major chickpea growing areas of India. However, high levels of resistance to DRR and CR is not available so far. Recently in collaboration with NARS and International Agricultural Research System (IARS), new source of highly resistant breeding lines for AB and few multiple resistant lines for FW, AB and BGM have been identified. Further, at ICRISA T, multi location evaluation of
these resistant lines were also initiated through the disease nurseries for wilt and root rots, AB and BGM with the following objectives i) to share the resistant germplasm and breeding lines with NARS ii) Identify stable and broad based resistant sources iii) monitor changing scenario of races/pathotypes and iv) identify resistant sources to multiple races/pathotypes. Several stable sources of resistance to wilt, AB and BGM have been identified through a multilocation, multi year evaluation of chickpea lines through these nurseries. Several of the resistant and advanced breeding lines have been shared globally with chickpea researchers in both public and private institutions.

**Looking ahead**

Due to the highly variable nature of the pathogens, resistant cultivars succumb to these diseases and consequently needs to be replaced with a new resistant cultivar. Further, as climate change further increases climate variability, the risk of droughts and floods, diseases and pests, and threats to agricultural productivity and production will escalate. Hence the key to a sustainable future lies in improving crop productivity through ecologically friendly farming systems that are more effective in harnessing nature, and that will go a long way in enhancing the livelihoods of the poor. Therefore, developing appropriate strategies for disease management effective under these situations in future are critical. For example, four races of *F. oxysporum* f.sp. *ciceris* (race 1, 2, 3 and 4) has been reported from India in 1981 (Nene and Haware, 1981). However, recent research indicated a change in the race scenario of *F. oxysporum* f.sp. *ciceris* and studies indicated that these four races do not restrict to a particular geographical location. Thus, due to the existence of several physiological pathogenic races of *F. oxysporum* f.sp. *ciceris*, control of wilt through resistance breeding has become a challenge. Therefore there is a need to study the interaction of root rots and wilt and their sequential occurrence in sick plots. Also there is an urgent need to develop rapid, convenient and highly reproducible diagnostic test including molecular characterization using biotechnological tools to identify races of pathogens to develop area specific multiple disease resistant varieties and their strategic deployment.

**REFERENCES**


References to plant protection are found in Vedas (Rigveda c.3700 BC Atharvaveda c.2000 BC), Kautilya’s Artha-sastra (c.300 BC), Buddhist literature (c.200 BC), Krishi Parashar(c.100 BC), Sangam literature of Tamils (200 BC-100 AD), Agnipuran (c.400 AD), Brhat Samhita of Varahamira (c.600 AD), Kashyapiyakrisuki (c. 800-900 AD), Surapala’s Vrikshayurveda (c.1000AD, Someshwara Deva’s Manasollasa (c, 1100A D), Lokopakara ) by Chavundaraya (c.1108 AD), Sarangadhara’s Upavanavinoda (c.1300 AD),Viswavallabh of Chakrapani Mishra (c.1577 AD), and some documents of the medieval and pre-modern period. But Surapala c.1000 AD) has given plant protection in a very systemic manner right from seed treatment to the storage of grains. Therefore, this period may be considered as the starting point of systematic plant protection in Indian agricultural history.

Ailments described by Surapala

Diseases of all kinds of trees are stated to be of two types: internal and external. It is unfortunate that all textbooks on plant pathology give credit to the French botanist, Tournefort (1705 AD) for classifying diseases as internal and external. This was more than 700 years after Surapala had already done such classification. For the ‘internal disorder of plants he borrowed the tridosha principle of Ayurveda, classified “internal causes as the imbalance of humors, vata, kapha and pitta; and external ones are caused by insects, cold weather, etc. ( for details please read the chapter Plant Protection in “A Textbook on Ancient History of Indian Agriculture by R C Saxena, S L choudhary and Y L Nene., 2009).

Treatments of ailments suggested by Surapala

Diseases caused by vata can be cured by flesh, marrow, and ghee; sprinkling of kunapa water and liberal fumigation of the mixture of fat of hog, oil of Gangetic porpoise, ghee, hemp, hair of horses and cow’s horn-all boiled and set to a decoction. Likewise diseases caused by kafa humor can be cured with bitter, strong and astringent decoction made out of Panchamula (roots of five plant species-sriphala, sarvatobhadra, patala, ganikarika and synoka) with fragrant water or the paste of white mustard should be deposited at the root and trees should be watered with a mixture of sesame and ashes. In case trees are affected by the kafa disease, soil around the roots of the tree should be removed and fresh dry soil should be replaced for curing them. To get cured from pitta type of diseases, treat trees with cool and sweet substances-when watered by decoction of milk, honey, yastimadhu (Glycyrrhiza glabra Linn.) and madhuka (Madhuka indica J. F. Gmel). Further, when watered with the decoction of fruits of triphala (the three kinds of myrobalan-Terminalia chebula Retz, T. belliraca Roxb., and Phyllanthus emblica Linn.), ghee, and honey the trees are freed of all diseases arising from of state of.

To remove insects both from the roots and branches of the trees, water the trees with cold
water for seven days. The worms population can be over come by the paste of kunapa jal (water) and cow dung mixed with water and also by smearing the roots with a mixture of white mustard, vaca (Zingiber zerumbet Rosc. Ex Smith.), kusta (Saussurea lappa C. B. Clarke), and ativisa (Aconitum heterophyllum Wall ex Royle). Likewise the insects on the leaves can be destroyed by sprinkling the powder of ashes and dust. A wound caused by insects heals if sprinkled with milk after being anointed with a mixture of vidanga, sesame, cow's urine, ghee, and mustard. Other wounds of the trees are healed by the treatment of anointing with the paste of bark of nyagrodha (Ficus bengalensis Linn.), and udumbara (F. glomerata Roxb.), cow dung, honey, and ghee. The oozing can be cured by the use of above paste and covering the part with the bark of dhava (Anogeissus latifolia), siparnika (Myrica esculenta Buch-Ham.), syama (Ichnocarpus frutescens R. Br.), vetasa (Salix capera Linn.) and arjuna (Terminalia arguna (Roxb.) Wight & Arn.)

Similarly Surapala had suggested the different treatments like sprinkling of kunapa water and milk, anointing the branches of trees with vidari (Pueraria tuberose DC), sugar, nagajivha (red arsenic) and sesame mixed together and sprinkled with milk water to the trees suffering from frost, scorching heat; and if branches burnt , respectively. Further, if the trees dried due to bad soil, the original soil from the root should be removed and it should be replaced by healthy soil and milk-water should be sprinkle on it. If the drying is due to lack of water the trees should be watered with milk-water and properly fomented by smoke of the crab shells.

Diseases caused by wrong treatment can be conquered by sprinkling the mixture of water and milk and also by applying a paste of vidinga mixed with thick mud. Jaundice (yellowing) can be brought under control only in weeks by sprinkling water mixed with the powder of barley and wheat added to honey and milk.

**Infectious Diseases**

Surapala suggested that before planting cuttings in the pits, the latter should be ‘burned’ using dry plant material, cow dung etc. This is an indication of a suspicion that Surapala must have known about existence of infectious entities. Chakrapani Mishra (1577 AD) suggested that diseased plants found in the midst of healthy plants should be removed and burned, this again pointing towards existence of infectious entities. It is unfortunate that all the current textbook on plant pathology credit Tillet, who in 1755 AD dusted wheat seed with ‘bunt’ spores to produce the disease called wheat bunt. We should, however know that Koch’s postulates have to be followed to prove infectious nature of a disease, Here again, Indians have not been given due credit by the authors of the West.

Vishavavallabha is an another treatise written by Chakrapani Mishra under the patronage of Maharana Pratap of Mewar on the science of plant life which resembles Surpala’s Vrikshayurveda and deals more or less with the same subject but with some additions. For example, several new herbs have been mentioned for the control of disorders, such plant species are, ambu (Pavonia odorata Willd.), aragavadha (Cassia fistula L.), arishta (Sapindus emarginatus Vahl.), ingundi (Nalanites aegyptiaca (L.) Delile), karanja (Pongamia pinnata (L.) Pierre), katphala
Apart from Vrikshayurveda and Vishvavallabha paramount documents concerning plant protection were Someshwara Deva’s Manosollasa (1131 AD), Sarangdhara’s Upvanvinoda (1300 AD), Bhavprakash-nighantu (1600AD), Tuzak-i-Jahangiri (1605 AD), Dara Shikoh’s Nuskha Dar-Fanni-Falahat (1650 AD), Jati Jai Chand Diary (1658-1714 AD), an anonymous Rajasthani manuscript from Mewar region of Rajasthan(1877 AD), and Watt’s Dictionary of Economic Products of India (1889-1893).

Jahangir, the Mughal Emperor of India (1605-1627) described in his memoir “a disorder of marigold” which could be ascribed today to species of *Alternaria*, *Botrytis* or *Sclerotium*. Similarly in Jati Jaichand diary the early blight (*Curvularia penniseti*) of pearl millet and possibly Botrytis gray mold of chickpea have been described.

In a document of early 19th century from the Mewar region of Rajasthan, powdery mildew has been described infesting various plants alongwith canker or anthracnose of orange. In this document a number of plant protection practices have been given. Some interesting practices are:

1. Use of oil (probably sesame) for soil and foliar application to trees to protect from frost and termites.
2. Sprinkling of curd (9 L) with asafetida (112 g) on trees to prevent powdery mildew.
3. Use of asafetida and *vidanga* mixed with curd every 10 days to protect against Orange canker.

Use of cow dung for smearing the cutting of fig before planting is mentioned in Dara Shikoh’s Nuskha Dar Fanni_Falahat (1650 AD). Garlic has been mentioned specially for insect control. In addition to these he has mentioned the use of salt solution for soaking fig cuttings before planting. This is followed by cow dung application.

**Indigenous Plant Protection Practices Still Followed**

In traditional agricultural practices, farmers evolved an effective system of crop protection through generations of experience and intimate knowledge of their environment which are still followed by the farmers in different parts of the country. Some of such practices are:

- Application of organic manure, summer ploughing, crop rotation, use of *neem* leaves and *neem* cake, seed treatment with ash, etc.

Besides these several indigenous practices which are still followed by the farmers of Arunchal Pradesh and Rajasthan are mentioned below:

**Arunachal Pradesh**

1. **Buttermilk for pest control.** Farmers treat garlic seeds with buttermilk @ 10-12 l/ha before sowing for protection against different diseases and insect pests.

2. **Asafetida to control of ergot of sorghum.** About 50-60 g of asafetida in water is used for
making solution to treat sorghum seeds for protection against ergot.

3. **Control of ginger rot and yellowing.** The tribal farmers sow ginger after treating with a solution of cow dung. About 10-15 kg cow dung and asafetida (40-80g/) are mixed in 8-10 L of water. This is enough to treat ginger rhizomes required for one hectare. This practice is helpful for protecting ginger plants from rotting during vegetative growth. The farmers grow papaya as an intercrop for providing shade to ginger and to prevent yellowing. The leaves of ginger do not turn yellow and high yields are obtained.

4. **Control of tomato wilt.** Farmers use turmeric powder @ 15 to 20 kg/l of water to control wilt (*Fusarium* sp.) of tomato. This solution is used to treat the roots of seedlings grown in nurseries of tomato before transplanting.

5. **Control of early stem borer in sugarcane.** To control the stem borer (*Chilo infuscatellus*) in sugarcane, farmers use *neem* oil @ 1.5-2 L/ha. This practice is repeated thrice in the whole period of sugarcane vegetative growth.

6. **Control of termites.** Farmers keep asafetida in a pack of cotton cloth at two or three points in the irrigation channel of 10-15 m irrigation for controlling termites (*Odonotermes obescus*) in affected crops.

7. **Control of storage pests.** Farmers used different simple practices for the control of storage pests viz. fuel wood ash for pests of pulses (250 g ash/250 kg of pulses); dry *neem* leaves @ 2.5 kg/100 kg of wheat for controlling storage pests, dry chillis @ 5-6 per kg of seed of mung bean and black gram.

**Plant protection in Rajasthan- Semi-arid region**

In Rajasthan some of the following methods of plant protection in semi-arid and tribal regions are used by farming communities.

**Control of termites**

1. Attack of termites and cracking of epidermis in fruits can be avoided by using a paste on the main trunk with a mixture of mustard oil (one l)+turmeric powder (200 g).
2. Mustard oil attracts ants which remove termites while turmeric powder helps in healing the cracks. Another practices is chopped the *aak* (*Calotropis*) leaves, filled in gunny bags and kept in irrigation channel. The exudates from these leaves have been reported to kill termites and other soil-borne pathogens.
3. Farmers amend the soil with the pre-incubated mixture of *aak* leaves (5 bags)+*neem* kernels and leaves (95 bags)+asafetida (200 g) to check termite attack in the field and soil-borne diseases. They claimed good growth of crop due to this amendment.

**Control of thrips, aphids, whitefly and other pests as well virus diseases**

1. To prevent thrips and aphids they apply cow dung ash on foliage of vegetables e. g., chilli, onion, garlic, and cucurbits
2. In Jodhpur district some farmers use cow urine based bio-pesticide to check whitefly,
jassids, and other sucking pests of chilli and cumin. This is prepared by mixing cow urine (10 L) + neem kernels and leaves (2 kg) + garlic (100 g). The ingredients are crushed and kept in copper container for 15 days. The solution is then heated till 5 L of solution is left. After cooling, the liquid is filtered and diluted with 500 L of water before spraying. The farmers even claimed its efficacy in controlling viral diseases of chilli also.

**Control of nematodes.** Mixture of cow dung + aak (Calotrips spp.) + kheip or khip (Crotalaria burhia), local xerophic plant foliage is allowed to rot in a pit for about two months. This mixture (manure) is then applied in chilli and tomato fields for control of root-knot nematodes, termites as well as for good growth.

**Tribal region**

1. In paddy, spraying a solution of 4 L of cow urine and 10 g asafetida in 10 l of water repels the sucking pests (aphids and jassids).

2. To control paddy blast and bacterial blight, spraying a solution of cow dung prepared by mixing 3 kg cow dung in 3 L of water is commonly used by the farmers.

3. In case of insects holes made by shoot borer and bark eaters in mango trees, jaggere is placed in the holes to attract other predators (ants), which will feed on the insects present in the holes. Similarly the practice of pouring kerosene oil in holes made by insects and blocking holes with cow dung is also popular.

4. A peculiar method of controlling pathogen attack in chilli is practiced by tribals wherein the twigs of aak (Calotropis spp.) are placed in between rows. Similarly some farmers placed fresh cow dung near the collar region of chilli plant to prevent it from fungal diseases viz., damping off and die back.

5. In case of soil-borne diseases viz., root rot, collar rot, etc. and termites, the cakes of castor, karanj or neem are used as control measures.

6. During sprouting of sets in sugarcane crop, putting stem of aak (Calotropis spp.) in the irrigation channel during intercultural operations has been found effective against termites.

**Scientific basis of age-old plant protection practices**

It has been now realized that the techniques adopted for commercial agriculture are unsustainable on long term basis. Therefore, agricultural scientists are diverting their attention to the traditional or indigenous technology and exploring possibilities of using them wherever possible. Our old traditional technologies were scientific and almost eco-friendly as all the plant protection practices were based on organic materials both of plant and animal origin which includes honey, ghee, milk and milk products, cow dung and urine, and extracts from number of plant species like Brassica ssp., Madhuka indica, Ficus ssp., Piper nigrum, Azadirachta indica, Vitex nigundo, Embelia ribes etc. The biochemical analysis of these materials clearly indicated now that all these materials have antimicrobial activities.

Milk and ghee have been used for centuries. Even buttermilk was found useful. About 40% of total amino acids in milk are glutamate, leucine, and proline. A recent report claimed that milk
sprays induced systemically acquired resistance in chilli against leaf curl, a viral disease. Milk (10% aqueous suspension) has also been effectively used for controlling powdery mildews.

The use of cow dung by our farmers for different purposes like seed dressing, plastering cut ends of vegetatively propagating units such as sugarcane sets, dressing wounds, sprinkling dilute suspension of plants and applying to soil has been indicated since the time of Kautilya (c.300 BC). The cow dung from the cattle shed is a mixture of dung and urine in a ratio of 3:1. Cow dung consists crude fibre, crude protein and materials that can be obtained in nitrogen-free extracts. There are more than 60 species of bacteria and 100 species of protozoa encountered in the rumen of cow. Thus when seed is treated in various ways with cow dung, it gets coated with cow dung residue. The residue contains several organic elements, enzymes, macro and micro-nutrients, epithelial cells, bile salt and pigment and large number of bacteria. The dung residue has emulsifying properties and readily absorbs moisture from the surrounding soil to the advantage of seeds. The presence of bacteria may antagonize potential pathogens ready to attack seed.

Neem cake application to the field reduces population of soil-borne fungi and nematodes and also reclaims alkaline soil due to presence of calcium and magnesium. The ancient practice of spreading of neem leaves over groundnut in storage has a scientific basis. It has now proved that neem leaves inhibit the growth of Aspergillus flavus and thereby prevent aflatoxin production.

The utility of neem tree has been recognized long back in Indian agricultural history. Every part of this tree is used for a number of purposes. Now this tree is found to be an effective air filter and protects environment.
Exploitation of Natural Compounds in Eco-friendly Management of Plant Pests

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Plant diseases are known from times preceding the earliest writings. The Bible and other early writings mention plant diseases, such as rusts, mildews, blights, and blast. Plant disease control measures are as old as modern civilizations and were first recorded long before the Renaissance in the Western and the Oriental worlds. The use of locally available plants in the control of pests is an ancient technology in many parts of the world. Some plants viz. Derris, Nicotiana and Ryania were used to combat agricultural pests during prehistoric period. Used widely until 1940's, such botanical pesticides were partly displaced by synthetic pesticides that at the time seemed easier to handle and longer lasting.

Sustainable agriculture aims to reduce the incidence of pests and diseases to such a degree that they do not seriously damage the farmer's crop without upsetting the balance of nature. One of the aims of sustainable agriculture is to rediscover and develop strategies whose cost and ecological side-effects are minimal. The use of synthetic pesticides has undoubtedly resulted in achievement of green revolution in different countries through increased crop production. However, in recent years there has been considerable pressure on consumers and farmers to reduce or eliminate synthetic pesticides in agriculture. This concern has encouraged researchers to look for better alternatives to synthetic pesticides. Botanical pesticides may be recommended as eco-chemical and sustainable strategy in the management of agricultural pests. Because of biodegradable nature, systemicity after application, altering the behaviour of target pests and favourable safety profile, plant based pesticides are looked to play significant role in achieving ever green revolution

Higher plants harbour numerous compounds which provide them resistance to pathogenic organisms. During course of evolution, the selection pressure caused by pathogens and herbivores has probably been highly acute and intense and resulted a vast chemical diversity in higher plants. Unlike compounds synthesized in the laboratory, secondary compounds from plants are virtually guaranteed to have biological activity protecting the producing plant from pathogen, herbivore, or competitor. In general, the plant secondary metabolites are considered to have co-evolved with herbivory.

Knowledge of the pests to which the secondary compounds produced in the plants are resistant may provide useful leads in predicting which pests may be controlled by compounds from a particular plant species. This approach has led to the discovery of different botanical pesticides

Neem pesticides do not leave any residue on the crop also work as a systemic pesticide, absorbed into the plant and carried throughout the tissues, ingested by insects when they feed on the plant. Azadirachtin is considered non-toxic to mammals, fish and pollinators, having low
mammalian toxicity with LD$_{50}$ of >5,000 mg/kg for rat. It is classified by Environment Protection Agency (EPA) in class IV. It is felt that none of the synthetic pesticides developed so far has the excellent virtues in pest management which neem products possess. Pyrethrum, the another oldest and safest insecticide, extracted from the dried flower buds of *Chrysanthemum* sp. were used in the early 19th century to control body lice during the Napoleonic Wars. Pyrethrum is a mixture of four compounds: pyrethrins I and II and cinerins I and II. Pyrethrum is nontoxic to most mammals, making it among the safest insecticides in use. Sabadilla, also known as `cevadilla` is derived from the seeds of the sabadilla lily (*Schoenocaulon officinale*), a tropical lily that grows in Central and South America. The active ingredient is an alkaloid known as veratrine which is commonly sold under the trade names "Red Devil" or "Natural Guard". Sabadilla is considered as the least toxic botanical insecticide, with an oral LD$_{50}$ of 4,000 to 5,000 mg/kg. Carvone, a monoterpene of the essential oil of *Carum carvi*, is a nontoxic botanical pesticide under the trade name TALENT. It inhibits sprouting of potato tubers during storage and protects them from bacterial rotting without exhibiting mammalian toxicity. Thus, it enhances the shelf life of stored fruits and vegetables and inhibits microbial deterioration without altering the taste and odour of the fruits (Varma and Dubey, 1999). Such plant chemicals can improve shelf-life, quality and nutritional value of stored food commodities. Different crude extracts and plant materials rich in polyphenolics are becoming increasingly important in food industries because of their antifungal, antiaflatoxicogenic and antioxidant activity (Kumar et al., 2007).

Many aromatic plants commonly used as culinary herbs and spices and their essential oils have attracted the attention of scientists regarding their exploitation as botanical fumigants against storage losses of food commodities by pests and mycotoxins. Such products possess favourable safety profile having comparatively low mammalian toxicity and are generally exempted from toxicity data requirements by EPA. Mycotech Corporation has formulated Cinnamite-TM, and ValeroTM which are used as aphicides / miticides as well as fungicides for glasshouse and horticultural crops viz. grapes, berry crops, citrus and nuts. Both products are based on cinnamon oil, with cinnamaldehyde as the active ingredient. EcoSMART Technologies have formulated several essential oil-based pesticides. Some essential oil constituents, for example, d-limonene, pulegone, citronellal and 1-8 cineole are active ingredients of commercially available flea shampoos, mosquito repellents and different agrochemicals (Duke, 1990).

Some higher plant secondary metabolites have also been reported to alter the behaviour and life cycle of insect pests without killing them. Such chemicals are termed as semio-chemicals by Organisation for Economic Cooperation and Development (Regnault-Roger and Philogene, 2008). Semio-chemicals act by modifying the behaviour of pest species rather than killing them and are target specific. Some of the essential oils and their components show chemosterilant activity. β-asarone extracted from rhizomes of *Acorus calamus* possesses antigonadial activity causing complete inhibition of ovarian development of different insects. The products showing chemosterilant activity are highly required in integrated pest management programmes to limit the...
chances of physiological (resistant) race development by insects. Many of the essential oils and their products are included in the Generally Recognised as Safe (GRAS) list fully approved by FDA and EPA for food and beverage consumption. They can be regarded as low risk and the data requirements are not as enormous as for synthetic chemical substances.

It has long been observed that plants repel pests from stored products, houses and field crops. Repellents and attractants modify the behavioural response of insects. This is the basis for the principle of behavioural insect control, whereby a given species is either attracted to a bait, or pheromone; or repelled from a host plant by a repulsive agent (Fagoonee, 1981).

Pesticidal compounds of plant origin are effective against pests, mostly through diverse modes of action and can express several properties such as growth retardation, feeding deterrent, oviposition deterrent and reduction in fertility. Such allelochemicals needs proper attention of plant biologists in exploiting plant-pest chemical ecology in integrated management of plant pests. Most of the essential oils of higher plant origin act in biorational mode of action interrupting the function of octapamine receptors found in insects but absent in mammalian system (Hollingworth et al., 1984). Hence, their exploitation in pest management would be an ideal eco-chemical approach.

A Push-Pull or Stimulo-Deterrent Diversionary Strategy has been developed in South Africa for minimising damage due to maize stem borer insects. This strategy involves selection of plant species employed as trap crops to attract stem borer insects away from maize crop or some plant species are used as intercrops to repel insects. The trap and repellent plants contain some semio-chemicals which attract or repel the insect. The Push-Pull Strategy is also employed in control of Heliotris sp. in cotton field (Pyke et al., 1987). The Push-Pull Strategy exploiting chemical ecology of plants would prove an indigenous and readily available concept in management of insect population in field crops. Plant flowers like marigold and certain kinds of vegetables help to control pests in or around the main crop. Such a strategy is sometimes called “companion planting” in pest management.

Reports on negative effects of synthetic pesticides and environmental risks resulting from their indiscriminate application, have renewed interest towards botanical pesticides as eco-chemical approach in pest management. In the context of agricultural pest management, botanical pesticides are well suited for use in organic food production and may play a much greater role in the production and protection of food in developing countries (Isman, 2006). Among the variety of nature’s ecosystem services, the natural pest control is an important aspect. The current desire of modern society towards ‘green consumerism’ desiring fewer synthetic ingredients in food may favour the recommendation of plant based products which are “generally recognized as safe” (GRAS) in eco-friendly management of plant pests as botanical pesticides (Smid and Gorris, 1999).

Natural plant chemicals will play a significant role in the future for pest control in both industrialised and developing countries. Because of biodegradable nature, systemicity after application, altering the behaviour of target pests and favourable safety profile, the botanical
pesticides are looked to play significant role in achieving ever green revolution and are regarded as a new class of ecological strategy for controlling agricultural pests. There is a wide scope of use of plant allelochemicals for plant health. Hence, the biodiversity rich countries should quickly bioprospect their traditionally used flora to document pesticidal plants in order to check future cases of biopiracy and establish their sovereign right on the botanical pesticides developed from such plants.

REFERENCES


Breeding Strategies for Management of Tomato Disease

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Tomato is one of the most important vegetable crops grown throughout the world. Tomato is a native of Peru in South America. The crop spread to North America primarily by migrating birds. The largest concentration of wild tomatoes is in Mexico and the name Tomato itself comes from the aztec word Tomatl. Spanish priests introduced it to Europe around 1550. In Europe it was known as Poma amoris-Amorous apple or love apple. It was also known as Poma peruviana apple of Peru. Only as late as 1880, did the British finally concede that tomato is edible.

As it belong to the night shade family Linnaeus called it Solanum lycopersicum. It was Robert Gibbon Johanson, an ordinary farmer in the U.S.A who first ate tomato on a hot day of August 1820 to demonstrate its edibility. From then onwards, the tomato spread throughout the world.

The genus Lycopersicon is divided into two sub genera: Eulycopersicon: Red fruited varieties which are self compatible and Eriopersicon: green fruited varieties, self-incompatible.

Eulycopersicon consists of:
(a) Lycopersicon esculentum – fruits are larger, generally solitary, plant is hairy, strong odour
(b) L. pimpinellifolium Mill (Syn. Solanum pimpinellifolium) – fruits are small, in bunches, deep red colour of fruits, plant is smooth, very slender plant, a little or indifferent odour.

The subgenus Eriopersicon consists of:
(a) L. hirsutum: this is the closet species to Lycopersicon esculentum.
(b) L. parviflorum
(c) L. peruvianum
(d) L. pennellii
(e) L. chmielewskii
(f) L. cheesmani
(g) L. chilense

Impotence of tomato crop

Tomato is highly nutritative crop. Following table shows nutritive value of tomato

<table>
<thead>
<tr>
<th>Nutritional value per 100 g of Tomato</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>75 kJ (18 kcal)</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>4.0 g</td>
</tr>
<tr>
<td>Sugars</td>
<td>2.6 g</td>
</tr>
<tr>
<td>Dietary fiber</td>
<td>1 g</td>
</tr>
<tr>
<td>Fat</td>
<td>0.2 g</td>
</tr>
<tr>
<td>Protein</td>
<td>1.0 g</td>
</tr>
<tr>
<td>Water</td>
<td>95.0 g</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>22.0 mg</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>300 IU</td>
</tr>
</tbody>
</table>
Tomatoes are now eaten freely throughout the world, and their consumption is believed to benefit the heart among other things.

- They contain lycopene, one of the most powerful natural antioxidants.
- Lycopene has also been shown to improve the skin's ability to protect against harmful UV rays.
- Tomato varieties are available with double the normal vitamin C, 40 times normal vitamin A, high levels of anthocyanin, and two to four times the normal amount of lycopene (numerous available cultivars with the high crimson gene).
- Tomato consumption has been associated with decreased risk of breast cancer, head and neck cancers, and might be strongly protective against neurodegenerative diseases.
- Tomatoes are used extensively in Mediterranean cuisine, especially Italian and Middle Eastern cuisines.
- The tomato is acidic; this acidity makes tomatoes especially easy to preserve in home canning whole, in pieces, as tomato sauce, or paste.
- Tomato juice is often canned and sold as a beverage; Unripe green tomatoes can also be breaded and fried, used to make salsa, or pickled.
- The fruit is also preserved by drying, often by sun, and sold either in bags or in jars in oil.

**Tomato production in the world**

Tomato production in India ranks forth after China, USA and Turkey. Following table shows production of different countries and the world.

![Top Tomato Producers of the World— 2008](image)

<table>
<thead>
<tr>
<th>Country</th>
<th>Production (in tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>338,117,02</td>
</tr>
<tr>
<td>United States</td>
<td>125,739,00</td>
</tr>
<tr>
<td>Turkey</td>
<td>109,854,00</td>
</tr>
<tr>
<td>India</td>
<td>102,606,00</td>
</tr>
<tr>
<td>Italy</td>
<td>89,769,12</td>
</tr>
<tr>
<td>World Total</td>
<td>1,296,499,83</td>
</tr>
</tbody>
</table>

**Important disease of tomato:**

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Damping off</td>
</tr>
<tr>
<td>2.</td>
<td>Late Blight</td>
</tr>
<tr>
<td>3.</td>
<td>Early Blight</td>
</tr>
<tr>
<td>4.</td>
<td>Fusarium wilt</td>
</tr>
<tr>
<td>5.</td>
<td>Bacterial Wilt</td>
</tr>
<tr>
<td>6.</td>
<td>Tomato mosaic virus</td>
</tr>
<tr>
<td>7.</td>
<td>Leaf Curl Virus</td>
</tr>
</tbody>
</table>
Disease in plants

- Disease is an abnormal condition in the plant produced by an organism.
- The plant affected by a disease is known as host, while the organism that produces the disease is termed as pathogen.
- The diseases are produced by fungi, bacteria, viruses, nematodes and insects.

Disease Management

- Much of the breeding effort has been directed against diseases caused by fungi.
- Disease management is the managing the genotype or environment to remove the disease/pathogen or minimize the incidences of disease so that produce can be harvested in economic way.
- Management of
  - Genotype
  - Environment

Breeding Strategies to Manage of the Tomato Disease

- By breeding early varieties to escape disease incidences.
- By breeding resistant genotypes against diseases.
- By breeding or multiple disease resistance
- By creating resistant genotypes through biotechnological tool.

Disease Escape

- Disease escape refers to freedom of susceptible host varieties from a disease due purely the environmental factors.
- Early varieties of tomato-

BREEDING FOR RESISTANCE

History Of Breeding For Disease Resistance

- Theophratus in the third century BC, noted that cultivated varieties differed in their ability to avoid diseases.
- Diseases are produced by pathogen was shown by Benedict Prevost.
- Biffen (1905) demonstrated genetic basis of disease resistance in crops.
- Erikson (1894) showed that pathogens, although morphologically similar, differed from each other in their ability to attack different related host species.
- Barrus (1911) showed that different isolates of a micro organism differed in their ability of pathogen to attack different varieties of the same host species; this finding is the basis for physiological races and/or pathotypes.
- The ability of a pathogen to infect a host strain, ie pathogenicity, is genetically determined.

Gene for Gene Hypothesis

- GENE for GENE hypothesis by Flor (1955) is gene for gene relationship between host and pathogen, which holds true in most of the cases and is widely accepted.
The ability of host to resist invasion by pathogen as well as the ability of pathogen to invade its host are genetically controlled.

Pathogenicity is ability of pathogen to attack a host and is synonymous to virulence.

A study of the inheritance of virulence is possible only when a host with a resistance gene is available.

**Type of Disease Resistance**

- Host varieties are classified as susceptible or resistant according to their response to the pathogen.
- Resistance may be two types -
  - Vertical Resistance
  - Horizontal Resistance

**Vertical Resistance**

- It is also known as race specific, pathotype specific or simply specific resistance.
- It is generally determined by major genes and is characterised by pathotype specificity.
- Pathotype specificity denotes that the host carrying a gene for vertical resistance is attacked by only that pathotype which is virulent towards that resistance gene; to all other pathotype the host will be resistant.
- An avirulent pathotype will lead to the susceptible reaction.
- Immune or susceptible response depends on the presence of virulent pathotype. When the virulent pathotype becomes frequent, epidemics are common in the case of vertical resistance.

**Horizontal Resistance**

- It is also known race non specific, pathotype non specific and partial or general resistance.
- It is generally controlled by polygenes, that is, many genes with small effects.
In this case reproduction rate of the pathogen is not zero.

This type of resistance does not prevent the development of symptoms of the disease, but it slows down the rate of spread of the disease in the population.

BREEDING METHODS FOR INCORPORATING DISEASE RESISTANCE

1. Selection:
   - Selection of resistant plants from a commercial variety is the cheapest method of developing a resistant variety.
   - Selection may be done from available germplasm.

2. Introduction:
   - Resistant varieties may be introduced for cultivation in new area.
   - This offers a relatively simple and quick mean of obtaining resistant varieties.

Limitation
   - The introduced varieties may not perform well.
   - They may become susceptible in the new environment.
   - They may be susceptible to other diseases common in the new area.

3. Hybridization
   - Hybridization is the most common method of breeding for disease resistance.
   - Hybridization serves two chief purposes:
     1) Transfer of disease resistance from an agronomically undesirable variety to a susceptible but otherwise desirable variety.(by back cross method).
     2) Combining disease resistance and some other desirable characters of one variety with the superior characteristics of another variety (by pedigree method).

Donor for disease resistance in tomato spices and germplasm

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Disease</th>
<th>Donor</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td>Late Blight</td>
<td>West Virginia 63</td>
</tr>
<tr>
<td>4.</td>
<td>Early Blight</td>
<td>68B 134, Southland, <em>L. pimpinellifolium</em></td>
</tr>
<tr>
<td>5.</td>
<td>Anthracnose</td>
<td>PI 272636</td>
</tr>
<tr>
<td>6.</td>
<td>Verticillium wilt</td>
<td>VR Moscow</td>
</tr>
<tr>
<td>8.</td>
<td>Leaf Curl Virus</td>
<td><em>L. peruvianum</em>, <em>L. hirsutum</em></td>
</tr>
<tr>
<td>9.</td>
<td>Bacterial Canker</td>
<td>Bulgarian 12, Utah 737</td>
</tr>
</tbody>
</table>

Mutation:
- Mutation is a sudden heritable change in a characteristic of an organism.
When variability for resistance are not present in available breeding material then variability may be created by mutagen.

Resistance may be induced through spontaneous or induced mutation

Breeding for Multiple Disease Resistance

- Variety having resistance against two or more than two diseases is known as multiple disease resistant variety
- Multiple disease resistance in vegetable crops so far has not been given serious attention in the country.
- In tomato, a large number of wild species and cultivars are available as sources of resistance (Peter and Joseph, 1986)

Approaches for developing multiple disease resistant lines/genotypes

   - One can use a line already resistant to one or two diseases and incorporate resistance for other disease in the same line from other sources.
2. Development hybrid based on parental lines each having a resistance to one or more diseases. (Singh, 1986)
3. Three or four way cross and select resistant plants to more than one diseases in subsequent generations. (Gardner, 1985 and Bosch et al., 1990)
   - Florida 1011 tomato breeding line was found to be resistant to verticillum wilt, fusarium wilt, grey leaf spot and leaf mould. (Volin et al., 1977)
   - Rotam-4 a multiple disease resistant fresh market tomato, was resistant to bacterial wilt, fusarium wilt, Verticillum wilt and bacterial speck. (Bosch et al., 1990)
   - 1-7-1xpatriot, 7-9-6-10 and EC 177401xSylvestra are resistant to fruit rot and early blight diseases. (Cheema et al., 1992)

BIOTECHNOLOGICAL TOOLS TO INCORPORATE THE RESISTANCE

- Identification of resistant gene in the source.
- Functional transfer of gene/genes from the source to desirable genotypes.

Single gene for disease resistance

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Gene designation</th>
<th>Gene Symbol</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Fusarium immunity</td>
<td>I -1, I -2</td>
<td>Pan American</td>
</tr>
<tr>
<td></td>
<td>- Race 1</td>
<td></td>
<td>Walter</td>
</tr>
<tr>
<td></td>
<td>- Race 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Verticillum resistance</td>
<td>Ve</td>
<td>VR Moscow</td>
</tr>
<tr>
<td>3.</td>
<td>Late Blight resistance</td>
<td>Ph -1</td>
<td>New Yorker</td>
</tr>
<tr>
<td>4.</td>
<td>Septoria resistance</td>
<td>Se</td>
<td>Targinnie Red</td>
</tr>
<tr>
<td>5.</td>
<td>Alternaria resistance</td>
<td>Ad</td>
<td>Southland</td>
</tr>
<tr>
<td>6.</td>
<td>Tobacco mosaic resistance</td>
<td>Tm -1, Tm -2</td>
<td></td>
</tr>
</tbody>
</table>
|    | Nematode resistance | Mi | Rossil
|----|---------------------|----|--------|
| 8. | Leaf mold resistance| Cf 1 | Sterling Castle
|    |                     | Cf 2 | Vetamold
|    |                     | Cf 3 | V121
|    |                     | Cf 4 | Purdue 135

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Recent Molecular Biology Tools for Rhizospheric Community Analysis for Effective Introduction of Bioagents Application for Organic Agricultural Practices

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Rhizosphere and plant interactions have been realized of utmost importance by virtue of natural selection of microbial communities most suited its growth. Since rare plants of medicinal importance are required to be adopted in different climatic zones for sustainable harvest, therefore, it becomes necessary job to characterize these rhizospheric communities more precisely adopting new and advance molecular biology and other specified tools. Such microbial diversity characterization shall also provide good application approaches of biofertilizers/biocontrol agents in organic farming practices. Many of the time culturing practices of rhizospheric microbes are difficult and as a result denaturing gel electrophoresis, temperature gradient gel electrophoresis, single strand conformation polymorphism, gene polymorphism, amplified ribosomal DNA restriction analysis, terminal RFLP, etc techniques could successfully adopted for microbial characterizations.

Global human population and urbanization in southeastasian countries posed once again a major challenge of productivity and food production with an additional issue of at least sustainable environment adopting ecofreindly practices. While studying biodiversity an important issue of conserving natural resources and their sustainable harvest has also been emerged. Products of aesthetic values from rare plants lead toward organic pharming for atleast nutraceutical development. Therefore, understanding of microbial ecology precisely through utilizing present day advance tools for better understanding of soil biology at molecular level of various natural habitat which in turn will help protecting biodiversity at different level.

Introduction

Biofertilizers and biocontrol agents represent broad range of soil microbes, their introduction in different soils need carefull characterization in terms of composition and structure with the help of advance technology available such as 16s ribosomal DNA for phylotyping and redox potential of carbon sources for phenotyping by sequence/ microarray analyses tools which will allow right type of introduction of agents as bioferilizers/biocontrols in different agroclimatic zones with special reference to cultivation of medicinal plants. The concept and compilation of detailed methodology for said applications will be discussed. Biolog Inc. developed a screening technology, “Phenotype MicroArray” it ia an integrated system of cellular assays, instrumentation, and bioinformatics software for high-throughput screening of cells, available for fungal and bacterial cells. Testing process and the technology were reconfigures a diverse range of phenotypic tests into sets of arrays. Wells are prepared for a total of 1,920 conditions, hence each well is designed to test a different phenotype in the array. The OmniLog® monitored
simultaneously thousands of phenotypes and up to 450,000 data points generated in one 24 h run. Much of known aspects of the cell, directly or indirectly can be monitored by PM. Recently, a researcher demonstrated the global effect of the CbrAB and NtrBC two-component systems of carbon and nitrogen utilization in *Pseudomonas aeruginosa* which was characterized by phenotype microarray analyses with single and double mutants and the isogenic parent strain.

The gene common to all organisms identify by the use of PCR, that allows the identification of these previously unknown organisms. Genes commonly amplified for this purpose codes for the RNA sequence of the small subunit (SSU) of the ribosome. Different bacterial genomes were estimated per gram of soil to occur in terrestrial environments. Extensive diversity of the soil could be competed by even comprehensive culture collection. In the whole world, many culture-independent surveys of the microbial diversity in soil had been performed e.g. DGGE, TGGE, TRFLP, ARDRA. All were based principally on the PCR amplification of the small-subunit rDNA from directly extracted soil DNA with universal primers. Comprehensive SSU rDNA clone libraries are subsequently generated by using these amplicons, allowing subsequent sequencing analyses. Unfortunately, all the studies used different studies used different cell lysis methods and primer sets. Comparability is thus limited, all these sequence provide the first indication of microbial diversity based on “real environment” 16S rDNA data. The presence of hitherto unidentified bacteria demonstrated by the analysis of such 16S rDNA clone libraries, that were remotely related to known strains. Only a minority of sequences retrieved from directly isolated soil DNA could be closely related to cultured organisms.

**Materials and Methods:**

**Biofilm quantification assay.** Biofilm formation assayed by the ability of the cells to adhere to the wells of microtitre plates made of polystyrene. Bacterial supernatants discarded after incubation, and loosely adherent bacteria removed by three washes with phosphate-buffered saline (pH 7.2). The microtiter plates then inverted and allowed to dry before each well filled with 25 µl 0.1% (w/v) crystal violet (CV) solution and incubated at room temperature for 30 minutes. Unbound CV removed by three washes with water, and the plates inverted to dry. Cell-bound CV then released from bacterial cell by the addition of 200 µl 95% ethanol and, after incubation at room temperature for 30 minutes on a rotary shaker, the concentration of CV in each solution determined by the optical density reading at 590nm (Tecan Infinite 200 Microplate Reader, Manndorf, Switzerland). Similarly, wells containing only NB but no bacteria were used as negative controls.

**EPS quantification assay.** Cell suspension of O.D. about 1.0 (600 nm), centrifuge the cell suspension at 10,000 rpm for 10 min. The sedimented material is used for the total carbohydrate assay. To 0.5 ml sample grown in NB/LB, add ml phenol (5% w/v) then add 1 ml sulphuric acid, incubate it for 1 h in dark. Dilute the resultant solution by adding equal volume of water to the material. Incubate for 60 min in dark and measure absorbance at 490 nm.
Alginate quantification assay. Grown bacterial culture in 40 ml of NB for 48 h centrifuged using Sorvall RC 5C at 10,000 rpm for 10 min at 4°C. Supernatant was collected in a fresh vessel; alginate was precipitated by the equal volume of isopropanol by keeping it for one day in static conditions. Again centrifuge at 10,000 rpm for 10 min and collect the pellet, wash with 70% ethanol followed by 96% ethanol then dry by keeping at 37°C for 15 min. Dissolve pellet in 500 µl of sterile DW. 100 µl was used for quantification, dilute it 1:10 fold by adding 900 µl sterile DW to make it 1 ml. Add equal volume of Borate sulfuric acid (10mM H$_3$BO$_3$ in Conc. H$_2$SO$_4$), then 30 µl of Carbazole reagent (0.1% in ethanol) added. Distinguishable purple colour develops; absorbance of the mixture has been taken at 500 nm. Alginate can be calculated in terms of mg/g wet biomass using alginate from sea weed as a standard.

Characterization of clones

Restriction mapping. In order to construct the restriction map of the recombinant positive clone digestion is required with a number of restriction enzymes. The restriction enzymes selected form the multiple cloning sites usually common amongst them are Eco RI, Xho I and Hind III. Digestion with restriction endonucleases generally carried out as per the conditions recommended by the manufacture(s) of the restriction endonucleases. The restriction digestion pattern analyzed on 0.8% agarose gel along with λ DNA Eco RI + Hind III double digest as marker for fragment size determinations. After electrophoresis, the gel was stained with ethidium bromide and visualized in UV light.

Sequencing of cloned fragment. The nucleotide sequence of the cloned DNA requires to be determined on DNA sequencer. Initially universal sequencing primers were used subsequent sequencing was accomplished by primer walking.

Analysis of sequences. Nucleotide sequences of the plasmid analysis manually performed to find the insert DNA sequence. Sequences beyond the matched sequences of vector treated as insert sequences. Insert sequences matched for nucleotide-nucleotide homology by using the BLAST search (www.ncbi.nlm.nih.gov) and hosted tools of website www.justbio.com used to create inverse complementary sequences, sequences oriented in same frame then aligned manually to get a complete sequence in same orientation.

Phenotype microarray

Phenotypic microarray analysis is a recently developed analytical tool to determine the phenotype of an organism. This technique can be useful to understand the growth changes of an organism when changing medium, temperature, or adding a stressor, or when testing mutant strains. The plates, which are commercially available from Biolog (Hayward, CA), consist of array of 20 plates, The first eight plates test a variety of metabolic agents, including electron donors, acceptors, and amino acids. Plates 9 and 10 cover a pH and osmotic stressors, while plates 11-20 contain a variety of inhibitors, including toxic agents and antibiotics.

The layouts of the 2,000 PM tests, PM 1-8 test the main catabolic pathways in cells for carbon, nitrogen, phosphorus and sulphur, as well as biosynthetic pathways. PM9 tests osmotic
and ion effects on the cell. PM10 primarily tests pH growth range and pH regulation.

**Community profiling on biochemical basis**

Substrate utilization from rhizosphere of a plant under different treatment could be determined using (Biolog Inc., Hayward, California, USA). The rate of utilization is indicated by tetrazolium reduction with the help of dye, on the basis of colour change. Suitable aliquots were used into microplate wells, after incubation of these plate at 30°C. The absorbancy was measured using visible microplate reader as per Garland (1996). Diversity indices and related were calculated using formula described by Derry et al.(1998).

**Results and Discussion**

It is inferred that in the environment the bacterial communities were composed mainly of uncultured species. The production of clone libraries, however limits the number of samples and time-consuming that can be analyzed and compared with each other. The number of samples that can be analyzed may be a critical factor for many ecological studies, because the natural variability of a community needs to be differentiated from effects that were triggered by a changing environmental condition. Since, to promote the circulation of plant nutrients and reduce the need for chemical fertilizers microorganisms are most important, therefore, rhizosphere bacterial communities could be explored for reasonably correct identification by use of culture-dependent and culture-independent methods, in relation to variables such as the host plant species and soil properties. Rhizosphere bacterial communities characterization methods involved soil sampling followed by bacterial community assessment, as well as the magnitude of interactions that can result from different plant/soil/environmental systems for biopharming practices.

**REFERENCES**


Cultural Management of Plant Diseases Control with Special Reference to Sugarcane Crop

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Sugarcane is one of the major commercial crops playing pivotal role in agriculture and industrial economy of the country. Agro- climatically, sugarcane growing areas in the country are broadly classified in five zones viz. NWZ, NCZ, NEZ, ECZ and peninsular zones encompassing over 4.0 million hectare of agricultural land with annual cane production of about 300 million tones. Agro climatic conditions influence the crop growth, nutrient utilization efficiency and diseases and pest incidence which individually or collectively affect cane yield. FAO estimates revealed that sugarcane diseases account 19-20% losses in cane yield.

Sugarcane crop suffers more than sixty diseases. Sugarcane being vegetatively propagated crop and having longer stay in the field harbors diseases right from planting till harvesting. However, the spectrum of diseases varies from one region / zone to another (Table 1).

**Table 1: Sugarcane diseases complex, cane yield loss and distribution in Uttaranchal/U.P.**

<table>
<thead>
<tr>
<th>Disease</th>
<th>Estimated cane yield loss</th>
<th>Period of activity</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red rot</td>
<td>30-90%</td>
<td>July onwards</td>
<td>Entire U.P./Uttarakhand</td>
</tr>
<tr>
<td>Smut</td>
<td>10-30%</td>
<td>April – June, Nov and Feb</td>
<td>U.P./Uttarakhand</td>
</tr>
<tr>
<td>Wilt</td>
<td>Up to 100%</td>
<td>October onwards</td>
<td>Western/Central U.P./U.S. Nagar &amp; Haridwar district</td>
</tr>
<tr>
<td>GSD</td>
<td>10-20%</td>
<td>April onwards</td>
<td>Entire state</td>
</tr>
<tr>
<td>LSD</td>
<td>Up to 20%</td>
<td>July onwards</td>
<td>Eastern &amp; Central U.P. / Udham Singh Nagar</td>
</tr>
<tr>
<td>RSD</td>
<td>40-70%</td>
<td>November onwards</td>
<td>Entire state</td>
</tr>
<tr>
<td>Top rot/ Pokkha boeng</td>
<td>up to 50%</td>
<td>June to September</td>
<td>East and Central U.P.</td>
</tr>
<tr>
<td>Red stripe</td>
<td>up to 10%</td>
<td>June to September</td>
<td>East and Central U.P.</td>
</tr>
<tr>
<td>White leaf</td>
<td>up to 10%</td>
<td>July onwards</td>
<td>Eastern U.P.</td>
</tr>
<tr>
<td>Yellow syndrome</td>
<td>up to 10%</td>
<td>June onwards</td>
<td>East and Central U.P.</td>
</tr>
<tr>
<td>Red leaf spot</td>
<td>up to 10%</td>
<td>July onwards</td>
<td>West U.P./Uttarakhand</td>
</tr>
<tr>
<td>Brown leaf spot</td>
<td>up to 10%</td>
<td>July onwards</td>
<td>West U.P./Uttarakhand</td>
</tr>
<tr>
<td>Mosaic</td>
<td>30-40%</td>
<td>June onwards</td>
<td>Eastern U.P.</td>
</tr>
</tbody>
</table>

**Factors affecting crop disease:**

**Agro climate:**

- Hot and dry climate favour build up of smut and mosaic diseases
- Moderate temperature and high humidity are conducive for build up of red rot, GSD, top rot, stinking rot, red stripe, red leaf spot, white leaf disease and yellow leaf syndrome
- Dry climate and moderate temperature favour built up of wilt, LSD and RSD
Edaphic conditions:
- Poor drained soils favour wilt, red rot
- Soil type-aeration, thermal conductivity and soil moisture affect disease occurrence

Micro climate / crop climate:
Climate with in plant canopy is the resultant of interaction among climate / weather condition, soil condition, topography of land and crop diversity / crop cover. However, some of the cultural practices viz., selection of genotypes, planting date, plant population, planting techniques, scheduling irrigation, fertilizer doses etc also have bearing on microclimate.

Cultural management of crop diseases:
Since economically important sugarcane diseases are seed cane transmitted, hence use of healthy / disease free seed cane is of most significance. Reducing inoculums in the field is another important approach as secondary infection needs to be checked. There are numbers of methods disease management involving cultural, biological and chemo and thermo therapy. However, no single method is effective in controlling diseases.

Cultural approach of disease management involves the measures to prevent and control diseases by manipulating crop plants. This is targeted in reducing the amount of initial inoculums, reducing the rate of spread and planting crop at a site not favourable to pathogen. The following measures may be adopted to ensure effective management of crop disease.

Effective Quarantine:
The import/transport of the seed / planting material from disease/pest infected area may be banned. In accordance with the Destructive Insects-Pests Act (1914), sugarcane cutting from Australia, Fiji and Philippines cannot be imported. Like wise import of Cocoa from Africa and Sri lanka, Rubber plants/seed from South America and west India and Sunflower from Argentina and Peru is banned. Transport of seed cane between states/zones without effective quarantine should be discouraged.

Use of healthy planting material:
Selection of disease / insect free healthy seed cane and seed cane treatment involving chemotherapy (mercurial fungicide) and or thermo therapy (MHAT at 54 °C for 2.5 hours at 95-99% RH) are important against sett transmissible diseases.

Use of resistant cultivars:
Cultivars having horizontal resistance are more useful in sustaining crop production. Management of diseases by employing resistant/tolerant genotypes is the best and cheap method of diseases control.

Selection of land:
Water logging favors rapid red rod development, while moisture stress may promote wilt and smut incidence. Upland fields are suitable where inundation is a recurrent problem.

Field sanitation:
Well-tilled soil, free from crop debris especially left over stubble and cane pieces, is ideal for sugarcane planting. Stubble and cane pieces harbor the pathogens of many diseases like red rot and wilt. Like wise stem rot of rice and black arm of cotton survive in plant debris. Therefore, all
plant residues should be removed either mechanically or manually. Many weeds serve as alternate hosts to many pathogens viz., rice tungo virus, rice blast etc.

**Crop diversification:**

In many parts of the country, monoculture of sugarcane is practiced. If the area is prone to disease, monoculture should be discouraged and recommended crop rotation and intercropping be taken up. Crop rotation helps in two ways. In the absence of sugarcane, the pathogens in the soil do not survive and the soil gets enriched with nutrients especially when legumes are grown. Intercropping of coriander/garlic/methi and many other crops reduce the build up of diseases by checking the aerial spread of spores, plant-to-plant contact and also acts as barrier between two rows of sugarcane. It is advisable to grow suitable crop other than sugarcane in a field where red rot and other diseases appear in severe form. Similarly, continuous cultivation of rice crop may result in new pathotype of *Puricularia oryzae* (rice blast).

**Roguing:**

When the infected cane setts get access into the field, the disease appears as post-emergence stage. Symptoms of smut, GSD and mosaic are observed even before onset of monsoon. Under high temperature and soil moisture stress; smut whips emerge out more frequently; GSD symptoms are readily observed two months after planting. Mosaic symptoms appear on young foliage. As soon as disease symptoms appear, the plants should be uprooted and burnt to check the secondary spread of the disease. On the onset of monsoon when grand growth phase of sugarcane crop starts, crop canopy become dense and survey for diseased clumps become difficult. At the same time red rot develops rapidly and mortality of canes occurs. In a red rot prone area, survey must be continued to locate and destroy the affected clumps. The affected field must be separated through bunding to check flow of water borne propagules of *C. Falcatum* and other pathogens to other fields.

**Stubble shaving:**

In plant crop, the surface layer of the soil becomes rich in pathogens like smut, red rot etc. The subterranean buds of the cane, therefore, get infected and help in build-up of diseases in the ratoon crop. It is advisable to remove stumps and for this mechanized stubble shaving is recommended. It has been found that incidence of smut becomes less after stubble shaving. Trash burning may be followed if there is heavy attack of pests and diseases.

**Avoidance of ratooning:**

Ratooning is an essential feature of sugarcane cultivation as it does not require preparation of field and seed material for planting. Thus, ratooning makes sugarcane cultivation more profitable. However, it allows many diseases viz, RSD, GSD to build up and therefore; frequency of ratooning would depend on the level of disease incidence.

**Time of planting:**

Early planting in spring reduces the chances of infection into the setts from soil borne pathogens. It also reduces the early appearance of smut disease. Early sowing of Pearl millet
reduces ergot disease.

**Irrigation / water management:**

Frequent irrigations during March to June help increases build up of top rot, stinking rot and red stripe. Heavy irrigations and waterlogging conditions favour the infection of root rot and bacterial stem rot diseases. Bacterial blight of rice spreads mostly through irrigation and drainage of water.

**Earthing up:**

Earthing up prevents the growth of weeds which serve as co-lateral host of leaf spot diseases.

**Soil solarization:**

Summers ploughing eliminates/minimizes occurrence of various fungal diseases viz., *Verticillium, Fusarium* etc.

**Tillage practice:**

Deep tillage practices can bury residues carrying pathogen to deep layer where they are less likely to cause diseases. Conversely, minimum tillage can encourage some pathogen feeding on crop residues. Tillage practices can alter soil structure, aeration, soil moisture levels and release of soil nutrients affecting crop growth.

**Planting techniques / crop density:**

Planting geometry facilitating better light penetration in the canopy discourages the occurrence of disease. Under paired row planting of sugarcane less occurrence of disease / pest is noticed. Crop spacing favors many air borne diseases due to high humidity. Tikka leaf spot of groundnut is more in dense canopy. Damping off increases under high seed rate.

**Soil Amendments:**

Use of green manures, crop residues (wheat/rice/sugarcane straw/pressmud etc) tended to minimize the occurrence of soil borne fungi. Potato back skruf (*Rhizoctonia solani*) was found less in soil amended with wheat straw. Lucerne meal and barley straw reduce root rot of cotton.

**Fertilizers and crop nutrition:**

A well balanced supply of nutrients results in healthy, vigorous crop pants which have greater chance of with standing attack by pathogen. The major nutrients that influence plant and pathogen success are nitrogen, phosphorus, potassium, calcium, molybdenum, manganese, iron and silicon. High doses of nitrogen fertilizer delays crop maturity, increasing the risk of infection, apart from altering the activity of microorganisms. Rice blast becomes severe in the high nitrogen applied plots. Split nitrogen application reduces blast and bacterial blight of rice. Late nitrogen application increases wheat leaf blotch and powdery mildew. Ammonical nitrogen favors *Fusarium* wilt and rots whereas nitrate nitrogen favors *Verticillium* wilts and *Pithium* root rot.

Phosphorus application delays the onset and lessens the severity of most of the diseases. Potassium applications counteract the effect of nitrogen and reduce the severity of diseases by increasing phenolic synthesis. Calcium produces cell walls more resistant to penetration by
facultative pathogen by altering pectin metabolism of the host. High level of calcium raises soil pH, disadvantaging pathogen favoring acid soils. However, high soil calcium can also promote development of some diseases, Been root rot caused by *Rhizoctonia solani* was reduced due to potassium application. Molybdenum application reduces infection of *Phytophthora infestans* and *Ascochyta* blight of beans and peas. Manganese reduces late blight of potato. However, Ferric chloride controls rice brown spot. Likewise, silicon application reduces rice blast (*Puricularia oryzae*).

**Trap and decoy / hostile crops:**

Trap crops of susceptible plants are grown on land known to contain pathogens. They become infected and are then destroyed before the pathogen life cycles are complete thus reducing the amount of inoculums in the area. Decoy crops stimulate the hatching or germination of pathogen eggs or propagate but pathogens are unable to establish. Decoy host dies again reducing the amount of inoculums. The decoy crop which has economic value can be ideal to grow in routine crop rotation. Groundnut / some flower crops / marigold can be grown to minimize infestation of root knot nematode. Similarly planting tomatoes in pineapple plantation and destroying them before root knot nematode produce eggs serve the same purpose.

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Micro-Climate and Plant Diseases

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Introduction

Initiation and progress of plant diseases is the outcome of interaction of four vital elements viz. Host (susceptibility), Pathogen (Virulence), Environment (Favourable) and time (Duration of interaction). These four elements form the "Disease Pyramid" and if these arms representing four elements can be measured / quantified, the volume of Pyramid will be a measure of disease produced. All these four elements are vital, but the role of environment become more important as it influences both host as well as the Pathogen. The severity and the extent of this interaction is markedly affected by the environment and the element of time. Not only the growth of the host is affected by environmental factors such as air temperature, leaf temperature, relative humidity, wind, precipitation, duration of leaf wetness, intensity and duration of radiation, but also they have profound influence on Pathogen and disease development. The amount of primary inoculums present is important for subsequent disease development. The climatic conditions significantly influence dormancy of plant pathogens and therefore, the plant inoculums, when growth commences. Apart from the biological factors the micrometeorological factors such as duration of leaf wetness, duration and intensity of rain, wind speed and its direction within and above the crop canopy play a very important role in release and dispersal of the Pathogens. The plant surface is linked to the environment through the flow of energy between them. Humidity conditions and specially dew affects the growth and development of many phytopathogens, especially the fungal organisms. The temperature of the surface is the equilibrium temperature at which the sensible and latent heat fluxes from the surface equal the net gain by radiation. Leaf temperature is, therefore, sensitive to any changes or differences in the levels of exchange. Each leaf or part of a leaf has its own equilibrium level and in this way has a unique microclimate responsible for disease outbreaks. All the activities of agriculture, from pre-sowing to post harvest, are affected by weather conditions prevailing in a region. In most part of the world and specially in India, the source of weather information for efficient management and monitoring of field crops in relation to application of agricultural inputs, are the standard synoptic meteorological observatories. In many areas they are located far away from the crop fields.

Since the meteorological instruments in the meteorological observatories are exposed over the short cut grass, apparently the values of some of the important weather variables especially the air temperature, relative humidity, leaf wetness and the wind in particular may differ significantly from those observed in a cropped field. Therefore, the validity of such meteorological data recorded at a location from an experimental field will decrease with the distance from the meteorological station. Keeping in view the above constraints in mind it is,
therefore, necessary to monitor and characterize these important weather variables over and within the crops under natural field conditions. These fields have variability in terms of crops their type and stage, soil moisture, ground water table, tillage operations for soil manipulation etc. as compared with the meteorological observatory field. Also detailed and reliable weather information is also not available in many locations in the country due to non-availability of meteorological observatories. For this purpose, a Scientific Automatic Weather Station attached with micrologger and Computer will be very useful for recording of weather parameters within and over the crops accurately and then correlate them with crop observations for understanding the real crop - weather relationships in general and disease - weather relationships in particular for major crops of the area. There is a close relationship between crop diseases and weather variables and, therefore, under prevailing weather conditions, the incidence of several diseases may occur in an area and the application of chemicals in these crops will depend on the intensity and durability of the weather conditions prevailing at particular and sensitive crop stage.

2. Macro Weather Variables

The major macro and micro-meteorological variables which are important from the point of view of disease management are maximum and minimum air temperatures, relative humidity, wind speed and its direction, rainfall, intensity and duration of solar radiation, duration of leaf wetness. It is also important to distinguish between macro-climate (meteorological screen) and microclimate (climate at or very near to the host surface, canopy). Micro-climate affects growth and development of diseases to the extent to which it causes changes in the microclimate. Rain is a macroclimatic factor and the continuous drizzle or occurrence of dry and wet spells influence some diseases. Dew is a microclimatic factor and when the relative humidity increases above 70 % condensation begins on plants. Micro-climatic factors influence plant diseases more than macro-climatic factors.

Keeping in view the importance of meteorological variables, it is essential to measure them accurately by correct meteorological instruments. The measurement of important meteorological weather variables is done in the meteorological observatory which are situated almost in all the State Agricultural Universities / ICAR Agricultural Research Institutes all over the country. However, the micrometeorological weather variables are monitored by Automatic Weather Stations which are being installed in the cropped fields for specific research purpose.

A plain area of 55 m (N-W) x 36 m (E-W) size with short cut grasses provides a good exposure for all the meteorological instruments in the observatory. If a person stands at the gate facing the observatory plot, he will find the tall instruments in the back row and shorter instruments in the front rows. In general the instruments are separated at a distance of 9 m from each within rows of 12 m apart. The important meteorological variables are:

1). Maximum and Minimum Temperatures:

2). Relative Humidity:

3). Soil Temperature:
4. Rainfall:
5. Bright Sunshine Hours:
6. Solar Radiation:
7. Wind Speed and Wind Direction:
8. Dew:
9. Recording Instruments:
   i). Air Temperature:
   ii). Relative Humidity:

3. Macro-Weather Variables Ind Plant Diseases: Some Examples

There is a close relationship between plant diseases and the weather variables. The viral and bacterial diseases are more weather-dependent due to the fact that viral and bacterial pathogens remain at fixed locations, consistently exposed to a particular type of weather for a sufficiently long period. Some of the examples of disease-weather relationships are given below:

1. High air temperatures may set limits to the development of plant diseases. A high temperature of $> 35 \, ^\circ\text{C}$ is detrimental to the organism causing blister blight in tea. A temperature of $> 25 \, ^\circ\text{C}$ prevents spore formation in "Phytophthora infestans", the late blight fungus. Relatively high temperatures are important for the rate of inoculum build up of downy mildews. In potato blight, temperatures near the optimum for vegetative mycelial growth (19 -22 \, ^\circ\text{C}) stimulate the development of blight within the potato leaves, thus favouring spread by conidia produced by the leaves.

2. Soil temperature play an important role in management of various diseases especially seed and soil born diseases. Heating of soil by solar radiation can be managed by using the mulches. Killing of fungal spores may be higher under high soil temperature conditions compared to low temperatures. Generally the soil temperature data is recorded during 0700 and 1400 hours of the day and an average value is calculated. But it does not give clear picture of periodic soil temperature variations under mulch and non mulch conditions. For example, the effect of soil solarization on soil temperature regimes showed that degree day accumulation varied from 919 (38.3 \, ^\circ\text{C}) to 787 (32.8 \, ^\circ\text{C}) degrees under plastic mulch and non-mulch, respectively, in a single day at Pantnagar.

3. Microclimatic humidity is of importance for fungal plant diseases, and not the macroclimatic humidity as registered in meteorological screens. Further, disease is more affected by microclimatic conditions in the plant canopy than by the macroclimatic ones as measured at the standard meteorological stations / observatory located at a distance from the crop field.

4. The duration of leaf wetness (LWP) is important in the development of plant diseases. The germination and substantial crop infection by "Phytophthora infestans" requires a minimum LWP of 13 hours. The LWP for infection by several pathogens varies from 0.5 hours to more than 100 hours. The accomplishment of substantial infection by "Venturia inaequalis ", the fungus causing scab on apples and pears, require a period of wet leaves the minimum duration of
which is linked to the temperature error. Duration of precipitation and persistence of fog are of prime significance in LWP. Typically the infection process on wet leaves proceeds more quickly at high temperatures, so that temperature during the wetting period as well as the LWP must be considered. Different combinations of LWP and temperatures are important for development of different diseases. Often the two factors are combined to construct an index for the occurrence of a plant disease of interest.

5. Mather (1974), reported that in United States, the bacterial wilt and leaf blight in corn was related to the previous weather conditions. When the sum of the average temperatures of December, January and February remains below 38 °C, there was no chance of wilt on corn. If the sum of the average temperatures was above 29.5 °C, corn blight is likely to occur. This follows that if the winters are mild, the bacterial wilt and leaf blight are likely to spread in an epidemic form in the coming crop while severe winters reduce the chances of blight.

6. Also, in United States, the severity of blue mold of tobacco is directly correlated with climatic conditions viz. temperature and relative humidity during early spring. The mean temperature for the month of January in all the tobacco growing areas of the USA directly affects the time of sowing, and the severity of blue mold. If the mean temperature of January is above normal, blue mold will appear earlier and the disease will be severe. If temperatures are below normal, blue mold will appear later and the disease will be less severe.

7. Air temperature influences the epidemic development of diseases. There is an optimum temperature for growth of any organism with limits of maximum and minimum temperatures (cardinal temperatures) outside which the organism survives but can not grow. Paria and Raj (1987), reported that the groundnut rust disease was favoured by warm and humid weather and spread from the lower most to the 5th leaf.

8. Butler and Wadia (1997), reported that 70 % infection in groundnut leaves occurs within 12 hour wetness period with optimum temperatures of 20-25 °C. The period of wetness after inoculation with spore suspension must be continuous. Spread of disease within crop is facilitated by wind movement, rain splash and insects as well. It is now well established fact that at 35 °C, the incubation period of groundnut rust enhanced beyond 19 days and during summer months of April and May when ambient temperatures range from 40-45 °C, rust remain confined to host tissues without expression. They also reported that for late leaf spot disease infection was greatest if leaf wetness was intermittent. Further the leaf spots were most prevalent in wet areas with annual rainfall exceeding 500 - 600 mm. Also fungal infection is highly influenced by wet periods which created surface wetness of plants.

9. Jensen and Boyle (1966) reported that leaf wetness by rainfall, also caused germination of conidia and produced green tube for proper infection to the host. They further observed that rain helped spore dispersal also.

10. Rao et. al. (1994) reported that besides rain, cool temperatures of less than 20 °C also play a role in the mechanisms of spore release. Low rainfall (11 mm) with 89 % relative humidity
(RH) could increase disease scale and RH of 86% may aid the entry of germ tube through open stomata.

4. Method of Disease – Weather Studies

So in terms of prevailing weather conditions, the incidence of several diseases could be even forecast if the relationship between the weather conditions of an area and the diseases in it can be visualized. A very simple example is given below to understand the disease-weather relationship:

Let the range of climatic conditions for the development of the disease be represented by D, and let C₁, C₂ and C₃ represent the climatic conditions in region 1, 2 and 3. Following three relationships can be established between disease and weather:

i). In first case the range of weather conditions favouring a disease (D) is entirely outside the range of weather (C₁) encountered in the area. Therefore, the disease can not flourish in that region.

ii). In the second case the weather (C₂) irrespective of the prevailing weather conditions, is always favorable and lies within the limits (D) for the appearance of disease. In such cases, the weather factors are not very important for disease forecast.

iii). In third case, which is most frequent and important one, if during the year the weather shifts and is no longer favourable for the disease, then the disease may not occur or spread at all that year. When weather conditions are close to or favourable for disease, the chances of attack from the disease will be comparatively greater.

5. Micro-Climatic Variables and Plant Diseases

The continuous recording of micro-climatic variables is done by Automatic Weather Stations, which are installed in the cropped fields to monitor the microclimate of crops. Campbell Scientific Automatic Weather Station has been designed and developed to a very high standard for reliable measurement and recording of wide range of important micrometeorological variables in and above the crops. The station is soundly engineered and based on Campbell’s proven 21X micrologger whose comprehensive specification enables the user to undertake virtually any monitoring task. The automatic weather station is equipped with various micrometeorological instruments for monitoring of micrometeorological weather variables such as Air temperature (°C), Relative humidity (%), Wind speed (m s⁻¹), Wind direction (degrees from North), Leaf temperature (°C), Leaf wetness (% of total wet), Solar radiation (W m⁻²), Net radiation W m⁻², Rainfall (mm) and Soil temperature (°C).

Data pertaining to Conidial concentration (conidia m⁻³ air) of Alternaria brassicae in relation with air temperature (°C) and wind speed (m s⁻¹) over an inoculated oilseed rape crop at pod maturity stage during 0900 to 1000 hours is given in Table 4. However, the relationship between wind speed and spore concentration (conidia m⁻³ air) of the same species is given in Table 5. Varying wind (both steady and gusty) also had influence of spore concentration (Table 6).
6. Conclusion

1. For studying plant disease development, accurate & reliable weather data of nearest met. observatory be collected.

2. Quantification studies between weather variables and crop disease can be worked out and in long run, a suitable disease forecasting system can be development for sustainable management of plant diseases under field conditions.

3. However, for more precise study of relationship between micro-climatic variables and plant diseases for a particular location Automatic Weather Station can be purchased and installed in the field itself in that location.

REFERENCES


Table 4. Conidial concentration (conidia m⁻³ air) of Alternaria brassicaceae in relation with air temperature (°C) and wind speed (m s⁻¹) over an inoculated oilseed rape crop at pod maturity stage during 0900 to 1000 hours.

<table>
<thead>
<tr>
<th>Height from ground (m)</th>
<th>Air Temperature (°C)</th>
<th>Wind speed (m s⁻¹)</th>
<th>Conidial concentration (conidia m⁻³ air)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>-</td>
<td>-</td>
<td>11.0</td>
</tr>
<tr>
<td>2.0</td>
<td>15.9</td>
<td>0.29</td>
<td>7.0</td>
</tr>
<tr>
<td>3.0</td>
<td>15.3</td>
<td>0.57</td>
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</tr>
<tr>
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<td>1.0</td>
</tr>
<tr>
<td>5.0</td>
<td>14.8</td>
<td>0.75</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Table 5. Relation between wind speed (ms⁻¹) spore concentration (conidia m⁻³ air) of Alternaria brassicaceae at various heights in an oilseed rape field experiment.

<table>
<thead>
<tr>
<th>Height from ground (m)</th>
<th>Wind speed (m s⁻¹)</th>
<th>Conidial concentration (conidia m⁻³ air)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.75</td>
<td>-</td>
<td>682</td>
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<tr>
<td>1.25</td>
<td>0.834</td>
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<tr>
<td>2.75</td>
<td>1.425</td>
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</tr>
<tr>
<td>3.75</td>
<td>1.593</td>
<td>869</td>
</tr>
<tr>
<td>4.75</td>
<td>1.761</td>
<td>928</td>
</tr>
</tbody>
</table>
Table 6. Relation between wind speed (m s$^{-1}$) spore concentration (conidia m$^{-3}$ air) of *Alternaria brassicae* in an oilseed rape in Rain Tower and Wind Tunnel experiment at Rothamstat.

<table>
<thead>
<tr>
<th>Steady wind speed (m s$^{-1}$)</th>
<th>Conidial concentration (conidia m$^{-3}$ air)</th>
<th>Gust Wind speed (m s$^{-1}$)</th>
<th>Conidial concentration (conidia m$^{-3}$ air)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>0.42</td>
<td>4.16</td>
<td>0.01</td>
<td>12.48</td>
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<td>1.00</td>
<td>8.32</td>
<td>0.23</td>
<td>83.20</td>
</tr>
<tr>
<td>1.66</td>
<td>25.00</td>
<td>0.66</td>
<td>70.70</td>
</tr>
<tr>
<td>2.29</td>
<td>96.00</td>
<td>1.23</td>
<td>125.00</td>
</tr>
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<td>3.03</td>
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<td>3.71</td>
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<td>158.00</td>
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<td>5.15</td>
<td>408.00</td>
<td>3.32</td>
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</tr>
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<td>5.85</td>
<td>462.00</td>
<td>4.19</td>
<td>483.00</td>
</tr>
</tbody>
</table>
Bio-Fungicides: Their Role in Plant Disease Management

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The biological control process sparks many questions. First, what is biological control of plant disease? It is the involvement of the use of beneficial microorganisms, such as specialized fungi and bacteria, to attack and control plant pathogens and the diseases they cause. So what are these "specialized fungi and bacteria" that can attack and control plant pathogens? They are microorganisms that are part of the normal microbiological environment of most "healthy" soils. They are not genetically engineered. In their native habitat, these beneficial microorganisms compete with other microorganisms for space and food. In some cases, they are parasitic on other microorganisms and/or they produce toxic substances that kill other soil-inhabiting microorganisms such as Pythium sp., Phytophthora sp., Rhizoctonia sp. and other plant pathogens. Scientists are well aware of these beneficial microorganisms and have studied them for many years. They have shown that these microorganisms play a vital role in the makeup of the soil environment and are part of the normal checks and balances that make up a "healthy" soil.

Biofungicide is a naturally based microbial or biochemical product. There are three types of biopesticides. (a) Microbial biopesticides have an active ingredient that is a biological control agent (organism capable of attacking or competing with a pathogen or pest). (b) Plant biopesticides or plant-incorporated protectants are defined by the EPA as "pesticidal substances that plants produce from genetic material that has been added to the plant". (c) Biochemical biopesticides contain naturally-occurring substances. Some biochemicals may also be products of fermentation. Biochemicals can directly affect disease-causing organisms or may stimulate SAR. Biopesticides generally are narrow-spectrum, have low toxicity, decompose quickly, and thus are considered to have low potential for negative impact on the environment (www.epa.gov/pesticides/biopesticides/). Many biofungicide products are being approved for organic crop production (www.omri.org). While many have low toxicity, biopesticides are not necessarily safer than pesticides containing synthetic ingredients.

Many beneficial fungi and bacteria have been isolated from the soil and tested in private and university-based laboratories as to their ability to control plant pathogens. Recently, some of the more promising of these beneficial fungi and bacteria have been further developed and marketed to ornamental plant growers as an alternative to traditional chemical-based fungicides.

How They Work?

There are four different mechanisms by which beneficial or biocontrol agents interact with other microorganisms. Most biocontrol agents apply only one of these four mechanisms; however, some may employ more than one.

Direct competition. In this case, the biocontrol agent out-competes the target organisms for nutrients and space. This is typically a fungus or bacteria that grows very fast and overwhelms the
target organism with sheer numbers. The target organism is suppressed due to lack of food and space. The target organism may not die out completely, but its population becomes so low it is no longer a legitimate threat to the host plant. In order for this type of biocontrol agent to be most effective, the environmental conditions must favor the growth and reproduction of the biocontrol agent.

**Antibiosis.** With antibiosis, the biocontrol agent produces a chemical compound such as an antibiotic or some type of toxin that kills or has some sort of detrimental effect on the target organism. Many microorganisms produce antibiotics and toxins. Some of the more common antibiotics humans use to warrant-off infections came originally from common soil-inhabiting fungi and bacteria. In some cases, antibiosis can be accompanied by other detrimental mechanisms. Antibiosis is one of the most effective methods of controlling microorganisms.

**Predation or parasitism.** This is the mechanism that most of us envision when we think of biocontrol agents. In this case, the biocontrol agent attacks and feeds directly on the target organism, or the agent produces some sort of toxin that kills the target organism and then feeds on the dead target. Like direct competition, the environment must favor growth and development of the predator or parasite since populations need to be high enough to overwhelm the target organism.

**Induced resistance of the host plant.** Scientists have known for decades that once a plant is infected with a pathogenic microorganism, infection triggers some sort of biochemical reaction in the infected host plant that helps keep it from being infected with further pathogens (super infection). The infected plant becomes more "resistant" to other infections. Plants do not have immune systems to protect them from infection as we do; however, they do have physiological and biochemical systems that help inhibit infection and spread of pathogens within tissues of the affected plant. Some biocontrol agents are known to trigger these mechanisms, and in the case of induced resistance, host plants are purposely inoculated with this agent in an effort to trigger the resistant response. The microorganism that triggers the response is usually not a severe pathogen of the host. If it were, it would defeat the whole purpose. Induced resistance is not highly understood and is currently a very exciting area of research throughout the scientific community.

**Advantages and Disadvantages**

Even though it appears as if these biocontrol agents are the cure-all, there are distinct advantages and disadvantages to using them, when compared to traditional chemical controls.

**Advantages**

- If used properly, they help reduce the use of chemical-based fungicides. This is good for the environment and is one of the most important reasons to consider their use.
- They help reduce the risk of developing pathogen resistance to traditional chemicals. Due to the overuse of certain chemical fungicides, some common plant pathogens such as Pythium sp. and Botrytis sp. have become resistant to these fungicides. This is less likely
to happen with biocontrol agents because the beneficial organism co-evolves along with the target organism and adapts to the changes. Something a chemical cannot do.

- In most cases, they are safer to use. Most biocontrol agents have very low or no toxicity to humans and other mammals. This is a tremendous benefit in this day and age.
- They tend to be more stable than chemical pesticides if stored properly. These are living organisms and must be stored as such. If they spoil, they are no longer affective.
- In most cases, they have lower re-entry interval (R.E.I.) times. This is a significant factor especially when it is necessary to enter the production facility immediately following application.
- In most cases, they are less phytotoxic. Because they are "natural" they are less likely to cause toxic effects on the host plant, especially if mistakes are made and rates are miscalculated.

### Disadvantages.

- Biocontrol agents tend to be more difficult to implement when compared to chemicals. Since most of these products have to be implemented prior to the onset of disease, greater preparation by the user is necessary. Biologicals work best in greenhouses that routinely scout for diseases and insects and detect problems early.
- In most cases, they have a narrower target range. Most are not broad-spectrum products. Identification of the correct target organism is imperative.
- They may not work as quickly as chemicals. Since their populations need to take time to build up they can take more time to be effective. That is why it is necessary to apply them prior to the onset of severe disease outbreak.
- These products do not eradicate the pathogen or rescue the host from infection. They have to be administered prior to the onset of disease, in most cases at preplant.
- They may have a shorter shelf life if not stored properly. Remember, these are living organisms that don't take well to extreme temperatures.
- In most cases, biocontrol products are more expensive to use. This includes both time and money. They may be a bit more expensive to purchase initially, and they take more time to initiate, if used properly.
- They may not be compatible with the use of other chemical fungicides and bactericides. The product label should be checked to see with what chemicals the product is compatible. Many of these beneficials are fungi, and some of the more common greenhouse fungicides have the potential to kill these beneficial microorganisms.

### The Products

Currently there are close to 40 commercial products that are marketed as biological controls worldwide. Not all of these are available in the United States. For greenhouse floriculture and perennial production, there are about a half dozen products that are currently popular (See
Figure 1, page 43). Of these, PlantShield appears to be the most widely used. Plantshield is the T-22 strain of the soil inhabiting fungus Trichoderma harzianum (TH). TH's mode of action against the target organism is multifaceted. It uses both antibiosis and predation against many common soil-inhabiting fungi that cause root and crown rots such as Pythium, Rhizoctonia, Fusarium and Sclerotinia. It appears to be one of the most popular biofungicides in the greenhouse industry and can be an asset to a disease management program if used properly.

**Keys to Success**

In order for any of these biological control agents to work for you, two simple rules must be followed. First, all of these products must be used in conjunction with standard disease cultural controls. Cultural controls include: growing plants in a well-drained media; not over watering; keeping the greenhouse relative humidity below 85 percent; practicing strict sanitation; and making sure that the nutrient and pH conditions of the host plant are within the ideal range for proper growth and development. This will help assure that the environment is favorable for the growth and development of the beneficial organism.

Second, all of these biocontrol products must be applied at preplant or prior to the onset of disease. In most cases, they will not rescue plants that are already infected. If you abide by these two critical conditions, the likelihood of you having success with a biocontrol agent is good. If you don't, they won't work.

Manufactures who have traditionally been the source of chemical fungicides will be producing and marketing biofungicides. Growers need to be aware of what products are available, the way they work and their limitations. It will be a while before we see a biofungicide that controls Pythium sp. as good as Subdue. However, under the proper growing conditions, bio-fungicides can be a viable alternative to chemicals.

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Soil Solarization for Control of Plant Diseases

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Several methods have been developed for the management of diseases incited by various plant pathogens, which include fungicidal application, breeding for disease resistance, sanitation, crop rotation, biological control and soil disinfestations. The need for different methods of plant disease management stems from the fact that usually none of them is perfect nor can any one be used under all circumstances. Moreover, the life cycles of pathogens may vary in different crop systems, thus requiring different management strategies. Therefore, any new method of disease management is of value since it adds to our rather limited arsenal of control methods. This is particularly true with novel non chemical approaches which are needed to replace hazardous chemicals.

The concept of managing soil borne pathogens has now changed. In past, control of these pathogens concentrated on eradication. Later it has been realized that effective control could be achieved by interrupting the disease cycle, plant resistance or the microbial balance leading to disease reduction below the economic injury level, rather than absolute control. The integrated pest management concept encompasses many elements. In this context soil solarization can play a significant role.

In Israel, extension workers and growers suggested that the intensive heating that occurs in mulched soil might be used for disease control. By mulching the soil with transparent polyethylene sheets in the hot season prior to planting, a team of Israeli workers developed a solar heating approach for soil disinfestation (Katan, 1995). Soil solarization is a method of controlling soil borne pests and pathogens by raising the temperature of the soil through application of transparent polyethylene sheet to a moist soil surface. With solarization vast possibilities for disease control are possible. Use of this method has been reported to reduce the population of many soil borne pathogens including fungi, bacteria and nematodes as well as weeds (Pullman et al., 1981; Katan et al., 1983; Barbercheck et al; 1986; Verma et al; 2005).

**Mechanism of disease control**

Reduction in disease incidence occurring in solarized soils, results from the effects exerted on each of the three living components involved in disease (host, pathogen, and soil microbiota) as well as the physical and chemical environment which, in turn affects the activity and interrelationships of the organisms. Although these processes occur primarily during solarization, they may continue to various extents and in different ways, after the removal of the polyethylene sheets and planting. The most pronounced effect of soil mulching with polyethylene is a physical one, i.e. an increase in soil temperatures, for several hours of the day. However, other accompanying processes such as shifts in microbial populations, changes in chemical composition and physical structure of the soil, high moisture levels maintained by the mulch, and changes in...
gas composition of the soil, should also be considered while analyzing mechanisms of disease control. The following equation proposed by Baker (1968), for relating the various factors involved in biological control, should be adopted for this analysis:

Disease severity = inoculum potential x disease potential, where inoculum potential is the energy available for colonization of a substrate (infection court) at the surface and disease potential is the ability of the host to contract disease. More specifically the equation becomes:

Disease severity = (inoculum density x capacity) x (proneness x susceptibility), where capacity is the effect of the environment on energy for colonization, and proneness is the effect of the environment on the host. Of these four components, inoculum density (ID) is the one most affected by solarization either through the direct physical effect of the heat or by microbial processes induced in the soil. The other components, however (except for susceptibility which is genetically determined) might also be affected. Microbial processes, induced in the soil by solarization, may contribute to disease control, since the impact of any lethal agent in the soil extend beyond the target organisms. If induced by solarization, biological control may affect the pathogen by increasing its vulnerability to soil microorganisms or increasing the activity of soil microorganisms toward pathogen or plant, which will finally lead to a reduction in disease incidence, pathogen survivability, or both. Thus both short and long term effects might be expected. Biological control may operate at any stage of of pathogen survival or disease development during or after solarization, through antibiosis, lysis, parasitism, or competition. The mechanisms of biological control, which may be created or stimulated by solarization are summarized as follows:

I. The effect on the inoculum existing in the soil.
   A. Reduction in ID (in the dormant stage or during host penetration) through
      1. microbial killing of the pathogen, already weakened by sublethal heat;
      2. partial or complete annulment of fungistasis and subsequent lysis of the germinating propagule;
      3. parasitism or lysis by antagonists stimulated by solarization.
   B. Reduced inoculum potential (IP) due to competition or antibiosis induced by solarization.
   C. Diminished competitive saprophytic ability of the pathogen, in the absence of the host, due to antibiosis or competition.

II. Preventing reinfestation through activities of microorganisms possessing mechanisms A, B, and C

III. The effect on the host due to cross protection

Combining solarization with other methods such as pesticides or biocontrol agents improves disease control. Whenever a pathogen is weakened by heating, even reduced dosages might suffice for improved control combining with biocontrol agents, organic amendments, etc.

Advantages

Soil solarization as a disinfestations method, has potential advantages. It is a non chemical
method which is not hazardous to the user and does not involve substances toxic to the consumer, to the host plant or to other organisms. In the right perspective it is less expensive than other methods. This technology can easily be transmitted to the ordinary farmers and can be applied in large areas manually and mechanically. Thus, it is suitable for both developed and developing countries. It may have a long term effect, since effective disease control lasts for more than one season. This method has the characteristics of an integrated control, since physical, chemical and biological mechanisms are involved and because the control of a varieties of pests is achieved.

Limitations

Solarization involves limitations, difficulties and potential negative side effects. It can only be used in regions where the climate is suitable (hot) and the soil is free of crops for about one month or more at a time of tarping with PE sheets.

- It is too expensive for some crops and ineffective in the control of certain diseases
- Heat tolerant pathogens might develop after repeated application, though selection for tolerance to lethal agents is not likely to develop with disinfestation methods which are not target specific
- Another possibility would be an increase in pathogen population due to a harmful effect on its antagonists

Disease Management

Soil solarization has been demonstrated to control diseases caused by many fungal pathogens such as *Rhizoctonia solani*, *Fusarium* spp., *Pythium* spp., *Phytophthora* spp., *Verticillium* spp., *Sclerotium rolfsii* etc. in many crops (Katan et al., 1983; Abdul et al., 1995; Raoof and Rao, 1997). Soil solarization has also been shown to significantly decrease the population of disease causing *Agrobacteria* and *Pseudomonas* (Raio et al., 1997; Chellemi et al., 1994). Many nematode diseases caused by *Meloidogyne* spp., *Heterodera* spp. etc. have been successfully controlled by soil solarization (Rao and Krishnappa, 1995; Grinstein et al., 1995).

Beneficial side effects

Control of weeds

Solarization results in an effective weed control lasting in some cases for more than two or three seasons (Abdel Rahim et al., 1988; Verma et al., 2005). In general most of the annual and many perennial weeds have been found to be effectively controlled.

Increased growth response

The increased growth response of plants in solarized soil is a well documented phenomenon and has been verified both in green house experiments and under field conditions (Katan, 1987; Chen et al., 1991; Singh, 2008).

Conclusion

Soil solarization for soil disinfestations has been well established and demonstrated under experimental or commercial conditions in a number of countries. The ultimate goal to develop this method for use under field conditions requires both basic and practical studies. Although SS is a
simple method, the research involved for its establishment in new areas is complicated and requires interdisciplinary efforts. SS should not be regarded as a universal method but rather as an additional one which, if used correctly, can reduce pest damage safely, effectively and economically.

More than 100 years after the introduction of soil disinfestations and more than 50 years after Sanford’s classical publication on biological control our hungry world is still crying out for new methods for reducing crop losses caused by soil borne pathogens. We are always confronted with difficulties such as the appearance of new physiological races and development of resistance to pesticides while using conventional control methods. We are frustrated by the large gap between promising results in the green houses and failures in the fields. Thus we have acquired modesty. We no longer aim to achieve absolute control, but rather an economic reduction in disease level. It is only natural, that the integrated control approach, which calls for adequately combining all available control methods, was adopted by the plant pathologists the world over. Solarization is a new additional option to use and include suitably in such IPM programs. Its scope and rate of dissemination in the future will depend on our capacity to both weigh its pros and cons and use it effectively.

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IPR and WTO in Relation to Plant Protection

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The WTO was established on 1st January 2005 and is responsible for making and enforcing rules for trade between nations. WTO marks a major change in global trade rules. As an organization, it replaces the General Agreement on Tariffs and Trades (GATT), which had been in existence since 1947. The Eighth Round of Multilateral Trade Negotiations under GATT, which started in Uruguay in 1986, was concluded in 1994, leading to the creation of WTO as the new permanent international trade organization. The role of WTO is much more extensive than that of GATT, which dealt with trade in goods. Apart from goods, the two other broad areas that WTO covers are services and intellectual property, which previously belonged to the domestic domain. Accordingly, WTO administers not only the Multilateral Trade Agreements (MTAs) in goods but also the General Agreement on Trade in Services (GATS) and the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS), which came into existence with WTO. All the agreements annexed to the Agreement establishing the WTO were signed as part of a package deal. Member countries did not have the option of choosing some and rejecting others. Another important difference with the erstwhile GATT is that WTO has a stronger compliance mechanism that did GATT- a member's failure to meet the obligations can invoke retaliation across agreements and sectors (Chawla, 2007a).

As one of the WTO agreements, TRIPS is binding on all member countries of WTO. TRIPS aims at establishing strong minimum standards for intellectual property rights (IPRs). Apart from patents, intellectual property includes copyrights, trademarks, geographical indications, industrial designs, integrated circuits and trade secrets. The protection of IPRs is binding and legally enforceable.

Intellectual property (IP) is a product of the mind. Intellectual property is intangible in contrast to real property (land) or physical property, which one can see, feel and use. With any type of property there are property rights. When IPs are expressed in a tangible form, they can also be protected. Intellectual property rights (IPRs) have been created to protect the right of individuals to enjoy their creations and discoveries. In fact, IPRs can be traced back to the fourteenth century, when European monarchs granted proprietary rights to writers for their literary works.

IPRs have been created to ensure protection against unfair trade practice. Owners of IP are granted protection by a state and/or country under varying conditions and periods of time. This protection includes the right to: (i) defend their rights to the property they have created; (ii) prevent others from taking advantage of their ingenuity; (iii) encourage their continuing innovativeness and creativity; and (iv) assure the world a flow of useful, informative and intellectual works.

Forms of protection

IPRs can be defined as the rights given to people over the creation of their minds. They
usually give the creator an exclusive right over the use of his/her creation for a certain period of time. Intellectual property includes patents, copyrights, trademarks, geographical indications, industrial designs, integrated circuits and trade secrets (Chawla and Singh, 2005). The protection of IPRs is binding and legally enforceable.

**Patents**

A patent is a government granted exclusive right to an inventor to prevent others from practicing i.e. making, using or selling the invention. A patent is a personal property, which can be licensed or sold like any other property. The purpose of a patent is to encourage and develop new innovations. The Patent Law recognizes the exclusive right of a patentee to gain commercial advantage out of his invention. There are three criteria to issue a patent for the innovation (Chawla and Singh, 2007).

i. **Novelty:** The inventor must establish that the invention is new or novel. The novelty requirement refers to the prior existence of an invention. If an invention is identical to an already patented invention, the novelty requirement is not met, so a patent cannot be issued.

ii. **Inventiveness (Non-obviousness):** It is an invention and not merely discovery. It is non obvious to one skilled in the field. The non-obvious requirement refers to the level of difficulty required to invent the technology. If an invention is so obvious that anyone having an ordinary skill would have thought of it, then it does not meet this requirement.

iii. **Usefulness (Industrial application):** It has a utility or is useful for the society. The useful requirement refers to the practical use of invention. If an invention provides a product that is required or needed in some manner, then it meets this requirement.

In the patent adequate disclosure should be made so that others can also work on it. It should have the features: i) be a written description; ii) enables other persons to follow; iii) adequate and iv) deposit mechanism.

The present law, Patents Act 1970, amendment 2005 is effective from January 1, 2005. Product patents on all items including food, agro-chemical and pharmaceuticals have also been allowed making the Patents Act fully TRIPS compliant.

The patent system was developed as a means to reward inventions which would be useful to the society. However, in order to ensure the interests of society, as per the Indian Patents Act, certain things have been excluded from the purview of patentability. The sections relevant to plant material and agriculture which are excluded from patentability are:

Section 3(h): a method of agriculture and horticulture.

Section 3(i): any process for medicinal, surgical, curative, prophylactic (diagnostic therapeutic) or other treatment of human beings or any process for a similar treatment of animals to render them free of disease or to increase their economic value or that of their products.

Section 3(j): plants and animals in whole or any part thereof other than microorganisms but including seeds, varieties and species and essentially biological processes for production or propagation of plants and animals.
Section 3(p): an invention which in effect, is traditional knowledge or which is an aggregation or duplication of known properties of traditionally known component or components.

Further the mere discovery of any new property or new use for a known substance or the mere use of a known process, machine or apparatus unless such known process results in a new product or employ at least one new reactant is not patentable. Also a patent claim for a substance obtained by merely mixing ingredients resulting only in the aggregation of the properties of the components is not a patentable invention.

Microorganisms per se can be claimed for protection provided they are not mere discovery of organisms. It is mandatory to deposit the biological material in International Depositary Authority (IDA). In India, Institute of Microbial Technology (IMTECH), Chandigarh is a recognized international depositary for some category of micro-organisms. If an applicant mentions a biological material in the patent specification then disclosure requirements prescribed for biological materials have been notified in the list of the Central Government or for indicating its source and geographical origin [Section: 10,4(d)]. However, in India, method for rendering plants free of diseases or to increase their economic value or that of their products can be claimed for patent protection.

The purpose of a patent is to promote the progress of science and useful arts. The patent law promotes this progress by giving the inventor the right of exclusion. In exchange for this right to exclude others, the inventor must disclose all details describing the invention, so that when the patent period expires, the public may have the opportunity to develop and profit from the use of invention. A patent is enforced in the country which issues it, meaning thereby territorial in nature. For each country a separate application is to be filed in that country where protection is sought.

Microorganism patents

The first patent on living organism was granted to a micro-organism Pseudomonas. The first example was the classical judgment in the Diamond vs. Chakrabarty case in 1980. In the Chakrabarty case USPTO rejected the patent application on the ground of product of nature but the US Supreme Court decided that a microorganism was not precluded from patentability solely because it was alive. Thus a Pseudomonas bacterium manipulated to contain more than one plasmid (four plasmids were present) controlling the breakdown of hydrocarbons (therefore more useful in dispersing oil slicks than the natural organism containing only one such plasmid) was “a new bacterium with markedly different characteristics from any found in nature” and hence not nature’s handiwork but that of inventor. The “product of nature” objection therefore failed and the modified organisms were held patentable. This precedent is being followed even today to define the patentability of microorganisms (Chawla, 2007 b).

Plant patents

Plant patents are obtainable in US, Europe and Japan. The US Plant Patent Act of 1930 (PPA) granted property rights for privately developed plant varieties of asexually reproducing plants. These rights were extended to new and distinct asexual varieties for a period of seventeen years. Advances in breeding technology provided the momentum for the 1970 Plant Variety
Protection Act (PVPA). The PVPA provided protection for sexually reproducing plants, including seed germination. In 1980 Diamond vs. Chakrabarty case set in motion the trend towards the legal acceptance of the commodification of germplasm. The court held that a live, man made bacterium was patentable under the PPA and the ‘product of nature’ objection therefore failed and the modified organisms were held patentable. In the Hibberd case (1985), involving a tryptophan-overproducing mutant, the patent office ruled that plants could be patented and there is no distinction between asexually and sexually propagated plants. Following the principle established in the Chakrabarty case, it was decided that normal US utility patents could be granted for other types of plant e.g. genetically modified plants. Plant patents have been granted by European Patent Office (EPO) from 1989. But in 1995, EPO severely restricted the scope of Plant Genetic Systems (Belgium) patent on herbicide resistant plants and allowed claims only on the herbicide resistant gene and the process used in the generation of plants. In Japan, plant patents are allowed, but there are some disputes over territorial rights. Life forms of plants and animals except microorganisms are not patentable in India. In pursuance to the TRIPS agreement, India has enacted “Protection of Plant Varieties and Farmers’ Rights” (PPV&FR) Act, 2001, a *sui generis* system of plant variety protection which has been described in detail separately.

**Plant Variety Protection in India**

As stated India is signatory to WTO agreements and it has to abide by the TRIPS regulations. As per article 27.3(b) of the TRIPS which demand that member countries should protect their plant varieties either by patent, or an effective system of *sui generis* protection, or a combination of these two. In this context India chose a *sui generis* system for protection of plant varieties. An Act named as Protection of Plant Varieties and Farmers’ Rights (PPV&FR) Act 2001 has been passed and Rules have been framed. PPV&FR Authority has been constituted with its Head Office located at Delhi. The PPV&FR Act is TRIPS compliant and compatible with UPOV system of plant variety protection (Anonymous, 2003).

The PPV&FR Act 2001 provides protection to following types of plant varieties (Anonymous, 2003):

i. Newly bred varieties.

ii. Extant varieties – The varieties which were released under Indian Seeds Act, 1966 and have not completed 15 years as on the date of application for their protection.

iii. Farmer’s varieties – The varieties which have been traditionally cultivated, including landraces and their wild relatives which are in common knowledge, as well as those evolved by farmers.

iv. Essentially derived varieties.

v. Transgenic varieties.

An application for registration can be made by any person claiming to be the breeder of the variety, successor of the breeder, assignee, any farmer or group of community of farmers, any person authorized for the above mentioned categories or any University or publicly funded
agricultural institution claiming to be the breeder of the variety. It is pertinent to note that the Act recognizes the farmer as a cultivator, conserver and breeder. This embraces all farmers, landed or landless, male and female. To qualify for registration under the act, a new variety has to conform to the criteria of novelty (N), distinctiveness (D), uniformity (U) and stability (S). Besides, a denomination has to be given for the registration of variety. Denomination refers to the label or title of the variety. It is the denomination that is registered. For extant and farmers' varieties which are in public domain the DUS features will be considered while the novelty feature will not be taken because these varieties are not new and are in public domain. In this act a special clause has been put which states that any variety with terminator gene sequences will not be registered. Thus any transgenic material with genetic use restriction technology (GURT) sequences will not be registered.

All the varieties will be registered with PPV&FR Authority. DUS guidelines for 35 crops have been prepared by ICAR while guidelines for 12 crop species have been notified by PPV&FR Authority in the gazette. PPV&FR Authority has established testing centres for each and every crop species. In the first phase which has started in May, 2007, the registration of varieties will be done for 12 crop species of cereals and legumes. The registration will then extend to 35 crops which includes cereals, pulses, oilseeds, vegetable and two flower species. DUS guidelines are also being prepared for medicinal and aromatic plants, spices, ornamentals and forest trees for which task forces have been constituted by the PPV&FR Authority.

Indian PPV&FR Act allows farmers to save, use, sow, resow, exchange, share or sell his farm produce including seed of a variety protected under this Act, but it prohibits that the farmer shall not be entitled to sell branded seed of a variety protected under the Act [Sec. 39, 1(iv)]. The farmers have been given the right to register farmers varieties themselves [Sec. 39,1(i)], right to claim compensation for under performance of a protected variety from the promised level [Sec. 39(2)], benefit sharing for use of biodiversity conserved by farming community [Sec. 41]. According to the concept of benefit sharing, whenever a variety submitted for protection is bred with the possible use of a landrace, extant variety or farmer's variety, a claim can be referred either on behalf of the local community or institution for a share of the royalty [Sec. 41(1)] (Anonymous, 2003). In the Act a provision of compulsory license has also been put. According to this, after the expiry of three years from the date of issue of certificate of registration of a variety, any person interested can claim in an application to the authority alleging that reasonable requirements of the public for seeds or other propagating material have not been satisfied or that the seed or other propagating material is not available to the public at a reasonable price and pray for the grant of a compulsory license to undertake production, distribution and sale of the seed or other propagating material of that variety [Sec. 47(1)] (Anonymous, 2003).

The Act had laid down the norms for registration of plant varieties, fee structure, provisions of opposition, DUS testing of material, etc. If any farmer or association of farmers is applying for registration of a plant variety then this category is not required to pay any fee for either registration...
or DUS testing. Once the variety has been tested for its features then the Registrar of the Authority will issue the certificate of registration. It shall have the validity of nine years initially in case of trees and vines with renewal up to a period of 18 years. For other crops certificate of registration will be issued for six years initially with renewal up to 15 years. In case of extant varieties the validity period is 15 years from the date of notification of that variety by the Central Government under section 5 of the Seeds Act 1966.

REFERENCES


Kunapjala for Crop Health

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There are two basic requirements for production of healthy crops or we may say that proper nourishment and plant protection are the two important components for crop health management.

In Vrikshayurveda of Surapala about one thousand ago, kunap has been mentioned as liquid manure. Kunap is a Sanskrit word derived from the word ‘Ku’ meaning dirty and ‘nap’ means water. In verses 101 to 105 Surapala describes; “The excreta of marrow of bones, and flesh, brain and blood of a boar mixed with water and stored underground is called kunap. As per availability the fat, the marrow and flesh of the fish, the ram, the goat and other horned animals should be collected and stored. These should be boiled after mixing with water, and the mixture should be stored in an oilpot after adding sufficient quantity of husk (source not mentioned but probably it is paddy). After roasting in an ironpot sesame oil cake and honey should be added. Soaked black gram of good quality should also be added. A little ghee (butter milk) should then be poured. The items stated above should be taken at random as there is no measure for anything. One by one it should be placed in the pot in a warm place by a competent person.

Surapala further quoted that “this kunapjala is highly nourishing for trees. This is stated by the ancient sages and I (Surapala) repeat it here after verifying the same”.

Similarly the verses 171-174 of Sarangadhara’s Upavanvinoda (1283-1301 AD) and Chakrapani Mishra’s Vishvavallabh mentioned about kunapjala and its constituents described by Sarangadhara and Chakrapani Mishra are almost the same with slight variation. Sarangadhara also indicated that any material waste can be used for the preparation of kunapjalal.

Since the components of kunapjala mentioned by these scholars may not be easily available and every farmer can not handle them as this kunap is a non-vegetarian kunap, therefore, looking towards availability of nutrients and antimicrobial compounds as reported in other wasted products, efforts have been made to develop vegetarian kunap and simple non-vegetarian kunap for nourishment and protection of crops. Some of such preparations which have been tried over and further to be tried are as follows:

Herbal Kunapjala

This is prepared from plants, which are either considered unwanted or called weeds in the modern agriculture and are destroyed under weed management systems. Some of them are having anti-microbial properties also. The materials required for preparation of this kunapajala are: plastic container of 200 L capacity (with lid), raw cow dung- 10 kg, fresh chopped leaves (locally available weed plants or other plants)-20 kg, molasses/cane jaggery-2kg, sprouted black gram seeds-2kg, water 10 L., and water-around 100 L.

Method of preparation

Fresh and green leaves of weeds or other plants are chopped and kept in the plastic container.
1. Cow dung, sprouted gram seeds, and molasses/cane jaggery are added
2. Water is then added and the mixture is stirred well.
3. The lid is then closed
4. The container is kept in a warm place for 10-15 days depending on the temperature.
5. The mixture is stirred clockwise and anticlockwise 2-3 times daily to release the gas formed.
6. The preparation is ready to use when it stops producing gas.
7. It is filtered and then used.
8. The solution is used at 1 to 2% concentration or even in pure form depending on the condition of the plants.

**Dhanyagavya**

Dhanyagavya is made by fermenting paddy husk in cow urine or cow dung and water at least for one month. To prepare dhanyagavya, put 40 kg of paddy husk in 200 L plastic container, then add 20 kg of cow dung or 40 L cow urine and filled the drum up to the brim and covered with the lid. The mixture is stirred well 2-3 times a day in clockwise and anticlockwise direction. The end product contains silica in soluble form which can be sprayed and drenched in soil at required concentration for the control of fungal diseases.

**Indasafari:**

As per Vrikshayurveda, the animal products are boiled for the kunapjala. The indasafari is a kunapjala prepared by using dead fishes which are discarded by the fisherman as well as waste of fishes. In this preparation the waste fishes with cow dung and water are fermented for 10-15 days. Some quantity of molasses or cane jaggery may be added to avoid the foul smell emit out from the preparation during stirring. This preparation can be used as drench as well as foliar spray with functions both as growth promoter and as an insecticide. This is quite effective to destroy the termites besides other pests.

**Cow dung water to protect from drought**

Now a days drought is a severe problem throughout the country due to unusual climate especially erratic rainfall during monsoon. Spraying of cow dung water in such condition was found effective to save crops from dehydration up to 30-40 days. The materials required for this preparation are: cow dung, rice water (starch), molasses/cane jaggery, pastic barrel of 200 L capacity, nylon bag, and water.

**Method of preparation**

1. Take 30 kg fresh cow dung, 2 kg molasses/cane jaggery and 4 L rice water (starch).
2. Tied the above material in a nylon bag (50 kg capacity.)
3. Suspend this bag in a 200 L barrel filled with water.
4. Allow it to ferment for 36-48 h in this condition.
5. The preparation is ready to use after 48 h.

Spray this solution at 10% concentration to save the crops from drought.
Quality Spawn Production

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The term spawn is used for the vegetative growth of the mushroom mycelium and the substrate on which it grows. The word ‘spawn’ is derived from old French verb ‘espandre’ meaning to expand. Spawn has been defined in various ways by different workers as merely the vegetative mycelium from a selected mushroom grown in a convenient medium. In layman’s term, it is seed for cultivating mushrooms. Before the advent of grains spawn, different kinds of spawn were virgin/natural spawn, flake spawn, brick spawn, manure spawn. Now a days only grains spawn is being used for seeding the compost through out the world. In foreign countries rye grains are preferred over other grains whereas, in India, wheat, jowar and bajra are commonly being used for spawn preparation.

Spawn plays an important role in the mushroom industry because the failure or success of mushroom cultivation depends upon the availability of the quality spawn. The quality of spawn and yield of mushroom is mainly governed by the genetic make up of the strain of mushroom species and to some extent, the technology including the substrate used in spawn production.

Production of spawn in large quantities needed for commercial use is much more difficult than for experimental use. Strict hygiene must be maintained when spawn has to be produced daily and also great care need to be taken in the maintenance of strains; failure to do so can have disastrous consequences.

Spawn preparation methodology

Methods of spawn preparation can be divided into three steps:

I. Raising of pure culture:
There are two ways of raising pure culture:
   a) Tissue culture raised from a mushroom tissue.
   b) Spore culture raised from single or multispores.

a) Tissue culture
   A big and healthy fruit body with veil still intact is selected from cropping tray for tissue culture. Lower portion of the stipe is cut off at the soil level with the help of a pre-sterilized knife and fruit body is cleaned with a bit of cotton moistened in 50 per cent ethanol to remove the soil particles if any, adhering to the surface of pileus and stipe and finally dipped in a 0.1 per cent mercuric chloride solution for 30-60 seconds to avoid any chance of contamination.

   A small piece of tissue from the junction of cap and stem is taken out with the help of sterilized inoculating needle and the same is transferred aseptically in 2% malt extract-agar medium in culture tubes. The inoculated tubes are incubated at 25°C for about 10-15 days till the surface of the medium is fully covered with the mycelial growth.

b) Spore culture
   (i) Spore collection: A big and healthy fruit body with veil still intact but tightly stretched is selected for
basidiospores collection in a sterilized petri-dish. Lower portion of the stipe is cut off at the soil level with the help of a pre-sterilized knife and the fruit body is washed with distilled water and dipped in 0.1 per cent mercuric chloride solution for 30-60 seconds to avoid any chance of contamination to be introduced with the spore mass. The fruit body is then mounted on a sterilized petri-dish so that the lower portion of stipe as well as pileus do not touch the petri-dish. This is covered by a sterilized beaker for 24-48 hours. After a thick deposition of spore mass, the glass beaker and mushroom alongwith the wire-stand are removed and sterilized lid is placed on the petri-dish which is then stored in refrigerator until use.

(ii) Single spore culture: In order to isolate single spore, spores are transferred aseptically with the help of inoculation needle (pre-wetted with sterilized distilled water) into sterilized distilled water and diluted. One ml of spore suspension containing about 20 spores is transferred and mixed with 2 per cent melted water agar medium in petri dish. After solidifying, the petri-dishes are turned up-side down and single spores are located under microscope and marked with ink. Single spores are picked individually and transferred on to wheat extract agar medium in test tubes. These tubes are incubated for 10-15 days at 28°C for spore germination.

It must be remembered that all the monosporous cultures of mushrooms of heterothallic nature (Agaricus bitorquis, Lentinus edodes) are sterile. In secondary homothallic fungus (A. bisporus), 30 per cent of monosporous cultures are sterile.

(iii) Multispore culture: Spore suspension (1%) is mixed with 10 ml liquid malt extract agar medium in culture tubes and slants are prepared. The slants are incubated at 28°C for spore germination for about two weeks. The mycelial threads become visible on slant surface after 14-15 days.

II. Preparation of master spawn / mother spawn

Next step in the spawn preparation is the preparation of master spawn. Pure culture is raised either from tissue or spore is inoculated in a suitable substrate (wheat, jowar, bajra, or rye grains) which provides food to the mycelium. In principle, the quality of spawn is determined by the biological value of the strain. However, there are some important aspects of spawn making such as proper understanding of moisture content, pH and sterilization which deserve special attention for quality spawn production. Therefore, boiling, soaking, addition of calcium carbonate and calcium sulphate and sterilization of substrate assumes special significance. For spawn preparation, ten kg of wheat grains or any other grain is boiled in 15 litres of water for 20 minutes and allowed to remain soaked in the hot water for another 15 minutes without heating which gives a moisture content of 48-50% of grains after sterilization. At this moisture content the mycelial growth is fast and number of days taken by the mycelium to cover the entire substrate is less. Next day 12.0 g calcium sulphate and 3.0 g calcium carbonate are mixed with one kg of boiled grains. The calcium sulphate prevents the sticking of grains together and calcium carbonate is necessary to adjust the pH (6.5-6.8).

The grain is filled into half or one litre milk bottles (250 or 450 g/bottle). Bottles are plugged with non-absorbent cotton and sterilized at 22 psi for 2 hours. After autoclaving, bottles are allowed to cool down slightly and later shaken vigorously to avoid clumping of grains. The sterilized bottles are surface sterilized by dipping in 2 per cent formalin solution without wetting the cotton plug. These
bottles are inoculated with approximately equal mycelial bits obtained from pure culture. Inoculated bottles are incubated at 25°C. About 7 days after inoculation, bottles are shaken vigorously so that mycelial threads are well mixed with the grains. About 20 days after inoculation, the bottles are ready as master/mother spawn for further multiplication of the spawn.

III. Preparation of Commercial Spawn

The spawn is also prepared in similar way as described for the preparation of master spawn. One bottle of master spawn is sufficient for inoculation of 25-30 polypropylene bags of commercial spawn (1 kg capacity). Inoculated bags are incubated at 25°C. In three-four weeks spawn bags are ready for use.

Characteristics of good spawn

The spawn should be fast growing in the compost, and should form pin heads quickly after casing, should be high yielding and produce good quality mushrooms. There should be a proper coating of the mycelium around each and every grain used as a substrate for spawn production. No loose grain should be seen in the bottles when these are bound together with the mycelium. The grains left over without mycelial coating will invite mould growth in the compost during spawn run period. The growth of the mycelium in the spawn bottles should be silky/strandy type. It should not be cottony type because there is likelihood of stroma formation on the casing layer, which interferes with gaseous exchanges and absorption of water in the casing material resulting in low productivity. The growth of fresh spawn is more or less white. Brown colouration develops as spawn grows older. Fresh spawn gives higher yield than the old one. There should not be any slimy growth in spawn bottle which is an indication of bacterial contamination. There should not be any greenish or blackish spot in the spawn bottles. Such type of spots indicate that the spawn is contaminated with moulds.

Transit and storage of spawn

Studies on thermal death point show that the spawn bottles exposed to 40°C for 48h result in killing of the mycelium. However, the spawn exposed to 35°C remains viable for 14 days. Care must be taken during transit that spawn bottles are not exposed to a temperature higher than 35°C. To avoid such risk spawn bottles can be packed in thermocol boxes containing ice cubes or can be transported during when it is cool.

Storage of spawn should be avoided as far as possible. However, the spawn can be stored between 3-5°C for one to six months in case it is not used due to certain unavoidable circumstances.

Precautions in spawn preparation

Although a number of precautions have been suggested in relevant chapters, still the major precautions are listed below:

1. Strict hygiene should be maintained throughout right from raising of pure culture to storage and transport of spawn.
2. Inoculation room should be disinfected regularly by exposing it to formalin.
3. During incubation of spawn, bottles and bags should be inspected frequently to remove contaminated bags.
4. Before spawning into substrate the stored spawn under refrigerated conditions should be brought to ambient temperatures.

5. To avoid spread of contamination in the vicinity, the contaminated bags must be autoclaved and buried in the soil.

6. Regular floor cleaning with surface disinfectants should be done daily.

7. Cultures should be wrapped with aluminium foil to prevent contamination of cultures during storage under refrigerated conditions.

8. Excess of visitors to inoculation room should be denied.
Management of insect pests has become a costly affair in most part of India where different IPM modules are being copied blindly without proper analysis of insect pest problems and evaluation of management tools/techniques which are highly specific to agro-ecosystem. Moreover, even after spending a huge amount in crop protection, farmers are unable to turn cost benefit ratio in their favor. According to most acceptable definition of IPM, pest management is an ecological approach to pest control in which all available techniques are evaluated and consolidated in a unified program to manage the pest population so that economic damage is avoided and adverse side effects on environment are minimized. Most unfortunately, in most of the agro-ecosystem available techniques are being consolidated without proper evaluation due to which neither economic damage nor adverse side effect on environment is being minimized even after putting a lot of resources.

Insecticides are the most important tool for the management of insect pests and presently it is not possible to control any major insect pest without its use. However, its application proves to be very costly if not used judiciously. In most of the agro-ecosystem the cost of protection increases mainly due to injudicious use of insecticides as insect pests quickly develop resistance against it which is also inherited to future generations. On the other hand, manipulation of cultural practices and natural control significantly check the insects to become pest at no extra cost. Under such conditions the insect management may be made cost effective, by strengthening the cultural and natural control and checking or delaying the development of resistance by adopting insecticide selectivity. However, such attempts will succeed only when it is based on ecosystem specific information.

A. Why the management of insect pests is so costly at farmer's level?

The cost of protection is increasing day by day due to various reasons the most important of which are:

1. **Use of ineffective methods:** In most of the agro-ecosystem in India the farmers are spending a lot of money in implementation of ineffective control measure. Generally such control measures are implemented on the basis of their performance in other ecosystem. Since most of such measures are ecosystem specific, they fail to deliver desired result even after huge expenditure. For example, generally it is reported that parasitoids such as *Trichogramma chilonis* or *japonicum* are useful in management of Yellow Stem Borer of Rice. Although, such parasitoids parasitize the eggs of YSB in some agro-ecosystem, they fail completely in others. Similarly, so many bio-pesticidal formulations of neem, bacteria, viruses and fungi are being used at large scale in so many agro-ecosystem, although, their performance is not appreciable everywhere. The farmers also use so many insecticides which are not effective due to various reasons.
2. **Non-implementation of cultural control methods:** Purposeful manipulation of agronomic practices such as tilling and cultivation of soil, use of resistant varieties, time of sowing and harvesting, use of clean seed, regulating irrigation, controlling crop growth with fertilizers, clean cultivation, cropping scheme and trap crop, pruning and thinning and destruction of crop residue etc. have been found to be very effective in controlling the insect pest. However, such cultural control practices are not followed by farmers seriously, although, no extra cost is involved in its implementation.

3. **Injudicious use of insecticides:** Insecticides are costliest input in crop protection and injudicious use of it makes the pest control even more costly. These chemicals are useful and cost effective alternative only when applied at right time, at right dose by using right application technology. Most unfortunately, the insecticides in Indian agriculture are the highly misused tools which are mainly responsible for increasing cost of protection.

4. **Development of resistance against insecticides:** Resistance develops rapidly if most of the pest population is exposed to the specific insecticide, if the insect can multiply quickly or if there is limited immigration of unexposed individuals. Selection pressure for resistance is reduced if part of the pest population is on alternative host plants or other crops which are not treated with the chemical. Migration of these susceptible individuals may be important in delaying the onset of resistance, thus emphasizing the need to minimize drift of chemical beyond the treatment area to other host plants. Unfortunately, the user is often tempted to increase either the dosage, or frequency of application, or both, when resistance is suspected, and this merely aggravates the situation and increases the cost of protection.

**B. Strategies for cost effective insect pest management**

Cost effective management of insect pest is possible only when agricultural ecosystem is planned after proper understanding and control measures are applied after cost/benefit and benefit risk analysis.

1. **Proper understanding of pest and IPM:** Proper understanding of pest is prerequisite of any pest management programme, as in many instances, the farmers have been found applying fungicides or other chemicals for the control of insects. Also, in so many conditions the farmers are themselves responsible for elevation of insect to pest level. Under such conditions the farmers should be ready to answer following questions:

   **What is pest?** Any form of plant or animal life or any pathogenic agent, injurious or potentially injurious to plants, plant products, livestock or man are known as pest.

   **What is insect pest?** Insects which feed on crop plants and cause economic dame directly or indirectly by transmitting the diseas are known as insect pest.

   **Should all the insects present in the crop field be treated a pest?** Never. Many of the insects present in crop field are beneficial to it as they control harmful insects or pathogens. Even those who damage the plant are not always a pest and their presence in the field as non-economic population is essential for successful integrated pest management as they serve as food of
parasites and predators.

When insects become a pest? When they get most suitable food over a long period of time, the climatic conditions become most favorable for their growth and development and when their natural enemies are killed due to various reasons.

Do we have any role in helping insects or pathogens to become a pest? And how? Yes. By cultivating most susceptible variety of crop over long area for longer duration, enhancing vegetative growth of susceptible variety by excessive use of fertilizers or by killing natural enemies of pest by using insecticides injudiciously.

Do all the insect pests cause economic damage all the time, everywhere? No. They cause economic loss when their population exceeds a certain level – Economic Injury Level.

Do all the pests have equal pest status? No. Depending on the level of damage they may be classified as:

Key or Major pest: These pests occur perennially and cause serious and persistent economic damage in absence of effective control measures. E.g. Brown plant hopper, Stem borers in rice.

Minor pest: These pest cause economic damage only under certain circumstances in their local environment, e.g. Leaf folder, Gall midge.

Occasional pest: In certain years and in certain locality they build up their population and achieve pest status, e.g. Army worm, Ear-cutting caterpillar.

Potential pest: They have potential to develop into major pest depending upon circumstances, e.g. Leaf folder, Gall midge, Whorl maggot.

Migrant pest: Move from one zone to another, e.g. Locust.

Is it necessary to eradicate all the pests from the field? No. A non economic population of the pest should always be maintained in the field so that natural enemy of the pest could survive and multiply itself. With the eradication of the pest the natural enemy of the pest may also be eliminated from the field.

How to control insect pests? Insect pests may be controlled by:
- Manipulation of agronomic practices – Cultural control
- Causing mechanical injury to pest or killing them mechanically – Mechanical control
- Manipulation of physical factors – Physical control
- Introduction and enhancement of natural enemies – Biological control
- Application of pesticides – Chemical control
- Legislation for pest control related activities – Legislative control

Is chemical control always necessary to reduce crop losses? No. Chemical control should be adopted only when the population of the pest or their damage reaches to Economic Threshold Level even after implementation of non-insecticidal control measures.

Are other non-pesticidal methods of control effective? If applied timely, they are highly effective against concerned pest.
Why should we adopt Integrated Pest Management?

To avoid the collapse of control system based on single technology.
To avoid pest control to enter exploitation, crisis and disaster phase

**Exploitation phase:** The pest control programme is dependent solely on chemical pesticides which are exploited to the maximum resulting in high yield.

**Crisis phase:** After many years in exploitation phase and heavy use of pesticides, pesticide resistance, pest resurgence and outbreak of secondary pest occur which increases the production cost?

**Disaster phase:** The use of pesticide increases the cost of production to the point where crop could no longer be grown profitably. High residue of pesticide in the food makes the produce unacceptable to consumers.

Currently most control is in exploitation phase and integrated pest management should be quickly adopted to avoid the crisis and disaster phase.

2. Proper understanding of area specific agro-ecosystem

**Crop:** Cropping pattern of the area, seasonal history of the crop, growth stages of crop, agronomic practices

**Pests:** Taxonomic category and common name of the pest: Insect, Fungi, Bacteria and mycoplasma like organisms, Virus and viroides, Nematodes Protozoans, Algae, Phaenerogamic parasites, Rodent, Molluscs, Weeds

**Status of the pest:** Key or major pest, Minor pest, Occasional pest, Potential pest, Migrant pest

**Economic injury and economic threshold level**

Economic Injury Level: It is the lowest pest population density/disease index that will cause economic damage

Economic Threshold Level: It is the pest density/disease index at which control measures should be applied to prevent an increasing pest population/disease from reaching the Economic Injury Level.

**Seasonal and life history of pests:** In which month they appear in the crop? In which stage they infest the crop? How they damage the crop? Where they lay the egg and in how many days egg hatch to larva? Where and how the adult or larvae feed? Where the larvae pupate? When the adult emerge and mate? In how many days the pests complete its development? How many generation of the pest are there in that area? Do they remain active through out the year? Where they hibernate/survive during the off season?

**Abiotic and biotic conditions favorable to pest:** Alternate hosts of the pest susceptibility of main host, shelter of pest, susceptible stages of the pest, Temperature, Relative humidity, Rain fall.

**Natural enemies of the pest:** Taxonomic category of natural enemy, seasonal and life history of natural enemy, susceptible stages in the life history of natural enemy, alternative host and artificial food of natural enemy, super or hyper parasites of natural enemy, climatic conditions unfavorable to natural enemy, susceptibility of natural enemies to pesticides
3. Integrated Pest Management Tools

**Cultural methods:** They comprise regular farm operations, which are so performed as to destroy insects or to prevent them from causing injury. Practices such as tilling and cultivation of soil, use of clean seed, regulating irrigation, use of resistant varieties, controlling crop growth with fertilizers, clean cultivation, cropping scheme and trap crop, pruning and thinning, time of sowing and harvesting and destruction of crop residue are helpful in reducing pest population and damage.

**Mechanical methods:** They comprise various mechanical devices to kill the pest. Hand picking, use of hand nets and bag nets, beating and hooking, shaking and jarring, sieving and winnowing, trenching field and use of mechanical traps are highly effective in small fields.

**Physical methods:** Application of physical factors such as heat, cold or moisture to the disadvantage of pest is also useful in management of storage pests.

**Biological control:** They constitute a deliberate attempt to use natural enemies either by introducing new species in the environment of the pest or by increasing the effectiveness of those already present by conservation and enhancement. It is implemented by preservation of inactive stages, avoidance of harmful cultural practices, and maintenance of diversity of agro-ecosystem, providing natural food, artificial food supplement and shelter, control of honeydew feeding ants and protection from pesticides.

**Chemical control:** Use of different chemicals such as insecticide, attractants, repellants, sterilants, growth inhibitors for killing or reducing insect population.

**Genetic method:** Propagation and release of sterile or genetically incompatible insect to check breeding.

**Regulatory method:** Legislation to control pest activity and pest control operation by plant and animal quarantine, eradication and suppression program.

4. Implementation of insect control methods after proper evaluation

None of the insect control methods are equally effective in all the agro-ecosystem due to difference in cropping system, climatic conditions, biotic and abiotic stresses and level of resistance. Therefore, before implementation all the available insect pest controlling techniques should be evaluated at farmer or institutional level. Special attention should be given to bio-control agents and bio-pesticides whose performance is highly unstable in different agro-ecosystem.

5. Consolidation of effective control measures in unified program

In the Integrated Pest Management only effective control measures should be integrated in unified programme to achieve maximum yield without any adverse effect on natural enemies or other biotic components of environment.

6. Insecticide Selectivity

Judicious application of insecticide is strongest strategy to make the insect management cost effective and it can be implemented through following ways:

**Need based application:** Schedule based application of insecticides are very costly and ineffective alternatives in pest control as in most of the conditions the chemical is not present at
lethal concentration when the insect pests attack the crop. On the other hand, need based application based on ETL is cost effective alternative in IPM as application coincides with attack and requires less insecticides.

**Use of recommended insecticides:** All the insecticides are not effective against all the insects on all the crops. Therefore, crop and insect specific recommendations should be followed to effectively control the insect at minimum cost.

**Use of new active ingredients:** Most of the insect pests have developed resistance or cross resistance against so many chlorinated hydrocarbons, organophosphates, carbamates or synthetic pyrethroids which are being used since long and they are not much effective in most of the conditions. Under such conditions newly developed active ingredients of spinosyn, oxadiazine, pyrazole, nicotinoid, nereistoxin, growth regulators, antibiotic should be preferred to make the control more effective.

<table>
<thead>
<tr>
<th>Group</th>
<th>Active ingredient and formulations</th>
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<tr>
<td>Organochlorine</td>
<td>Endosulfan 35 EC</td>
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<td>Organophosphorus</td>
<td>Acephate 75 SP, Chlorpyrifos 20 EC, Dichlorvos 76 SC, Dimethoate 30 EC, Oxydemeton-methyl 25 EC, Profenofos 50 EC, Quinalphos 25 EC, Triazophos 40EC</td>
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<tr>
<td>Carbamate</td>
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<tr>
<td>Pyrethroid</td>
<td>Bifenthrin 10 EC, Cypermethrin 10 EC, Deltamethrin 2.8 EC, Lambda-cyhalothrin 5 CS</td>
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<tr>
<td>Spinosyn</td>
<td>Spinosad 45 EC</td>
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<tr>
<td>Oxadiazine</td>
<td>Indoxacarb 14.5 SC</td>
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<tr>
<td>Pyrazole</td>
<td>Ethiprole 10 SC, Fipronil 0.3 GR, Fipronil 5 SC, Chlorantraniliprole</td>
</tr>
<tr>
<td>Nicotinoid</td>
<td>Acetamiprid 20 SP, Clothianidin 50 WDG, Imidacloprid 17.8 SL, Imidacloprid 70 WG, Thiamethoxam 25 WSG</td>
</tr>
<tr>
<td>Nereistoxin</td>
<td>Cartap 4 GR, Cartap 50 SP</td>
</tr>
<tr>
<td>Growth regulators</td>
<td>Buprofezin 25 SC, Diflubenzuron 25 WP, Lufenuron 5 EC, Novaluron 10EC</td>
</tr>
<tr>
<td>Antibiotic</td>
<td>Emamectin benzoate 5 SG</td>
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<tr>
<td>Diamide</td>
<td>Flubendiamide</td>
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**Use of broad spectrum insecticides:** Some active ingredients are very effective against defoliators, borers and sucking pests while others are specific to each type of pest. Broad spectrum insecticides should be selected if crop is attacked by different types of pest.

**Use of branded products:** Markets in almost all agro-ecosystem are flooded with spurious products the efficacy of which is very low. It is advantageous to use the product of reputed manufacturers even if is costly.

**Use of safe products:** Products which are toxic to natural enemies and non-target organism should not be used. Newly developed active ingredients are comparatively safer to natural enemies.

**Use of proper formulation:** Granules are safer as compared to sprays and dust as they contain systemic insecticides. Water dispersable granules are safer ac compared to wettable powder.
**Use of different active ingredients in successive applications:** Repetition of same group of active ingredients in successive application leads to fast development of resistance.

**Use at right time:** Time of insecticide application is very important in reducing the cost. Seed treatment or application in nursery cost less but provide adequate protection for longer duration. Application at ETL controls the pest at low cost. Late application is more effective to nocturnal pests.

**Use at recommended dose:** Application of insecticide at lower or higher dosages accelerates the development of resistance and increases the cost of protection. Crop, stage and insect specific recommended dose applied with recommended quantity of water gives maximum coverage and distribution.

**Proper application method and equipment:** All the pesticide application equipments are not suitable for application of insecticides. To increase the coverage and distribution and check the drifting of insecticide due care should be taken in selection of equipment and nozzles.

**Spot treatment:** If the infestation is restricted in some pockets spot treatment is less costly alternative.

**Application in clear weather:** Application of insecticides in bad weather is always disadvantageous as droplets are drifted or washed on windy or rainy days. Endo and exo-drift cause more than 50% loss of insecticide due to which its efficacy is reduced. Repeated applications are required if deposits are washed with in 3 hours.

7. **Check or delay the development of resistance**

To check or delay the development of resistance different groups of active ingredients should be selected in different applications and insecticides should be applied at recommended dose at right time using right application technology.

Adoption of abovementioned strategy may lead to long lasting and cost effective management of insect pest without any adverse effect on environment and non-target organism.
Phytosanitary Measures and International Seed Trade

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Successful international trade in seeds depends on the development and implementation of science-based phytosanitary legislation and regulations.

**Seed health testing vs Phytosanitary regulations**

Seed health testing requirements are among the most important and science-intensive aspects of phytosanitary regulations.

**International Plant Protection Convection**

Phytosanitary requirements vs seed import

Phytosanitary requirements for seed imports went through a period of rapid increase during 1990s, largely driven by the approval of North American free Trade Agreement (NAFTA) and other free-trade agreements. Prior to 1991, for example, there were no phytosanitary requirements for vegetable seed imports to Mexico from the United States, but by 1994, nearly 60 pathogen restrictions on vegetable seed imports were proposed in Mexico.

**Seed trade vs seed borne pathogens**

Increased trade in seed and other agricultural products spawned some legitimate concerns about risks of pathogen movement between nations. However, some phytosanitary regulations were not based on pest risk but instead were enacted as substitutes for previously existing trade barriers.

**Pest risk analysis vs International seed trade**

Faced with these new challenges, several organizations with interest in international seed trade began to address the scientific basis of the burgeoning lists of quarantine pests, using pest risk analysis processes. One of the main obstacles to the development of science-based phytosanitary regulations has been a lack of accessibility to up-to-date information about seed-
borne aspects of plant pathogens. A major step forward in this area came with the publication of the Crop Protection Compendium (CPC) in 1997 by CAB International. The CABI CPC includes sections describing seed-borne aspects of each plant pathogen in the database. It also includes a pest risk analysis function that can be used as a tool to guide phytosanitary regulation development. Information compiled in the CPC was considered along with other information sources resulted in dramatic reductions in numbers of pathogens and pests on quarantine lists. Reason being:

1. Many pathogens and pests appeared on the lists but were not seed-transmitted or
2. Likely to be transported with seed, but already occurred throughout the region, or
3. They did not pose an economic risk.

**Seed Health Test Standardization**

Seed health testing methods have been a research focus at some institutions since at least 1918. However, there has been a disconnection between method development and implementation. Many methods may exist, even for a single pathogen on a single crop, but little effort was made to validate tests under different conditions or to form agreement among trading nations about the acceptability of different methods.

As a result, there has often been a lack of consistency between exporting and importing nations regarding acceptable methods for documenting phytosanitary compliance.

In 1994, a symposium titled “Plant Pathogens and the Worldwide Movement of Seeds” was held at the APS Annual Meeting, and its proceedings were published by APS Press. The majority of seed health tests used throughout the world have never been subject to standardization that would ensure accuracy and repeatability.

Apart from the ISTA sheets on seedborne diseases, there has been no systematic effort to develop standardized tests that are accepted internationally.

During the past decade, several organizations have begun to address this situation by promoting research, development, implementation, and standardization of meaningful seed health testing methods.

These efforts are guided by the International Plant Protection Convention, especially its International Standards for Phytosanitary Measures. These organizations include:

- the International Seed Testing Association (ISTA),
- International Seed Federation (ISF),
- International Seed Health Initiative (ISHI), and
- the National Seed Health System (NSHS) In the United States,
- Earliest among these was probably ISTA, which formed a Seed Health Committee (SHC) as early as 1928. The committee was alternatively referred to as the SHC or Plant Disease Committee (PDC) through 2002, when the PDC designation was finally dropped.
- During its first several decades, most of the committee efforts were focused on cataloguing
seed-borne microorganisms rather than the practical aspects of detecting pathogens in a phytosanitary context.

- Subsequently, the approach evolved and the current Seed Health Committee’s objective is to “develop and publish validated procedures for seed health testing, and to promote uniform application of these procedures for evaluation of seeds moving in international trade.”

- The committee has published a handbook on validation of seed health testing methods and ISTA’s *International Rules for Seed Testing now* includes a supplement on seed health testing methods.

- The ISTA SHC has approved approximately 28 different seed health test methods.

- During the mid 1990s, ISHI was formed through collaboration between seed companies (primarily vegetable seeds) and the ISF.

- The objective of ISHI is to facilitate international movement of healthy seeds through collaboration among private seed companies, public and private seed testing labs, and academic and government research institutions.

ISHI efforts are coordinated with ISTA for test validation. The most active area within ISHI has been in vegetable crops (ISHI Veg), with membership from France, Israel, Japan, the Netherlands, and the United States, representing more than 75% of the world’s vegetable seed supply.

- Two more initiatives for herbage (ISHI-H) and field (ISHI-F) crops were established in 1997 and 1998, respectively. The focus of work in ISHI-F is on pathogens affecting maize and soybean.

- However, these areas have not been active, with only a single method approved for field crops.

- A test method for *Phomopsis* in soybean developed by ISHI-F was validated by ISTA in 2002.

- Some ISHI-Veg methods have been accepted as ISTA rules and as standards by the USDA-APHIS National Seed Health System (NSHS).

- NSHS is an accreditation and coordination system authorized by USDA-APHIS and administered by the Iowa State University Seed Science Center.

- The mission of NSHS is to facilitate international trade for seed industry by providing resources to assist seed companies in meeting phytosanitary regulations.

- NSHS cooperates with ISTA and ISHI to normalize methods approved by the different entities for standard use internationally.

- Effective conduct of accurate seed health testing depends on numerous public and private laboratories throughout the world.

- Significant progress has been made in training personnel and establishing seed testing laboratories in the developing world, through national initiatives and the efforts of
organizations such as the Danish Seed Health Center for Developing Countries (DSHC), CIMMYT and, the Iowa State University Seed Science Center.

**Method standardization**

Seed health test method standardization, as a component of the overall harmonization of phytosanitary regulations, remains a long term goal for the global seed industry. However the progress depends on sustained financial support (always inadequate) for the careful scientific evaluation of existing methods and development of innovative new methods and sustained communication and lobbying efforts, coupled with positive and consistent working relationships between seed industry representatives and government regulatory agencies. Organizations such as ASTA, ISTA, ISHI, ISF, and NSHS are attempting to address this challenge from many different angles. Since 2000, ISF administers the ISHIIs with the goals of harmonizing national regulations on phytosanitary issues and eliminating unjustified and unfair barriers to seed trade.

**International Sanitary and Phytosanitary Measures**

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Integrated Disease Management in Rapeseed-Mustard

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The oleiferous *Brassicas* including *B. juncea* (L) Czern, L.) *B. rapa* (syn. *B. campestris* L.) and *B. napus* L. are the important sources of edible oil in India. The world production of rapeseed-mustard has been increasing at a rapid rate in several countries largely in response to the continuing increase in demand for edible oils and its products. The projected demand for oilseeds in India is around 34 million tones by 2020, of which about 14 million tones (41%) is to be met by rapeseed-mustard. Evidently further enhancement in productivity potential of rapeseed-mustard genotypes is, therefore, essential.

In agriculture economy of India, oilseeds stand next only to food grains in acreage, production and value. India witnessed 26.95% (21.42 million tones) increase in production during VIII plan over VII plan (16.92 million tones). This increase in production was contributed both by increase in area as also yield level.. Moreover, there is a lot of scope for further enhancement in the productivity level of oilseed crops in India as the same is at low level as compared to world average. Protection of oilseeds from the ravages of pests and diseases through adoption of IPM would not only increase productivity but quality of produce as well.

**Major diseases of rapeseed mustard their causal organism**

- **Black/Leaf Spot**  *Alternaria brassicae*
- **White Rust**  *Albugo candida*
- **Downy Mildew**  *Peronospora parasitica*
- **Stem Rot**  *Sclerotinia sclerotiorum*
- **Blackleg**  *Leptosphaeria maculans*
- **White Leaf Spot**  *Mycosphaerella brassicola*
- **Root Rot Complexes**  *Rhizoctonia solani*
- **Aster Yellows**  Phytoplasma
- **Seedling Blight**  *Pythium* spp.
- **Black Rot**  *Xanthomonas campestris*
- **Viral diseases**  BWY and CaMV and TuMV

**Alternaria blight of mustard**

**Pathogen:**  *Alternaria brassicae, A. brassicola, A. Raphani*

**Symptoms:** Formation of spots on leaves, stem and siliqua. *Alternaria brassicae* appear grey in colour with black sooty velvety spots produced by *A. brassicola*. Spots produce by
A. raphani show distinct yellow halos around them. Lower leaves show the symptoms first as black points which later on develop into prominent, round, concentric spots. Later spots appear on siliqua and stem.

**Survival**-All the three species survive in soil on affected debris or on weed hosts; also reported to survive through seeds.

**Management**

- **Disease resistance**
  - Absolute resistance or very high degree of resistance to Alternaria blight is not available in existing cultivars of desirable maturity type.
  - Among different species, *B. juncea* and *B. rapa* are more susceptible than *B. carinata* and *B. napus*.
  - Germplasm lines found tolerant to Alternaria blight in *B. juncea* are: PHR-2, PAB 9511, PAB 9534, EC 399301, EC 399299, EC 399313, JMM 915
  - Early dwarf high yielding mustard strain “Divya” developed at Pantnagar possesses the growth and developmental traits associated with a high degree of tolerance to Alternaria blight.

- **Sources of resistance to** *A. brassicae*, however, have been spotted in wild crucifers:
  - *Brassica (=Synapis) alba*, *B. desnottesii*, *Camelina sativa*, *Capsella bursa pestoris*, *Coincya pseuderucastrum*, *Diplotaxis berthautii*, *D. catholica*, *D. cretacea*, *D. erucoides* and *Erucastrum gallicum*. *B. campestris ssp. rapifera* is also reported to be resistant to *A. brassicae*

  - These wild crucifers are found to elicit phytoalexin production on challenge inoculation of such plants with *A. brassicae*. For example, two thiazoyl substituted indole phytoalexins, Camelexin and methoxycamelexin, have been isolated from *C. sativa* leaves following elicitation by *A. brassicae*.

- **Resistance or Tolerance to Alternaria blight** is found to be associated with factors like:
  - Resistance to deposition or settling of spores, i.e. failure of spore (conidia) retention due to epicuticular wax.
  - Resistance to germination of spore and penetration, i.e. reduction in rate of conidial germination and germ tube formation due to high phenolic compounds viz, Polyphenol oxidase, peroxidase and catalase activities in leaves
  - Partial or infection rate-reducing (race-nonspecific) characteristics of tolerant genotypes. There has been indication that components of partial resistance like:
Small lesion size
Low intensity of sporulation
High incubation period
Longer latent period

Genetic Basis of Alternaria Resistance or Tolerance

Mechanism of resistance/tolerance when studied genetically, it has been reported to be governed by additive genes or polygenes with resistance being controlled by genes of partial dominance.

From the above it could be seen that breeding for resistance to Alternaria would involve exploitation of horizontal resistance by pyramiding of minor genes which would involve study of heritability of components of resistance, introgression of genes from materials found resistant, reciprocal recurrent selection or diallel selective mating.

BIO-TECHNOLOGICAL APPROACHES

Transgenic for Alternaria resistance

Transgenic expression of cDNA encoded lectin genes appears to be crucial:
- the rubber tree lectin, hevein (chitin binding lectin) (in mustard cv. RLM 198)
- Mustard plants have been transformed with RR protein genes:
  - Chitinase genes
  - Tomato glucanase gene
- NPR 1 transcript level in mustard can be elevated upon treatment with salicylic acid for resistance to powdery mildew pathogen (revealing nuclear translocation of BjNPR1 protein upon induction with SA)

Control measures:
- Proper cleaning to remove discolored shrunken seeds.
- Storage of seed at 35°C eliminates the fungus.
- Early planting of toria in September escape the disease.
- 2-3 sprays of mancozeb or 2 sprays of Iprodione (Rovral) at 0.2% during flowering period of the crop.
- Iprodione (Rovral) use to control seedling infection through seed treatment (@ 2.5g a.i./kg seed).
- The fungus Nectria inventa is reported to be a destructive parasite of A. brassicaceae.

Botanicals or Plant–based products
- Bulb extract of Allium sativum (1% w/v)
- Leaf extract of (1.5-2.0%) :
  - Acacia nilotica
  - Eucalyptus species
  - Azadirachta indica
  - NSKE (10%)

Downy mildew
Pathogen: *Hyaloperonospora parasitica* (*Peronospora parasitica*)
Symptoms: Fungus appears as white mealy growth on the lower surface of leaves and on green stagheads caused by the white rust. The upper leaf surface turns yellow.
Survival: The fungus is soil-borne and seed-borne and may persist in the soil for 5 to 10 years.
Management
- Crop rotation of 3 years with non cruciferous plants.
- Destroy crop refuse.
- Control volunteer plants, and wild mustard.
- Metalaxyl applied as seed treatment (@ 2.5g a.i./ kg seed) and through spray of ridomil-MZ @ 0.25 % shows effectiveness in controlling the disease.

White rust
Pathogen: *Albugo candida*
Symptoms: In case of local infection, symptoms appear on leaves and characterized by white or creamy yellow raised pustules which later coalesce to form patches. During floral infection the fungus becomes systemic in plant tissue and causes hypertrophy and hyperplasia known as staghead phase.
Survival: The oospores are formed in the hypertrophied tissue which serves as the source of survival through affected plant debris in soil.
Management
- Resistance to White Rust:
  - Race-specific nature of resistance; governed by major genes ( 1- 3 genes)
  - The genes could be located on the same locus or different loci
  - Molecular markers associated with resistance have been described
  - Some exotic *B. juncea* genotypes are resistant to white rust. These are EC 129126, EC 399301.
  - White rust resistant *B. juncea* varieties are released: Bio- 902, JMMWR 914-1-2
  - *B. napus, B. carinata* and *B. maurorum* shows resistance to a predominant isolate
of *A. candida* from main mustard-growing region (from north). But *A. candida* isolate from Karnataka is virulent on *B. carinata* and most *B. juncea* varieties.

- Resistance to white rust has been transferred from *B. napus* cv EC 151964 to *B. juncea* cv RLM-198
- (Progeny line NRG-49 has been recovered which is superior to RLM 198)
- Some genotypes of *B. juncea*, viz., EC 399301 are susceptible at cotyledonal stage but resistant at true leaf stage indicating involvement of two separate genes for reaction to *A. candida*
- *A. candida* (white rust) can predispose *Hyaloperonospora parasitica* (downy mildew) resistant plant/variety to infection by downy mildew; hence complicate the procedure for breeding for resistance to downy mildew
- *B. nigra* is moderately resistance and *B. napus, B. Carinata* are resistant hosts.

**Control measures:**
- Crop rotation of 3 years with non cruciferous plants.
- Destroy crop refuse.
- Suitable planting dates offer a good control of white rust.
- Metalaxyl applied as seed treatment (@ 2.5g a.i./ kg seed) and through spray of ridomil-MZ @ 0.25 % shows effectiveness in controlling the disease.

**Sclerotinia stem rot**

**Pathogen:** *Sclerotinia sclerotiorum*

**Symptoms:** Water-soaked spots on stem later covered with cottony white growth. Affected stem become bleached and eventually the tissues shred. Girdling of the stem, premature ripening, lodging of plants are other symptoms. Hard sclerotia are formed inside the stem.

**Survival:** *Sclerotinia* survives in the soil for up to 4 years as sclerotia.

**Management**

- Resistance to Sclerotinia Stem Rot
  - Breeding for resistance to Sclerotinia stem rot appears to be less successful because of
    - Wide host range
    - Lack of tissue specificity to infection.
  - Morphological and developmental traits of plants can be exploited in breeding for early, apetalous varieties with stiff stem.
  - Apetalous lines are less susceptible to *Sclerotinia* in comparison to normal petalled
The apetalous flower mutant “ap-Tengbe” can be useful to develop completely apetalous lines (homozygous recessive genes p1 p1 p2 p2).

Infection is avoided due to depriving of ascospore germination in the absence of petals falling on susceptible sites.

Control measures:
- Some varieties of *B. napus* are resistant.
- Adequate supply of boron governs resistance in plants.
- Burial of crop residue speeds up sclerotia breakdown and reduces disease spread.
- Use at least a five year rotation with cereals for severely infested fields.
- Control of susceptible weeds and volunteer plants.
- Use thoroughly cleaned seed.
- Avoid dense stands.
- Fumigation of infested seed lot with methyl bromide is useful.
- 3 sprays of benomyl (0.05%) give highest degree of control with increase in seed yield.

### Black Leg or Stem Canker

**Pathogen:** *Leptosphaeria maculans*

**Symptoms:** Leaf spots are dirty white, round to irregularly shaped, dotted with numerous small, black pycnidia. Lesions found at the stem base or at points of leaf attachment, several inches in length, white or grey with dark border. Many pycnidia form in the centre of the lesion, general blackening at the base. Severe infection results in dry rot or canker symptoms at the base that girdles the stem.

**Survival:** Over winters on stubble. The taproot being very woody in nature, resist decay and promotes the survival for 3 years.

**Management**
- *B. juncea* appears to be more resistant as compared to *B. rapa, B.carinata* and *B. napus*.
- Crop rotation of four years to allow stubble to decompose.
- Bury stubble in the top 12 cm of soil to speed stubble decomposition and reduce infection.
- Control volunteer plants and weeds.
- Use shallow tillage or direct seeding to avoid bringing infected residue, to the surface.
• *Paenibacillus polymyxa* (syn. *Bacillus polymyxa*) strain PKB1 reduces germination and germ-tube length and Inhibits several other fungi pathogenic on canola.

• Seed treatment as well as foliar spray with benomyl (1-2%).

**Club Root**

**Pathogen:** *Plasmodiophora brassicae*

**Symptoms:** Galls appear on the roots of infected plants. Severely affected plants are stunted and wilt.

**Survival:** Resting spores of the fungus can survive in soil for many years.

**Management**

• Infested fields must be kept free of susceptible crops for many years because of the long-lived resting spores.

• Equipment Sanitation.

• Do not move cultivating equipment from infested to non-infested areas before thoroughly cleaning the equipment.

• Soil Amendments.

• Liming may reduce disease severity on acidic soils.

• Soil fumigants like benomyl, quintozene are effective.

**Seedling Disease Complex**

**Pathogen:** *Rhizoctonia solani*, *Fusarium* and *Pythium*.

**Symptoms:** The symptoms appear as patchy emergence during the four weeks following seeding; may cause seed decay or pre-emergence damping-off.

**Survival:** The fungi grow in the soil when conditions are suitable or are stimulated by secretions from germinating seeds or roots of host plants.

**Fusarium wilt**

**Pathogen:** *Fusarium avenaceum* and *Fusarium oxysporum*

**Symptoms:** Yellow or reddish-brown streaks on one side of the stem or on the branches, orange discoloration at the stem base; chlorosis and necrosis of stems, vascular discoloration, poor seed set and premature desiccation can also occur. Patch formation in the field.

**Survival:** Fungi are soil-borne.

**Root Rot Complex**

**Brown Girdling Root Rot.** Light brown lesions with irregular margins on the taproot or main lateral roots. As the lesions develop they expand, grow together, become sunken and dark brown and eventually girdle the taproot.
Foot Rot. Brown, hard, clearly defined lesions occur near the stem bases. Pink spore masses may develop on diseased root tissues.

Root Rot. Light grey oval lesion of the upper taproot.

Management of root diseases

- **Seed Treatment**
  - Pre-emergence and post-emergence seedling blight and damping-off diseases caused by *Rhizoctonia solani*, *Sclerotium rolfsii* and *Fusarium* species can be controlled by seed treatment with effective fungicides. Usually a mixture of thiram + carbendazim (2:1) or thiram + carboxin (2:1) @ 0.2% and for *Albugo candida* and *Hyaloperonospora parasitica*, apron @ 6 gm/kg seed should be used. This ensures plant stand establishment.
  - Maintain recommended N, P, K and S levels in the soil.
  - Allow at least three years crop rotation by taking non-host crops.
  - Use moderately susceptible *B. napus* varieties.

Aster Yellows of Canola

It is usually a minor disease involving. The causal organism Phytoplasma is transmitted by leaf hoppers and have a wide host range.

Symptoms

Leaf spots are angular, light green; malformation of the floral parts; hollow bladder-like structures replace pods which do not produce seed.

Management

- Early seeded crops may escape infection.
- Monitoring of leafhoppers (insecticide spray).
- No chemicals available to control aster yellows.
- No resistant varieties

Viruses infecting mustard

- Beet Western Yellows (BWY)
- Cauliflower Mosaic (CaMV)
- Turnip Mosaic Potyvirus (TuMV)

Transmission: by aphid vectors from infected weeds

Symptoms

- Reddening, stunting and puckering of leaves.
- Pods distorted
- Seeds are poorly filled

Management
Once a plant is infected, it cannot be cured. Certified virus-free seed should be used and insecticide may be sprayed to kill vectors.

**Biological Control**

Despite a good potential of biocontrol agents for disease and pest control, their usages in rapeseed-mustard are limited.

- *Trichoderma harzianum*
- *T. viride* (G R isolate)
- *Streptomyces rochei*
- *Bacillus subtilis* strain UK-9

**REFERENCES**

Strobilurin Fungicide: Benefits and Risks

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Many of the newest and most important disease-control chemicals are in the Q_oI family of fungicides. The first fungicides in this family were isolated from wood-rotting mushroom fungi, including one called Strobilurus tenacellus. The name strobilurin was coined for this chemical family of fungicides in recognition of the source of the first compounds of this type. These natural fungicides were thought to help the fungus defend itself from competition by microbes present in rotting wood.

Industry chemists improved on these natural fungicides by making chemical modifications that resulted in compounds which were less subject to breakdown on the leaf surface by sunlight. Several of the Q_oI fungicides currently registered in the United States are considered by the Environmental Protection Agency to be reduced-risk pesticides. This means these compounds pose less risk to human health and/or the environment than alternative pesticides available at the time of their commercial introduction.

Chemical name- methyl (E)-2-{2-[6-(2-cyanophenoxy)pyrimidin-4-yloxy]phenyl}-3- methoxyacrylate
Empirical formula- C_{22}H_{17}N_{3}O_{5}

![Chemical Structure](image)

Table 1. Q_oI fungicides commercially available or expected to be available soon

<table>
<thead>
<tr>
<th>Trade name</th>
<th>Active ingredient</th>
<th>Manufacturer/Marketer</th>
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<tr>
<td>Solo Products</td>
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<td></td>
</tr>
<tr>
<td>Abound™ 2.08F</td>
<td>azoxystrobin</td>
<td>Syngenta</td>
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<tr>
<td>Amistar™ 80WG</td>
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<td>Syngenta</td>
</tr>
<tr>
<td>Heritage™ 50WG</td>
<td>azoxystrobin</td>
<td>Syngenta</td>
</tr>
</tbody>
</table>
Quadris™ 2.08SC  azoxystrobin  Syngenta
Reason™ 500SC  fenamidone  Bayer
Disarm™ 480SC  fluoxastrobin  Arysta
Evito™ 480SC  fluoxastrobin  Arysta
Cygnus™ 50WG  kresoxim methyl  BASF
Sovran™ 50WG  kresoxim methyl  BASF
Cabrio™ 20EG  pyraclostrobin  BASF
Headline™ 2.08EC  pyraclostrobin  BASF
Insignia™ 20WG  pyraclostrobin  BASF
Compass™ 50WG  trifloxystrobin  Bayer
Flint™ 50WG  trifloxystrobin  Bayer
Gem™ 500SC  trifloxystrobin  Bayer

**Premixes**
Tanos™ 50DF  famoxadone (QoI) + cymoxanil  Dupont
Pristine™ 38WDG  pyraclostrobin (QoI) + boscalid  BASF
Stratego™ 2.08EC  trifloxystrobin (QoI) + propiconazole  Bayer
Uniform™ 2.09EC  azoxystrobin (QoI) + mefanoxam  Syngenta
Quilt™ 1.67SC  azoxystrobin (QoI) + propiconazole  Syngenta
Quadris Opti™  azoxystrobin (QoI) + chlorothalonil  Syngenta

**Spectrum of Activity**

With important exceptions, the QoI fungicides control an unusually wide array of fungal diseases, including diseases caused by water molds, downy mildews, powdery mildews, leaf spotting and blighting fungi, fruit rotters, and rusts. They are used on a wide variety of crops, including cereals, field crops, fruits, tree nuts, vegetables, turf grasses, and ornamentals. While QoI fungicides provide important benefits, like all fungicides, their use as replacements for older fungicides can sometimes led to unexpected changes in disease activity. For example, in turfgrasses, azoxystrobin provides excellent control of a number of important diseases. However, it can sometimes enhance the severity of certain diseases, such as dollar spot of creeping bentgrass and *Pythium* blight of tall fescue. Mechanisms of disease enhancement are not understood, but one possibility is that use of azoxystrobin at labeled field rates may suppress certain naturally occurring microorganisms that are antagonistic to the pathogen.

Azoxystrobin possesses the broadest spectrum of activity of all presently known antifungals. It is presently the only counteragent that has the ability to protect against the 4 big groups of fungal diseases:

- **Ascomycota**: Septoria
- **Deuteromycota**: Pyricularia (rice harvesting)
- **Basidiomycota**: Stripe rust
- **Oomycota**: Water mould (grape harvesting)

**Examples**

Azoxystrobin is widely used in farming, particularly in wheat farming. Applying agents containing azoxystrobin provides protection against many types of diseases, including:

- **Septoria leaf spot**
- **Wheat leaf rust** (*Puccinia recondita*)
- **Rye leaf rust** (*Puccinia triticina*)
- Powdery mildew
- Downy mildew
- Stripe rust
- Pyrenophora teres

Mobility

All of the QoI fungicides exhibit translaminar movement (which means "across the lamina", or leaf blade). When these fungicides are applied, most of the active ingredient is initially held on or within the waxy cuticle of plant surfaces. Some of the active ingredient "leaks" into the underlying plant cells. For those fungicides with an affinity for the waxy cuticle (such as trifloxystrobin and kresoxim methyl), active ingredient that "leaks" all the way through the lamina quickly rebinds to the cuticle on the far side of the leaf blade. Thus, the fungicide can be found on both leaf surfaces even if only one leaf surface was treated. Translaminar movement can take one to several days to be fully effective.

The fungicide azoxystrobin moves translaminarly as well as systemically (in the plant's vascular system, or "plumbing"). The fungicides kresoxim methyl and trifloxystrobin move translaminarly but not systemically. These latter fungicides, however, appear to move as a gas in the layer of still air adjacent to the leaf surface called the boundary layer. As they move in the vapor phase, they readily re-bind to the cuticle. In terms of practical significance, systemic movement (when it occurs) and translaminar movement help to compensate for incomplete spray coverage. Redistribution in the vapor phase can also help compensate for poor crop coverage, but only to a limited extent. These processes may be especially important in crops with dense or difficult-to-spray canopies (cucurbits, for example). Be aware that several days may be required for adequate protection to be achieved via translaminar movement. Thus, growers may not achieve optimum disease control if a QoI fungicide is applied with incomplete coverage within 24 hr of an infection period.

Another practical consequence of the dynamics of translaminar movement concerns curative disease control. QoI fungicides are excellent as preventive fungicides, because they all effectively kill germinating spores. However, several of them provide poor performance against certain diseases when used curatively—that is, after infection has taken place. Recall that some QoI fungicides bind tightly to the cuticle, where most of the active ingredient can be found. Even though the active ingredient "leaks" into the leaf blade, it has such a strong affinity for the cuticle that it quickly re-binds with it when the chemical reaches the other side of the leaf. Consequently, at any one time, the dose of active ingredient actually present inside the leaf blade may be low, sometimes too low to suppress the growth of fungi within the leaf. The best use of QoI fungicides is to apply them before infection takes place.

Effects on Plant health

Growth enhancement.

Several QoI fungicides are known to cause growth-promoting effects in certain plants. For
example, kresoxim methyl has been shown to cause changes in the hormonal balance of wheat which results in increased grain yield, apparently from delayed leaf senescence and water-conserving effects. Growth-enhancing effects independent of disease control have been observed in QoI-treated plants of several species, although these effects are very much dependent on the crop, the fungicide used, and environmental conditions.

Phytotoxicity.

While the QoI fungicides are very valuable for disease control, several are known to cause phytotoxicity in certain, limited circumstances; these are described in product labels. For example, apple cultivars with a genetic background which includes MacIntosh are extremely sensitive to azoxystrobin. Another example: while trifloxystrobin may be used safely on most grapes, it can cause injury to Concord grapes. Kresoxim methyl is phytotoxic to certain sweet cherry varieties but not others. Another aspect of the phytotoxicity risk is the possibility that tank-mixes of QoI fungicides with materials that solubilize the cuticle-oils, surfactants, certain liquid formulations of insecticides—could increase their phytotoxicity potential.

Resistance

All QoI fungicides share a common biochemical mode of action: they all interfere with energy production in the fungal cell. To be precise, they block electron transfer at the site of quinol oxidation (the Qo site) in the cytochrome bc1 complex, thus preventing ATP formation. The preceding sentence may "seem like Greek" to even the most knowledgeable crop consultant, but it contains an important point—that the mode of action of the QoI fungicides is highly specific. Of the millions of biochemical reactions that occur in the fungal cell, these fungicides interfere with just one, very specific biochemical site. It is a very important biochemical site for the fungus, to be sure, but it is just one site. Thus, these are called site-specific fungicides. This is important because, commonly, just one mutation at that biochemical site (the target site of the fungicide) can result in a fungicide-resistant strain. If such a fungicide-resistant strain occurs, repeated application of QoI fungicides can lead to buildup of a fungicide-resistant pathogen subpopulation.

Experience with the QoI fungicides worldwide indicates there is a high risk of development of resistant pathogen subpopulations. Worldwide, resistance has been reported in an increasing number of pathogens of field crops, fruit, vegetable, and nut crops, ornamentals and turfgrass.

There are two general types of fungicide resistance: quantitative and qualitative. With quantitative resistance, resistant strains are somewhat less sensitive to the fungicide as compared to the wild type, but they often can still be controlled with higher rates and/or more frequent applications (within labeled limits, of course). A good example of this type of resistance is that observed with strains resistant to the DMI (demethylation-inhibitor) fungicides, such as propiconazole or triadimefon. With qualitative resistance, the resistant strain is vastly less sensitive to the active ingredient, and is no longer controlled at labeled field rates. The effect on disease control is the same as if one were spraying water on the crop instead of a fungicide. A good example of this type of resistance is that observed with the benzimidazole fungicides, such as
benomyl or thiophanate methyl. Natural occurrences of resistance to the QoI fungicides indicate that most cases of control failure are due to resistance of the qualitative type, but that instances of quantitative resistance to certain QoI fungicides have also been recorded.

Fungicides that share a common biochemical mode of action for poisoning the fungus are thought to be in the same "fungicide family". When different fungicidal products share a common mode of action, the fungus does not distinguish between the fungicides, even if the chemical structure of the active ingredients is different and the fungicides are produced by different manufacturers. Biochemically, the fungus sees them all as the same active ingredient. When a fungus is resistant to one fungicide in a chemical family, it is usually resistant to all fungicides in that family. This is called cross resistance. In many situations, fungal strains resistant to QoI fungicides exhibit cross-resistance to other QoI fungicides. In such cases, efficacy of all QoI fungicides may be compromised, even if some of them have never been used on that farm. Cross-resistance only applies within a given chemical family. Therefore, QoI-resistant subpopulations can be controlled with other fungicides not in the QoI family.

**Reducing Resistance Risk**

One can *reduce* the risk of its development by following practices that delay development of a resistant subpopulation.

Guidelines for reducing the risk of resistance against fungicides are issued by the Fungicide Resistance Action Committee (FRAC). In addition to the key guidelines described below, growers should understand that reducing the risk of fungicide resistance begins by using non-fungicidal means for disease control: crop rotation, selection of varieties with reduced susceptibility, sanitation, pathogen-free seed, etc. These practices help reduce overall disease pressure. The occurrence of an adapted mutant with resistance to a fungicide is a matter of chance, like a "roll of the dice". The larger the pathogen population, the greater the chance that such a mutant will arise. Reducing disease pressure through non-chemical practices helps lower the chance that a fungicide-resistant mutant will occur; it does this by keeping the overall size of the pathogen population small.

**Limit the number of applications of QoI fungicides in a given season.**

The basis of this guideline is this: the more often a QoI fungicide is used, the higher is the selection pressure towards the development of a resistant subpopulation. Limiting the number of applications reduces the opportunity for selection pressure, potentially extending the useful life of the QoI family of fungicides on a particular crop.

**Limit the number of consecutive applications of a QoI fungicide.**

The product labels indicate the number of consecutive applications of QoI fungicides that are allowed on each crop, before the user must switch to an equal number of applications of non-QoI fungicides. For most crops, the number of consecutive applications will be limited to two before the grower must switch to a fungicide with a different mode of action. FRAC guidelines on certain crops are even more strict; for example, on cucurbits, it is advised never to apply QoI fungicides.
consecutively. Like the seasonal limit described above, this guideline is designed to reduce the opportunity for selection pressure towards resistance.

**Mixing QoI fungicides with other fungicides can reduce selection pressure towards resistance.**

Mixtures do not prevent resistant mutants from arising on a farm. They can, however, can slow the rate of spread of these mutants. A proper mixing partner is one that provides satisfactory disease control when used alone on the target disease. Also, the mixing partner must be from some fungicide family other than the QoI group. Tank-mixing fungicides from the same chemical family do nothing to reduce the risk of fungicide resistance. The application rates of the components should not be reduced below the minimal labeled rate.

**Use of QoI fungicides at the early stages of disease development.**

Some researchers believe that curative use of a fungicide increases the risk of resistance, because the producer is treating a much larger population of spores and mycelium (the body of the fungus) than would be treated preventively. Allowing a buildup of a large population of spores before treatment increases the chances that a resistant mutant will be present when the chemical is applied.
Metagenomics: An Introduction

Although genomics has classically focused on pure, easy to obtain sample, such as microbes that grow readily in culture or large animals and plants, these organisms represent only a fraction of the living organism. Many species are difficult to study in isolation because they fail to grow in laboratory culture.

Methods that are based on DNA sequencing circumvent these obstacles, as DNA can be isolated directly from living or dead cells in various contexts. Such methods have lead to the emergence of the new field, which is referred to as Metagenomics. Metagenomics has been defined as the functional and sequence based analysis of the collective microbial genome in an environmental sample. The process begins with the collection of raw DNA from the environment and then proceeds to the cloning of the DNA by various means into a suitable host to produce a metagenomic library.

Why we need Metagenomics?

Microbiology has traditionally been based on pure cultures grown in the laboratory, but most microorganisms can not be grown in this way and we have been ignorant of their existence. This cultivation bottleneck has skewed our view of microbial diversity and limited our appreciation of the microbial world. Metagenomics provides a relatively unbiased view of not only community structure but also the functional potential of a community.

The beginning of Metagenomics

Norman Pace (1986) cloned and sequenced 16S rRNA genes from the natural environment to determine phylogenetic diversity. The next breakthrough occurred in 1990 when Giovannonui and colleagues first amplified 16S rRNA gene to phylogenetically analyze clone libraries from natural population of Sargasso Sea picoplankton.

Once a metagenomic library has been collected, it is mined for information, either the presence of particular genes of interest by PCR or the direct expression of enzyme activity. One of the main limitations of metagenomic libraries is that each clone represents only a small fragment of the genome from representative source.

Uncultivated species are identified by their 16S/18S rRNA genes, which are commonly used as phylogenetic markers because every cellular organism contains these genes and almost all gene variants can be amplified by standard set of degenerate primers.

Low cost high throughput sequencing coupled with a metagenomic approach, now provides a means to access the nuclear genome of extinct organism without amplification. This was recently applied to the analysis of the cave bear, (*Ursus spelaeus*), which is a relative of...
modern black bear that lived in caves throughout Europe but become extinct tens of thousand years ago. The investigators exploited a metagenomic strategy to demonstrate the presence of cave bear sequence in libraries that were created by directly cloning DNA extracted from 40,000 year old bones. This approach is also called palaeogenomics.

**Commonly used molecular tools and techniques in Metagenomics**

- Polymerase Chain Reaction (PCR)
- Molecular finger printing techniques
- DGGE & TGGE
- RFLP, RADP, SSCP (Single stranded conformation polymorphism)
- T-RFLP (Terminal restriction fragment length polymorphism)
- DNA microarray and DNA hybridization
- RISA (Ribosomal Intergenic Spacer Analysis)
- ARISA (Automated Intergenic Spacer Analysis)
- Shotgun Metagenomic Libraries &
- G+C content

**Limitations of molecular tools**

- Harsh DNA extraction based methods such as bead beating, can shear the nucleic acid, leading to problem in subsequent PCR detection.
- Different methods of DNA extraction yield different products.
- Humic acid is major component of soil sample which may interfere with molecular biology method.
- Metagenomics is an emerging field in which the power of genomic analysis is applied to entire communities, by circumventing the need to isolate & cultivate individual microbial species.

**Future Prospective**

Metagenomics has changed the way microbiologists approach many problems, redefined the concept of a genome, and accelerated the rate of gene discovery. The potential for application of Metagenomics to biotechnology seems endless. Functional screens have identified new enzymes and antibiotics and other reagent in libraries from diverse environment.

A number of barriers have limited the discovery of new genes that provide insight into microbial community structure and function that can be used to solve medical, agriculture, or industrial problems. With improved methods for analysis, metagenomics will expand and continue to enrich our understanding of microbial world.
Non-target Effects of Pesticides on Soil-borne Plant Pathogens

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The application of pesticides to the soil environment usually can be expected to result in a diverse array of effects on target and nontarget organisms (Munnecke, 1967). Only when the side effects become apparent are questions raised regarding the adequacy of a pesticide for generalized field use, the environmental and economic importance of the side effect, and the desirability of testing for such effects prior to use of the material. There are many pesticides having a wide range of biological activities other than those specified by the manufacturer. However, groups of toxicants are named according to their intended use. Therefore, insecticides are formulated to uses against insects, fungicides are designed to control pathogenic fungi, nematodes are intended to provide a certain spectrum of activity against undesirable nematodes, and herbicides are manufactured to control noncrop (weed) plants. Within this commonly accepted terminology, unintended or nontarget activities of certain pesticides on pathogens/diseases will be discussed below.

The toxicants used represent a wide diversity of chemicals varying in chemical, physical, and toxicological properties as well as persistence, degradability, and a range of other properties. With the prospect of continued use pesticides in agriculture and the possibilities of adverse or beneficial interactions, there is a need to develop a thorough understanding of the total effects of the these important compounds in our environment. The biological activity of any pesticide is usually not restricted to the target organism, but extends to nontarget organisms as well. Therefore, inhibitory and stimulatory effects of beneficial or harmful nontarget organisms in the environment are possible. It seems, however, that less emphasis has been given on the indirect effects of pesticides as compared to the direct ones.

Pesticides may affect crop plants in addition to targets (weed/pathogens/insects) whether directly or indirectly by their effect on other organisms which may lead to harmful or beneficial effects. Crop plants form various kinds of relationships with other organisms, e.g., pathogens. Plant diseases are the final result of a compatible interaction which occurs under suitable conditions between a particular pathogen and host. Other living components connected with disease are the surrounding microflora and fauna which may affect the pathogen, the host, or both by their antagonistic or synergistic action. Pesticides in their original form or their degradation products may interact in different way with any one of the organisms involved in the disease, at one or more points in the chain of events leading to disease development (pathogenesis). The final result may be an increase, decrease, or no change in disease severity or its incidence. The extreme case may be a severe outbreak of a “new” disease which was of negligible importance before the application of the herbicide, whereas the other extreme would be the complete elimination of an existing severe disease. The effect on disease might be immediately during the
same growing season, or it might be a long-term effect due to build-up, especially where persistent chemicals are involved. Changes in disease were also noticed following the uses of toxicants, particularly insecticides and fungicides. Soil pathogens are more likely to be affected, since most of the pesticides reach the soil sooner or later irrespective of the method of application used. This occurs upon direct application to the soil, as seed treatment, as drift from treated aerial parts of the plants, or through the decomposition of treated plant tissues after their incorporation in soil. When in the soil, the pesticides are in continuous contact with soil borne pathogens which survive there and invade the host through its subterranean parts. Furthermore, pesticides, particularly herbicides used as pre-emergence treatment, are usually applied at higher rates as compared to when used for foliar treatments.

Pesticides affect disease indirectly in addition to their effect on the host, the pathogen, and the surrounding microorganisms. The eradication of weed and plant residues by herbicides may in turn affect disease incidence, because many weeds serve as hosts or symptom less carriers of many agricultural crop pathogens. Plant residues often harbor pathogens: weeds also affect the microclimate and, therefore, disease development (Gooding and Lucas, 1969).

1. Fungicides

A. Direct Nontarget Effects of Nonsystemic Fungicides

Nonsystemic fungicides have an inherent toxicity for a broad spectrum of microorganisms. Although they might be expected to have a greater impact on the soil microenvironment, they have not been implicated in several undesirable effects on nontarget soil borne plant pathogens. Little information is available in the literature on the subject.

Gibson concluded that the nontarget enhancement of the disease was brought about by proliferation of the pathogen in the soil environment under attenuated competition. The fungicide neither directly stimulated growth of the pathogens involved (Pythium ultimum and Rhizoctonia solani) nor damaged pine seedlings. Pentachloronitrobenzene (PCNB) reduced damping-off of the two pine species incited by R. solani and enhanced postemergence damping-off caused by a Pythium species (Gibson et al, 1961). The nontarget effect of PCNB was presumed to be due to the suppression of the natural antagonist Penicillum paxilli, as this chemical was not toxic to Pythium. Rich and Miller (1964) obtained slightly more complex nontarget effects for PCNB. They reported increase in straw berry wilt (Verticillum alboatrum) which was attributed to an increase of the nematode (Pratylenchus penetrans) by PCNB, which, in turn, enhanced wilt in tandem. Powell (1971) has demonstrated synergism between nematodes and fungi in the development of soilborne plant pathogens.

Another example on the subject is the increase of Sclerotinia blight (S. sclerotiorum) disease in the U.S. Application of chlorothalonil significantly enhanced the blight on peanuts. Porter (1917) demonstrated that chlorothalonil enhanced Sclerotinia blight and decreased peanut pod yields in two field locations in Virginia heavily infested with S. sclerotiorum.
B. Direct Nontarget Effect of Systemic Fungicides

Systemic fungicides are known for their chemotherapeutic activity for reducing or controlling plant diseases otherwise uncontrolled by nonsystemics (Erwin, 1973). Of the several systemic fungicides, benzimidazoles are known for their side effects on nontarget soil microorganism. Soilborne nontarget fungi nonsensitive to benzimidazoles formerly of no pathogenic significance was observed to be enhanced in numbers (Papavizas and Lewis, 1979). Extensive use of benzimidazoles for longer periods of time as compared to other systemics led to this situation. There are many reports showing that application of benzimidazole fungicides applied to control certain plant diseases increased nontarget soil borne pathogens of minor importance, making them economically important. Benomyl increased the severity of blight caused by *P. aphanidermatum* and a *Pythium* species, when it was used to control turf grass diseases caused by *Fusarium*, *Rhizoctonia* and *Sclerotinia* (Warren *et al.*, 1976). Williams and Ayanaba (1975) obtained a positive relationship between a field increase in the incidence of Pythium stem rot of cowpea (*Vigna unguiculata*) and the application of benomyl, thiobendazole, methyl-2 benzimidazole carbamate (MBC), and several non benzimidazole fungicides. In six field trials in Nigeria, benomyl and MBC produced the highest nontarget increase in stem rot. They concluded that increase in stem rot is probably due to an enhanced activity of *Pythium* brought about by the suppression of nontarget antagonistic microorganisms in the agro-ecosystem.

2. Herbicides

A. Herbicide Effect on Pathogen Physiology and Survival

There are several published reports to assess the influence of herbicides on plant pathogens. However, most of this work has been done in culture in the laboratory. These laboratory results are contradictory. In spite of voluminous research work *in vitro* and *in vivo*, meaningful correlations or extrapolations between laboratory, greenhouse, and field results have rarely been observed. The response of fungi to herbicides greatly depends on dosage, quality of the toxicant, and pH and nutritive value of the assay medium. Sinha *et al.* (1979) demonstrated that growth of *Sclerotium rolfsii* was completely arrested by Diuron at 20 ppm and by alachlor at 160ppm, while growth of other pathogenic fungi (*Pythium aphanidermatum*, *R. bataticola*, and *Fusarium moniliforme*) continued up to 640 ppm of these herbicides. The sporulation of most fungi was also affected, particularly at higher doses of these herbicides. In *P. aphanidermatum*, a high concentration of these herbicides (80 ppm) induced conspicuous vacuolization in the mycelium and appreciably reduced its branching. The fungus did not produce either sporangia or zoospores in the presence of the two toxicants. *S. rolfsii* produced abundant reddish-brown sclerotia of mustard size in the control plates, but not in the presence of alachlor or Diuron. Chopra *et al.* (1970) observed that prometryne at 2µg/ml decreased germination of chlamidiospores of *F. oxysporum f. sp. vasinfectum*. Zoospore germination of *A. euteiche* in maltose-epitone broth and germ tube development was suppressed by .06 and 0.12 µg/ml of dinitramine and trifluralin,
There are several reports showing side effects of herbicides on sporulation and propagule germination and survival in soil. This information may provide a substantial base to analyze nontarget disease changes and delineate mechanisms of action of herbicides. Percich and Lockwood (1975) observed that atrazine enhance the population of F. solani f. sp. pisi and F. culmorum as well as microconidial germination and chlamydospore formation. These observations are substantially more useful in interpreting nontarget effects on disease development and survival as compared to in vitro studies on similar processes.

Garren (1959) pointed out that Dinoseb, a fungistatic herbicide, decreased stem rot of peanut (S. rolfssii). The reduction could have been the result of direct fungistatic activity of the chemical on the pathogen and its ability to reduce weeds and therefore, deprive the pathogen of an important source of organic matter (food bases) in the peanut stem rot development.

B. Increase of Plant Diseases due to Herbicides

Increased incidences of soil borne disease caused by the application of herbicides have been reported primarily in green house and to a lesser extent in field studies. The phenomenon of disease increase is not restricted to a specific group of herbicides, pathogens, or crops (Altman and Campbell, 1977). Preplant applications of trifluralin at label rates caused stunted cotton seedling development and enhanced damping-off caused by R. solani (Pincard and Standifer, 1966).

Application of EPTC, Chloramben, Dinoseb, or fluorodifen in the field increased root rot of navy bean caused by F. solani f. sp. phaseoli (Wyse et al, 1976). Atrazine incorporated in a field in Michigan at label rates enhanced pea root rot severity caused by F. solani f. pisi three times over that in the control (Percich and Lockwood, 1975). At 5 µg/g the herbicide enhanced the incidence of corn seedling blight caused by F. culmorum twofold over the control. Mussel and Russell (1977) found the bentazon, trifluralin and triallate in sand at 10 µg/g significantly enhanced root rot and damping-off of beans caused by F. solani. f. phaseoli. Black root rot of two crops caused by Thielaviopsis basicola was also increased by some herbicides. Chloramben, applied at recommended rates, increased black root rot of soybean (Glycine max) caused by T. basicola and reduced plant stand, height and yield (Lee and Lockwood, 1977).

C. Mechanisms Involved in Increase of Disease

The increase in disease incidence due to herbicides is the result of the positive or negative effects that the herbicide might have on each of the living organisms involved: the pathogen, the host, and the surrounding microorganisms. The sum of all these effects determines whether and to what extent the disease will be increased. A disease may be increased if the herbicide is toxic to the pathogen causing disease, and at the same time it reduces host resistance or the activity of antagonists of the pathogen (Katan and Eshel, 1968).

Sikka et al (1965) hypothesized that the stimulatory effect of a small quantity of atrazine was due to better utilization of sugar from the media and not due to supplementary carbon and
nitrogen. Richardson (1970) has given a different explanation for the stimulatory effect i.e. herbicides may neutralize or arrest the formation of self-inhibitors produced by the fungus. There are some fungi which can utilize herbicides as energy sources (Guillemat et al, 1960). This is probably of little importance in natural soil, because the rates of herbicide incorporated to soil at the commercially used doses of application amount to less than 0.1% of the organic content of the soil. Due to physicochemical forces the effective biological activity of a given concentration of most chemicals is much lower in soil than the activity of the same concentration in culture. The explanation for the stimulatory effect might be attributed to the fact that the concentration of the herbicide fell within its stimulatory range when used in soil (Katan and Eshel, 1973). The possible increase of different soil borne plant pathogens by the herbicides used is too dangerous to be overlooked and hence, needs a thorough investigation. There are reports indicating that many pesticides affect metabolism of pathogens and thus they may also enhance their virulence. The mechanism which might be responsible for the increase of disease caused by an herbicide has not received much attention.

Herbicides may increase the susceptibility of hosts or even break their resistance, by interfering with one or more stages of the plant’s defense mechanism. The possibility that after the use of herbicides the increase in susceptibility of the host is responsible for an increase in disease incidence has been demonstrated by several workers. Herbicides are known to induce abnormal growths of cells and tissues and, therefore, may provide conditions for easier penetration of the pathogens. Trifluralin, which is known as an inhibitor of root growth, increased damping-off disease (Katan and Eshel, 1973). Anderson and Griffin (1972) demonstrated increased inhibition of root and top growth in both alfalfa and tomato when infestation with root knot nematode was in the presence of trifluralin. Abnormal growth of the diseased plant is usually accompanied by changes in the content of growth-regulating substances in the tissues (Wood, 1967). Many studies attribute greater susceptibility of changes in the nutrient content of host tissues following soil application of herbicides. Fusarium wilt was more severe in tomato plants with a lower phosphorus content following treatment with MH (Waggoner and Dimond, 1952). MH also increased susceptibility of flax to Fusarium (Nair, 1958).

It is an established fact that many plant pathogenic fungi survive in the soil in an inactive form mostly as resting structures, in the absence of a host (Garret, 1970) and also that carbohydrates and amino acids in root exudates of the host incite propagule germination, which is then followed by penetration of the host. Root exudates have a direct effect on disease incidence. Herbicides which enhance root exudates will, in turn, increase the degree of infection by soil borne diseases. Altman (1969) postulated the increased susceptibility to Rhizoctonia to the greater amount of glucose exudates at the soil-plant interface when sugar beet plants were grown in herbicide-treated soil. Similarly, increase of root rot of corn in picloram-treated soil was associated with increased carbohydrate exudation (Lai and Semeniuk, 1970). Incomplete selectivity of herbicides to plant species may result in different kinds and degrees of phytotoxicity and stunting
of the crop. Damping-off diseases are mainly connected with the young seedling stage of the plant. It has been observed that herbicides increase these diseases by retarding plant growth and exposing them to infection for a longer time.

Soil borne pathogens exist in the soil in active or in passive forms and are much influenced by the dense population of the microbes which exist in natural soil. The quantity, quality, and activity of these organisms in the soil are important to determine the inoculum density of the pathogens and consequently, the disease incidence. These factors also determine the survival of the pathogens in the soil in the absence of their host (Katan and Eshel, 1973). Soil organisms which are antagonistic to pathogens are very common in soil. This phenomenon of antagonism is the main reason for the frequently observed lower pathogenicity of pathogens in natural soil than with a sterile one. Several different possible mechanisms of antagonism may exist in soil (Alexander, 1961): (1) competition for limited amount of nutrients, oxygen, space, or other common requirements; (2) the release of toxin products (antibioticity) which inhibits the growth of the pathogen; and (3) direct parasitism or predation. Herbicide(s) incorporate into soil might be injurious to a certain pathogen per se and yet be beneficial to it in the soil environment. This occurs when the herbicide reduces the antagonists to a greater extent as compared to the pathogen. Herbicides might result in the disturbance of the biological equilibrium from the following adverse effects on the antagonists of the pathogen: (1) reduction of their number (2) decrease in their capacity to produce antibiotics or lytic enzymes and (3) decrease in their capacity to compete with pathogens for nutrients. Paraquat sprayed on potato haulm altered the outcome of competition between *F. culmorum*, a known cereal pathogen and the known antagonist *Trichoderma viride* in favour of the farmer (Wilkinson & Lucas, 1969), perhaps due to the higher sensitivity of *T. viride* to paraquat. Chopra *et al* (1969) reported that Prometryn affected the magnitude of antibiosis of certain antagonists of *F. oxysporum f. sp. vasinfectum* using the baiting technique. Neubauer and Avizohar-Hershenzen (1973) observed an increase in the saprophytic activity of *R. solani* in trifluralin-treated soil. Since this chemical is inhibitory to the pathogen, its stimulating effect on saprophytism was attributed to a shift in the biological equilibrium. Enhanced saprophytic activity of *R. solani* was observed with diphenamid (Katan and Eshel, 1972).

D. Decrease of Plant Disease due to Herbicides

Herbicide incorporation may result in a decrease in the incidence of various plant diseases. It might be due to the effect the herbicide has on the pathogen, the host, or the surrounding microorganisms. Owing to its potential usefulness, this type of effect deserves much attention. Huber *et al* (1966) obtained better development and higher yield from winter wheat treated with diuron, which was attributed to the reduction (at 50% or more) in root rot, while trifluralin was found to increase the disease in some instances. Harvey *et al* (1975) demonstrated reduction in root rot (*Aphanomyces euteiches*) on shelled peas with peas with trifluralin at 0.56kg/ha followed by propachlor at 0.56 kg/ha application. They concluded that trifluralin was responsible for the protection observed. In green house test, Dinitramine and trifluralin also reduced *Aphanomyces*...
root rot and enhanced pea yields in Minnesota fields (Papavizas and Lewis, 1979). Trifluralin, in combination with Dinoseb, significantly reduced pea root rot caused by a complex of fungi (A. euterches, F. exysporum, F. solani, R. solani, Pythium sp.) and enhanced yield. Papavizas and Lewis (1979) demonstrated that Dinoseb added at normal rates to soil naturally infested with *P. aphanidermatum*, *P. myriiotylum* and *P. ultimum* 1 week before planting greatly decreased damping-off and blight.

Buczacki (1973) found that trifluralin mixed with soil before sowing of cabbage lowered the incidence of club root (*P. brassicae*). Benfluralin and isopropalin also reduced club root, while nitrinal and Dinitramine did not. Huber et al (1966) showed that diuron at 1.12kg/ha reduced severity of root rot of winter wheat caused by *Cercosporella herpotrichoides*. Growth of *C. herpotrichoides* was not inhibited below 100 ppm Diuron on cornmeal dextrose agar. Initial host penetration by the pathogen was not affected, but host resistance seems to be enhanced by the herbicide. Cole and Baston (1975) demonstrated that diphenamid added at 6.72 kg/ha to a steamed sand and silty clay loam decreased preemergence damping-off and enhanced post emergence damping-off caused by *P. aphanidermatum* and *R. solani*, which resulted in overall increased tomato stand.

### E. Mechanism Involved in Decrease of Diseases

According to Katan and Eshel (1973), the following three mechanisms may be associated with decrease of diseases due to herbicides: (1) direct toxic effects on the pathogen, (2) resistance of the host, and (3) relationships with microorganisms. Most studies on the effect of herbicides on plant pathogens have been made in culture, which showed various degrees of inhibition. Based on these studies an herbicide is usually regarded as potential fungicide. Various workers have generally used different concentrations of chemicals and based on the data “nontoxic” and “toxic” effects are reported. In some cases an herbicide was considered “nontoxic” when it did not inhibit the tested pathogen at concentrations as low as 10 ppm, whereas in other cases, an herbicide was considered to be “toxic” when it partially curtailed the growth of a pathogen at concentrations as high as 500 ppm or more. Paraquat inhibited *S. rolfsii* in sterilized soil (Rudriguez-Kabana and Curl, 1967). The fungitoxicity of herbicides might be affected by secondary factors. Richardson (1959) reported that Dinoseb was very toxic to *F. oxysporum* at a concentration of 2.5 ppm at pH 3.5; at pH 7.5 it was not toxic even at 10 ppm. The wetting agent in the commercial formulation enhanced the fungitoxicity of paraquat (Wilkinson and Lucas, 1968). *Botrytis* was more inhibited by 500 ppm of 2,4-D than was Fusarium (Mostafa et al, 1960), 2,4-5-T was more toxic to several pathogenic fungi than 2,4-D (Erickson et al, 1958). Some pathogens, however, were more sensitive to 2,4-D than those mentioned above. *Pythium* was completely inhibited by 250 ppm of Sodium and amine salt of 2,4-D (Bever and Slife, 1948) and *Actinomyces scabey* by 50 ppm of the methyl ester (Michaelson et al, 1949). Pathogens differ greatly in their sensitivity to the same herbicide. In several studies *Fusarium* was observed to be less sensitive to herbicides than other pathogens. *Rhizopus stolonifer* was fully inhibited by paraquat at 10 ppm, while *F. culmorum* was
only partially inhibited at 500 ppm. (Wilkinson and Lucas 1968). *B. cinerea* was more sensitive to bromoxynil than *F. nivale*.(Smith and Fletcher, 1964). *R. solani* was more sensitive to four dinitroanilines than was *Fusarium* (Eshel and Katan, 1972). *Rhizoctonia* and *S. rolfsii* were more sensitive to 11 herbicides than *S. bataticola* (Bain, 1961).

According to Katan and Eshel (1973) few studies on herbicidal inhibition of fungi deal with the mode of action involved and its possible similarity to that in plants. It appears that the inhibitory effects of the chemical result from interference with fundamental physiological processes of the fungus which are similar to those of other organisms. Physiological disturbance are therefore to be expected in fungi, especially when the herbicide is a mitotoxic poison, an uncoupler, or an agent which affects essential metabolic processes such as proteins and nucleic acid synthesis. Even herbicides whose toxicity is specific to processes occurring in higher plants such as photosynthesis (atrazine and substituted ureas) were found to be toxic to fungi. In such cases, fungitoxicity perhaps results from the secondary effects which are of minor importance in higher plants. It has been demonstrated that the dynamic rate of glucose catabolism by *Monilinia fructicola* was reduced by atrazine, Simazine, and fluometuron. Atrazine also suppressed the hexase monophosphate shunt (pentose) pathway. EPTC caused accumulation of oxalic acid in *S. rolfsii* cultures with no increase in mycelium production. Rodriguez-Kabana and co-workers (1970) suggested that this could result from a blockage in the tricarboxylic acid (TCA) cycle, which shuttles glucose into enhanced oxalic acid production.

There are several reports showing that herbicides may reduce diseases by mechanisms other than toxicity to the pathogen. It has been reported that Prophan (IPC) and TCA reduced *Fusarium* wilt of tomato, but were not toxic to the fungus in culture (Altman & Campbell, 1977). Richardson (1989) suggested that changes in metabolism of the host might have affected disease development. Similarly, Davis and Dimond (1953) reported that 2,4-D reduced *Fusarium* wilt in tomato. They concluded that growth regulators probably reduced disease by inducing changes in host metabolism which regulate the growth of the parasite and/or the elaboration of toxins. Miller and Ahrens (1964) reported that Simazine reduced *Rhizoctonia* infestation of roots of taxus, though the growth of the fungus in culture was little affected. Diuron reduced foot rot in winter wheat, but did not suppress penetration of the fungus or its growth in culture, nor did it affect population counts of soil fungi, bacteria and actinomycetes. Therefore, alternation in host resistance is again suggested as being responsible for decrease of the disease (Huber *et al.*, 1968).

There are reports indicating stimulation of antagonists by the application of herbicides, which suppress soil pathogens. Curl *et al* (1968) observed that in sterile soil treated with Simazine and amended with sources of carbon and nitrogen, the pathogen *S. rolfsii* was inhibited while the antagonist *T. viride* was stimulated. Growth of *T. viride* was also stimulated by fluormeturon (Bozarth et al, 1969), atrazine and Simazine (Eno, 1962). At some rates atrazine stimulated the inhibitory effect of certain antagonists to *S. rolfsii* (Curl *et al*, 1965). Kaufmans (1964) observation
was that Linuron and Diuran decreased the total number of *Fusarium* and stimulated fungi, known to be antagonists of this pathogen, a shift which might contribute to its control. Von Yegen and Heitefuss (1970) observed an increased population of actinomycetes by application of TCA antagonistic to *Pythium*.

3. Insecticides and Nematicides

Richardson (1959) observed that the insecticides isodrin (an isomer of aldrin) and lindane enhanced tomato wilt caused by *Fusarium oxysporum f. sp. lycopersici*, whereas aldrin, endrin and DDT reduced wilt. Aldrin also reduced barley seedling blight; none of these materials was toxic to the pathogens in culture. He concluded that the insecticides may alter the metabolism of the host, thereby decreasing or increasing resistance. Ethoprop was shown to be a toxic to *S. rolfsii* and *R. solani* on PDA, but did not significantly affect growth of the antagonistic species of *Trichoderma* or saprophytic fungi in the genera *Rhizopus* and *Aspergillus*. Ethoprop suppressed growth of *R. solani* and *S. rolfsii* in soil and enhanced invasion of *S. rolfsii* colonies by antagonistic *Trichoderma* spp. Thompson (1978) also observed reduced incidence of *S. rolfsii* in peanut fields by fensulfothion application. Insecticides and nematicides could decrease or increase soilborne plant diseases by various mechanisms not clearly understood or elucidated. These toxicants may be directly fungicidal or fungistatic to a given soilborne pathogen *in vitro* or in the field over prolonged periods of time. Direct fungistatic activity has been reported for aldicarb on *R. solani* (Tisserat et al, 1976), for Phorate on *R. solani* (Sinha *et al*, 1980) and *S. rolfsii* for 1,2-dibromo-3chloropropane (DBCP) on pythiaceous fungi (Brodie, 1961), for fensulfothion on *R. solani* and *S. rolfsii* (Rodriguez-Kabana et al, 1976) for dasonit on *S. rolfsii* and *P. aphanidermatum* (Sinha *et al*, 1980) and for lindane on *R. solani*, *R. bactaticola*, *S. rolfsii* and *P. aphanidermatum*. Ethoprop greatly inhibited growth of *S. rolfsii* *in vitro* and eliminated production of sclerotia (Rodriguez-Kabana *et al*, 1976). Nematicides and insecticides may bring about nontarget effects on soil-borne diseases by increasing or decreasing inoculum density and saprophytic activity of a given pathogen. Inoculum density of *Sclerotinia sclerotiorum* was enhanced by D-D mixture added to soil for nematode control in lettuce (Paryka and Mai, 1958). Enhanced D-D rates progressively enhanced stipe production from sclerotia, thus increasing ascospore inoculum. Toxicants may indirectly affect soil borne pathogens by increasing or destroying nontarget antagonistic microorganisms. Rodriguez-Kabana *et al* (1976) observed the ethoprop stimulated growth and proliferation of *Trichoderma* spp. and *Aspergillus* spp.in soil and indirectly increased invasion of *S. rolfsii* colonies by *Trichoderma*. This latter organism (*Trichoderma*) seems to be sensitive not only to ethoprop, but also to fensulfothion. The mycoparasitic action of *Trichoderma*, coupled with the fungistatic ability of ethoprop on *S. rolfsii*, may explain reduction in peanut stem blight by these toxicants.

Toxicants may indirectly affect soilborne diseases by the remaining predisposing factors (insects and nematodes). Erwin (1977) has well reviewed nontarget effects of fumigants on vascular wilts by removing the predisposing insects or nematodes. Nematicides and insecticides
may also enhance root diseases by being phytotoxic to a potential host, a side effect that appeared to be the case in aldicarb in the damping-off problem of sugarbeet caused by R. solani (Tisserat et al, 1976) and that of heptachlor in the barley seedling blight problem (Richardson, 1957).

4. Pesticides-Soil-Root Interface: Pathogens in the Rhizosphere

The behavior of plant pathogens and associated microorganisms at the soil-root interface is mediated by factors which manipulate host physiology and the quantitative and qualitative nature of root exudates (Rodriguez-Kabana et al, 1980). There are toxicants which are known to incite changes in root zones by which pathogens are affected, and changes in mycorrhizal fungi can also be expected to influence the mineral nutrition of plants with a resulting potential for predisposition to disease.

Little attention has been devoted to the pesticide effects on pathogens, especially in the rhizosphere or at the root surface. At this zone a pathogen concentrates sufficient inoculum supplemented with a readily available energy source (primary exudates) necessary for infection. Bensen (1976) studied trifluralin and another cotton herbicide fluometuron for their effects in the rhizosphere of seedlings. Fluometuron increased root development of cotton seedlings and trifluralin adversely affected root systems, which suggest that stress by the latter probably induced a greater quantity of exudation that affected spore germination. According to Rodriguez-Kabana and Curl (1980), this study clearly demonstrates that the effects of herbicide applications on plant pathogens can vary considerably with season and various cropping systems.

5. Pesticide-Mycorrhizae Interaction

Mycorrhizae are necessary components of most plant systems. The role of mycorrhizae forming fungi in plant nutrients, uptake, water transport and the biological control of some root diseases in well demonstrated (Marx, 1972). However, there is comprehensive information available in the literature on direct and indirect effects of pesticides on those fungi. Any herbicides that severely damage the host will almost certainly damage the mycorrhizae and this the mycorrhizal fungus. The influence of alachlor, trifluralin and diazinon on the development of endogenous mycorrhizae in soybeans was investigated. It was observed that these herbicides applied at commercial rates (2kg/ha) did not significantly affect root colonization by mycorrhizal fungi (Pincard and Standifer, 1966). Dasilva et al (1977) studied mycorrhizae-forming Sullus and Rhizopogon and showed that six pesticides significantly affected the growth and metabolism of these fungi in vitro.

Henderson and Stone (1970) demonstrated that stunting and chlorosis were caused by the complete destruction of Endogone spp. that enters into endomycorrhizal associations with citrus. Earlier this “disease” was believed to be caused by soil toxicity. Stunted plants from nurseries grew normally when they were inoculated with Endogone. The effects of nonfumigant nematicides on vesicular arbuscular mycorrhizae (VAM) have not been studied extensively. However, influence
of these compounds on VAM has been noticed. Backman and Clark (1977) examined the effects of several soil toxicants on VAM in ‘Florunner’ peanuts in field experiments and noticed that the nematicide carbofuran caused a significant decrease in VAM in peanut roots 30 days after planting. In view of the importance of mycorrhizal associations in plant growth and the relative lack of knowledge concerning pesticide-mycorrhizae interactions, further research should include and evaluation of potentially beneficial and detrimental interactions whenever pesticides are incorporated directly to soil or are translocated from the plant into the soil after a foliar application.

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Biological control is defined as the mechanism involved in the management of disease symptoms and reduction of pathogen inoculum on plants, a treatment mediated through the use of organisms other than man. Currently to prevent these crop losses, farmers resort to indiscriminate, and mostly irrelevant crop protection measures, which over the time, have led to serious situations of resurgence in pest populations, increased crop losses and importantly, environment including ground water and foodstuff pollution. There can be cases of resistance development in pest population as well. Use of beneficial rhizobacteria (Plant Growth Promoting Rhizobacteria) having biocontrol (BCA) and plant growth promoting (PGP) activities is a viable alternative to minimize the use of synthetic chemicals and their hazardous effects, and to provide protection to the plants against resident pathogen populations.

PGPR affect plant growth in two ways, directly and indirectly. The direct promotion of plant growth by PGPR entails providing the plant with a compound that is synthesized by the bacterium or facilitating the uptake of certain nutrients from the soil. The indirect promotion of plant growth occurs when PGPR lessen or prevent the deleterious effects of one or more phytopathogenic organisms.

Research on plant growth promoting rhizobacteria (PGPR) over the last three decades has unraveled their efficacy in improving plant growth by increasing seed emergence, plant height, weight and ultimately crop yield (Kloepper et al., 1980, 1986). Among PGPRs, most common are *Acenatobacter*, *Azotobacter*, *Bacillus* spp., fluorescent *Pseudomonas* spp., *Rhizobium* spp., etc. During last decade much of the research, however, has focused on organisms belonging to *Pseudomonas* and *Bacillus* species. These organisms have shown great antagonistic activity against several soilborne pathogens of economically important crops (de Boer et al., 1999; Fernando et al., 2004; Savchuk and Fernando, 2004; Negi et al., 2005; Sirari et al., 2008).

In these organisms biocontrol activity is mediated through the production of antibiotics and lytic enzymes, as well as through competitive exclusion (Duffy and Defago, 1999; Schnider-Keel et al., 2000). The global regulatory two component system, GacS/ GacA is known to positively control secondary metabolite production whih includes phenazine, pyrolnitrin, 2,4-diacetylephlorogucinol, pyoluteorin, HCN, exoprotiases and chitinases (Chancey et al., 1999; Duffy and Defago, 2000).

Diverse populations of PGPRs have been reported to play a major role in plant growth promotion and suppression of root diseases, and are the subject of on going investigations worldwide (Keel et al., 1996; McSpadden et al., 2000, Picard et al., 2000; Negi et al., 2008). Generally, diverse populations of PGPRs provide better resource for the improvement of plant growth promotion and biocontrol ability, as different strains possess varied modes of action and
survival in diverse environmental conditions (Ramesh et al., 2002; Stutz et al., 1986). Equipped with beneficial activities, use of these bacteria is being promoted as a viable alternative to chemical measures, to increase yield and manage diseases in agriculture crops. In response to environment and health concerns about the extended use of pesticides, there is increasing interest in finding such effective alternative approaches for plant growth promotion and management of crop diseases. The biocontrol strains of PGPRs have different molecules and mechanisms to encounter pytopathogens. A few are discussed below.

**Siderophore production**

Iron, one of the most abundant minerals on earth, is an essential requirement for almost all organisms including microbes. To date, the only known exception is lactobacilli, which are devoid of haem proteins, and hence have no iron requirement. However, iron in the soil is unavailable for direct assimilation by microbes because of its unavailable form i.e., ferric iron or Fe$^{3+}$, which is prominent in the soil and sparingly soluble about $10^{-18}$ M at pH 7.4. This amount of soluble iron is too low to support microbial growth in soil, which generally needs concentrations approaching $10^{-6}$ M for normal growth. Consequently to survive in such environments, organisms secrete iron-binding legends (siderophores), which can bind the ferric iron and make it available to the host microbe. These compounds have been identified as “low molecular weight, ferric specific legends, the biosynthesis of which is carefully regulated by iron and the function of which is to supply iron to the cell”.

Siderophore secreted by PGPRs have been shown to have a very high affinity for iron and bind most of the Fe$^{3+}$ that is available in the rhizosphere, and prevent the pathogens present in immediate vicinity from proliferation because of lack of iron. Similarly, siderophore-mediated inhibition of *Pythium ultimum*, *Pyricularia oryzae*, *Rhizoctonia solani* and *Xanthomonas oryzae* has been reported by Seong and Shin (1996) using *P. fluorescens* ps88.

**HCN production**

Cyanide production by rhizospheric pseudomonads has been reported to have a detrimental effect on plant establishment in some crops, but on the other hand, is beneficial in others being suppressive to root pathogens (Defago et al., 1990). HCN production by *Pseudomonas* spp. has been suspected to be involved in the inhibition of potato rot development, root rot of forage legume caused by *P. ultimum* and *R. solani*, *Sclerotinia* wilt of sunflower.

**Production of antibiotics and antifungal metabolites**

Secretion of various secondary metabolites by *Pseudomonas* spp. has been well studied, and found to be inhibitory against different phytopathogens including soil borne fungal pathogens (Weller, 1988). Inhibition of fungal pathogens in the plant rhizosphere was also achieved by *Pseudomonas* spp. equipped with abilities to produce HCN, catalase and siderophore (Table 1). Antibiotic production by fluorescent *Pseudomonas* spp. is considered as an important factor in the disease suppression ability of the organism. The diversity in the type of antibiotics produced by different strains is only now being fully recognized. Antibiotics such as phenazine, pyoluteorin, pyrrolnitrin, tropolone, and 2,4-diacetyl phloroglucinol have been isolated from soil fluorescent
pseudomonads. Moreover, DAPG producing fluorescent *Pseudomonas* spp. were shown to be highly enriched in take-all suppressive soils.

The production of AFMs in *Pseudomonas* is subject to complex regulation. Key factors in the regulation of the biosynthesis of most AFMs are global regulation and quorum sensing. Global regulation is directed by the *gacS/gacA* genes, which encode a two-component regulatory system that senses an as yet unknown signal(s). Quorum sensing involves the production of *N*-acyl homoserine lactone (AHL) signal molecules by an AHL synthase such as LuxI. At a threshold concentration of AHL, which is reached only when a certain density of bacterial cells is present, the AHL will sufficiently bind to and activate a transcriptional regulator, such as LuxR. The activated form of the transcriptional regulator then stimulates gene expression.

**Table 1:** Some of the well-reported fluorescent *Pseudomonas* spp. and antifungal compounds produced by them to exhibit biocontrol against various phytopathogen.

<table>
<thead>
<tr>
<th>Bacterial strain</th>
<th>Origin</th>
<th>Antifungal compound produced</th>
<th>Plants in studies</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. fluorescens</em> F113</td>
<td>sugar beet rhizosphere</td>
<td>2,4-diacetylphloroglucinol (DAPG), siderophore, hydrogen cyanide (HCN)</td>
<td>Pea, Sugar beet</td>
</tr>
<tr>
<td><em>P. fluorescens</em> CHAO</td>
<td>Soil suppressive to black root rot of Tobacco</td>
<td>DAPG, pyoluteorin (plt), hydrogen cyanide</td>
<td>Wheat, Pea Cucumber</td>
</tr>
<tr>
<td><em>P. fluorescens</em> DR54</td>
<td>sugar beet rhizosphere</td>
<td>Viscosinamide, cellolytic enzymes</td>
<td>Barley</td>
</tr>
<tr>
<td><em>P. fluorescens</em> Q2-87</td>
<td>Wheat rhizosphere</td>
<td>DAPG</td>
<td>Pea</td>
</tr>
<tr>
<td><em>P. fluorescens</em> Q8r1-96</td>
<td>Wheat rhizosphere</td>
<td>DAPG</td>
<td>Wheat</td>
</tr>
<tr>
<td><em>P. fluorescens</em> Pf-173</td>
<td>Mustured rhizosphere</td>
<td>Siderophore, catalase, HCN and antibiotics (to be identified)</td>
<td>Wheat, Pea, French bean, Ragi</td>
</tr>
</tbody>
</table>

Spontaneous *gacS* or *gacA* mutants of *P. fluorescens* strain CHA0 have a substantial selective advantage over the wild-type strain when growing in a liquid medium (as has been demonstrated in a nutrient broth medium that contained yeast extract). This can present a severe problem to the production of inoculants. This difficulty can be reduced, however, by mineral amendments or by simply diluting the medium (Duffy and Defago, 1999).

**Genetic Diversity among PGPRs**

Generally, greater diversity of introduced bacterial inoculants results in a diverse but potentially more stable rhizosphere community to colonize the root system and survive against biological, physical and chemical changes occurring in rhizosphere throughout the plant growth. These changes are very likely to occur in rhizosphere of host plant in all growing seasons. Further, diverse populations of PGPRs increase the spectrum of action, as different strains possess different modes of action. Therefore, it is quite reasonable to assume that performance of the isolates of the same genotype will be more or less same depending upon the environment.
provided during characterization. Nevertheless, genetic characterization tends to be necessary to render provide a clearer picture. Different techniques have been employed to assess the genetic diversity among different rhizobacterial PGPRs including biochemical, immunological and molecular tools. A number of PCR based techniques have been devised and are strengthened over last decay. These include RAPD-PCR, BOX and ERIC PCR, Rep PCR etc., which have been used extensively to assess the genetic diversity among PGPRs. Higher diversity level among the pseudomonads was also reported by Raaijmakers and Weller (2001) and Ramesh Kumar et al. (2002) Specific groups could be identified using different molecular tools including RAPD-PCR. Mavrodi et al. (2001) estimated genetic diversity among 123 P. fluorescens using RAPD-PCR, BOX-PCR and correlated identification of 2, 4-DAPG producing strains on the basis of phlD gene by RFLP analysis. Similarly, McSpadden Gardener et al. (2000) developed a rapid and reliable PCR based assay for rapid characterization of 2, 4-DAPG producing Pseudomonas population based on the amplification of phlD gene sequence. Recently, Negi (2006) has shown a tremendous diversity in rhizospheric Pseudomonas population isolated from Uttarakhand hills using RAPD PCR. In this study RAPD-PCR profile could group the different pseudomonads in different lineages on the basis of their host of origin and habitat. The study remarks first large scale characterization of Pseudomonas spp. from Uttarakhand hills.

**Future Prospects**

As our understanding of the complex environment of the rhizosphere, of the mechanisms of action of PGPR, and of the practical aspects of inoculant formulation and delivery increases, we can expect to see new PGPR products becoming available. The success of these products will depend on our ability to manage the rhizosphere to enhance survival and competitiveness of these beneficial microorganisms. Rhizosphere management will require consideration of soil and crop cultural practices as well as inoculant formulation and delivery. Genetic enhancement of PGPR strains to enhance colonization and effectiveness may involve addition of one or more traits associated with plant growth promotion. The use of multi-strain inocula of PGPR with known functions is of interest as these formulations may increase consistency in the field. They offer the potential to address multiple modes of action, multiple pathogens, and temporal or spatial variability.

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Factors Affecting Efficacy of Biocontrol Agents Against Sheath Blight of Rice

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Sheath blight of rice caused by *Rhizoctonia solani* is a potential threat to rice cultivation, causing severe yield losses (up to 69%) to the crop (Naidu, 1992). Due to intensive and changed cultivation practices and use of higher quantity of chemical fertilizers the minor disease like ShB has occupied a prominent place in the disease scenario of the country. In India, first report of the occurrence of ShB of rice was made by Paracer and Chahal (1963) from Gurdaspur (Punjab) and later from Uttar Pradesh (Kohli, 1966). Since then, it has become one of the most common and destructive disease in Kerala and in many rice growing tracts of Tamil Nadu (Kannaiyan and Prasad, 1979). The disease has caused endemic in various parts of M.P. and Maruteru, East Godawari (A.P.) and Cuttack (Orissa) (Gangopadhyay and Chakrabarti, 1982) and Manipur (Mathur, 1983). The organism was identified by Saksena and Chaube (1972) as *Thanatephorus cucumeris* (Frank) Donk (Ou, 1985). Higher ShB incidence has been reported from those rice growing areas where heavy dose of fertilizers are applied to high yielding cultivars which have large number of tillers, resulting in an increase in the humidity near the base of tillers of rice plants (Ou, 1985).

Use of resistant cultivars has not been successful to control the disease because adequate level of host resistance has not been found. Fungicide application is effective, but their use is being discouraged because it is known to cause serious threat to environment, imbalance in the ecosystem and human health hazards. Hence, other disease management methods have to be integrated to realize the maximum yield output from the available rice cultivars. The possible use of fungal and bacterial antagonist(s) against the pathogen has been viewed as an alternate disease management strategy. Although bioagent(s) have been found effective in reducing disease under *in vitro* conditions, but their application in field has given inconsistent and erratic results.

Among the several antagonists tested by various scientists spp. of *Trichoderma*, *Gliocladium*, *Aspergillus* and *Pseudomonas fluorescens* etc. have been found effective in inhibiting the sheath blight. Out of these antagonists, *Trichoderma spp.* and *Pseudomonas fluorescens* were extensively explored for the control of sheath blight. Although, bioagent(s) have been found effective in inhibiting the growth of *R. solani* under *in vitro* condition, they fail to control the pathogen in field in most of the cases due to various seasons. It is because of the fact that biocontrol recommendations may hold promise under certain set of conditions only. Time of application, plant growth stages, the inoculum level and potential of pathogen as well as bioagents, mode and form of application or delivery system of the bioagent etc. play vital role in biocontrol strategy. In the present article an attempt has been made to discuss various factors that
may contribute to biocontrol of sheath blight of rice in transplanted rice by the use of fungal and bacterial bioagents.

Biological control of plant pathogens can be achieved by either promoting the native antagonists to reach a density sufficient to suppress a pathogen(s) or by introducing alien antagonists. Though some of the earlier works, related to promoting the native antagonists was by using organic amendments, the recent trend is to isolate, multiply and introduce the antagonists to soil or specific court of infection to achieve a successful biological suppression of a disease.

**Fungal bio-control agents:**

Several fungal biocontrol agents, *i.e.* Trichoderma, Gliocladium, Aspergillus etc. have gained wide attention due to their ability to control ShB (Khan and Sinha, 2005 a; Sinha and Singh, 2005). Trichoderma sp. colonizing the sclerotia of Thanetephorus cucumeris in a dry land rice field was isolated and tested for antagonism in vitro. Pathogen growth ceased after contact with the Trichoderma sp. which eventually covered the whole plate (Rosales and Mew, 1982). Coiling of hyphae by Trichoderma spp. followed by vacuolation, coagulation of cytoplasm and lysis have been recorded (Rosales and Mew, 1982; Khan, 2003). In vitro test by using different biocontrol agents isolated from soil and irrigated water from paddy fields indicated that A. niger and T. viride were most antagonistic fungi, inhibiting linear growth of *R. solani* (Gokulapalan and Nair, 1984). When, *T. harzianum* was introduced under rainfed conditions, it decomposed rice straw and by replenishing the substrates reduced survival of *R. solani* (Mew and Rosales, 1984).

Manibhushanrao *et al.* (1989) reported that in the antagonistic potential of *G. virens* and *T. longibrachiatum*, there was no specific connection between antibiotic production and mycoparasitic potential of either of biocontrol agents. However, considerable variation in mycoparasitic and antibiotic potential was found between various strains both were able to utilize various components of fungal cell as carbon sources and their mycoparasitic potential was reduced by cycloheximide. Fungi from rice phylloplane were screened for activity against *R. solani* the cause of ShB. Inhibition zone were formed when *R. solani* was grown with *T. harzianum*, *T. viride* and Chaetomium globosum. After seven days, the *Trichoderma* spp. completely over grew and parasitize *R. solani* (Gokulapalan and Nair, 1991).

Dubey (1995) evaluated some fungal biocontrol agents against *R. solani* and showed that *T. harzianum*, *T. viride* and *G. virens* significantly inhibited the mycelial growth and sclerotial production of *R. solani*. Of these, *G. virens* found to be most effective. The spraying with *T. viride* on artificially inoculated rice plants had given significant control of disease (Das *et al.*, 1996). The application of *T. viride* and Bacillus subtilis as seed treatment reduced sheath infection (*R. solani*) of rice in pot experiment in Assam, India. *T. viride* was more effective than *B. subtilis* in reducing infection (Das *et al.*, 1998). It has been definitely shown, however, that *T. harzianum* destroys the rice stubbles/straw on which the pathogen, *R. solani* survives and also parasitizes the sclerotia. So reducing the viable *R. solani* in straw from 100% occurrence in freshly incorporated straw to 20% after two weeks and causing complete removal of pathogen by 16 weeks (Mew and Rosales,
Spraying of Talc+ CMC formulation of bioagents viz., *T. harzianum*, *T. virens*, *T. viride* and *A. niger* were found quite effective against ShB (Khan and Sinha, 2006). A number of commercial formulations of fungal biocontrol agents are available in the market viz Soil gard / Gliogard *G. virens* based product for controlling many soil-borne diseases (Cook 1993), (WRC-AP1) *G. virens* based product for control of Pythium and Rhizoctonia root rot on ornamental plants (Ristaino and Thomas 1997), Trichostar *T. harzianum* based bio-pesticide for controlling *R. solani*, *Fusarium*, *sclerotenia* disease (Mukhopadhyay 1996).

**Bacterial biocontrol agents**

Bacterial antagonists have emerged as an effective most promising means for ShB management. Several bacterial species have so far been tried as biocontrol agents viz *Agrobacterium*, *Actinoplanes*, *Acaligenes*, *Amorphosprangium*, *Arthobacter*, *Azatobacter*, *Bacillus*, *Bradyrhizobium*, *Cellulomonas*, *Enterobacter*, *Erwinia*, *Flavobacterium*, *Micromonaspora*, *Hafnia*, *Pseudomonas*, *Pasteuria*, *Rhizobium*, *Serratia*, *Streptomyces* and *Xanthomonas* (Weller, 1988).

Reports are on hand indicating effectiveness of *Pseudomonas fluorescens* against *R. solani* (ShB pathogen). *P. fluorescens* has been attempted in biocontrol against various diseases because of the properties like its ability to colonize the rhizosphere of plants. short generation time, ability of utilize a large number of organic substrates commonly found in root and seed exudates (Rao and Johri, 1999), relatively easy cultivation under laboratory conditions, mobility as well as potential to produce an array of compounds inhibiting growth of fungal pathogens, compatibility with commonly used pesticides and other biocontrol agents (Hass *et al.*, 1991 and Tripathi, 1999). They can be manipulated by current genetic techniques. Some strains of fluorescent pseudomonads induce systemic resistance and reduce plant diseases (Van Peer *et al.*, 1991). It is well known that different *Pseudomonads* (fluorescent) have different abilities to colonize a particular root-niche (Loper *et al.*, 1985; deWeger *et al.* 1987). There was good colonization of roots of rice seedlings, when *P. fluorescens* was applied as seed treatment (Kamala *et al.*, 1998; Vidhyasekaran and Muthamilan, 1999; Trane *et al.*, 2001). A number of commercial formulations viz. Biomass, Biosheld, Cingaurd, Dagger-G, Deny, Epic-Gus 376, Mycostop, Pant Biocontrol Agent-1, Pant Biocontrol Agent-3 and PfALR2 of bacterial biocontrol agents are available in the market for controlling the diseases caused by *R. solani*.

**Factors affecting efficacy of fungal/bacterial bioagents:**

Scanty information is available in the literature on the factors which may affect the efficacy of biocontrol agent against ShB. Isolate, time, rate mode of application and formulation of bioagent, pathogen inoculum level, plant growth, soil factors, nutrition availability etc. play important role in biocontrol strategy (Singh, 2003). The amendments protected plants gave better control than the antagonists alone. The highest grain yield was obtained with a combination of organic manures and *G. virens*. Plant growth and disease incidence were recorded for 22-days old plant of rice cultivar IR 50 inoculated with 2% *R. solani* and grown in pots in acidic (pH 5.2) or neutral (pH 6.8) soil. Inoculation with 2% *T. harzianum* significantly reduced infection in all
treatments in both seasons, but was more effective in reducing ShB incidence in acidic soils than in neutral soils. Gamliel and Katan (1991) reported that regression analysis showed a significant, inverse relationship between soil pH and increased growth and between soil pH and population densities of fluorescent Pseudomonads in rhizosphere. Disease incidence was also significantly lower when it was applied simultaneously of 7 days before inoculation with *R. solani*. Grain yield increased significantly in the presence of *T. harzianum* when it was applied either simultaneously or 7 days before *R. solani* (Khan and Sinha 2005 b; Singh and Sinha, 2005c). Effectivity of *T. harziznum* against ShB was more in soil having low pH (5.2) as compared to neutral and high pH (Khan and Sinha, 2006).

Harman et al (1991) reported that field application of biocontrol agent is hampered due to absence of suitable technique and carrier/substrates. Farmyard manure (FYM) has been found to be an effective substrate for growth and mass multiplication of *T. harzianum* (Kausalya and Jeyarajan, 1988). Baby and Manibushanrao (1993) observed that both the antagonists (*T. longibrachaeatum* and *G. virens*) and the organic manures, alone or together, reduced ShB. Organic amendment such as green manures, stable manures, and compost can provide the food base and has long been recognized to facilitate the biological control if applied well ahead of planting. *Trichoderma* spp. is reported to be a predominant effective biocontrol agent of *R. solani* in compost prepared from lignocelluloses wastes. Incorporation of *T. harziznum* in soil having soil nutrition P 180 and k 40 showed maximum reduction of the disease. Among different combinations of NPK fertilizers tested on the effectivity of *T. harzianum* on ShB, maximum reduction in ShB was observed with N60P60K40 (Khan, 2005c). Babich and Stotzky (1978) reported that concentrations of Zn$^{2+}$ upto 1 mM did not significantly inhibit the growth of fungi. However, 10 mM Zn$^{2+}$ significantly decreased the mycelial growth of *F. solani, A niger* and *T. viride* and completely inhibited the growth of *R. solani*. The addition of Zn to zinc deficient soils resulted in reduced yield loss in the presence of *R. solani*, a reduction in disease score and no changes in the concentration of nutrients in the shoots. However, under zinc deficiency, increasing levels of added *R. solani* resulted in significant yield loss, and increase in disease score (Streeter et. al., 2001). Soil application of the bioagents in zinc amended soil showed 15.96% disease severity and 30.17% incidence. However, application of bioagents in zinc deficient soil resulted in 20.36 and 32.29% disease severity and incidence, respectively. Soil application of neem cake enhanced the effectivity of the bioagent in increasing seedling emergence and reducing ShB severity and incidence (Singh, 2003).

(Singh and Sinha 2004) tested different isolates of *P. fluorescans* against ShB and found that isolate Pf1 exhibited maximum reduction in disease severity and incidence and increase the grain yield and 1000- grain weight. Talc+ CMC based formulation exhibited maximum reduction of disease severity and incidence than others formulations. (Singh and Sinha, 2005 a). They also tested different combinations of NPK fertilizers on the effectivity of *P. fluorescens* on ShB, maximum reduction in disease was observed with N60P60K40 however, the effectivity was
Application of *P. fluorescens* 7 days before inoculation of *R. solani* was found highly effective in increasing seedling emergence, reducing disease severity and incidence than simultaneous application (Singh and Sinha 2006). Of the three rates viz., 2, 4 and 8 g/litre of the *P. fluorescens* tested against ShB on transplanted rice, higher rate (8 g/litre) was found highly effective in reducing disease severity and incidence and increasing grain yield and 1000-grain weight (Singh and Sinha 2005a).

REFERENCES


Visit to Meteorological Observatory and Automatic Weather Station in Cropped Field at CRC

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Introduction

Since the meteorological instruments in the meteorological observatories are exposed over the short cut grass, apparently the values of some of the important weather variables especially the air temperature, relative humidity, leaf wetness and the wind in particular may differ significantly from those observed in a cropped field. The major meteorological instruments available at meteorological observatory included Stevenson screen to house maximum thermometer, minimum thermometer, dry bulb thermometer and wet bulb thermometer, three soil thermometers each at 5, 10 and 20 cm soil depth, USWB Class A open Pan evaporimeter, Ordinary & self recording rain gauges, Anemometer, Wind vane, Bright Sunshine recorder, dew gauge etc. The data is recorded daily twice a day at 0712 hrs and at 1412 hrs at Pantnagar by IMD trained meteorological observers and record is maintained in pocket registers supplied by IMD. However, the validity of such weather data recorded at meteorological observatory at a location from a field experiment will decrease with the distance from the meteorological observatory. Keeping in view this constraint, for disease-weather relationship it is, recommended & advised to monitor these important weather variables over and within the crops under natural field conditions. These fields have variability in terms of crops their type and stage, soil moisture, ground water table, tillage operations for soil manipulation etc. as compared with the meteorological observatory field. Also detailed and reliable weather information is also not available in many locations in the country due to non-availability of meteorological observatories. For this purpose, a Scientific Automatic Weather Station (AWS) attached with micrologger and Computer will be very useful for recording of weather parameters within and over the crops accurately and then correlate them with crop observations for understanding the real crop - weather relationships in general and disease - weather relationships in particular for major crops of the area. There is a close relationship between crop diseases and weather variables and, therefore, under prevailing weather conditions, the incidence of several diseases may occur in an area and the application of chemicals in these crops will depend on the intensity and durability of the weather conditions prevailing at particular and sensitive crop stage. The details of observations are given below:

A. Meteorological Observatory

A plain area of 55 m (N-W) x 36 m (E-W) size with short cut grasses free from all obstacles including highway, high building, big trees, canals, rivers and wild animals provides a good exposure for installing all the meteorological instruments in the observatory. If a person stands at the gate facing the observatory plot, he will find the tall instruments in the back row and
shorter instruments in the front rows. In general the instruments are separated at a distance of 9 m
from each within rows of 12 m apart. All observations are taken manually by meteorological
observer daily twice a day.

B. Automatic Weather Station (AWS)

A Campbell Scientific Automatic Weather Station has been designed and developed to a
very high standard for reliable measurement and recording of wide range of important
micrometeorological variables in and above the crops. The station is soundly engineered and
based Campbell,s proven 21X micrologger whose comprehensive specification enables the user
to undertake virtually any monitoring task. The main and important features of the system are
described as below:

1. Wide range of sensors: A maximum of 20 sensors can be attached to this at a time.
2. Flexible data storage: It has Internal memory to store 19, 200 data points i.e. hourly data for
   continuous 40 days at a time can be stored.
3. Versatile data transfer: Software package is available for automatic routine collection of data
   at pre determined time interval which can be modified as per the need and requirement.
4. Fully protected: It has a weather proof enclosure to protect data logger and peripheral against
dust and moisture. The logger can operate over the range from - 25°C to + 50 ºC without any
error.
5. Integral data processing: The processing includes the averages of maximum and minimum
   averages of all weather variables, standard deviations, wind vector integration etc.
6. Robust construction: Tripod and mast are built from thick walled, galvanized steel tubing
   with nickle-plated fittings. The mast is 3 metre in height with adjustable cross-arm supports for
   sensors. The mast can be positioned precisely by independently adjusting tripod legs. Each leg is
   provided with a flat foot with 12 mm hole which allows anchorage to the ground by stake or to
   concrete. A lightning conductor and earth spike are also included to save the sensors and
datalogger from destructive effects of Thunderstorm and Lightning as and when experienced in the
area. For measurement of weather parameters in and over the Horticultural crops, a mast of 30
metre height (existing in the nearby site in the same field) can be used for sitting the sensors at
desired heights depending upon the height of horticultural crops as per the need and requirement.
7. Minimum maintenance: Once erected, the station requires very little routine attention.
8. Recording device

It has a 21 X Micrologger as recording device. It is a rugged field-proven datalogger
suitable for any application requiring data acquisition, on line data processing or electronic control.
It is compact and powerful battery-powered device which effectively combines the functions of
micro-computer, clock, calibrator, scanner, frequency counter and controller with one smaller
enclosure. The 12 volt Nickle-Cadmium battery is chargeable by solar pannel. The micrologger is
programmed to handle almost any task including signal averaging, exit and delay, totaling,
maximum and minimum, standard deviation, scaling, 5th order polynomial processing, low-pass
filtering and wind vector calculation which are fully supported by simple program statements, together with a histogram command for direct calculation of frequency distributions. Software support is available to simplify more complex programming tasks and to avoid inspection and processing of stored data.

**Structure, Functioning and Sitting of Various Micro-Meteorological Sensors on Automatic Weather Station**

This Automatic Weather Station (AWS) is composed (Fig.1.) with various micrometeorological instruments / sensors for monitoring the micrometeorological weather variables such as Air temperature (°C), Relative humidity (%), Wind speed (m s⁻¹), Wind direction (degrees from North), Leaf temperature (°C), Leaf wetness ( % of total wet), Solar radiation (W m⁻²), Net radiation (W m⁻²), Rainfall (mm), Soil temperature (°C) etc. within and above the crop canopy. A brief description of sensors measuring these weather variables is given under the following subheads:

1. **Air temperature and relative humidity**
   
The air temperature and relative humidity in and above crop canopy are measured by HMP 35 AC Temperature and Relative Humidity (RH) probes (two sensors). The probe contains a Vaisala capacitive relative humidity sensor and a precision thermistor. The probe is designed to be housed in a 41004-5 or URSI radiation shield and is attached with a 3 m long lead wire and a connector. The length of lead wire can be increased as per the requirement.

2. **Wind speed**
   
   Wind speed in and above crop canopy is measured by A100R Switching Anemometer (two sensors) in which a magnet rotates with the rotor spindle. The varying field forces a mercury wetted reed switch to make contact once per resolution. This instrument is a precision instrument which is easily interfaced with Datalogger to give accurate measurements of wind run or mean wind speed in m/s. This instrument is constructed from anodised aluminium alloy, stainless steels and weather resisting plastics. A stainless steel shaft runs in two precision, corrosion-resistant ball races. The bearings are protected from the entry of moisture droplets and dust, resulting the instrument suitable for permanent exposure to the weather. Its sensitivity is 0.80 revolutions per metre with an overall accuracy of 2 % + 0.1 m s⁻¹.

3. **Wind Direction**
   
The wind direction at 3 m height is measured by W200P Potentiometer Wind Vane (one sensor). This instrument is manufactured by Vector Instruments Ltd. and measures the wind direction directly in degrees from North. The windvane incorporates a 358 degree micro - torque potentiometer (wire wound type). The 2 degree gap is filled to ensure operation and a long service life. The precision ball - bearing races are corrosion - resistant and are protected against the entry of moisture and dust.

4. **Leaf Temperature**
   
The temperature (°C) of leave is measured by K-Type Thermocouples (two sensors).
Copper and constantan thermocouple wires were twisted to form the sensors and are connected to the leaves of the plants. There is provision of adding two more leaf temperature sensors.

5. Soil Temperature

The soil temperature (°C) at 10 and 20 cms soil depths are measured by 107 Thermistor Probes (two sensors). These probes incorporate a precision thermistor in a water resistant probe with a standard 3 m long cable.

6. Leaf Wetness Period

The duration of leaf wetness at crop surface is measured by 237 Wetness Sensing grid. This grid is suitable for a range of Scientific and Industrial wetness sensing applications. It provides a simple measure of the degree of wetness of the surface to which they are attached / exposed and they can also be used to measure the percentage of time for which the surface is wet or dry. The sensor consists of a rigid epoxy circuit board (75 mm x 60 mm) with interlacing gold-plated fingers. Condensation or rain on the sensor lowers the resistance between the fingers which is measured by the datalogger.

7. Solar Radiation

The Solar or Global radiation at 3 m height is being measured by SP1110 Pyranometer sensor (one sensor). This is a compact high - output thermally stable solar radiation sensor. The cosine-rectected head contains a special high grade Silicon Photocell sensitive to short-wave radiation with wavelength between 350 and 1100 nm. The head is completely sealed and can be left indefinitely in exposed conditions. A levelling mount is also available which enables the pyranometer to be accurately positioned. The output is 10 mv / 1000 W m⁻² with excellent linearity.

8. Net Radiation

The net radiation which is the difference between the incoming solar radiation and the outgoing radiation received on the crop surface is being measured by Q-7 Net Radiometer (one sensor). This instrument is high - output thermopile sensor which measures the algebraic sum of incoming and outgoing all-wave radiation (i.e. short- and long-wave components). Incoming radiation consists of direct (beam) and diffuse plus long wave irradiance from the sky. Outgoing radiation consists of reflected solar radiation plus the terrestrial long-wave components. It consists 60 - junction thermopile with low electrical resistance. The top and bottom surfaces are painted black and are protected from convective cooling by hemispherical heavy duty polyethylene windshields.

9. Rainfall

The rainfall is measured by ARG 100 Aerodynamic Tipping Bucket Raingauge (one sensor). It is a well designed tipping bucket raingauge which combines durable construction with very reasonable cost. The gauge offers less resistance to air flow and helps to reduce the sampling errors that inevitably occur during wind-driven rain. This instrument is constructed from UV-resistant, vacuum-moulded plastic and consists of a base and an upper collecting funnel.
The base splits into two parts, the inner section supporting the tipping bucket mechanism and the outer providing protection and allowing the unit to be bolted firmly to a suitable mounting plinth or concrete slab. The gauge resolution is 0.2 mm / tip. the funnel diameter is 25.5 cms.

10. Micrologger enclosure

All the sensors and the logging equipment are supported on a sturdy tripod and mast. A fiberglass housing with lock and key provides as excellent environmental protection for the datalogger and ancillary equipment. Glass fitted nylon water proof connectors are fitted to the base of the enclosure and sensors may be removed or replaced with minimum disturbance to the weather station.

C. Recording & Data Logger Programming in Automatic Weather Station

All these above sensors have been hooked into the 21X Micrologger (Datalogger) which runs through a chargeable battery charged with Solarex Solar Panels. In order to record the output of these sensors, a datalogger programme has been prepared in the Computer depending upon the number of the sensors attached with different channels in the datalogger and also the frequency and time of observations. This has been done with the help of micro -programmes developed in the Computer, and the output is converted into the desired units for each weather variable. Each variable is sensed after each minute and an integrated value over a period of five minutes is calculated. Twelves such values of each data point is totalled or averaged over a period of say one hour and is stored in the memory of the datalogger at an appropriate location at each hour of the day. The data is also averaged or totalled from each day called Julian day (i.e. the day of a year from 1st January) from the date of planting / sowing of the crop in the field. In the present study the recording of micrometeorological weather variables by AWS were started one month before the first sowing of potato crop and continued till the end of the Potato crop season. The crop var. Kufri Bahar which is sensitive to Late Blight of Potato was planted in three dates viz. D1 (24 - 10 - 2009), D2 (08 - 11 - 2009) and D3 (23 -11 - 2009) under four irrigation treatments viz. one irrigation, two irrigations, three irrigations and four irrigations. The observations on micro-meteorological variables in crop field since October 01, 2008 and will continue till harvesting of crop of all planting dates depending upon the maturity of crop in March 2009. The incidence of Late Blight of Potato is monitored on day by day basis and will continue till maturity of crop in all plots. The recording of micro- meteorological data observations is also continuing till date. The current data of this hour can be noted on the provided sheet. At a time, the micro-meteorological data of last 40 days can stored in this datalogger and it can be seen on hourly basis on liquid crystal display (LCD) of the datalogger.

From this data logger each week the micro-meteorological data thus stored in its memory is transferred into the SM 192 Storage Module by connecting it to the 9 - pin serial I / O port. This Storage Module is taken to the laboratory and connected to the Computer. From SM -192 using SC – 532, 9 - pin Peripheral to RS - 232 interface, the data is then transferred into the Computer in ASCII form using SMCOM programmes developed for this purpose in the form of a Computer
file. From this file the data is then split into the hourly as well as into daily values using splitting programmes like SPLIT 03. PAR and SPLIT 04. PAR, respectively, which have also been development on Computer. The data will then be used for identification of micro-meteorological weather conditions conducive for the occurrence of late blight of potato during the 2009-10 season.

**Data Sheet for Recording of Current Observations of Micro-Meteorological Variables in the Potato Field at CrC Using Automatic Weather Station**

The current micro-meteorological weather variables are being recorded by Automatic Weather Station (AWS) in the field from 01-10-2009 and the date of planting of Potato crop var. Kufri Bahar in plot is 24-10-2009 during this Rabi season of 2009 - 10 at CrC Research Centre of the University. The current data can be read on Liquid Crystal Display (LCD) of the Datalogger of the AWS in the table given below in the specific sequence of attached sensors:

1. Name of the crop : Potato
2. Date of 1st planting of crop : 24-10-2009
3. Stage of the crop : Tuber Formation
4. Julian day : 92
5. Date of observation : 02-04-2010
6. Time of observation : 1600 hrs

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<th>S.No.</th>
<th>LOCATION NO.</th>
<th>WEATHER VARIABLE</th>
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<td>%</td>
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</table>

Anil Kumar and Manoj Singh
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Introduction

Important agricultural crops are threatened by a wide variety of plant diseases and pests. These can damage crops, lower fruit and vegetable quality and wipe out entire harvests. About 42% of the world’s total agricultural crop is destroyed yearly by diseases and pests. Conventional methods of pathogen identification have often depended on identification of disease symptoms, isolation and culturing of the organisms, and identification by morphology and biochemical tests. The major limitations of these culture based morphological approaches, however, are the reliance on the ability of the organism to be cultured, the time consuming nature and requirement of extensive taxonomic expertise. Furthermore, diagnosis of plant diseases can be even more difficult with asymptotically infected propagative materials such as tree grafting stocks or potato tubers. Accordingly, there have been significant developments in the area of molecular detection of plant pathogens in the last three decades. The advent of antibody based detection, the monoclonal antibodies and the enzyme linked Immunosorbert assay (ELISA), was an important turning point in plant pathogen detection.

The development of immunotechnique began at the end of 19th century and today they are among the most widely used of the analytical tools globally. They have been applied to an extensive range of substances, from single molecule to whole cells. The basis of antigen-antibody reaction has been extensively exploited to devise techniques to qualitatively and quantitatively detect the presence of different biomolecules with high sensitivity and specificity which constitute as immunotechnique. Any biomolecule that has a complex structure, is protein in nature and possesses high molecular mass (> 1000 Dalton) and internal complexity when injected into an animal body produces specific proteins termed as antibodies. The complex carbohydrates (bacterial LPS or Lipopolysaccharides) and nucleic acids (RNA and DNA) are also immunogenic albeit to a lesser extent. The antibodies have the inherent property to bind to the antigen used to elicit antibody response with high avidity and sensitivity. The purified monoclonal antibodies or polyclonal antibodies generated are use in highly specific and sensitive techniques like immuno-diffusion, ELISA, Immuno- blotting, Immuno-flourescence microscopy, immuno-electrophoresis, etc which were used extensively in past for immuno-analysis.

Immuno-Assays for Detection

Presently, immunoassays are performed routinely, with or without sophisticated instrumentation. With the boom of scientific technology and global monitoring of disease, immunoassay design has become a rapidly growing field. Immunoassays range from simple point-of-care tests for use in the field or doctor’s office to advanced clinical assays being run in high –
throughput instruments with advanced robotics in clinical reference laboratories. Immunodiagnostics use the antigen-antibody reaction as their primary means of detection. Simply stated, the immunoassay concept is to use one analyte—either antigen or antibody to sequester and detect the presence of the other. For example, the antigen from an infectious agent can be used in an external assay to detect the presence of antibodies produced in response to infection by that agent. Some of the common assays used in the detection of plant pathogens are given below:

- Multiwell ELISA
- Dot blot ELISA
- Tissue print ELISA
- Electro blot immuno assay
- Immunofluorescent assay
- Rapid immunofilter paper assay
- Immuno gold labelling
- Radio immunoassay
- Delayed enhanced lanthanide fluorescence immunoassay
- Chemiluminescence vassay
- Bio luminescence immunoassay
- Substrate labelled fluorescence immunoassay

Detection systems can be divided into two types, based on the test format—

- For rapid-type assays, analyte specific visual detection agents, such as reagents conjugated to colloidal gold or selenium or colored latex—type particles, are used. These particles are sensitive, but usually not as sensitive as ELISA.
- For instrument–compatible assays such as ELISAs, a solid or liquid phase system is most desirable. In this format various enzymes, including horseradish peroxidase, alkaline phosphatase, and beta-galactosidase can be conjugated to analyte specific reagents. Following the analyte reaction, certain enzyme activities are studied using a sensitive substrate. This can include either chromogenic, fluorogenic or chemiluminescence-generating substrates, which are typically detected by light-absorbance measurements (optical density). In addition analyte specific reagents can be coupled directly to a fluorescent, chemiluminescent or bioluminescent tag.
- This new generation of detection agents provides extremely sensitive detection systems that can be used with high throughput instrumentation and are helpful in developing simultaneous multianalyte assays.

Some examples of Immuno-assay

**Quantitative detection of plant viruses**

ELISA has been used to assay for a variety of plant viruses and several other plant pathogens. We applied the Positive-negative threshold to ELISA for potato leaf roll virus (PLRV) in
Development of polyclonal antibodies for the detection of Aflatoxigenic mould(fungus):

Fungi are one of the principal cause of reduced quality in stored grains and foods. Use of immunological techniques in Mycology provided a review of immunosorbent assays in plant pathology but dealt chiefly with the use of ELISA for detecting plant viruses.

Studies involving immunological assays, which make use of antibodies (either Monoclonal Antibody or Polyclonal Antibody) to detect common food and grain inhabitants have also been conducted, and some of them have been aimed at detecting Mycotoxigenic fungi involving Penicillium.

Immunoblotting is used for detection of plant pathogenic bacteria

Immuno-PCR for the detection of Woody plant Pathogen

The method has been successfully used in the development of highly Sensitive Reverse Transcription – Polymerase chain Reaction (RT-PCR) techniques for the detection of a number of viruses in their Woody hosts. The viruses detected included Apple Stem Grooving Capilloviruses (ASGV), Apple Stem Pitting Virus, Prunus necrotic ringspot ilarvirus (PNRSV), Grape Vine fanleaf and Arabis Mosaic Nepoviruses, and Grapevine Leafroll – associated Closterovirus types.

Immunological methods for KB detection developed at Pantnagar

In our lab we have developed antibody and DNA-based as well as biophysical methods for KB diagnostics. Among the serological methods are micro-titre ELISA, Immunofluorescence staining test (IFST), Seed immunoblot binding assay (SIBA), and Dyed latex bead agglutination test and immunodipstick assay.

Micro-titre ELISA

It is being used for early detection of KB pathogen in the host when the infection levels are very low, in-planta proliferation of pathogen, determination of fungal biomass in infected tissues, characterization of genetic races, based on their immuno-reactivity pattern.

Seed Immunoblot Binding Assay (SIBA)

To check out the teliospore concentration on the wheat seeds at the time of vigour testing, a technique called seed immunoblot binding assay (SIBA) was developed and optimized (Kumar et al., 1998). The principle behind this technique is that when the infected seeds are kept on the nitrocellulose membrane, the teliosporic antigens are adsorbed and diffused according to the teliosporic load on the nitrocellulose sheet. These sheets are immunoprocessed using anti-teliosporic antibodies (primary) and goat anti-rabbit immunoglobulin IgG conjugated with alkaline phosphatase (secondary) for which a substrate NBT/BCIP is used. The coloured imprint develops and appears to have a direct correlation with the grade or severity of KB infection on bunted grains.

Immunofluorescence assays

In immunofluorescence, pathogen specific antibodies are conjugated with fluorescent dye molecules, commonly fluorescence isothiocyanate or rhodamine isothiocyanate. Antigens present
in samples bound to microscopic slides are made visible by means of a fluorescence microscope. This type of fluorescence assay is called direct immunofluorescence assay. Specific antigen antibody reaction may be visualized by addition of labeled antibody directed against the primary antibody in a specific reaction. This is called indirect immunofluorescence assay. The indirect method has an advantage of utilizing a single labeled antibody to detect many different antigen-antibody reactions occurring within a given species. Indirect assay is more specific than direct assay. The procedure is based on the principle of indirect ELISA where polyclonal antibodies are raised against the surface teliosporic antigens and binding is monitored by a goat-rabbit antibody conjugated to a fluorescien label. The teliospores can be seen as bright green, patchy and ring shaped fluorescence under the microscope(Gupta et al, 2000).

**Dyed Latex Bead Agglutination Assay:**

The dyed latex bead agglutination test developed in our laboratory is considered better for detection of solubilized teliosporic antigens over intact teliospores of KB. The teliosporic antigens are solubilized using sonication and detergent extraction and are allowed to adsorb on the surface of blue colour dyed latex beads, which are then immunoprocesed using polyclonal anti-teliospore serum. Positive agglutination reaction reflects the presence of KB infection. The method has the advantage as it is more economical, rapid and user friendly with an absence of pseudo-agglutination which is the most important factor for on-site diagnostics single step test (Kesari, et al., 2005). The test has the sensitivity to detect solubilized teliosporic antigens equivalent to 750 intact teliospores and it is suitable for immunodetection of different grades of infected seeds having teliospores mass ranging from 1000 to more than 10,000. Hence this seed health testing procedure could also be used for single seed analysis.

**Immuno-dipstick Assay:**

The immuno-dipstick Assay developed in our lab is sensitive enough to detect the teliospore antigens as low as five teliospores (Kesari and Kumar, 2003).

**ADVANCED IMMUNO –TECHNOLOGY**

**The Hybridoma-Technology**

The advent of hybridoma technology has provided the immunotechnologist a finely tunable instrument that should permit a marked advance in the immunological sciences. Using an antibody with a specific affinity and recognition for a specific antigenic determinant can greatly influence the shape and range of a radioimmunometric calibration curve. With monoclonal antibodies, assay systems based on immune complexes (e.g., turbidimetric assays and counterimmunoelectrophoresis) can be made more precise, thus permitting study of the basic physicochemical principles underlying the antigen-antibody reaction and the development of greatly improved quantitative assays. The ability to choose the precise antibody required and the virtually unlimited availability of easily purified antibodies have already resulted in the simultaneous immunometric assay and potential reagents for immunodiagnostics. This technology is revolutionizing the field of immunodiagnostics tremendously and have bright future to use these
monoclonal antibodies in the development of modern tools which include immuno-flow cytometry, lateral flow immuno diagnostic assays based on nanogold particles and quantum dots and immunosensors.

**Biosensors/Immunosensors**

Biosensors are analytical devices which combine a biological recognition ligand with physical or chemical signaling devices (transducers). The recorded biomolecular interactions are transformed into digital signals which are interpreted by a computer-aided readout, thereby providing the user with a representation of the interaction that occurs between the bound (ligand) and free (analyte) entities. Many different sensor formats have been utilised for pathogen analysis using antibodies; namely electrochemical, mass-based, magnetic and optical. The sensitivities of these assays are depend upon the properties of the transducer and the quality of the antibody.

**Electrochemical Immunosensors**

The principle behind these assay formats is the coupling of a specific antibody with an electrode transducer which functions to convert a binding event into an electrical signal. In general, electrochemical biosensors can be based on four transducer types; namely amperometric, impedimetric, potentiometric and conductimetric.

**Mass-Based Immunosensors**

Piezoelectric biosensors operate on the principle that a change in mass, resulting from the biomolecular interaction between two entities, such as an antibody and its respective antigenic determinant, can be determined.

**Thermometric and Magnetic Immunosensors**

In thermometric biosensors thermistors are frequently selected as temperature transducers. Magnetic biosensors, in contrast, implement magnetic beads coated with a suitable ligand that can be detected within a magnetic field.

**Optical Immunosensors**

Surface-plasmon resonance (SPR) is a phenomenon that results from the illumination of a metallic surface, such as gold, by visible or near-infrared radiation from a monochromatic light source via a hemispherical prism which exits to a detector (photodiode array) at an angle related to the refractive index (RI). The resultant oscillation of free electrons generates surface plasmons (electromagnetic waves) which resonate and absorb light. The specific wavelength/angle at which this occurs is a function of the RI in the proximity of the gold surface and relates to the mass on the chip surface. A change in mass, effected by the immobilisation of a ligand and, subsequently, further interactions which take place when analytes are passed over the modified sensor surface, causes a shift in the resonance to a longer wavelength and, hence, introduces a refractive index change.

**Conclusion**

There is an urgent need to develop reliable, user-friendly and inexpensive diagnostic
tools and vaccines for countering infectious diseases world wide. Monitoring Potential Pandemics has become increasingly difficult with today’s global migration patterns, and effective isolation of a disease requires quick diagnosis. Furthermore, the specificity and sensitive of a test must be of the highest quality to be fully adaptable. The Considerations for immunoassays design presented here represented an overview of the multifaceted development process.

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Pathogen Population Considerations in Developing Durable Disease Resistance: A Case Study of Rice Blast Pathosystem

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Rice (Oryza sativa L.) is a staple food for over 2 billion people, providing 20% of human food calories. “Blast”, caused by the heterothallic ascomycete Magnaporthe grisea (Hebert) Barr. (anamorphe: Pyricularia grisea Sacc.) is the most important disease of rice and can cause severe losses in most rice-growing environments. Although only known to reproduce asexually in nature, the pathogen is notorious for its pathotypic diversity. Disease resistant rice cultivars are the preferred means of blast management, considering that most rice farmers are poor and that effective fungicides are quite costly. However, resistance in such cultivars is frequently short-lived. Typically, a variety released as blast-resistant shows signs of susceptibility after only very few seasons of cultivation in blast-prone environments.

Resistance “breakdown” is usually ascribed to extreme diversity and/or virulence variability in the pathogen. In the case of extreme diversity, it has been proposed that much of the observed resistance breakdown resulted from simple “escape” due to inadequate challenge in screening nurseries. That is, either because conditions are not suitable for disease development, or if some pathotypes are so rare as to not encounter a compatible line, lines may be incorrectly interpreted to be ‘resistant’. As a breeding line is multiplied for release and eventually planted over large areas, chances increase for encounter between compatible pathotypes and the new variety. With a large host population the previously rare pathotype reproduces rapidly, and the observed ‘new’ susceptibility of the cultivar is interpreted as a resistance ‘breakdown’.

There is some evidence for escape being an important phenomenon in the lack of durability of blast resistance. By conducting a blast resistance breeding program in a site with a highly diverse pathogen population and an environment that supports continuous blast epidemics, durably resistant cultivars could be developed. One such cultivar, Oryzica Llanos 5, has been grown continuously over thousands of hectares for over 15 seasons in a severely blast-prone environment. Furthermore, it has been evaluated in a number of countries across the world and found to be highly resistant in all sites.

The question of pathotypic variation has long been controversial. At one extreme the pathogen was described as hypervariable, with the capacity to generate a seemingly endless array of new pathotypes from a single asexual spore. Thus, varieties evaluated for resistance to a single pathotype would be exposed to an infinite range of pathogenic variation once released into the field. A variety stood little chance of surviving under the onslaught of such variation, and the reasonable conclusion was that race-specific resistance to the pathogen could not yield durable resistance. This led to a major effort to develop race non-specific, or partial, resistance. At the other extreme, the pathogen was described as completely stable, with no new races generated
even after years of culture in the laboratory. It is noteworthy that the proponents of hypervariability worked with isolates from Asia (the center of origin of rice), recently recovered from the field, while proponents of stability worked largely with isolates from the US (where rice was introduced only a few hundred years earlier) and that had been in culture for a number of years.

Blast populations are very diverse, regardless of the mechanisms (genetic or otherwise) that generated the diversity, and the design of most breeding programs is such that a blast-resistant variety is simply not exposed to pathogenic variants that it would likely encounter under production conditions. In other words, real-world rice varieties would be exposed to populations of the pathogen, not just one or two races.

**Virulence variation in pathogen populations**

Plant pathologists and plant breeders have long understood the importance of pathogen variation to the effectiveness and durability of host resistance. Pathogen genotypes can interact with specific host genotypes leading to the "breakdown" of resistance within very short periods of time. Detection of pathogen variation has traditionally relied upon the identification of virulence variation (races) in the pathogen population by inoculating a sample of pathogen isolates on a series of hosts with defined resistance genes (differentials) and observing the resulting compatible or incompatible disease phenotype. This approach to monitoring pathogen populations has been tremendously valuable in the development and deployment of host resistance, and has provided important insights into the evolution of pathogen populations in response to selection by host resistance genes. Pathotype monitoring is still used extensively in many pathosystems today and continues to provide timely information about the structure of pathogen populations that is relevant to breeding programs and resistance deployment.

**Limitations on the use of virulence phenotype**

Despite the obvious value of pathotype data, the use of virulence phenotypes to assess genetic variation in plant pathogens has several important limitations. Host differential lines used in virulence assays are often poorly defined genetically. A common set of differentials must be used among labs to obtain comparable data, and assays are subject to environmental variation. A more important limitation is that virulence variation in plant pathogens is almost always determined in terms of virulence phenotype rather than genotype, which means that frequencies of virulence genes cannot be estimated from these assays. This lack of genetic information coupled with the fact that virulence phenotypes are subject to strong selection by the host limits the value of virulence markers as population genetics tools.

**Molecular markers in pathogen population analysis**

Lately, plant pathologists interested in genetic variation in pathogen populations have adopted the use of molecular markers as population genetics tools. Motivating this shift has been the availability of a myriad of molecular techniques which makes the quantification of genetic variation a relatively straightforward endeavor. Molecular markers such as allozymes, restriction fragment length polymorphisms (RFLP) and random amplified polymorphic DNA (RAPD) have
been extensively used to characterize pathogen populations. More recently, amplified fragment length polymorphisms (AFLP) have proven to be highly polymorphic and robust markers and will likely be used extensively with plant pathogenic fungi in the future. In contrast to virulence and fungicide resistance markers, molecular markers are presumed to be selectively neutral and therefore may be used to study evolutionary processes in addition to selection.

The discovery of a neutral repetitive DNA sequence, MGR (for Magnaporthe grisea repeat) in the rice blast pathogen in the late 1980s provided a means of analyzing populations independently of the pathogenicity of the constituent isolates. The similarity of the MGR "fingerprints" generated by analyzing the DNA of different isolates permitted an estimate of their relatedness. Initial analysis of archival US P. grisea isolates revealed a direct relationship between fingerprint type (subsequently referred to as lineages) and pathogenic races. Application of this analytical tool to the Santa Rosa population yielded a less direct, but intriguing, relationship between lineage and race: Sets of closely related races fall within a single lineage and the race constitution of lineages differed. Furthermore, in what had been described as an extremely race-diverse population, all isolates could be grouped into only six lineages. This led to the suggestion that rice breeding could focus on selecting for cultivars that combined resistance that was effective against the virulence spectrum of all lineages in a target population.

**Lineage exclusion**

This breeding approach, referred to as "lineage exclusion", assumes that P. grisea populations are comprised of a few number of discrete lineages and that these lineages have different and stable virulence spectra. These assumptions were tested in two populations from blast resistance screening nurseries in the Philippines. It was found that, as in Colombia, there were relatively few lineages comprising the populations. Analysis of lineage virulence spectra (i.e., the virulence of isolates on sets of isolates with known and different resistance) revealed that they were indeed different. "Composite pathotypes" could be created for a lineage by considering any compatibility within a lineage as reflecting the virulence capacity of that lineage. Comparing the composite pathotypes of all the lineages of a population could predict what combination of resistance would be effective across the entire population. In the case of the Philippines, a combination of resistance genes Pi-1 and Pi Z^5 (Pi-2) should yield resistance effective across all lineages.

A similar analysis in Santa Rosa (Colombia) also predicted that the same two genes should yield broad-spectrum resistance. This was tested by crossing two sources of resistance and then evaluating the progeny in the field (exposing them to a diverse, well-characterized population) and in the greenhouse (exposing them to isolates representing the full virulence spectrum in all lineages in the population). As expected, progeny resulted with full spectrum resistance in both greenhouse and field evaluations. Based on this positive result, parents in crosses for blast resistance in Santa Rosa have been selected to combine complementary resistance. This has yielded an significant increase in the efficiency of the breeding programs.
How effective can lineage exclusion be as a breeding tool for obtaining durable blast resistance world-wide? A few critical issues suggest that with present technology, all areas may not be suitable for its adoption. The situations in the Philippines and Santa Rosa may be somewhat atypical in that these populations are from areas where modern varieties have been grown and, because of a bottleneck effect of earlier deployed blast resistance, the pathogen population may be much simpler than those populations in other rice-growing regions. i.e. if populations are very complex it could be practically impossible to characterize the virulence spectra of all lineages. Furthermore, for lineage exclusion to yield durable resistance, lineages should be genetically isolated from one another so that virulence genes cannot be exchanged among lineages.

A population analysis of *P. grisea* from a traditional rice-growing area of northeast Thailand revealed a very complex population: 49 lineages were identified from 527 isolates, and most were represented by only one or a few isolates. No obvious relationships between pathotype and lineage were discerned within these samples using either lines near-isogenic for resistance genes or cultivars with known resistance. Very high lineage diversity was also observed in the Indian Himalayas and very high pathotypic diversity was observed in the Himalayan Kingdom of Bhutan, although the corresponding lineage data are sketchy. It would be impossible to determine the virulence spectrum of lineages comprising these populations. The problems however notwithstanding, the analysis of the NE Thailand population revealed the same complementary effectiveness of resistance genes Pi 1 and Pi z5.

An important assumption of the lineage exclusion approach is that there is no gene flow across or genetic recombination among lineages. Several lines of evidence suggest that this may not be the case in some areas. Reports of sexually fertile field isolates from India, China, and Thailand indicate that the capacity for sexual recombination exists in nature. Population structure and dynamics of Indian Himalayan populations are consistent with sexual recombination having influenced populations there. There is also the possibility that horizontal flow of genes, including those mediating resistance to entire lineages, can occur across lineages via non-sexual, or parasexual, means.

Despite indications that there may be very large areas over which a population analysis-based lineage exclusion breeding strategies may not be appropriate, there is ample evidence that population analyses can yield valuable dividends. First, in most cases examination of the virulence spectra of the most common lineages should indicate to breeders which crosses are unlikely to yield durable blast resistance, thus increasing their efficiency. Second, the repeated conclusion that the gene combination Pi 1 and Pi z5 is effective across very different populations suggests there is something fundamentally limiting to *P. grisea* carrying compatibility to both genes simultaneously. As more blast resistance genes are identified and placed in near-isogenic backgrounds population analyses will enable us to identify other broadly effective gene combinations. Finally, there are large and important rice growing areas where *P. grisea*
populations are relatively simple. These may be where rice has only recently been introduced, or
where very large areas have been planted to a few varieties carrying several major resistance
genes. Breeding strategies for these areas should be adjusted accordingly.

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Sclerotinia sclerotiorum: Biology, Epidemiology and Eco-friendly
Management of White Mold of Rajmash

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*Sclerotinia sclerotiorum* (Lib) de Barry, belonging to subdivision -Ascomycotina, class
Discomycetes, order-Helotiales and family- Sclerotiniaceae infects over 400 plant species.
Mycelium is hyaline, septate, much branched and both intra and intercellular. It grows by polar
elongation of its cells at the tip. This growth form gives rise to spreading and tunneling habit that
make fungi much successful colonizers of diverse substrate. The hyphae are 9-18 µm broad and
filled with dense protoplasm. No true conidia are produced.

Biology

When the vegetative growth has ceased the hyphae collect in small dense masses which
gradually become brown to black sclerotia. Sclerotia are globose to cylindric (2-15x2-30mm),
depending on where they are formed in or on the plant.

Apothecium

One or more apothecia may arise from sclerotium. Apothecia are light tan colour. Asci are
cylindrical, have a thickened apex and contain 8 ascospores. Ascospores are 4-6x9-14 µm,
uniseriate, hyaline, ellipsoid and biguttulate. It requires high moisture and senescent tissue serve
as nutrient sources for spore to germinate and infect plant tissues.

Sclerotal development

Sclerotia are quiescent, multicellular aggregates of vegetative hyphae that function in long
term survival. After sufficient vegetative growth, sclerotia develops. In culture plates inoculated
from the centre, they are most commonly observed forming sclerotia in a ring around the edge of
the plate.

Types of sclerotia

Three types of sclerotia are produced in *S. sclerotiorum*

1. Normal black sclerotia produced on various hosts are black with relatively smooth surface.
   Each sclerotium consists of three distinct tissue layer – a thick walled pigmented rind, a
   thin walled cortex and a white medulla. The medulla makes up the bulk of the sclerotal
   volume.

2. The abnormal sclerotia were wrinkled with a severely fractured rind and a brown medullary
   tissue.

3. Tan sclerotia lack melanin and are consequently brown in colour and produce albino
   apothecia, whereas normally melanized sclerotia are black and produced light brown
   apothecia.

Survival of Sclerotia

When sclerotia were air dried and stored at 20°C for 62 months, viability was reduced to
15% for abnormal and 65% for normal ones. Tan sclerotia survived poorly in soil compared to
normal black sclerotia. Both abnormal black and tan sclerotia were prone to microbial degradation.
Melanized cell walls and intact rind are important for increasing resistance of sclerotia to attack by microorganisms and improving survival of *S. sclerotinum* under unfavourable environmental conditions.

**Germination of sclerotia**

(i) **Carpogenic germination**

Sclerotia of *S. sclerotiorum* germinates carpogenically as well as myceliogenically. Carpogenic germination depends on temperature and soil moisture.

A cold conditioning period at 4°C is usually required to trigger carpogenic germination when sclerotia are produced at temperatures higher than 20°C. Soil moisture also has a significant effect on carpogenic germination of sclerotia of *S. sclerotiorum*. The number of apothecia produced by sclerotia on the soil surface or sclerotia buried at 1 cm in depth was the greatest at a water matric potential between -0.11 and -0.4 bar (1 bar = 100 kPa). This range of moisture is generally regarded as “Field capacity”, where soil contains moisture and oxygen adequate for most organisms. At water matric potential < -1 bar, sclerotia on the soil surface showed a lower percentage germination than those buried in soil.

(ii) **Myceliogenic germination**

High humidity is required for myceliogenic germination of sclerotia. Myceliogenic germination of sclerotia is associated with the degree of black melanin pigment deposited both external to, and within the cell walls of the rind. Myceliogenic germination of black sclerotia occurs in the presence of exogenous nutrients. However, in the absence of exogenous nutrient, myceliogenic germination occurs only in tan sclerotia which lack the black pigment. Myceliogenic germination also occurs among sclerotia produced on cultures amended with melanin inhibitors tricyclazole and pyroquilon.

**White mold of rajmash**

White mold, also known as sclerotinia blight is caused by *S. sclerotiorum* (Lib.) de Bary. This fungus attacks a wide range of hosts and has a world wide distribution on numerous field crops and vegetables. White mold frequently causes serious and unpredictable yield losses in beans (*Phaseolus vulgaris* L.). Crop losses may reach 100%. The disease typically becomes serious in crops that have a dense canopy, in field with a history of the disease and in seasons when cool, moist conditions occur during and after flowering.

**Symptoms**

Infected flowers may develop a white, cottony appearance as mycelium grows on the surface. Lesions on pods, leaves, branches and stems are initially small, circular, and water soaked but rapidly increase in size. Under moist conditions, these lesions may develop a white, cottony growth of external mycelium. Affected tissues dry out and bleach to white. Hard black sclerotia develop in and on the infected stem and pods. Entire branches or plants may be killed.

**Disease cycle and epidemiology**

Sclerotia may survive in soil for 5 or more years. Under suitable conditions of temperature, light and moisture, sclerotia within 5 cm of the soil surface germinate to produce a stipe(s) which develops an apothecium(a). Ascospores are released from turgid ascii by ‘puffing’. Ascospores
germinate and colonize flowers and other tissues that are senescing and the mycelium from colonized tissues invades adjacent organs. Flowers parts often fall onto pod, leaves, branches and stems and provide nutrients required by the fungus to penetrate these organs. Infected tissues are rapidly killed and become dry and bleached. Sclerotia form in or on infected tissues and may fall to the soil, remain in crop debris or be removed with harvested seeds or pods.

Sclerotia are preconditioned for carpogenic germination by exposure to moist, cool (4°C) or freezing conditions for several weeks. To produce apothecia, preconditioned sclerotia require moist soil (water potentials greater than -5 bars) at temperature of 11-20°C. Apothecia can produce ascospores for 5-10 days. Apothecia generally do not develop or persist until a dense crop canopy has formed to provide cool, moist microclimate. Ascospores are released by physical disturbance of apothecium. Most ascospores produced within a field are deposited within the crop canopy. Dissemination of the pathogens occurs by aerial transport of ascospores, irrigation water or infested seed. Ascospores can survive on plant surface for up to 2 weeks and mycelium in infected blossoms may remain viable for a month. Disease develops most rapidly at 20-25°C in the presence of moisture.

Management
Sowing dates

Rajmash sown on 25th October produced maximum disease incidence followed by 5th November sown crop. However, the crop sown on 5th November gave maximum yield (15.51 q/ha). At wider row spacing (40 cm), through the incidence of white mold was low than 30cm row spacing but yield was higher at 30cm row spacing. No disease was observed when the sowing was delayed to 25th November but yield was very poor. Minimum disease incidence of 25.62 per cent was recorded in 40 cm row spacing i.e. the widest spacing, grain yield was maximum in 30 cm row spacing (15.29 q/ha) followed by 25cm and 35cm row to row spacing.

Amendment of soil with saw dust @ 10 q/ha, one week before sowing was found to be the most effective in reducing the sclerotinia blight and showed 33.00 per cent disease control and gave maximum yield of rajmash. Saw dust inhibited 48.9% mycelial growth of *S. sclerotiorum* and checked sclerotia formation completely.

Two spraying of Bavistin (Carbendazim 50 WP) 0.1% proved the most effective and gave maximum disease control (70.02%) and highest yield followed by Kri- benomyl. First spraying was done at pre-flowering and second at full bloom. Pre bloom spray applications of Benlate 50 WP provided more effective control than did sprays applied at full bloom in Canada. Post bloom spray applications were generally ineffective. A spray programme consisting of a pre bloom spray followed by a full bloom spray provided outstanding control in all tests. A pre bloom spray plus a post bloom spray was no more effective than the pre bloom spray alone.

**Antagonism between Trichoderma and Sclerotinia sclerotiorum**

* T. viride, G. virens and T. harzianum were antagonistic to *S. sclerotiorum* and overgrew the colony of test fungus and completely inhibited the formation of sclerotia but *T. viride* parasitized the test fungus earliest. The rate of mycoparasitism was faster in *T. viride* and it showed 67.35 per
cent over growth on the colony of *S. sclerotiorum* in 72 hours. *T. viride* and *G. virens* exhibited sensitivity to carbendazim fungicides (Bavistin and Kri-Benomyl) and showed complete inhibition of growth at 50 μg/ml. However, *T. viride* showed 69.62 per cent tolerance to Thiophanate methyl at 100 μg/ml.

An integrated disease management schedule synthesized for management of this disease for NEPZ is given below:

- Selection of plant type with thin canopy and upright characteristics.
- Delay sowing (10th Nov.) and wider row spacing (35 cm).
- Seed treatment with Carbendazim (0.2%).
- Two foliar spraying of Carbendazim (Bavistin) @0.1%, first at pre bloom and second at full bloom.
- Integration of delay sowing, wider row spacing, seed treatment with Thiophanate methyl (Roko) @0.2% and soil application of farm yard manure preparation of *T. viride* in another option.

In addition to above, site selection, field sanitation, destruction of infected crop debris and deep ploughing during summer should also be followed.

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Mango Malformation: Does the threat continue?

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With 120 years of existence, malformation disease of mango continues to be one of the most serious plant diseases threatening mango cultivation in different countries of the world. However, ever since understanding of the disease was reviewed as a ‘Century Old Disease’, significant progress has been reported towards establishing the cause of the disease though not as many reports emphatically claim a successful disease management.

Symptoms of disease are associated with hormonal imbalance in the host that results in misshapen growth of both vegetative and reproductive parts of the tree. Vegetative malformation includes hypertrophy of young shoots, shorter internodes, dwarfed malformed leaves and an overall tightly bunched appearance of the shoot. Inflorescence malformation includes short, thick and branched axes of the floral panicles, larger flowers containing increased numbers of male and hermaphroditic flowers that are either sterile or eventually abort. Malformed inflorescences do not bear any fruit, resulting in great economic losses.

The etiology of mango malformation disease was controversial for many years and many factors have been suggested as causal agents of disease such as: nutritional deficiencies, hormonal imbalance, viruses, phytoplasmas, fungi and mites. *Aceria mangiferae*, the mango bud mite, was hypothesized as the causal agent of mango malformation for over 40 years mainly due to high numbers of mites observed in malformed trees, and also because other members of the Eriophyoidea are known to cause proliferation, “witches broom” and gall symptoms of inflorescences in other plants. Despite the fact that the fungal theory was well established following Koch’s postulates with several fungi, certain members of the genus *Fusarium* have been shown to cause the disease. It is also clear now that *A. mangiferae* is not the causal agent of mango malformation, however, various studies suggest that the mite interacts with the fungal pathogen resulting in increased severity of disease.

*Fusarium subglutinans* has been associated with mango floral and vegetative malformation, although confusion exists regarding the etiology of the disease. A wild-type isolate of *F. subglutinans* causing mango malformation disease was transformed with the GUS (β-glucuronidase) reporter and hygromycin resistance genes. Five stable transformants were isolated containing varying copy numbers at different integration sites. Specific GUS activity was quantified for the transformants, whereas no activity was recorded for the wild-type isolate. The transformants and the wild-type isolate were inoculated into healthy mango floral and vegetative buds. Typical symptoms of misshapen shoots with short internodes, stubby leaves, and gainy, malformed inflorescences were observed 6 to 8 weeks following inoculation. The presence of GUS-stained mycelium of the pathogen viewed microscopically within infected plant organs provided unequivocal evidence that *F. subglutinans* was the causal agent of mango malformation disease.

Based on nuclear and mitochondrial DNA sequences, a new species, *F. mangiferae*, has
now been established which included strains of *F. subglutinans* from Egypt, Florida, Israel, Malaysia, and South Africa, some of which had been shown to cause malformation disease by artificial inoculation. However, till date at least three additional taxa have been associated with mangomalformation disease: *F. sterilihyphosum* from Brazil and South Africa, and *Fusarium* sp. nov. and *F. proliferatum* (teleomorph: *Gibberella intermedia*) from Malaysia. Though, Koch's postulates have not been completed with them. In the future, gene sequencing will be essential to identify the *Fusarium* spp. that are associated with mango malformation disease.

*A. mangiferae*, initially described in Egypt, is commonly found within closed generative and vegetative mango buds in both malformed and healthy trees. These mites disseminate by wind from opening buds, land passively on a random tree, and actively find their way to mango buds. Thereafter, the mite settles and begins feeding by penetrating its stylets into the epidermal cell wall, creating shallow wounds of approximately 2 to 5 μm in depth. *A. mangiferae* was identified in both healthy and diseased trees and, in the absence of a direct correlation between the mite and mango malformation, it was proposed that mango malformation might result from an interaction between the mite and *F. mangiferae*. The role of the mango bud mite, *Aceria mangiferae*, in carrying conidia of *Fusarium mangiferae*, vectoring them into potential infection sites, and assisting fungal infection and dissemination was studied. Following the mite's exposure to a green fluorescent protein-marked isolate, conidia were observed clinging to the mite's body. Agar plugs bearing either bud mites or the pathogen were placed on leaves near the apical buds of potted mango plants. Conidia were found in bud bracts only when both mites and conidia were co-inoculated on the plant, demonstrating that the mite vectored the conidia into the apical bud. Potted mango plants were inoculated with conidia in the presence or absence of mites. Frequency and severity of infected buds were significantly higher in the presence of mites, revealing their significant role in the fungal infection process. Conidia and mite presence were monitored with traps in a diseased orchard over a 2-year period. No windborne bud mites bearing conidia were found; however, high numbers of windborne conidia were detected in the traps. These results suggested that *A. mangiferae* could carry and vector conidia between buds and assist in fungal penetration but do not play a role in the aerial dissemination of conidia between trees.

Inoculum availability and conidial dispersal patterns of *Fusarium mangiferae*, causal agent of mango malformation disease, were studied in an experimental orchard at Israel. The spatial pattern of primary infections in a heavily infected commercial mango orchard corresponded with a typical dispersal pattern caused by airborne propagules. Malformed inflorescences were first observed in mid-March, gradually increased, reaching a peak in May, and declined to negligible levels in August. The sporulation capacity of the malformed inflorescences was evaluated during three consecutive months. Significantly higher numbers of conidia per gram of malformed inflorescence were detected in May and June than in April. Annual conidial dissemination patterns were evaluated by active and passive trapping of conidia. A peak in trapped airborne conidia was detected in May and June for both years. The daily pattern of conidial dispersal was not associated with a specifically discernable time of day, and an exponential correlation was determined between mean relative humidity (RH) and mean number of trapped conidia. Higher
numbers of conidia were trapped when RH values were low (<55%). The study suggested airborne dispersal of *F. mangiferae*, that served as the primary means of inoculum spread. Thereof, it may be plausible to direct control efforts toward either reducing inoculum load or protecting trees from primary infections during the dissemination period.

Studies were conducted to investigate aspects of the epidemiology, survival and spread of the pathogen in general and specifically in seedlings, the majority of which are cultivated in infected orchards in Egypt. Survival of conidia of a representative isolate (506/2) declined very rapidly in soil under summer conditions (1·6 weeks for 50% population decline), but significantly less in controlled and winter conditions (17·9 and 15·0 weeks, respectively, for 50% population decline). Likewise, inoculum survival in naturally infected panicles on the soil surface declined faster than in those buried at 30-cm depths. Natural infections were evaluated on fruits and seeds in a heavily infected and a healthy orchard. In infected trees, the skins of all sampled fruits within a 2-m radius of infected panicles were infected, but the pathogen was not detected in the seeds, seed coats or flesh. The pathogen was not detected in any parts of fruits from a healthy orchard. Vegetatively malformed mango seedlings, growing under infected trees bearing infected panicles, were sampled in two locations in Egypt to determine whether infection in seedlings was systemic (evenly distributed within plant tissue) or whether the pathogen originated from malformed panicles. According to PCR-specific primer amplification, the pathogen was detected in 97% of seedling apical meristems, declining gradually to 5% colonization in roots. It was concluded that inoculum of the pathogen originates from infected panicles and affects seedlings from the meristem, with infections descending to lower stem sections and roots. Minor infections of roots may occur from inoculum originating from infected panicles, but the pathogen is not seedborne. While it was apparent that the fungus does not seem to be spread systemically throughout the tree, *F. mangiferae* may be windborne, being distributed in infected orchards only when sufficient inoculum is available, or spread with the aid of the mango bud mite, *Aceria mangiferae*.

A possible cycle for mango malformation disease caused by *F. mangiferae* has been proposed. Malformed inflorescences and malformed vegetative growth serve as a source of inoculum. Inoculum from infected panicles and malformed vegetative tissue disseminate passively in the air as conidia or fall from dry, malformed inflorescences as dry debris. Most of the conidia fall on the mango canopy and reach the infection site by at least three different routes: falling by chance on the apical bud, being vectored on the body of the bud mite *A. mangiferae*, or via conidia in dry debris falling into the funnel-like structure of the apical buds. Other possible routes, not tested in this study, could also assist conidia in reaching the apical bud (e.g., transport of conidia in dew droplets or splash dispersal of conidia from leaves to buds, although the latter route probably does not occur in Israel due to lack of rains in the early summer months when conidial dissemination takes place). Conidial germination and infection of apical buds may occur if appropriate conditions are met: temperatures of 5 to 41°C accompanied by at least 2 h of wetness. Moderate temperatures of 15 to 30°C and longer durations of wetness >3 h may accelerate the infection process. Presence of *A. mangiferae* inside the buds assists fungal penetration and increases frequency and severity of infection. After penetration, the pathogen colonizes the bud...
tissue but does not progress beyond this point. Apical buds could either differentiate into a reproductive inflorescence following appropriate exposure to cold temperatures or remain vegetative and develop into a young shoot. Inflorescences from a colonized bud may emerge malformed, probably due to a build-up of the pathogen until an infection threshold is met. Alternatively, when a young shoot emerges from an infected apical bud, the pathogen may colonize the apical or lateral buds of the young shoot, then remain localized and dormant in buds until bud break. This young shoot may show symptoms of vegetative malformation or bear the pathogen within bud tissue without showing typical disease symptoms. The study sheds light on infection dynamics and colonization patterns of *F. mangiferae* in infected mango trees. Protecting apical buds from airborne infections and maintaining strict sanitation in the orchard by immediate removal of malformed tissues may contribute to an improved management strategy for mango malformation disease. Thus the most effective measures for managing disease spread are to maintain a pathogen-free environment by using ‘clean’ nursery stock, to avoid grafting of budwood (which may harbour the pathogen latently) from infected orchards, and to practice a strict sanitation programme of removal and destruction of infected material.

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Epidemiological Approaches to Disease Management through Seed Technology

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Introduction

The quality of planted seeds has a critical influence on the ability of crops to become established and to realize their full potential of yield and value. A complex technology is required to ensure high standards of seed quality that involves producing, harvesting, processing, storing and plating the seed.

Throughout this process, careful handling to avoid mechanical injury and protection from adverse environmental conditions, pests, and diseases are imperative. No one factor is necessarily more important than another with respect to maintenance of seed quality but almost all seed crops require some measure of disease control. The knowledge of the epidemiology of seed diseases can promote disease management through modern Seed technology.

Disease impact on seed management systems

Seed Pathology emerged as a sub-discipline of plant pathology from analysis of seed quality in the early part of this century.

Since then a world wide process of cataloguing microflorae of seeds have been associated approximately 2400 microorganisms with the seeds of 383 genera of plants. Concurrently epidemiological studies were carried out on the seed-borne phase of economically important diseases e.g. bacterial blight of beans, smuts of cereals and Stewart’s wilt of corn. There are three environments in which seed exists:

A. The seed production field
B. Harvesting, processing and storing and
C. The planted field.

A. The seed production field

Disease can have an indirect effect on seed in the production field in that the seed is not associated in any way with the pathogen but other plant parts are diseased; this renders the plant physiologically ill equipped to complete the development and maturation of the seeds. Direct effects means that the seed itself is diseased, thus the viability and appearance of the seed is affected and/or the pathogen is transmitted to the plant grown from the seed.

(a). Seed infection in Seed production field

Seed infection can occur during the three distinct physiological phases in the seed production field; anthesis, which covers the period from initiation of floral primordia to fertilization of the embryo; seed development, which represents the period during which the fruiting structures grow and develop to full physiological maturity; and seed maturation, which is the dry down period that continues until the seed is harvested.
Each phase has unique characteristics with respect to the epidemiology and management of seed disease.

(b). Management of seed borne diseases in seed production field

- Elimination of Inoculum Sources
- Disease management during anthesis
- Disease management during seed development
- Disease management during seed maturation

Elimination of inoculum, sources

The first opportunity for management of seed diseases is to eradicate or reduce pathogen inoculum in the seed production field for e.g. Removal of crop residue (Phomopsis seed decay of soybean). Removal of Infected weeds as perennial source of contamination (Brassica seed fields by X. campestris pv. Campestris in Brassica ). Destruction of infested seeds, the primary source of inoculum, by burning or by vacuuming fields (for ergot in perennial grass seed production fields).

Disease management during anthesis

The optimal time for Fusarium moliniforme infection of maize kernels by silk inoculation occurs when silk begin to senesce. The infection process also may be influenced by environment. Rain and warm temperature following anthesis resulted in increased grain mold contamination of caryopses of sorghum. Knowledge of the mechanism and environmental influences on infection at this growth stage has been used to advantage in disease management. Several group of pathogens including smuts, ergots, viruses, and nematodes infect seeds during anthesis. A unique feature of infection at this growth stage is the facility for infection of embryos and other internal seed tissues. Embryo invasion by viruses from the mother plant is dependent on short-lived cytoplasmic connections to the male or female gametophytes. The potential for biological control during antesis was demonstrated by inoculation of wheat florets with a stain of C. purpurea that did not biosynthesize ergot alkaloids, but had sufficient parasitic vigor to displace alkaloid-producing strains.

Disease management during seed Development

Seed infection during seed development can occur by invasion through natural openings including the funicle and micropyle, by direct penetration of the seed or caryopsis, or from pods or freshy fruits. Infection also can be strongly influenced by environment. Osorio & McGee showed that exposure of soybean pods to frost at --4.5 or -25°C immediately before physiological maturity predisposed seed to infection by Fusarium graminearum and Alternaria alternata but reduced seed infection by Phomopsis longicolla. More over there are numerous reports of fungicide applications in seed production field to control seed borne pathogens. But more strategically these studies are rarely considered in disease epidemiology. The pod infection occurs at any time from flowering onwards for number of seed borne pathogens e.g. in Phomopsis seed decay of soybean, X.campestris pv. Vignicola but the fungus will not infect seeds until seed maturation begins. This
disease epidemiological aspect may be used as predictive methods of fungicidal application. Cultural practices provide options to manage seed diseases in the production field; adjustment of planting time, crop rotation, elimination of weed hosts, irrigation practices etc. Bean intercropped with maize than on bean grown alone showed higher seed borne population of P. syringae pv. phaseolicola (Mabagala and Saettler 1992). Biological control of seed infection during seed development was demonstrated by the reduction of aflatoxin B1 in the cotton seed after simultaneous inoculation of wounded cotton ball with toxigenic and atoxigenic strains of Aspergillus flavus.

**Disease management during seed maturation**

Certain fungi, such as Fusarium moniliformae in corn, Botrytis, Alternaria, Cladosporium sp. commonly infest the soil and crop residues and may invade seed under prolonged periods wet weather at seed maturation growth stage and cause seed discoloration and loss of viability. Weathered seed experience physiological deterioration as well as pathological damages. Effective control of disease during seed maturation is achieved by harvesting the seed as soon as it is sufficiently dry.

Planting dates may be manipulated to avoid conditions favorable for seed infection as in the case of Phomopsis seed decay of soybeans in which the chances of temperature and humidity conditions favorable for seed infection occurring are much lower for late compared to early planted crops (McGee 1987). There are few examples for breeding specifically for resistance to infection of the seeds. E.g. a genotype resistance to Phomopsis seed decay and sources of resistance to Cercospora kikuchii, the cause of purple seed stain of soybean have been identified (Brown et al. 1987, Roy 1982). Grain Hardness, ergosterol content, and tannins have been implicated in resistant to moulding of Sorghum grains (Bosman et al., 1991).

**B. Harvesting Conditioning and Storing**

The harvesting process provides opportunities for pathogen structures, such as sclerotic, nematode soil peds, and teliospores to contaminate seed lots.

This type of contamination can be minimized by setting the harvesting equipment to avoid contact with the soil and to eliminate physically altered seeds or pathogen structures. Seed when passed over air screen cleaners and gravity separators help to reduce the fungal sclerotia or infected seeds (Phomopsis infected seeds of soybean and plant debris). Paulsen 1990 used a computer vision system to detect purple stained soybean seed infected with Cercospora kikuchii with 91% accuracy. Walcott developed an ultrasound signal to detect asymptomatic infection of Aspergillus and Penicillus spp. in storage in soybean.

**1. Disease management during storage**

Storage fungi (Aspergillus and Penicillus sp.) invade grains and seed stored at moisture contents in equilibrium with ambient relative humidity ranging from 65-90% and can cause major losses in seed viability.

Effective management of storage fungi invasion is obtained by drying of seeds below the
minimum moisture contents for storage fungi invasion and maintaining this moisture content by aeration.

The effectiveness of this practice often breaks down, however, when seed is held in storage facilities with poor environmental controls.

A few examples of management of storage fungi during seed storage are:

Soybean oil applied to reduce growth of storage fungi in maize and soybeans (McGree1988). Insect and storage fungi management by mineral oil and soybean oil treatment in beans (Hall and Harman 1991)

The fungicides thiabendazole and Iprodione supress growth of storage fungi in stored corn (White and Toman 1994). The potential for natural products (Flabonoids and Isoflabonoids, and their derivatives) to control storage fungi for seed of bean and soybean is demonstrated by Weidenborner et al., 1990.

2. Seed Health testing

Seed health testing is used primarily to manage diseases by inoculum threshold, to determine the potential effect of seed borne inoculum on stand establishment in the planted field, and to meet the requirements for phytosanitary certification of seed lots to be exported. For seed health testing following methods are routinely used:

Field inspection

It requires that the seed production field be examined for symptoms of a disease on growing plants. The method is based on the assumption that incidence of infection on plants and seed are related. Although there are few diseases where this relationship has been validated, procedure remains the back bone of Phytosanitary certification in many countries.

Direct seed assay

Seed may be examined visually for clear signs or symptoms expressed on the seed surface. Another approach is to soften seed tissues and then examine the internal tissues of the seed microscopically for mycelium of the pathogen.

Incubation test:

It requires that the seed be subject to conditions that select for and optimize growth of target pathogen. Assay usually require pretreatment with a chemical to surface disinfect the seeds, followed by incubation on blotters or culture medium under precisely defined environmental conditions.

Grow out test:

Seed are planted in the field or green house in the absence of other inoculum sources. Seedlings are examined for symptoms produced by the seed borne pathogens. The procedure requires much time, space, and labour. It also tends to lack sensitivity, but it can predict well the extent of seed transmission of Pathogens in the planted field.

Serological assays:

Serological assays for seed borne pathogens were first reported in 1965 with an
agglutination test for Pseudomonas phaseolicola in beans (Guthrie at al 1965) and double diffusion assay for barley stripe mosaic virus (Hamilton 1965). The introduction of ELISA to plant pathology in 1976 stimulated rapid advances in the use of serological assays for seed borne pathogens. With diagnostic kits now available from the private sector for ELISA and its variants, serology has become cost-effective and practical to detect seed borne pathogens throughout the world. However, a well known weakness in serological tests has been the propensity to detect false positive caused by the binding of antibodies to epitopes, which may no longer be a propagule of the pathogen which can be overcome by combining serological assay with a viability test.

**DNA hybridization assay**

DNA hybridization assay use a DNA probe that is complementary to DNA in the genome of the plant pathogen. The probe is applied to a DNA extract from seed and hybridized material detected by dot blot hybridization assay. The technique has successfully used to detect Peronosclerospora sorghi and P. sacchari in corn (Yao et al 1990) Pseudomonas syringae pv. Phaseolicola in bean seeds.

**C. The planted field**

1. **Seedling emergence and establishment**

   There are sound epidemiological bases to establish relationship between seed borne pathogens and seed quality and this impress upon the use of seed treatment to improve seed vigor and reduce the seed borne inoculum for better plant stand in field.

2. **Transmission of seed borne pathogens:** transmission of seed borne pathogens by following factors:

   a. **Epidemiological factors affecting seed transmission:**

      Seed transmission for some seed borne pathogens is well defined. Few most promising fungal pathogens such as Ustilago tritici, Neovossia indica, Telletia caries, Peronospora parasitica in rape seed mustard, and many seed borne bacteria and viruses.

      Physiological factors may affect the capacity of the seeds to transmit pathogens. Few examples are: Downy mildew pathogen in maize can be transmitted when seeds are freshly harvested, but not once the seeds are dried (Mc Gee 1988.) Arabis mosaic nepovirus is transmitted inefficiently in Nicotiana seed, because the virus reduce seed germination.

      Environmental factors play a major role in the efficiency of seed transmission of plant pathogens.

      The seed borne inoculum of Alternaria brassicaceae or A. brassicicola in rape seed mustard reduces with the seed storage and at temperature above 35°C the fungus is auto-eliminated in tropical conditions. In Cabbage seedling disease caused by Alternaria brassicicola for e.g does not occur below 15°C in heavily infected seed lots.

   b. **Inoculum threshold**

      Inoculum threshold have been established on a sound epidemiological basis for only a few pathogens, including Phoma lingum in Crucifers, Pseudomonas syringae pv. phaseolicola, and
lettuce mosaic virus. For many seed borne pathogens, inoculum threshold is determined either arbitrarily or by field observation data (Schaad 1988). To be of value, however the threshold should be established in well designed experiments. The first step is to have a suitable seed health assay. But very few methods are thoroughly researched to determine if they are specific, accurate reproducible, and practical.

The next step is to plant seed with different infection level in the field and establish a correlation with plant infection.

For diseases that have no repeating cycle of infection such as seedling infecting smuts, strong correlation between seed infection and field diseases can usually be expected. It is much more difficult to establish inoculum threshold for diseases for which secondary infections occur from other inoculum sources.

c. Certification Programme

This programme exists to protect against spread of disease by seeds within geographic regions. In this programme seed lots must meet certain minimum standards of quality which includes specific diseases, before seed can be marketed.

This programme uses knowledge of the epidemiology of the disease that includes laboratory assays of the seeds and field controls.

d. Phytosanitary certification

The system has some serious problems, however phytosanitary regulations are determined by individual countries and often are made on the basis of a poor understanding of the economic losses that introduction of particular pathogens could potentially incur; minimal knowledge of relationship between tolerances in seed assays to risks of transmission of the pathogen to the planted crop; and lack of standardized testing protocols.

e. Germplasm

International Agriculture throughout the world's are taking steps to minimize the introduction and spread of exotic seed borne pathogen by seed exchange.

Several international centers have implemented programs to manage seed borne pathogen through monitoring pathogens in the seed lots, modification of seed production practices to minimize the infection or transmission of pathogens by seed and use of seed treatment.

f. Seed treatment

Chemical, physical and biological seed treatment has dramatically changed in the last 20 years. As a result of new fungicide chemistry, advances in biological control and environmental regulation that have either banned or restricted the use of fungicides. Fungicide seed treatment remains the most widely used practice and established materials such as captan and thiram still are the mainstay of seed treatment chemistry. Several systematic fungicides such as metalaxyl, iprodione and triadimenol are being used for management of deep seated infections in seed and subsequent protection of seedling against infection.

Chemical control of seed borne bacteria has limited success, either because of lack of
control of internal inoculum or phytotoxicity to the seeds. Antibiotics, applied in polyethylene glycol (PEG), reduced infection by Xanthomonas campestris pv. phaseoli in bean seeds, but were phytotoxic.

Heat treatment, hot water treatment or microwave heating has successfully reduced seed borne infection.

There is numerous report of potentially valuable biological control microorganism for seed treatment but the developmental process to bring these into commercial practice is long and arduous. Mode of application of seed treatment with chemicals is also an important area to be discussed.

Traditional dust or slurry application of seed treatment fungicides are now regarded as inefficient in environmentally hazardous.

Application of chemical or bio pesticides in film coatings or pallets reduces the loss of material and allows the delivery of multiple products. Bio- protectants and chemical pesticides provided effective control when added together in solid matrix priming.

g. Resistance

No example could be found of resistance especially to seed transmission of fungal or bacterial pathogen in the planted field. However cultivar specific resistance to seed transmission has been reported for BSMV in barley, PsbMV in peas, SMV in soybeans and AMV in alfalfa.

Conclusion

A review of the literature on seed pathology over the period (1982-94) indicates that almost a quarter of approximately 2000 citations simply catalogued the presence of microorganisms on seed. These purely descriptive commentaries do not address the potential for crop damage by planting diseased seeds or the management of seed borne diseases.

Indiscriminate cataloguing of seed-borne microorganism on seeds obscures seed-borne pathogens that might be of genuine economic importance. Viruses and bacteria that traditionally have been neglected for lack of adequate assays.

Priority should be given to pathogens that meet the criteria of limited distribution and of potential economic importance, as in the class of maize chlorotic mottle.

Research on inoculum thresholds is both complex and expensive, but it is so fundamental to realistic and effective management of seed transmission of plant pathogens that little improvement in the seed health system worldwide will be possible unless priorities in seed pathology research are changed. “Guidelines for safe movement of germplasm”, sponsored by the International Board for Plant Genetic Resources, can lead to management system for seed diseases that protect against the spread of economically important plant pathogen without posing unnecessary barriers to the movement of seeds.
Microbial Inoculants for Sustainability

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The ever increasing population in India as well as in world demands the enhanced food production to fulfill the requirement. To meet this challenge there is no alternative other than intensive agriculture which dictates the global food supply. In India the marginal as well as the medium size farmers are forced by the circumstances to reduce the complexity of their agro ecosystems in a venture of enhanced production. Intensification in agriculture results in the reduction in above-ground biodiversity leading to an altered biological regulation of soil processes substituted by mechanical tillage, synthetic fertilizers and pesticides. The unabated use of chemicals and heavy tillage machinery is supposed to reduce the belowground biodiversity. The above and below-ground biodiversities are interlinked and complimentary to each other. Crop productivity is dictated by the ability of the roots to extract water and nutrients efficiently from the soils while the function of the root is governed by integrated set of biological processes. Soil is a habitat of a myriad diverse population of organisms forming below-ground diversity which is responsible for varying activities contributing to maintenance and productivity of agro ecosystems through their role in biogeochemical cycles.

Ecosystems in nature are generally in equilibrium state and have the capacity to sustain over a long period. However, the interventions for enhanced agricultural production carried out during the green revolution era disturbed ecosystem vis-à-vis deteriorated quality of natural base mainly soil and water. The certain concerns due to intensification of agriculture are:

- With agricultural expansion: soil degradation
- With use of fertilizers and agrochemicals: environmental pollution
  - nitrate contamination of soil and groundwater by leachates
  - microbial denitrification converts residual nitrogen into the greenhouse gas nitrous oxide (Nosengo, 2003; Reay, 2004).
  - excess phosphorous compounds leach into groundwater, rivers and streams-promote algal growth and other environmental problems: eutrophication
  - Disturb/ loss of below ground biodiversity
  - Pollution
- With increase in irrigation: soil salinization
- With deforestation and excessive ploughing: emission of CO2 into the atmosphere
- With increase in production: excessive reliance on fossil fuel energy

To achieve a balance and make the agro ecosystems sustainable maintenance of above and below-ground diversity in cropping systems is widely accepted management practice (Swift and Bignell, 2001). Such management practice of improving the biodiversity provides a buffer to farmers against short-term risks making the soils sustainable.
Aspect of sustainability

The challenge of meeting the need for food could only be achieved through intensification of the agriculture using modern technologies considering the sustainability aspects (Borlogue and Dowswell, 1994). Sustainable agriculture addresses the judicious management of varying natural resources satisfying the changing human needs while maintaining/improving the quality of natural resource base and environment. Among the various natural resources soil is the prime which supports the above-ground and harbors the below-ground biodiversity. If the soil is sick it reflects immediately on the tiny creatures of the soil i.e. microbes and thus soil biological properties would indicate the wellbeing of the soil. Healthy soil is a prerequisite for sustained crop production which concomitantly improves/maintains the balance between above and below ground biodiversity. The sustainability of overall agro-ecosystem can be achieved through enhanced relationship between above-and below ground biodiversity which would reestablish the biological system in soil for ensuring essential biological functions. Microbial inoculants is one of the most important component of management practices for sustainability for all categories of farmers.

What are microbial inoculants?

Microbial inoculants are the preparations of one or most efficient species of microorganism screened and evaluated for various activities such as organic matter decomposition, nitrogen fixation, P-solubilization/mobilization, K-solubilization, plant growth promotion, pest control etc. in suitable carrier (e.g. powder, liquid or pest).

Why microbial inoculants?

- Fertilizer use is inadequate, imbalanced and poorly managed.
- Neither chemical fertilizers alone nor the organic sources exclusively can achieve the production sustainability.
- The interaction advantage of combined use of organics and inorganics has been well established.
- INM is helpful in arresting the emerging deficiency of nutrients other than N, P and K.
- Improve the physical, chemical and biological environment of soils and bring economy and efficiency in fertilizer use.
- INM’ concept is economic and environment friendly.
- Synthetic pesticides cause environmental pollution and threats human health; sustenance of natural resources

Microbial inoculants comprise mainly biofertilizers and biocontrol agents.

Biofertilizers

Biofertilizers are the preparations containing live or latent cells of microorganisms, alone or in combination in a particular carrier, which increase crop productivity by way of helping in biological nitrogen fixation, solubilization of insoluble plant nutrients, stimulating plant growth or decomposition of plant residues. In recent years biofertilizers are gaining popularity due to health awareness among the consumers. The slogan of the 21st century is organic farming for safe and
quality food production. Throughout the world the concept of organic farming is being accepted in
developed and developing countries. However, the countries like India having about 1.2 billion of
population cannot afford to give up the intensification in agriculture and opt for organic farming
fully. To meet the challenge of feeding the ever increasing population in India Integrated Nutrient
Management supply system has been well researched and being adopted which is having the dual
capability of sustaining the soil health and enhanced food production. Microbial inoculants are one
of the most vital component of organic as well as integrated nutrient supply system due to
following advantages:

- Cost effective and eco-friendly
- Renewable and potential source of nutrients
- Solubilize and mobilize nutrients and replace 25-30 % chemical fertilizer
- Sustain soil health through improved below-ground biodiversity
- Required in less amount
- Easy in handling, transportation, application & farmers’ friendly
- Increase grain yield: 10-40 %
- Decomposition of plant residues
- Give long term benefits

**Types of biofertilizers**

Biofertilizers are classified based on the function carried/ nutrient made available by the
microorganism(s) in it. Broadly they are grouped into four groups (Table 1).

**Table 1. Types of biofertilizers and potential microorganism(s)**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Type</th>
<th>Microorganism(s) involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td><strong>Nitrogenous biofertilizers</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. Symbiotic</td>
<td><strong>Rhizobium, Frankia</strong></td>
</tr>
<tr>
<td></td>
<td>b. Asymbiotic</td>
<td><strong>Azotobacter</strong></td>
</tr>
<tr>
<td></td>
<td>c. Associative</td>
<td></td>
</tr>
<tr>
<td></td>
<td>d. Phototrophic</td>
<td><strong>Azospirillum</strong></td>
</tr>
<tr>
<td></td>
<td>e. Obligate endophytic</td>
<td><strong>Blue Green Algae (BGA) or Cyanobacteria</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Acetobacter diazotrophicicus</strong></td>
</tr>
<tr>
<td>II.</td>
<td><strong>Phosphate supplying biofertilizers</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. Phosphate solubilizer</td>
<td><strong>Bacillus megaterium var phosphaticum, B. polymyxa, Aspergillus awamorei</strong></td>
</tr>
<tr>
<td></td>
<td>b. Phosphate mobilizers</td>
<td><strong>Mycorrhizae (ecto mycorrhizae and Arbuscular mycorrhizae)</strong></td>
</tr>
<tr>
<td>III.</td>
<td><strong>Cellulose decomposers</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Cellulomonas, Cytophaga, Trichoderma, Chaetomium, Aspergillus, Nocardia, Streptomycyes etc.</strong></td>
</tr>
<tr>
<td>IV.</td>
<td><strong>Plant growth promoting rhizobacteria</strong></td>
<td></td>
</tr>
</tbody>
</table>
|         |                                           | **Pseudomonas, Serratia, Bacillus, Acetobacter etc.**
Nitrogen fixing bacteria (Diazotrophs)

Symbiotic root/stem nodule bacteria

Among the various physiological functions of microorganisms BNF plays a prominent role in sustaining the overall productivity in nature. *Rhizobium* has a special place among the diazotrophs as it forms symbiotic association with legumes. It has been widely studied and extensively used as a well known agronomic practice to ensure adequate nitrogen nutrition of legumes in place of fertilizer N and known to substantially improve the crop yields. Approximately 35 per cent of the total biologically fixed nitrogen comes through the legume-*Rhizobium* symbiosis (Burns and Hardy, 1975). The biological nitrogen fixation is an efficient source of nitrogen (Peoples *et al.*, 1995) and needs to efficiently used for improving the health of soil vis-à-vis crop productivity. Besides this rhizobial inoculants are also known to leave behind substantial amount of nitrogen in the soil for succeeding crop (Raverkar and Konde 1988). The benefit left over by preceding inoculated legume crop to succeeding cereal crop in terms of fertilizer N equivalents, range from 20 to 123 kg N ha⁻¹.

In non-leguminous crops the nitrogen fertilizer could be economized in addition to the other plant growth promoting benefits through employment of *Azotobacter/ Azospirillum*. Under field conditions in India *Azotobacter* inoculation improved the crop productivity in the range of 0-25 percent over the control in the absence of any amendments and by 8.75 per cent in the presence of NPK. The result of 401 unreplicated trials on the use of *Azotobacter* indicated that the crop productivity of oil seed crops increased to an average of 14.88 per cent.

A group of microorganisms has a capability to render the insoluble soil phosphorus in to plant available form. The application of phosphate solubilizing microorganisms as biofertilizer in various crops economized 30-35 kg P₂O₅ ha⁻¹. The response of different crops to various biofertilizers is depicted in Table 2.

**Table 2. Response of biofertilizers in farmers field (Mean of 1050 demonstrations spread over 25 states)**

<table>
<thead>
<tr>
<th>Biofertilizer (s)</th>
<th>Total No. of sites</th>
<th>Mean response (% increase over UC)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Rhizobium</em></td>
<td>153</td>
<td>Pulses 15.14, legume oilseeds 14.81, legume vegetables 17.47</td>
</tr>
<tr>
<td><em>Azotobacter</em></td>
<td>401</td>
<td>Rice 9.25, wheat 11.0, millets 9.71, oilseeds 14.88, sugarcane 8.84, vegetables 8.89, fruit crops 6.37, fiber crops 11.44, plantation crops 3.74, flowers 8.78</td>
</tr>
<tr>
<td><em>Azospirillum</em></td>
<td>96</td>
<td>Rice 10.8, millets 10.17, oilseeds 14.29, sugarcane 8.96</td>
</tr>
<tr>
<td>PSM alone</td>
<td>44</td>
<td>Wheat 8.04, millets 9.57, pulses 12.38, oilseeds 10.27, vegetables 11.08, fiber crops 16.60</td>
</tr>
<tr>
<td><em>Rhizobium</em> + PSM</td>
<td>40</td>
<td>Pulses 13.39, oilseeds 12.87, legume vegetables 17.61</td>
</tr>
<tr>
<td><em>Azotobacter</em> + PSM</td>
<td>160</td>
<td>Rice 16.0, oilseeds 12.20, flowers 26.32, fiber crops 13.37</td>
</tr>
<tr>
<td><em>Azospirillum</em> + PSM</td>
<td>70</td>
<td>Rice 14.20, wheat 16.67, vegetables 22.93</td>
</tr>
</tbody>
</table>
Blue Green Algae

These are also called cyanobacterial inoculants. These are one of the primary colonizers and primitive forms on the earth. Due to their phototrophic nature they grow abundantly wherever sunlight, water and even limited nutrients are present. During 1930 it was reported for the first time that fertility of rice fields in India is maintained due to the occurrence of cyanobacteria. The cyanobacteria are known to increase rice yield under flooded conditions by fixing atmospheric nitrogen and release of growth promoting substances for crop. It also control weed by forming algal mass and fix 20-50 kg N/ha/season. Besides above benefit, it found to improve soil texture by adding organic matter and amino acids. It increases rice yield by -30 per cent.

Azolla

Azolla is water fern having symbiotic relationship with blue green algae Anabaena azollae. It has been used as a green manure in rice for centuries in southern China and northern Vietnam. Azolla benefits farmer as well as soil in many was as below:

- It harbours a N fixing BGA
- Can grow in shallow water to produce large biomass
- Each kg Azolla can fix 1.9 to 2.5 kg N in one month
- Azolla contain about 3.0-5.0 % N on dry weight basis
- One crop of Azolla of 25-30 days gives benefit equivalent to 30-40 kg N/ha
- Can be used in rice crop by two ways: Green manure or as Dual crop
- The limitation in Azolla use is scarcity of water and high temperature in north India.

Phosphate Solubilizers

Next only to nitrogen phosphorus is a vital element for plants and microorganisms. The inorganic forms of the element in soil are compounds of calcium, iron, aluminum and fluorine while the organic forms are compounds of phytins, phospholipids, nucleic acids which come mainly by way of decaying vegetation. Most of the soils contain large amount of phosphate but much of it is not available to plants. Phosphate in insoluble forms that are not free for plant growth is said to be “fixed”. The reactions that fix phosphate depend on soil pH. In strongly acid soil (pH 3.5-4.5), insoluble iron phosphate and aluminum phosphates are formed. Calcium phosphate is important between pH 7.00 and 9.00. The availability of phosphorus to majority of crops range between 6.0-7.0. The microorganisms offers biological rescue system capable of solubilizing the insoluble inorganic phosphorus of soil and make it available to plants. The phosphate solubilizing microorganisms includes several bacteria, fungi, actinomycetes as well as cyanobacterial spp. The most efficient phosphate solubilizers are Pseudomonas striata, Bacillus polymyxa, Bacillus megatarium, Aspergillus awamori, Penicillium digitatum etc. Some PSM also produce plant growth hormones like I.A.A, G.A. etc. The inoculation with PSM provides 15-20 kg P/ha/season and increases yield of crops by 10-20 per cent. The mechanisms of solubilization are either through localized pH reduction in the vicinity of rhizoplane and rhizosphere due to organic acid(s) produced or chelation of metal and release of phosphorus.
Phosphae absorber/ mobilizer

Mycorrhizal fungi

Mycorrhiza is a symbiotic association between plant roots and fungal mycelia, which is similar to that of root nodule bacteria in legumes. The fungi takes carbohydrates and photosynthates from the plants for its growth and in turn supplies the plant with mineral nutrients, water, hormones etc. and protect it from root pathogens. Mycorrhizal association increases the surface area of the root system for better absorption of nutrients from soil especially phosphorus. There are two types of mycorrhiza viz., Ectomycorrhiza and Endomycorrhiza. In agricultural and most of the horticultural plants arbuscular mycorrhiza (AM) is predominant which forms special structures known as vesicles and arbuscules. These fungi includes the genera *Glomus*, *Gigaspora*, *Acaulospora*, *Sclerocystis*, *Endoggone*. Inoculation of soil with AM fungi increases the yield of agricultural and horticultural crops. It also helps in improving the soil health and reducing the heavy metal contamination in wasteland, flu ash dyke etc. In spite of having a great potential in improving the soil health the obligate nature of AM fungi poses a hurdle in its culturing on synthetic media and thus it has to be multiplied in dual culture. However, it can be used effectively in the horticultural crops which are grown in nursery and then transplanted in the field.

Factors affecting Biofertilizer response

The following various factors affect the response of biofertilizers in field:

- Host crop and genotype
- Inoculant quality
- Crop management
- Soil factors like available N, moisture, pH, temperature etc.
- Environmental conditions

Biocontrol Agents

Biocontrol agents are the preparations containing the most efficient one or more microorganisms having the capability to suppress and control the plant disease or insect pest. They offer a ‘start clean – stay clean’ approach to crop protection. Various biocontrol agents are available in the market. The G.B. pant University has developed the Pant Biocontrol agent-1 (*Trichoderma harzianum*), Pant Biocontrol agent-2 (*Pseudomonas fluorescens*), Pant Biocontrol agent-3 (*T. harzianum + P. fluorescens*), *Beuvaria bassiana*.

Constraints in Adoption of Microbial Inoculants

Being a biological product there are various constraints in popularizing the microbial inoculant technology among the users. The constraints are at production and distribution level; storage and distribution level and field level. The various constraints at different levels are as below:

At production and distribution level

- Unavailability of good strains
- Unavailability of good carrier
Poor storage facility

At storage and distribution level

- Low incentive to dealer
- Poor storage facility
- No sale net work
- Less expiry period
- No buy back Guarantee by manufacturers

At field level

- Poor technical backstopping to farmers/ field level extension workers
- Poor awareness among farmers
- Unavailability in the market
- Poor quality products
- Farmers do not no handling and use
- Specificity with crops/ insects/ diseases
- No spectacular response

Epilogue

Microbial inoculants are un-disposable component for the quality maintenance/ improvement of soil and environment vis-à-vis health of human beings. Among the microbial inoculants biofertilizers are potential source of plant nutrients where as biocontrol agents are having the capability to check/ control the occurrence of disease and pest in crop. For harnessing the potential of microbes maintaining the balance between above and below-ground biodiversity, there is a need to develop specific efficient strains capable of contributing to soil physical, chemical and/or biological properties under varying agro climatic situations; controlling the wide range of diseases and providing resistance against various diseases/ insects. For the development of such strains to work under normal as well as adverse conditions use of modern molecular tools is warranted. Simultaneously carriers should be developed for high shelf life and convenience for transport and application. We also need to strengthen the extension system for aware generation among users.

REFERENCES


Knowledge Transfer through Farmer Participatory Training and Research

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India was most successful in gaining from ‘Green Revolution”, the term applied to successful agricultural experiments in many Third World Countries. There were four basic elements of Green Revolution in India.

1. Introduction of high yielding crop varieties
2. Move to go for extensive irrigation
3. Extensive use of fertilizers and agro-chemicals and
4. Adoption of intensive cultivation practices.

But Green Revolution has certain limitations as indicated below:

1. The Green Revolution, however impressive, has not succeeded in making India totally and permanently sufficient in food because even to-day India agricultural output sometimes falls short of demand.
2. India has failed do extend the concept of availability of quality seed and other planting material of high yielding varieties to all crops and/or all regions.
3. It is disturbing to note that there are places like Kalahandi where famine like conditions have been existing for many years and where starvation deaths have also been reported.
4. Since early nineties deceleration in total factor productivity, over stress on natural resources and squeeze is net income of the farmers have been reported. This has caused discontentment among farming community. One of the important reasons of not reaching the fruit of Green Revolution to all especially at lower ladder of the society was failure of conventional development approaches in meeting the needs of resource-poor people.

Limitation of Traditional Knowledge Transfer Methods:

Expensive: it s very costly to train a chain of extension personnel at district, sub division, block to village level extension worker, prints extension messages brochures, to understand the new technology and to answer the possible queries form farmers.

Time consuming process: it takes many actors to understand the message form university/ Zonal Research Station (ZRS)/ Krishi Vigyan Kendra (KVK)/ and deliver it to next layer then to pass onto farmer.

Erosion in quality of message: student of Training and Visit (T&V) system indicate that the quality of extension messages gets heavily eroded b the time it reaches the farmers.

Poor Communication Capacity: the flow of the information from research to extension tends to be to-down, rather than a two-way, interactive process aimed at identifying and solving serious problems. Also, there is little use of up-to-date communications technology, the capacity of traditional extension system is very limited, and the challenge in terms of reaching all the villages
and all the farmers is becoming more and more difficult to meet.

**How to improve?**

Before we decide the strategies for improvement, it is important to discuss the factors affecting efficiency of extension:

- Better the technology, faster the adoption
- Economic viability of the new technology
- Infrastructure in terms of available consolidation of holding, availability of farm machinery, market, irrigation etc. has signigicant influence on the adoption of new technology.
- Input distribution backup

**Present Challenges faced by Extension system**

Indian extension worker-operating in tough socio-economic environment: The extension worker has to understand the technical, social, economic, educational, cultural environment he has to operate in. For this it is very important that he appreciates the various problems faced by Indian farmers, viz.

- Small and fragmented land holdings,
- Inferior per hectare yields as compared to international standards,
- Inferior quality of produce,
- Sub-standard market facilities,
- Poor post harvest and seasonal dependence
- Multiple produce in small quantities (lack of specialization) leading to wastages,
- Poor storage facilities,
- Problem in availability of adequate and timely credit,
- Distress sale of produce by farmers,
- Poor bargaining power of farmers,
- Inefficient market intelligence,
- Exploitation of farmer by commission agents.

**Our research and extension systems need to address the changed paradigm like:**

- Complex and changing consumer demand
- Increasing impact of international market
- Inadequate information with farmers connect with the market.
- Research system should have greater connect with the market.
- Critical need to build competitiveness to face imports and to increase share in exports will be heightened liberalized trade regime.
- Need to optimize the use of water resources.
- Logistics and transport cost are becoming extremely important.

**Factors Required for Agricultural Development**

- Research which acts as source of innovations, discoveries, inventions and continuous improvements.
Extension system which is capable of disseminating useful information to farmers as well as training and educating them on the utilization of technologies.

- Farmers who are willing to improve their productivity and make use of opportunities.
- Efficient market channels for ensuring farmer’s benefits.

**How Research is Being Done?**

- Conducted by highly trained researcher
- In highly controlled environment
- With high inputs
- With plenty of labour

**Result…? Invariably not adapted by the farmers……!**

**Reason?**

**Technology generated is:**

- Not economically viable;
- Not operationally feasible;
- Not stable;
- Not matching with the farmer’s needs; and
- Not compatible with the farmer’s system

**Research should address these questions**

- Will it increase the productivity and by how much?
- Will it decrease the coast and by how much?
- Will it improve the quality and to what extent?
- Will it spare, farmer’s time and resources and by how much?
- Whether the farmer needs this piece of time and resources to allocate them to another activity?

**Traditional Top-Down Model of Technology Transfer**

- Research
- Extension
- Farmer

**Steps in Technology Transfer**

- Generation
- Testing
- Adaptation
- Integration
- Dissemination
- Adoption and Diffusion

**Missing Links in Technology Transfer**

- Education
- Training
- Participation, and
- Motivation

**Farmers**
- Representing the greatest human resources in agriculture
- Can be extremely effective, if well involved, motivated and rewarded,
- With clear strategies and policies.

**Bottom-Up Model of Technology Transfer**

**Bottom up Model**
- More emphasis
- on
- Farmer’s knowledge
- Farming situations
- and
- Farmer’s involvement
- at
- Every steps
- of
- Technology

**Steps in Technology Generation through Farmer’s Participation**
- Diagnosis of the situation
- Identification of the problem
- Development of alternative solution
- Experimentation
- Evaluation, and
- Finally, diffusion of Technology

Therefore, strategy for improved way of knowledge transfer should be by involving farmer as co-researcher/ a human resource in whole business from very beginning.
Nutritional Deficiencies and their Corrections in Plants

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When crops cannot absorb any nutrient in sufficient quantities, their metabolism changes, which is indicated by specific hunger signs exhibited by crops. These hunger signs are called deficiency symptoms which appear first on older leaves of the whole plant when nitrogen, phosphorus, potassium, magnesium, molybdenum and zinc are deficient. These deficiency symptoms appear first on new leaves and buds when calcium, boron, manganese iron and sulphur are deficient.

Nitrogen

Nitrogen deficient plants have a stunted and spindly growth, the stem is erect but lateral buds do not develop. So tillering is reduced in cereals. Leaves make an acute angle with the main stem. First, older leaves become pale green or yellowish green. This starts from the apex of older leaves and moves towards the base. These pale green or yellow green areas often develop brilliant tints of lemon, yellow or orange or less frequently reddish purple. Later younger leaves are affected if the deficiency continues for a sufficiently long period when older leaves become completely dry. This is called firing.

Phosphorus

Growth of phosphorus deficient plants is severely restricted. They are thin, erect and spindly. Lateral buds do not develop and so tillering is reduced in cereals. The bluish-green older leaves become bronzed or develop reddish brown or purple tints. These effects appear first on the apex of older leaves and then gradually spread towards the base. The severely affected apical portions of leaves may become rolled. Leaves may be shed prematurely and flowering and fruiting maybe delayed.

Potassium

Potassium deficient plants have a stunted and bushy growth. Pale green older leaves develop chlorosis between veins and light grey to bronze, reddish brown or brown colouration along the leaf apex and the apical margin. The leaf tip and apical margin of the leaf become scorched and necrotic. Thin brown roots are poorly developed; the small leaflets of the potato are crinkled and curved downwards.

Calcium

The first symptoms of calcium deficiency is chlorosis of young leaves, followed by distortion of the growing points of the stem. In crops belonging to the genus Brassica, young leaves forming the terminal bud do not expand, but become hooked. The leaves near them become cupped and the growing point dies. In wheat and barely, the upper parts of younger leaves fail to unroll and appear thread-like.

Magnesium

The normal green colour of the foliage fades, resulting in chlorosis between veins, leading to chlorotic stripping in the parallel veined leaves and chlorotic mottling in the reticulate veined
leaves. These chlorotic areas later develop brilliant tints of orange, red, purple or mauve. The area between the veins may turn brown and necrotic if a severe deficiency continues for long time.

**Sulphur**

The most common symptom is the fading of the normal green colour of younger leaves followed by chlorosis. The young leaves of sulphur deficient plants *i.e.* cereals exhibit chlorotic striping between veins. Brassica crops are susceptible to sulphur deficiency the symptoms of which are curled leaves and a non-development of apical bud older leaves exhibit wrinkled and inwardly raised areas. They may be tinted with orange or red colour and shed prematurely. The plant becomes brittle.

**Iron**

Chlorosis appears first at the basal part of younger leaves and later spreads towards the apical portion. Veins remain green. A continuous deficiency may result in the total bleaching of leaves.

**Manganese**

Small chlorotic patches appear between the veins of middle leaves. Later, these chlorotic patches unite, resulting in a chlorotic striping between the veins in parallel veined leaves, and chlorotic mottling in reticulate veined leaves. The chlorotic areas of leaves turn reddish-brown and necrotic.

**Copper**

A copper deficiency results in first young leave exhibiting chlorosis and drying, and a distortion of the terminal leaves. The shoot apex may die prematurely, resulting in the development of several auxiliary buds. Apices of young leaves often dry up. Young leaves of cereals may turn severely chlorotic, fail to unroll and wither. In species of Brassica e.g. cauliflower and cabbage, young leaves develop fine chlorotic mottling between the veins; mottled areas often develop white necrotic patches, particularly along the veins and leaf margins.

**Zinc**

The commonest symptoms of zinc deficiency are chlorosis between veins, reduction in the sizes of young leaves, which are often clustered and a bronzing, purple, violet reddish brown or brown colouration of the foliage.

**Molybdenum**

In most plants with reticulate venation, the first symptoms of Molybdenum deficiency is chlorotic mottling between the veins of old or middle leaves, or all over the surface when nitrogen is supplied to the crops in the form of nitrates, Crops like cauliflower, a species of Brassica, exhibit chlorotic mottling and a cupping of the middle leaves. A drying of severely affected leaves begins from the margin and covers the whole leaf, leaving only the petioles. Later, younger leaves are also affected and fail to expand fully; ultimately the growing point becomes necrotic and further growth ceases.

**Boron**

The commonest symptoms of boron deficiency exhibited by crops include necrosis of the
softer tissue, particularly phloem and the death of the growing points. In heart rot of sugar beet, young leaves at the centre of the crown fail to expand fully and become curled. The petiole and the basal part of the mid rib turn brown or black and become brittle. The young terminal leaves of the growing points and later, the entire crown become necrotic.

**Corrections of Nutritional Deficiencies:**

Management of nutrient deficiencies in the field requires a thorough knowledge of the symptoms produced as a result of deficiency or toxicity of the specific nutrient. For the amelioration of deficiency, corrective measures need to be adopted based on the principles of integrated nutrient supply system.

Nutrient toxicities especially, in respect of micronutrients are important in certain geographical regions and can be best managed by using tolerant varieties and chemical amendments.

**Components of nutrient supply system:**

In agricultural ecosystem, major sources of plant nutrients are:

- Soil
- Mineral fertilizers
- Organic manures/matter
- Amendments
- Biofertilizers.

The main aim is to tap all possible sources in a judicious way and ensure their efficient use.

(A) **Soil source:**

In order to enhance the supply of nutrients from soil, the following measures need to be adopted.

- Adoption of appropriate soil management and conservation practices to reduce nutrient loss.
- Amelioration of problem soils to mobilize unavailable nutrients
- Maximum utilization of available soil nutrients using appropriate crop variety, cultural practices and cropping system
- Microbiological methods to mobilize unavailable soil nutrients using vesicular-arbuscular mycorrhizae and *Psuedomonas spp.*

(B) **Chemical fertilizers:**

More efficient use of chemical fertilizers in the production system is intended. In a country like India where the problems of low and unbalanced fertilizer use and food requirement of an ever increasing population coexist, any approach to further reduce the fertilizer application and supplementation through alternative sources should be advocated with great caution depending upon the current level of fertilizer use in the system. The direction should be to maximize production/unit area/unit time by optimizing fertilizer use efficiency through complementary use of
organisms and other alternative sources of plant nutrients. Any additional nutrient applied through other sources must be taken into account for making up the gap between the recommended and actual level of fertilizer application.

Higher fertilizer use efficiency can be achieved through:

- Use of appropriate fertilizer product
- Minimization of nutrient loss by using correct method and time of application
- Elimination of all nutritional limiting factors such as primary and secondary-nutrients and improvement in other production factors
- Scheduling of fertilizer recommendations

(C) Organic manures:

Organic manure/matter is valuable bye-product of farming and allied industries. The nutrient recycling is possible either by their composting or direct application or mulching. Some of such sources are:

- Farmyard manure, poultry litter, sheep and goat droppings.
- Crop residues.
- Municipal wastes (Night soil, urine, sewage, sludge)
- Slaughter house (blood, bones) and fishery wastes
- Bye-products of agro-industries (oil cakes, fruit and vegetable processing wastes, press-mud rice-husk, bran)
- Forest litter, marine algae, sea weeds, water hyacinth, tank silt etc.

(D) Biofertilizers

Suitable microbial culture should be used to tap unavailable soil nutrients. Besides improving the availability of N to plants, green manuring/leguminous tree leaf manuring and use of symbiotic and asymbiotic microorganisms also alter the supply of micronutrients. This involves use of vesicular-arbuscular mycorrhizae and suitable strains of *Psuedomonas spp.* Microbes capable of producing growth promoting, antifungal and antibacterial substances can also be used. A combined inoculation strategy can be adopted to partly reduce the dependence on chemical fertilizers. This involves an integration of a combination of inoculants with reduced doses of mineral fertilizers to meet the complete requirement of the crop under a given agro-climatic condition. The strategy has important relevance in organic farming.

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Integrated Disease Management of Temperate Fruits

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Uttarakhand is predominantly a Horticultural State of India, since the economy of its growers and orchardists largely depends upon the cultivation of fruits and vegetables. Ageo-climatic conditions of the state are well suited for the production of different types of fruits ranging from temperate to sub-tropical fruits. Fruit plants may be classified as 1, Deciduous plants having leaf fall during autumn season, e.g., apple, pear, peach, plum, apricot, walnut, almond, persimmon, etc. 2, Evergreen plants which do not shed their leaves but keep on growing during the whole of the year e.g., citrus, mango, litchi, loquat, etc. In horticultural crops that are grown as perennial monocultures, the disease problems are entirely different and complex in nature. Such disease situations have led to repeated and excessive use of chemical fungicides. In addition contamination of horticultural produce has led to its low acceptance in the international market due to the pesticide residue. Adoption of integrated disease management (IDM) for containing the disease problem is a new shift all over the world. The major diseases of horticultural crops in Hill and Mountain region are powdery mildew, scab, blotch, root rot, collar rot, wilt, gummosis, die back, canker, crown gall, decline diseases and over 96 total diseases are causing huge losses.

The future needs in plant protection technologies for horticulture crops is to develop, modify and advance the technology of IDM to successfully manage the diseases, and also by exploiting complementary role through production system approaches. From practical viewpoint, biological control may be considered as utilization of natural antagonists to reduce the losses inflicted by the disease to tolerable level. An Apple fruit is accounted for maximum area and production. Till recently the plant protection measures in apple crop were carried out by calendar based use of chemical pesticides. This has resulted in the development of resistance in the pest species, contamination of horticultural produce, environmental pollution as well as rejection of the export material in the international market due to pesticide residues.

A protective spray programme being adopted in apple orchards in India includes 7 to 8 spray of non-systemic and systemic fungicides during the growing season and a single application of urea in autumn. Based on the efficacy of different ergosterol- biosynthesis inhibiting (EBI) fungicides in controlling apple scab disease, was evaluated for the efficacy of premature leaf fall, powdery mildew and sooty blotch. Obviously, protective sprays of Thiophanate methyl methyl + mancozeb, Hexaconazole, Flusilazole, Penconazole, Carbendazim and Captan from pink bud through pre-harvest stage at 25 days interval effectively control the most of the foliage diseases in high altitude area of Gangotri fruit belt. The first spray of thiophanate methyl + mancozeb and 2nd spray of Hexaconazole or carbendazim were more effective in the suppression of symptoms development and sporulation of ascospore and conidia (powdery mildew). Under the severe conditions for disease in the test orchard, the tebuconazole-captan mixture gave excellent control.
of scab and sooty blotch. The contact fungicides captan, benomyl, mancozeb, metiram, and maneb are often tank mixed with EBI fungicides to increase the disease control of spectrum and to improve control of fruit scab and other diseases. In regions where sooty blotch is more severe than sulfur has not provided adequate control of this disease, while mancozeb, captan, and benzimidazoles were effective. The protective sprays of mancozeb (0.30 %) or carbendazim (0.05 %) or thiophanate methyl (0.05 %) or carbendazim + mancozeb or thiophanate methyl + mancozeb at pink bud stage with EBI fungicides, hexaconazole (0.03 %), penconazole (0.05 %), flusilazole (0.01 %) defenconazole (0.015 %) and captan (0.30%) or Zirum (0.15 %) from petal fall through pre harvest stage at 25 days interval effectively control the major diseases in Gangotri fruit belt. Sterol inhibiting fungicides viz., hexaconazole, fenarimol, myclobutanil, bitertanol, flusilazole and penconazole showed excellent after-infection, pre-symptom (curative) and post-symptom (eradicative) activities against the scab pathogen and were also utilized in eradicant spray programmes successfully. Complete control of Marssonina blotch was achieved by protective sprays of broad-spectrum fungicides. Prophylactic sprays of mancozeb (0.3 %) started at fruit set stage in May (Purola-Naugao, Koti-Kanasar, Gwaldam, Joshimath) and June (Harsil, Auli) and repated at 15 days intervals thereafter were equally effective to the ones initiated at the bud break. An integrated spray schedule was evaluated and found effective in controlling the major apple diseases with 1: 8 benefit: cost ratio in the field. Our approach is to suggest that apple production can not be done profitably without fungicides whose judicious and timely use in suitable spray schedules has obvious benefits in reducing environmental pollution and substantial benefits to the apple growers. Public demands to reduce pesticides in our food chain should lead to increased support for research to find alternatives. A number of profound changes in Western society point to greater support for disease prediction research and greater acceptance of forecasting based control strategy.

Installing an apple scab forecasting and monitoring system at Harsil, Purola-Naugaon, Koti-Kanasar, Gwaldam and Joshimath and recorded weather parameters. A model to predict ascospore maturity for use in Uttarakhand orchards. These model are designed to identify earliest date of ascospores are matured and discharged. In Garhwal Himalayas, scabbed infected apple leaves from unsprayed orchards of Red Delicious cultivars were collected periodically between 1st week of March to June each year from 1995 to 2009. The ascospore maturity started around 2nd week of March and continued upto last week of May at different place of Uttarakhand Himalayas. On examination of the primary infection period
of 15 years data from Gangothri fruit belt, some differences were observed between our results and Mills table developed by Mills (1944) and Mills and La Plante (1951) for ascospores infection. Only 5 to 8 light infection periods occurred during each year in the month of March, April and May which could initiate the primary infection and time required for symptom expression was 9 to 14 days under prevailing temperature condition. Whichever the infection time was more than predicted (1 to 4 days) as mentioned in Mills table. Six to eight moderate infection periods were recorded in each month during 1990-2009 and almost all indicated delay by a day in symptom expiration (1-3 days) in 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 °C) and leaf wetness (23.4 to 27.2 hr) period and indicated 1 to 2 days delay in symptom expression. This observation revealed 2 day (light infection), 1 day (moderate infection) and 1 day (severe infection) delay in symptom expression under orchard conditions. The regression analysis was used to describe relationship between Mills infection criteria and our light, moderate and severe infection period data of Uttarakhand for symptom appearance. In all the cases, the total variation was high in low moderate and severe, infection curves.

The prevailing microclimatic conditions, topography and apple cultivars might be the possible reasons for the delay of ascospore release and symptom development in Uttarakhand Himalayas.

Ascospore maturation data of fifteen consecutive years were pooled and plotted against Celsius degree day accumulation from the date of first ascospore discharge of Garhwal hills. Based on the results, two linear lines were developed, one for the use when the cumulative degree days from 1 February to 15 May was < 657 and another for use when the cumulative degree-days for these dates was > 657. Our results showed that 50 and 95 per cent ascospores matured after 418 and 792 cumulative degree days, respectively for the orchards situated at 1900-2200 m asl (villages Auli, Syori, Koti-kanasar, Talwadi and Gwaldam) while for orchards situated at higher elevation (i.e. > 2200 m; e.g. villages Harsil, Dharali, Jhalla, Sukhi and Auli) the cumulative degree-days was > 1182 (95% ascospore maturity). The duration of ascospore discharge in the field appeared to be longer and varied from place to place.

The scab development was monitored over 17 years in farmers’ fields from 1994 through 2009, the PAD varied from 39462 to 4, 89,738. All the variables showed highly positive correlation with each others. As is evident from Figure, PAD was high and there was no adverse effect of delaying the first spray till 14th day after the petal fall stage. At this time, the proportion of ascospore that was mature was very low and the amount of foliage infection was also low. Two-three spray of EBI fungicide at the end of primary infection inoculum season had no effect on scab development. As is evident in figure, PAD was low, the first Mills infection period for the season
occurred 13 days after petal fall. Fifteen to eighteen infection period were recorded from last week of May to September, three sprays during this period gave good control of disease compared to the unsprayed, and just one spray reduced scab on the leaves to a great extent, and eliminated scab on the fruits during 1999 to 2009. The reason for this was probably due to winter and early springs are more mild and rainy in the Himalayan range of Uttaranchal hills. The susceptible cultivars (Red, Royal and Golden Delicious) also served as one of the reason for increase of inoculum under favorable conditions. However, the overall results of this study and of Holb and Heijne (2002) and MacHardy et al. (1993) indicated that, the fungicide applications against apple scab can be omitted at the beginning of the season and could be a good strategy for saving cost in integrated orchards if PAD values are lower than 600 ascospores/m². Estimates of PAD are useful when comparing management strategies or control treatments in several orchards. However, the results clearly indicated that the PAD was not uniformly distributed in farmer’s apple orchard or other management practice was applicable in one orchard but not in another orchard subjected to the same weather conditions. Thus more reliable data would be obtained from managed orchard whether sanitation practices can be used effectively to lower the PAD and, as a consequence, lower the fungicide dose. For this reason, reduction of primary inoculum sources could have a play very important role in the improvement of effectiveness scab management of apple in Uttaranchal Himalayas.

Inspite of much advancement in the development and computation of mathematical models or predictive equations, and automatic monitoring of weather data for apple scab, majority of the orchardists in USA, UK and several other countries still rely on initiating the first spray at silver tip to ¼ “ green tip stage in spring, and following a 7-10 day spray schedule thereafter till the primary scab season is over.
Role of Multilines and Cultivar Mixtures in Plant Disease Management

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Introduction
Cultivation of resistant varieties is considered as most effective and economical method of disease management. Resistance breeding involves management of two biological entities viz. host plant and pathogen. In view of dynamic nature of pathogen the resistance gene(s) fall susceptible after few years and therefore the resistance breeding programme is a continuing approach. Breeding for disease resistance involve several methods like selection, line breeding, poly cross breeding, hybrid and synthetic variety development and hybridization followed by pedigree/bulk pedigree or back cross breeding. However for management of disease up to the level where it is not able to cause the economic loss is important aspect of resistance breeding. Since the mode of inheritance of resistance in host may be race specific (vertical) and/or non race specific (horizontal) therefore, depending on the mode of inheritance several methods have been proposed for better utilization of resistance gene(s) for disease management.

Management of Disease
Management of vertical resistance genes

Important factors for management of VR genes
- VR can only reduce the outside inoculum or exodemic
- VR is achieved by manipulating the host population for maximum disadvantage to pathogen population

For management of vertical resistance genes following approaches may be useful
- Recycling and sequential release of resistance genes: Varieties are replaced frequently with each increase in new races of pathogen such that release of one gene with resistance and wait until it become ineffective and then release second gene and so on.
- Pyramiding of resistance genes: Simultaneous introduction of diverse genes for resistance into cultivars such that the variety offer more than one physiological barrier against pathogen and also prevent stepwise development of races virulent to varieties possessing different but single genes for resistance.
- Regional deployment of resistance gene: Resistant varieties with different resistance genes are developed and recommended for different geographical regions of the country where the crop covers sizable area. This type of gene deployment is essentially a geographical multiline eg. control of Puccinia recondita of Wheat.
- Chromosome or genome substitution: If genes for resistance are not available in the cultivated species, it is some times transferred from related species/genera through inter specific/inter genetic recombination. Whole genome/whole chromosome/chromosome segment of recurrent parent is substituted by genome of donor parent with resistance genes.
e.g. transfer of resistance to Clubroot disease (Plasmodephera brassicae) from B. campestris to B napus

Multiline Cultivar

A multiline cultivar is a population of plants that is agronomically uniform but heterogeneous for genes that condition resistance to a disease organism. The concept of multiline is based on two philosophies for disease management (Marshall 1977)

Clean crop approach: In this approach all component lines of the mixture will be resistant to all prevalent races of the pathogens to be controlled. The objective of this approach is to keep the crop as free of disease as possible and at the same time reduce the threat of disease losses due to shift of racial composition of pathogen population.

Dirty crop approach: It is on the concept that each line in the mixture carries a different single gene for resistance however none of the line is resistant to all known races of pathogen.

Such multiline protect the crop in two ways (Frey et al 1973). First by stabilizing the race structure of pathogen population, thus ensuring that simple races carrying single gene for virulence dominate in the pathogen population, and second by stabilizing each component of multiline so that it is attacked by only one race (dominant in pathogen population) while remaining line (except for the line to which race has virulent gene) will act as spore traps thereby reducing the rate of spread of disease. In this way multiline cultivars would have an effect similar to the polygenic non race specific or synthetic horizontal resistance in delaying the intercrop buildup of the pathogen.

How the two approaches differ

- Component lines of multilines in dirty crop approach require to confer resistance to only part of the pathogen population and this will extent the useful life of strong resistance genes present in component lines which even with moderate level of resistance is able to control disease. Because of moderate level of resistance of component lines breeder will have greater choice for selection of other good characters like yield, maturity etc.
- With less risk of breaking down the resistance, breeder would also free/less bothered from difficult task of continuously searching and incorporating new sources of resistant.

Moreover in both the approaches, 6-15 phenotypically similar lines differing for gene for resistance are required.

Mechanism of action of multilines

The mechanism by which the multiline cultivars buffer against diseases is the reduction of initial inoculum ($X_0$) and rate of increase ($r$)

A component line of the multiline being selectively resistant to specific race population of pathogen, reduces $X_0$ but had no effect on $r$ whereas all component lines being resistant to all prevalent races of pathogen does not reduce $X_0$ but reduce $r$. Therefore by reducing both $r$ and $X_0$ the multiline matures with less damage due to less initial inoculums and reduced rate of epiphytotic
Another mechanism of action of multiline to buffer against disease can be explained on the basis of reduced $X_0$ and $r$ due to spore trap. A component line of multiline has high race specific resistance therefore reduce initial inoculum ($X_0$) but at the same time a component line will be completely susceptible to certain other races. However when series of such resistant genes are placed in the multiline the population of plants serve as the spore trap which keep under control the potential parental spore of pathogen to contribute off spring for future cycle thus reducing rate of infection.

**Vertical and horizontal resistance concept of mechanism**

Vander plank (1962) introduced these terms. A variety with vertical resistance is resistant to certain races of pathogen while with that of horizontal resistance the resistance is evenly spread against all races of pathogen

**Epidemy of VR and HR**

Epidemiologically, VR act by decreasing the effect of oxogenous (incoming) inoculum but does not effect the rate increase of virulent races whereas due to HR the rate of increase in reduced for all race

![](image.png)

Effect of VR & HR separately and in combination on disease progress (Vanderplank 1968)

From the two Programmes introducing the concept of multilines viz. New York Programme (Jenson 1952) and Rockefeller Foundation Programme (Borlang and Gibler 1953), from the later programme contorted, the first multiline viz Miramer 63 which was released for commercial cultivation. From the Indian Programme, multiline viz. KSML-1, KSML-3, KSML-4 of Kalyansona and PVML-1, PVML-2, PVML-4 of (PV-18) have been developed. These lines had better resistance to leaf rust as compare to their parents.

**Crop heterogeneity for disease management and Cultivars Mixture**

Dependence on monoculture has continued to spread rapidly despite serious setback as well as evidences that alternate methods are also feasible. In traditional agriculture, cultivation of mixtures within and between plant species help protect crops against stresses. Report of rice mixture containing two to five component lines matching for maturity and quality but otherwise heterogeneous has been available. Even in the recent and modern agriculture system mixtures are being cultivated commonly e.g. Barley-Oat mixture, Wheat-Barley, Wheat-Gram etc.
The earliest record of value of crop heterogeneity for disease control is from the eighteenth century (Groenewegen & Zadokas, 1979) where reduction in rust infection in mixtures of Wheat and Oat has been reported. In the recent time the concept of multiline approach (Jensen, 1952) is the example of scope of crop heterogeneity for disease control. The common theme is to have crop heterogeneous for disease resistance character to be achieved by multilines or variety mixtures.

**Potential of mixture for disease restriction**

To understand this we have to analyze the fundamental difference in ability of mixture to cope with abiotic and disease stress. While abiotic stress occur as single event e.g. frost, drought etc. Neither of which are influenced either by pure variety or mixture. The mixture can survive better through compensation between each other but will not ever effect the abiotic stress. On the other hand for biotic stress like disease/ pest, pure variety or mixture can influence disease/insect progress directly by controlling the degree of stress. Therefore, potential of gains from using mixture are greater for disease control/insect control (biotic stress) as compare to protection against drought/frost etc. (abiotic stress).

**Mechanism of disease restriction by mixtures**

Mixture may restrict the disease spread relatively more to the mean of their components provided that component differ in the degree of susceptibility. *With appropriate mixture of spring barley, reduction of up to 80% in powdery mildew infection compared with mean disease level of components grown as pure stand has been reported.*

**Effect on out side inoculums**

Mixtures affect the inoculum that comes from out side the crop differently from that generated within the crop by providing diversification of host resistance. The amount of infection caused by an exogenous spore shower landing on a mixture equals the mean infection of the component lines. On the product of initial infection, mixture has its effect on restricting the spread of pathogen population. The mechanism operates in three principal ways (Trenbath 1984, Burdon & Chilvers 1976 & 1982 and Burdon & Shattock, 1980)

- Through decrease in the spatial density of susceptible plant thus limiting the amount of susceptible tissue in a given area, reducing survival of spores and reducing possibility of them reaching to neighboring susceptible plant. Spore density is declined due to reduction in plant density and smaller effect of dispersal. e.g. *Due to shallow dispersal gradient, Powdery mildew (Erysiphe graminis spread is restricted by mixtures).*
- Through barrier effect provided by resistant plant that fill the space between susceptible plants. To work this mechanism, susceptible plants should be as small possible to minimize the number of spores available to blow in to the barrier.
- Through the resistance induced by non pathogenic spores such that normally pathogenic spores that land is same area are prevented from infecting or are limited in their
productivity. The phenomenon is cumulative at least by reducing the amount of inoculum in each pathogen generation and can account for a considerable proportion of the disease restriction noted in the mixtures. It should also be systemic which should increase the cumulative effect.

**Working of mechanism in epidemic conditions**

- As result of initiation of epidemic by exogenous inoculum, the duration of disease spread in the mixture changes in relation to that in pure stand. The stage of disease restriction may depend on constitution of mixture, quality and amount of exogenous inoculum at the beginning of epidemic and number of pathogen generation during active development of the epidemic. Infection may increase up to disease carrying capacity of pure line as it does not reach the same level in the mixtures. The host continues to grow until it is harvested.

- The amount of disease restriction varies depending on the structure of the mixture and quality and quantity of exogenous inoculum. Based on the monitoring of the air borne inoculum and its movement, theoretically it is possible to construct mixtures to give high level of disease restriction.

- In case of soil borne pathogen where the spread of pathogen is by spores or mycelium or by splash dispersal, the mixture will have little or no effect on disease. Moreover the plants resistant to soil borne pathogen will provide compensation for damage to susceptible plants in a mixture. The value of such compensation will be determined by the distribution of initial inoculum in the soil such that if patchy, then even un infected susceptible plants in the pure stand may compensate for damage plants (*e.g. restriction of spared of Helmithosporium victoriae in oats* - Ayanru & Browning 1977).

**Adaptation of Pathogen to Mixtures**

The rate at which the pathogen adapts to the mixtures, if able to do so, depends on the selection coefficient of the phenotype with different combinations of pathogenity genes and relative distribution of pathogen propagules within or between plants of the mixtures. It will also depend on the quality of matching pathogenity genes. Therefore, it is always desirable to use host resistance gene either that can not be matched by the pathogen or those which can be matched only by pathogenity genes that carry severe penalty for survival of the pathogen. Unit area of host genotype need to be as small as possible to maximize the restriction of disease spread.

**Durability of Mixture**

The potential durability of mixtures depends not only on the quality of pathogenity gene in pathogen population but also on the number needed to overcome host mixture. The potential durability of mixture will be much improved by increasing the number of different components or by increasing the complexity of resistant genes (oligogenic/polygenic).

The components of variety mixture possess many differences among genes of greater as well as lesser effect on resistance. Due to this complexity of gene, the evolutionary process in the
pathogen in relation to resistance gene, pathogenesis will therefore slowdown and chances of emerging out super race to overcome the resistance of mixtures may be least. Further, the evolution of new race of pathogen reached different limits of infection on different varieties. Therefore, if a particular mixture were to be used continuously it is desirable to provide diversification among mixture and minimize difference in resistance between component.

**Yield advantage in variety mixture for disease resistances**

Mixtures with genetic variation may be expected to yield more than component mean in variable environments. The yield advantage is achieved through restriction of disease spread (White 1982). The gain obtained is equal to what expected through single average fungicide treatment. Some time yield advantage may not be obtained because the restriction of infection is not sufficient to limit the damage or because other than disease, some other stress is predominant.

**Number & type of mixture components**

The number of component should be kept to minimum with reasonable restriction of disease progress. Dynamic use of all permutation of a small number of components will provide greater durability. Another constraint with number is in matching the components for harvest maturity and yield. Small number makes it easy to harvest them at the same time. While the component varieties with similar yield help to obtain mixture yields as high or higher than that of the best component.

Besides resistance and yield, the components should have ability to produce better quality when in mixture with other components or better than mean of component lines (e.g. Barley mixture have comparable mating quality).

**Management of Horizontal Resistance**

- HR is evenly spread against all races of pathogen
- It is stability is due to its polygenic inheritance
- It reduce the apparent infection rate
- Reduces the area of lesion progress of disease curve, sporulation capacity, infection efficiency
- Increase latent period and incubation period
  
  e.g. Slowing down of Wheat Powdery mildew of Wheat and slow rusting of Oat of Wheat

**Multigenic variety**

Concept given by Watson and Singh (1982). These are true breeding varieties/lines possessing two or more diverse genes conferring resistance to a predominant race or spectrum of predominant races of pathogen.

**Genetics basis**

If a variety has two genes at locus A and B, the probability of single mutation will be $10^{-6}$ however, probability of simultaneous mutation at both loci A and B will be $10^{-12}$ therefore the
multigenic variety will have longer life.

**How to develop**

- Select two varieties having diverse gene for resistance to same or different pathogen
- Combine both the genes in one variety provided that
  - Two genes should be linked
  - Have different level of resistance
  - Have lower level of resistance individually as compared to combination

**Multilines, Line Mixtures vs. Cultivar Mixture**

In multiline the component lines differ only by identified resistance genes while the line mixtures developed from lines selected from hybridization of common parent. However in case of variety mixtures, components may differ for many characters including disease resistance therefore varietal mixture provides greater potential for practical application (Wolf & Berect 1980). With varietal mixture the choice is extended to all available varieties. Besides, there is also greater potential of mixing with resistant to a range of diseases alongwith abiotic stress each with many qualitative and quantitative differences. Due to greater flexibility, better performance and problem in registering multilines under Plant Breeder Right (European Economic Community), intension is now shifted from multiline to heterogeneous crop or cultivar mixture.

**Other related strategies for disease management**

- Growing of range of varieties, randomly dispersed in each season
- Pyramiding resistance genes
  - Using particular set of resistance genes in pyramid form and none of the component gene are released for cultivation in simpler combination or alone.
- Integration of different strategies to maximize effectiveness of disease control
  - Diversification of variety mixture
  - Combining qualitative and quantitative resistance in component lines
  - Integrating use of fungicide with variety mixtures
  - Dynamic use of mixtures by changing their composition in space and time to delay the buildup of new race of major pathogens

**Strength**

- Control of endemic for air borne foliar disease of cereals
- Reduction in yield loss
- Least possibility of emergence of super race
- Better guarantee of high yield as compare to best variety
- Inexpensively and simple strategy of disease management which can be added to or integrated with other strategies
- Help to improve the efficiency and reduce fungicide use
- Mixed seed can be provided to the farmers
Weaknesses

- Problem in gaining acceptance of concept
- Not acceptable to industrial agriculture which is market oriented

Opportunities

- Mixtures can be grown as the seed crops
- Opportunities for change of component
- Opportunity to combine a range of positive characters not achievable in single crop genotype.
- Reduced dependency on mono culture

REFERENCES

Maize (Zea mays L.), a new world graminaceous crop holds a unique position in world agriculture, ranking third after wheat and rice in area as well as production. It is a food, animal feed and industrial crop par excellence. In India it is grown over the area of 7.58 million ha. with the productivity of 1938 Kg./ha which is quite low as compared to world’s average productivity of 4500 Kg./ha. One of the major constraints in production is stress due to biotic and abiotic factors where major role is played by various diseases.

Of the 65 diseases reported on maize from India, following diseases have been identified as economic important in one or the other area under cultivation.

**Biotic Stresses**

1. Seed-rot and seedling blight

2. Foliar Diseases

   a. Downy mildews
      (i) Brown stripe downy mildew
      (ii) Sorghum downy mildew
      (iii) Sugarcane downy mildew
      (iv) Philippine downy mildew

   b. Leaf blights
      (i) Maydis leaf blight
      (ii) Turcicum leaf blight

   c. Rust
      (i) Common rust
      (ii) Polysora rust

   d. Curvularia leaf spot

   e. Bacterial Leaf Stripe

3. Banded leaf and sheath blight

4. Brown spot

5. Stalk rots

   a. Pre-flowering stage
      (i) Pythium stalk rot
      (ii) Bacterial stalk rot

   b. Post-flowering stage
      (i) Fusarium stalk rot
      (ii) Acremonium stalk rot
      (iii) Late wilt/wet rot
6. Smuts
   (i) Common smut
   (ii) Head smut

7. Ear, Cob and Kernel rots
   (a) Nigrospora ear rot
   (b) Grey ear rot
   (c) Fusarium ear rot
   (d) Charcoal ear rot
   (e) Trichoderma ear rot

Abiotic Stresses
1. Nutritional deficiencies
   a. Macro-nutrients
      (i) Nitrogen
      (ii) Phosphorus
      (iii) Potassium
   b. Micro-nutrients
      (i) Zinc
      (ii) Copper
      (iii) Iron
      (iv) Boron
      (v) Manganese
      (vi) Molybdenum
   c. Magnesium

2. Moisture stresses
   a. Drought
   b. Water-logging

3. Environmental Factors
   a. Air Pollutants
   b. Frost
   c. High and low temperature
   d. Toxicity (Buggy-Whip)

Foliar diseases
(a) Downy mildews

Maize is attacked by at least nine species belonging to three genera (*Peronosclerospora*, *Sclerophthora* and *Sclerospora*). Of these *S. rayssiae*, *P. sacchari*, *P. Philippines*, *P. sorghi*, *P. heteropogoni* are important in India and South East Asian region and cause severe yield losses to the extent of 50% or more. Symptoms caused by these species are somewhat similar and include
chlorotic streaking, mottling, stunting, excessive tillering and malformation of ears and tassels. Symptom expression is greatly affected by plant age, pathogen involved and prevailing environmental conditions.

(i) **Brown Stripe downy mildew** (*Sclerophthora rayssiae var.zeae*)

In India this disease was first noticed in 1962 in Tarai region of Uttarakhand and occurs practically in all maize growing areas of the country. It also occurs in neighbouring countries like Pakistan, Bangladesh, Nepal and Bhutan. Yield losses have been estimated to about 50%. If the pathogen attacks the plant at early stage, losses can be even higher. The pathogen is mainly soil borne, survives through oospore buried in soil along with infected host debris. The severity of BSDM is greatly influenced by atmospheric temperature (28-32°C) and relative humidity around 95%. There is definite relationship between frequency of rainfall and duration of sunshine in disease development. Zinc deficiency has been reported to predispose the plants to infection. Symptoms start from lower leaves and infection moves upwards. Presence of narrow, chlorotic or yellowish stripes variable in length but 3-7 mm wide, which extend in parallel fashion through the entire length of the leaf. These stripes become necrotic as the plant grows. In advanced stage the plants exhibit a burnt appearance of leaves. Seed development may be suppressed and plant may die prematurely. Presence of fine, whitish or creamish downy growth on the lower surface of the leaf is also a characteristic symptom, which is visible during early morning hours.

(ii) **Sorghum downy mildew** (*Peronosclerospora sorghi*)

This disease is present in many parts of the world. In India it is prevalent in the states of Rajasthan, Gujrat, Maharastra, Andhra Pradesh, Karnataka and Tamilnadu. The losses varies from 40-60% depending upon the location and stage of infection. The pathogen survives through oospores for several seasons in soil. Systemically infected plants are chlorotic sometimes stunted and occasionally have white stripes on leaves and abnormal seed setting. A white downy growth may appear on both the surfaces of the infected leaves. Infection takes place during seedling stage at 15-20 days after planting. High humidity and temperature below 20°C favour the disease development and spread. Rajasthan downy mildew (*P. heteropogoni*) differs from sorghum downy mildew in terms of host pathogenicity.

(iii) **Sugarcane downy mildew** (*Peronosclerospora sacchari*)

This downy mildew is confined to Southeast Asian countries of the world, resulting 30-60 % yield losses. In India it is prevalent in the states of U.P. and Bihar. Moisture, temperature and age of the plants are the important factors in disease development. Local lesions leading to systemic infection characterize the symptoms. At initial stages these lesions are small, elongated, and choleretic appearing within two to four days of infection. Symptoms appear as pale yellow to white stripes that may some times extend to the entire length of the leaf. White downy growth of pathogen appears on both the surfaces of the leaf and leaf sheath. In some cases tassel malformation also takes place.

(iv) **Philippine downy mildew** (*Peronosclerospora philippinensis*)
This is most serious downy mildew in the Philippines. In India the disease occurs in the states of Punjab, Haryana, U.P., Bihar and Madhya Pradesh. Relatively low temperatures of 21-26°C and high humidity is favourable for infection. Systemic symptoms may appear at first two leaves as a complete chlorosis or chlorotic stripes. In general infected leaves show long chlorotic streaks with fine downy growth of the fungus. Tassels may be malformed producing less pollen, while ears may be aborted resulting in partial or complete sterility. If infection starts early, plants may die pre-maturely.

Management
- Grow resistant varieties such as Ganga safed-2, Prabhat, Sartaj, Navin, Kanchan, Shweta, Gaurav, Amar and Pragati.
- Treat the seed with metalaxyl @ 3-5 g/kg., one/two foliar sprays may be applied to save from severe infection.
- Two to three foliar sprays of Mancozeb (3 Kg./ha) at 10-day intervals starting at the onset of disease.
- Soil application of zinc sulphate @20 Kg/ha as basal application before planting.

(b) Leaf blights

(i) Maydis leaf blight (*Helminthosporium maydis*)
Also known as southern leaf blight and currently occurs through out the world being more important in the regions with warm (20-30°C) and damp climate (90% humidity). This disease was first recorded in 1960 from India and now prevalent in all maize growing states. In cases of severe infections it can cause 60-70% yield losses.

Two strains of this fungus race O and T cause leaf blight with slight difference in symptoms. Disease is characterized by the presence of lesions. Young lesions are small and diamond shaped and later on elongate with maturity. Growth of lesions is limited by adjacent veins thus the final shape of the lesion is rectangular. Lesions may coalesce, producing a complete blighting symptoms.

(ii) Turcicum leaf blight (*Helminthosporium turcicum*)
Like Maydis leaf blight this disease has a worldwide distribution. In India it is prevalent in Himalayan region, Peninsular India and also in state of Bihar. It is also known as Northern leaf blight and occurs particularly in areas of high humidity and low temperature. Yield losses due to this disease have been reported in range of 30-50%. Crop debris is the usual source of primary inoculum and secondary infection takes place through wind. Long, elliptical boat shaped grayish green or tan coloured lesions on the leaves measuring 2.5 to 15 cm. in length and 4 cm. in width recognize this disease. Symptoms first appear on lower leaves and travels upward. Infected plants present burnt appearance due to blighting.

Management
- Use resistant cultivars such as Deccan-103, Deccan-105, Gaurav, and Sartaj.
- Two to three foliar sprays of Mancozeb @ 2.5Kg/ha. at 10 days interval.
- Two to three years crop rotation, removal and burning of crop debris.

c) Rust

(i) Common Rust (Puccinia sorghi)

The disease is distributed throughout the world, particularly prevalent in countries with cooler environment. In India rust occurs mostly during Rabi season in states of U.P. and Bihar and in Karnataka and in Maharashtra it appears during kharif also. Yield losses ranging from 6% to 32% have been estimated. Disease spread through wind/rain showers in favourable conditions. Uredospores germinate and initiate the disease. Common rust is recognized by the appearance of circular to elongate, cinnamon brown, powdery pustules scattered over both the surfaces of the leaf. As crop matures, pustules turn black due to the formation of teliospores. Pustules may form on any part of the plant above ground surface but most abundant on leaves. In severe infection the entire plant appears brownish and rusted.

(ii) Polysora Rust (Puccinia polysora)

Also known as southern rust because it is more commonly distributed in areas that have hot and humid conditions. It is found in Mexico, Central America, South America, the West Indies and Africa. In India it is known to occur in parts of South India, especially in state of Karnataka. This rust is favoured by high temperatures (27°C) and high relative humidity. Symptoms produced by Polysora rust resembles to those of common rust with very little differences. Pustules are smaller, lighter in colour and more circular. They are also present on both surfaces, but the epidermis remains intact for longer time. Pustule development on lower surface occurs more slowly and less abundantly than on upper leaf surfaces. Pustules turn dark brown as plants approach maturity.

Management

- Use resistant varieties such as Prakash, Ganga-11, Deccan-103, Deccan-105, Navin, Weekly foliar sprays of Mancozeb @ 2.5 Kg/ha. can effectively reduce the rust severity.

(d) Curvularia leaf spot (Curvularia spp.)

This disease is prevalent in hot and humid maize growing areas and can damage the crop significantly. Two species of this fungus i.e. Curvularia lunata and Curvularia pellescens have been found to cause leaf spot on maize. The disease is characterized by the presence of lesions which are first small (1-2 cm), straw coloured, circular to oval with reddish or dark brown margins. They are sometimes coalescing to form large necrotic areas.

Management

- Use resistant cultivars such as Deccan-103, Deccan-101, Gaurav, Sartaj and Ganga-11
- Two to three foliar sprays of Mancozeb @ 2.5Kg/ha. at 10 days interval.
- Two to three years crop rotation, removal and burning of crop debris.
(e) Bacterial Leaf Stripe (*Acidovorax avenae* sub spp. *avenae*)

This disease is widespread but no substantial damage has been reported. It is more severe under extended periods of warm and wet weather. Bacteria enter the host through stomata when leaves are water soaked. Bacterial stripe affects susceptible maize plants to seedling to post pollination stages. Leaves develop several small pale green lesions. Under optimum conditions, lesions expend along veins producing a conspicuous striping, mainly in the youngest leaves. Stripes become dry and brown as the plants approach maturity. Severe damage of the top leaves results in tassel rotting as dead leaves enclose the tassel.

3. Banded leaf and sheath blight (*Hypochonus sasakii*)

This disease was first reported from Srilanka in 1927 as sclerotal disease and subsequently recorded from all over the world by various names. It occurs in almost all maize growing states of India, particularly severe in Tarai region of northern states, resulting 23-97% losses in grain yield. Symptoms of the disease are present on every part of the plant except tassels. Primary source of inoculum are sclerotia present in soil and on other hosts that grow in vicinity of maize crop. Secondary spread of the disease is by contact of infected leaf with parts of adjoining healthy plants. Hot and humid climate is essential for disease development. Disease starts from the lowest leaf sheath, which is in contact with the soil and travel up in form of bands on overlapping leaf sheath to ear. The disease symptoms are characterized by the presence of alternate bleached areas or bands on leaf sheath and leaves. Olive green and brown large continuous patches on stalks can be seen immediately below the diseased leaf sheath. Presence of sclerotia on diseased parts which are initially brown in colour turn blackish later on is also a characterized symptom.

**Management**

- Use promising released varieties.
- Removal of second and third leaf with sheath from the ground level at knee-high stage is effective in checking the disease.
- Two sprays of Propaconazole 25%EC (4 ml/l) at 30 and 40 day of germination have been found effective.
- Two –three years crop rotation have been found effective to reduce the disease severity.
Epidemiology and Plant Disease Management

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“Chemical industry and plant breeders develop the ‘weapons’, but the epidemiologists set the strategy”

(Vanderplank, 1963)

Methods of plant disease control were developed even before true nature of plant disease was understood. During early stages, 19th and early 20th century, the methods of plant disease control were more a wishful thinking of plant pathologists. Epidemiological studies generate lot of information on different aspects of disease development. This processed data (knowledge) helps in developing appropriate technology for plant disease management. The technology based on epidemiological principles is logical, as they are based on facts. The following points do suggest that epidemiology may make plant disease management biologically and economically justified and environmentally safe.

1. The monocyclic diseases (loose smut of wheat and wilts) and polycyclic diseases (rusts, powdery mildews, downy mildews and late blight of potato) should be given different treatment.

2. The information about source of primary inoculum and amount is vital as it can help us in forecasting disease and proper methods can be employed for disease management:

<table>
<thead>
<tr>
<th>Diseases</th>
<th>Source of Inoculum</th>
<th>Methods Employed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loose smut of wheat</td>
<td>Internally seed borne</td>
<td>Seed treatment-Hot water or Systemic fungicides</td>
</tr>
<tr>
<td>Wilts, root rots and nematode problem</td>
<td>Soil</td>
<td>Suitable crop rotations and cultural practices</td>
</tr>
<tr>
<td>Apple scab</td>
<td>Perithecia on fallen leaves</td>
<td>Destroy the infected leaves from orchard floor Prophylactic spray</td>
</tr>
<tr>
<td>Potato viruses</td>
<td>Tuber borne</td>
<td>Pathogen free certified seed</td>
</tr>
<tr>
<td>Wheat rust</td>
<td>Air borne</td>
<td>Prophylactic spray / H.R.</td>
</tr>
<tr>
<td>Post harvest decay of fruits and vegetables</td>
<td>Fruit surface</td>
<td>Treatment before transportation or storage</td>
</tr>
</tbody>
</table>

3. Information about potential for variability in pathogen population can help in adopting suitable breeding strategies, e.g. management of late blight of potato or wheat rust, with high chances of new races, should emphasize on development of horizontal resistance.

4. The economic threshold levels, once established, may justify the actions to be taken for disease management.

5. Field management of a disease on resistant crop cultivars will require much less fungicide use as compared to susceptible cultivars.
6. The behaviour of vector populations can be effectively utilized to control plant diseases. This has been demonstrated in case of potato viruses, and Stewart’s corn wilt).

7. Diseases forecasting can help in adopting the appropriate measures, which, can help in reducing pesticides use without risking crop health.

8. Fungicides should be used judiciously for plant disease management. Contact fungicides (mancozeb, copper oxy-chloride, sulphur dust etc.) are effective only as prophylactic. The systemic fungicides (metalaxyl, bavistin, tilt etc.) can be used for eradicative and curative action.

9. All possible information about pathogen and disease should be used for developing IPM schedule keeping local conditions in mind.

**Using \( X = X_0 e^{rt} \) for Plant Disease Management**

Above equation proposed by Vanderplank (1963), for polycyclic diseases, could be used for disease management. This reveals that final amount of disease \( (X) \) depends on (a) amount of initial inoculum \( (X_0) \), (b) rate of disease development \( (r) \) and (c) duration of disease development \( (t) \). Suitable manipulation that can bring any reduction in any one or more of the above three factors will reduce the final disease severity \( (X) \).

**Reducing amount of initial inoculum \((X_0)\)**

The practices discussed under sanitation viz. seed certification, rouging, burning of crop debris and other cultural and chemical methods are popular among the growers. Nurserymen are practicing sanitation. Use of disease/ pathogen free seed/ planting material, treating them suitably, changing the beds for raising seedlings and use of polythene as mulch for soil solarization is becoming popular as it overall improves the growth and vigor of seedlings.

**Reducing rate of infection \((r)\)**

Repeated sprays of fungicides, horizontal resistance and environment turning unfavourable can slow down the progress of disease, i.e. reduction in infection rate.

**Reducing duration of disease development \((t)\)**

In multiple cycle diseases the duration of disease determines the number of repeating or infection cycles completed by the pathogen. Manipulating time of planting or harvesting, duration of crop maturity and rate of seedling growth can bring about significant reduction in disease severity.

**Sanitation: a profitable practice**

Adoption of sanitary practices, clean cultivation, was an age-old practice that aimed at reducing inoculum. Vanderplank treated "sanitation as principle" and included all practices that reduce or tend to reduce initial inoculum. He included seed certification and treatment (seed borne inoculum), rouging, prophylactic fungicide spray (air borne inoculum), cultural and chemical methods (soil borne inoculum) and vertical resistance under sanitation. Sanitation is ‘buying time’, the time taken by pathogen, in plot with sanitation, to multiply up to the level in plots without sanitation. Vanderplank developed following mathematical formula for calculating benefit from sanitation (advantage time \( \Delta t \)).
Sanitation will be more effective under following conditions

- For single cycle disease where secondary infection does not take place. Any reduction in amount of initial inoculum will be proportional to reduction in amount of final disease, during log phase.
- In situations where the rate of infection is low, as advantage time is inversely proportional to rate of infection, (halving the r will double the Δt).
- In situations where the duration of disease development is short. For long duration diseases the benefits of sanitation are gradually lost.
- In case of seasonal or annual crops rather than perennials.

One of the most ambitious sanitation based programmes was barberry eradication in U.S.A. Gigantic human efforts were made to eradicate the barberry bushes where wheat rust fungus, *Puccinia graminis tritici*, was known to survive and breed. The aim was to control wheat rust. It was a logical thinking in two ways; (a) to reduce the chances of survival of pathogen and (b) not providing fungus the opportunity for sexual reproduction, thus reducing chances of development of new strains (races) that pose a constant threat to resistance breeding programme. But the practical limitations in implementation of ‘novel thought’ put a big question mark on utility and financial justifications of the whole effort. A similar case can be traced from the example of citrus canker eradication programme in U.S.A. and later in Australia, which also met the same fate.

**Plant Pathology**

Plant pathology is a multidisciplinary field that deals with all levels of biological organization, from molecules to ecosystem. Plant pathologists have the luxury of specialization in a niche epidemiologist.

Also involved in direct problem solving
Epidemiology 2009

- Plant disease epidemiology is a discipline concerned with understanding the dynamics of disease in time and space.
  It is a holistic science in terms of being concerned simultaneously with populations of pathogens and host plants within an environmental context

Epidemiologists

- Plant disease epidemiologists are concerned with elucidating the general principles underlying epidemic development, with an emphasis on being quantitative and predictive.

Plant diseases; the considerations

- 5th century Hippocrates “plant diseases are natural”
  be considered as outcome of ecological relationship
  eradication of pathogen / control of disease not feasible
  managing below EIL be the goal
  farmers be educated to allow ‘some’ disease in field
  pathology students be educated ‘logical recommendations’
  no single method be over emphasized
Integrated Management of Stalk Rots & Wilt Diseases of Maize

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In India the Maize crops is attacked by several pathogens including fungi & bacteria. The plants is infected immediately after node plate formation involving, pre-flowering, flowering and post flowering stages affected by environmental conditions. These stalk rots & wilt diseases are mentioned below.

(a) Pre-flowering stage
(i) Pythium stalk rot (Pythium aphanidermatum)

It was first reported from Delhi in 1964 and occurs in U.P., Bihar, Punjab, Haryana and West Bengal. The incidence of this disease is highly influenced by moderate temperature of 20-30°C and humidity of 90-100% just before flowering stage. Dull, cloudy weather with continuous rains are most favourable for disease development and spread.

Disease is usually confined to first or second internode just above the soil surface. The outer rind and pith tissues are rotten but the vascular bundles remains intact. Infected plants remain green and do not die up to two weeks and rise again upwards in arch fashion with the support of crown roots if the conditions improve.

Management

- Plant population should be maintained around 60,000 /ha.
- Proper sanitation and drainage to avoid water logged conditions.
- Use of resistant cultivars such as Navin, Kanchan, Shweta, Gaurav, Sartaj, Pratap, Amar and Pragati.
- Soil drenching with Captan (150g/10 litre water), when the crop is 5-7 week old.

(b) Flowering stage
(ii) Bacterial stalk rot (Pectobacterium chrysanthemi)

This disease occurs in tropical and subtropical parts of the world. In India it is most destructive in tarai region of Uttarakhand, U.P.,and Bihar and also found in Punjab, Himachal Pradesh and West Bengal. It attacks the plants at the onset of flowering. High humidity over 90%and high temperature (32-35°C) with frequent rains, providing hot and humid environment favours the infection and disease spread. The bacteria survive in soil and under favourable conditions starts infecting the plants. Primary symptoms generally appear at the onset of flowering when plant suddenly fall over. At first the upper leaves show sign of wilting and become faded green in colour. The basal internodes become soft and discoloured. With the advancement of the disease the pith is completely rotten and stalks become extremely rotten and pliable. Such plants collapse from infected lower internode as the stalks topple down. Disagreeable/unpleasant fermenting odour is emitted out from such infected plants.
Management:

- Delayed planting reduces bacterial stalk rot incidence.
- Apply balanced fertilizers, especially the potash.
- Two-soil applications of calcium hypochlorite (CaOCl₂) at the rate of 25kg/ha. first at the onset of tassel emergence and 2nd 10 days after to reduce the disease severity.
- Proper drainage to avoid water logged conditions.

(c) Post-flowering stage

(i) Fusarium stalk rot (*Fusarium moniliforme*)

Fusarium stalk rot is also known as pink stalk rot. The disease is prominent after flowering under dry and hot conditions. It is favoured by low soil moisture where fungus is more active. The disease first affect the lower internodes from roots and moves upward under dry hot conditions, destroying the vascular bundles leaving the plant dry. If the affected plants are split open longitudinally at lower internode, the vascular bundles appear pink in colour and at later stage they become dark pink to gray in colour. Fine light pink growth of the fungus is also visible at the nodal plates on the lower part of stem.

Management

- Grow certified seed of improved varieties such as Navin, Kanchan, Shweta, Gaurav, Amar and Pragati and Deccan -105
- Seed treatment with Bavistin @2g/kg
- Irrigate the field if the conditions become dry after flowering.

(ii) Acremonium stalk rot (*Cephalosporium acremonium*)

This disease has been noticed in relatively wet and hot areas. The infection is more severe when maize plants reach the dough stage. First symptom is purpling or reddening of the leaves and the stalks. If such infected plants are longitudinally split open the characteristic blackening of the lower vascular bundles in the stalk extending through several internodes upwards can be seen. Barren plants, excessive tillering, nubin and multiple ears at one node are other important symptoms.

Management

- Use resistant cultivars like Navin, Prakash, Kanchan, Shweta, Gaurav, Amar and Pragati.
- Seed treatment with Thiram or Captan @ 2.5g/Kg. Seed.
- Crop rotation (2-3 years) with rice may help in reducing the disease severity.

(iii) Late wilt disease (*Cephalosporium maydis*)

Late wilt was observed first time in USA in 1960. In India its occurrence was reported from Pantnagar and Hyderabad in 1969. It is essentially a vascular disease of tropical areas.

The fungus is primarily soil borne and infects maize through the roots or mesocotyl. The disease develops more rapidly in heavy clay soils than in light loam soils. Continuous rainfall and prolonged water stagnation in field favours the disease development. The first symptom of late wilt is wilting of leaves beginning after flowering. The leaves turn dull green and later become dry.
Vascular bundles in the stalks are discoloured shrunken and hollow with chaffy visible gas pockets in dull colour. Infected plants produce shrunken and underdeveloped kernels.

**Management**

- Use certified seed of improved varieties such as Deccan-105, Ganga-2, Navin, Kanchan, Shweta, Gaurav, Amar and Pragati.
- Drain out excess water, especially after flowering or grain filling stage.
- Excessive weeds contribute for disease spread, therefore weed out the field before flowering.

(iv) **Charcoal rot** (*Macrophomina phaseolina*.)

Charcoal rot is more prevalent in comparatively dry-hot rain fed maize growing areas particularly in West Bengal, U.P., Delhi and Andhra Pradesh. The pathogen is soil inhabitant, enters through roots and it multiplies both inter and intracellularly when soil temperature is around 35°C. Characteristic symptom of this disease becomes apparent as the plant approach maturity. The disease generally starts after flowering. Affected plants show premature ripening. The outside of the lower internodes becomes straw colored and pith is disintegrated. Presence of black pycnidia in black powdery mass appear in internodal areas of affected plant.

**Management**

- Use resistant varieties such as Deccan-103, Deccan-105, Navin, Kanchan, Shweta, Gaurav, Amar and Pragati.
- Crop rotation for two to three years.
- Delay in harvesting should be avoided.
- Avoid low moisture stress conditions.
Pseudomonas, A Promising PGPR and Biocontrol Agent

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It is estimated that in the coming years requirement of chemical fertilizers (NPK) would be around 20 millions tons to feed more than one billion populations in India alone. However increased use of chemical fertilizer is responsible for progressive deterioration of soil health. Reports from various parts of the country such as Punjab and Uttar Pradesh suggest that despite of all our efforts, production has come down, which may be correlated with decline in microbial biomass and the accumulation of nitrates, nitrites, phosphates and other essential nutrients in the soil. In this changed scenario, it is being realized seriously to accept biological means for the improvement of not only legumes but for other crops as well. Application of microbial inoculants is a low cost eco-friendly technology to enhance crop productivity.

Numerous microorganisms are commonly found in soil including fungi, bacteria, actinomycetes, protozoa and algae. A major group of bacteria belonging to rhizosphere zone exert beneficial/harmful effect on plant development when applied to crop seed or incorporated into soil. These rhizobacteria are frequently used as bioinoculants or as a biocontrol agent to enhance plant growth because indigenous phytopathogens can reduce crop yield by 25-75%, which is an enormous potential loss of crop productivity. With the realization that many commonly used chemical pesticides are hazardous to animals and humans and persist/accumulate in natural ecosystems for long, can be replaced or reduced by bacterial inoculum having biocontrol efficacy. Use of blue green algae (a major source of N₂ fixation) is a common practice in South Asian countries but it is used specifically in water logged crops like rice. Rhizobium has done wonders but only for leguminous crops. Mycorrhizal technologies are reaching new dimensions, whereas Azotobacter, Azospirillum, Acetobacter and now other groups of free-living microbes are gaining increased attention since they exhibit wider host range and can be used in various soil types, humidity and climatic conditions. These free-living rhizobacteria increase plant growth and yield via various direct/indirect mechanisms.

PGPR is a plant growth promoting rhizobacteria that lives in rhizosphere. Rhizosphere term was first used by Lorenz Hiltner in 1904. It is the volume of soil around the root zone and influenced by material(s) released by the plant roots. Plant root surface termed as rhizoplane, provide a unique environment for the growth of bacteria, because of excretion of variety of low and high molecular weight compounds. Among the free-living micro-organisms, fluorescent pseudomonad (FLPs) have attracted the attention mainly as biocontrol agents. This group is known to secrete a large number of secondary metabolites like antibiotics, growth hormones, siderophores, HCN and enzymes that help in plant growth by decreasing the activities of phytopathogens. Moreover, FLPs are ideally suited as soil inoculants irrespective of soil type and crops because of their rapid and aggressive colonization in the root zone (rhizospheric
Further more they can catabolize a diverse group of molecules and thus compete favorably with indigenous microorganisms.

Fluorescent pseudomonads make up a specific group of bacteria that can generally be visually distinguished from other pseudomonads by their ability to produce a water soluble yellow green fluorescent pigment. This pigment is a siderophore (an iron chelator) which is produced extracellularly during late log phase of growth of the bacterium. The specific iron chelating capability of this pigment provides a competitive advantage to the producer species. Siderophores is the low molecular weight compounds synthesized by microbes growing in iron deficient condition. With few exceptions, all living cells have an absolute nutritional requirement for iron mainly in metabolic pathways associated with iron protein and enzymes. A great diversity of chemical structures is encountered among microbial siderophores and more than one hundred different compounds have so far described. The common siderophores produced by pseudomonads are pyoverdines, pyochelin, salicylic acid and aerobactin.

**Why Pseudomonas**

1. Efficient colonizer
2. Production of numerous secondary metabolites
3. Solubilization of P, Zn, Fe through different systems
4. Rhamnolipid producer
5. wider host range
6. can metabolize more than 200 compounds
7. do not produce spore
8. fast grower and found almost everywhere
9. can be isolated easily

**Diverse array of gene play important role in plant root colonization**

The root exudates actually act as a source of nutrient for rhizobacteria and thus they increase their population tremendously in rhizosphere. These rhizobacteria then communicate with the plants using complex chemical signals. The signals include auxins, gibberllins, glycolipids and cytokinins.

**Mechanisms Involved in colonization**


**Compounds found in root exudate**

Volatile compounds: CO₂, Ethanol, Isobutanol, Isoamylalcohol
Low mol. Wt. compounds: Sugars, Amino acids, Vitamins, Organic Acids, flavanoids
High mol. Wt. compounds: Polysaccharides, Enzymes

PGPR genera include *Pseudomonas, Flavobacter, Bacillus* and *Achromobacter*, these bacteria can be added even in seed stage. If the bacteria have necessary attachment surface proteins, a critical phenomenon occurs on the surface of plant and particularly in the root zone - example associative nitrogen fixation, in which in nitrogen fixing microorganism is on the surface of the plant root, in the rhizoplane as well as in rhizosphere. The main microbes involved in this process are *Azotobacter, Azospirillum* and *Acetobacter*. These bacteria contribute to nitrogen accumulation by tropical grasses. Recent evidence suggested that their major contribution may not be in nitrogen fixation but in production of growth promoting hormones that increase root hairs and
thus greater ability of plant to take up other nutrients.

Direct and indirect benefits from PGPR

Direct Benefits


Indirect Benefits

1. Production of antibiotics 2. Induced systemic resistance

**Ethylene**

Cell elongation and proliferation

\[ \text{IAA} \rightarrow \text{Ado Met} \rightarrow \text{ACC synthase} \rightarrow \text{ACC} \rightarrow \text{ACC oxidase} \rightarrow \text{C}_2\text{H}_2 + \text{NH}_3 + \text{α-KB} \]

PGPR

Root elongation

Ado Met – 5- adenosyl methionine

**Role of Siderophores**

Iron plays a major role in cellular respiration, being a component of cytochromes and iron-sulfure proteins involved in electron transport. Under anoxic conditions iron is present in +2 oxidation state and soluble. However under oxic conditions, iron is present in the +3 oxidation state and forms insoluble minerals. To obtain iron from such environments, cells produce siderophores (iron binding proteins) that bind iron and transport it into the cell. One major group of siderophores consists of derivatives of hydroxamic acid, which chelate ferric iron very strongly. Once the iron – hydroxamate complex has passed into the cell, the iron is released and the hydroxamate can be
excreted back and used again for iron transport.

Bacteria such as *E.coli* produce structurally complex phenolic siderophores called *enterobactins*. These siderophores are derivatives of the aromatic compound catechol and have an extremely high binding affinity for iron.

<table>
<thead>
<tr>
<th>Metabolites (Siderophores)</th>
<th>Species of <em>Pseudomonas</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyoverdine</td>
<td><em>P.aeruginosa</em></td>
</tr>
<tr>
<td>Pseudobactin</td>
<td><em>P.fluorescens</em></td>
</tr>
<tr>
<td>Pyochelin</td>
<td><em>P.putida</em></td>
</tr>
<tr>
<td>Cyclohydroxamic acid</td>
<td><em>P.aeruginosa</em></td>
</tr>
</tbody>
</table>

**Rhamnolipids as Biosurfactant**

Bacterial genera like *Acinetobacter, Arthrobacter, Bacillus, Corynebacteria, Pseudomonas* and various fungal genera are efficient rhamnolipid producers. Glycolipid like rhamnolipid produced by *Pseudomonas*, a dominant rhizobacterial population has significant role as biocontrol agent. Purified rhamnolipids cause cessation of motility and lysis of zoospores within one minute. Zoosporic fungi like *Phytophthora, Pythium*, the causative agents of vegetable nursery have been reported to be checked by *P.aeruginosa*.

**P Solubilization**

Phosphorus is an essential plant nutrient which is added to soil as soluble inorganic phosphate that, in a large portion, becomes insoluble and, therefore, unavailable to plants. Furthermore, this mineral is most affected by the degrading processes of the soils. The continuous agriculture causes decrease in the soluble phosphorus and in smaller degree in the total inorganic phosphorus. The insoluble inorganic compounds of phosphorus can be converted by bacteria into available phosphates for plant roots. Many fungi and bacteria solubilize inorganic P compounds such as rock phosphate and make it available to the plants. Organic acids liberated by these bacteria act as chelating agent and have direct acidifying effect on the surrounding environment. Phosphatase enzymes have also been reported to play an important role in P solubilization. Improvement of acid production in the rhizosphere as the result of bacterial inoculation is certainly involved in phosphate solubilization by both bacteria and plants. The main active strains include a range of genera *Pseudomonas, Mycobacterium, Micrococcus, Bacillus, Flavobacterium, Rhizobium* and manymore. It is generally accepted that the mechanism of mineral phosphate solubilization by PSB strains is associated with the release of low molecular weight organic acids which through their hydroxyl and carboxyl groups chelate the cations bound to phosphate, thereby converting it into soluble forms.

**Production of Phytohormones**

Production of IAA, Gibberellins and related compounds has been found in *Pseudomonas* Sp. Growth promoting diazotrophs can enhance the growth and development of associated crops.
by transforming fixed N or by improving nutrient uptake through modulation of hormone linked phenomenon in inoculated plants.

**Production of Cyanide**

Some species of *Pseudomonas* excrete HCN which can effectively inhibit phytopathogens. Site of target is cytochrome oxidase.

**Production of Antibiotics**

Several studies have demonstrated that *Pseudomonas* sps. have great ability to produce antifungal metabolites like 2-4 diacetyl phloroglucinol (Phl), pyoluteorin, pyrrolnitrin and oomycin etc.. *Gaumannomyces graminis var. tritici* (Ggt), take all disease of wheat can be controlled by Phl producing pseudomonads in suppressive soil. Genetic engineering, modification in nutrient status, gene regulation at transcription level are some strategies which can be used for enhanced and fruitful effect of pseudomonads application as biocontrol agent.

<table>
<thead>
<tr>
<th>Metabolites (antibiotics)</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oomycin A</td>
<td><em>P. fluorescens</em></td>
</tr>
<tr>
<td>Oxychlorophin</td>
<td><em>P. chlororaphis</em></td>
</tr>
<tr>
<td>Pyoluteorin</td>
<td><em>P. chlororaphis</em></td>
</tr>
<tr>
<td>Pyrrolnitrin</td>
<td><em>P. fluorescens</em></td>
</tr>
</tbody>
</table>
Major Seed Pieces Transmissible Diseases of Sugarcane and their Management by Three Tier Seed Programme

R.K. Sahu
Department of Plant Pathology, G.B.P.U.A.&T., Pantnagar- 263 145 (Uttarakhand)

Sugarcane is one of the most energy rich plant and most efficient converters of solar energy in to not only in sugars (Sucrose) but also in other renewable forms of energy. Basically, it is an tropical region crop but grown very successfully in subtropical regions under diverse agro ecological situation for various agro industrial purposes through out the country.

Out of total sugarcane produced, it is estimated that 70% is used in sugar industry whereas 18% is used for the production of Gur (Jaggery), Khandsari, Rav and Juice and 12% is used as seed. In beginning the plant was domesticated only for its sweet stem but later on it was used for various other purposes. Now a days the by products of sugar industry are of much significant. Products like Bagasse, Molasses, Filter press cake or press mud which are generated during sugar production are used as raw material for the production of paper, different types of boards making, rayan, liquir, alcohol, gasohol and other derivatives of alchohol and chemicals, animal feed, antibiotic, biofertilizer and raw material for generating electricity. Due to crisis and limited availability of the mineral oil/crude oil, it is a hope for future ecofriendly fuel and may be a substitute. Among several countries Brazil is one where use as fuel in transportation has tremendously increased. Govt. of India in 2009 has also decided to mix 5% Alchohol in petrol.

It was estimated that in a typical sugar mill 100(t) of sugarcane, on an average produce 10 ton of sugar (sucrose), 4(t) of molasses from which ethanal is produced, 3(t) of press mud which is converted in to biofertilizer, 30(t) of bagasse used for co-generation of power to yield 1,500 Kw electricity and for manufacturing of paper. About 30(t) of cane tops and leaves are generally left in the field which again has multifold use like animal fodder. Dry leaves are used in thatching the huts and several other means and remaining is used for recycling in the field (mulch). Sugarcane thus play a major role in the economy of sugarcane growing areas in particular and nation as whole and hence increasing sugarcane production will certainly bring the smiles in the face of farmers and other stake holders associated with this crop directly or indirectly.

The cane area estimated during 2006 were 48.32 lakh ha and 51.54 lakh ha in 2007. In 2005-06 sugar production was 19.32 MT whereas in 2006-07 it was 28.36 MT and in 07-08 it was 26.35 MT. As the population is increasingly increasing day by day and is expected to be in between 1237 to 1262 million in the year 2011 and in between 1504 to 1690 million in year 2025. Correspondingly the land resources, what we are having are condensing day by day because of several uses especially in industries, infrastructure facility creation and residential purposes. To cater the need of this growing population, we have the only way out to increase the productivity of the crop hence forth. Productivity of southern & Maharashtra is 90-110 t/ha whereas in the major sugarcane producing Northern states (Uttar Pradesh, Uttarakhand, Punjab and Haryana which

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accounts for 67% area of the country) the productivity of these states is ranging some where 43-60 t/ha than the national average 67 t/ha which in lower and is of major concern.

As the vagarics of agroclimatic condition and many biotic & abiotic stress sugarcane crop is suffering. Among serval biotic stresses and constraints responsible for low cane production & productivity, diseases are one of the major constraints causing 19-20% losses. If we can minimize this loss, then it will help a lot for sugrpool.

More than 240 disease caused by Fungi, bacteria, Virus, Phytoplasma, Nematodes etc have been reported from various parts of the world causing low to severe losses every year. Out of these a dozen are important in our country which are occurring year after year. Among these only 7 disease (major) which are seed /sett borne are more prevalent and causing moderate to severe loss depending on the severity and agroclimatic condition, cropping pattern and the susceptibility of the host.

The diseases of sugarcane which are sett/ seed borne and exerting huge losses are Red rot, Smut, Wilt, GSD, Mosaic, Ratoon Stunting & Leaf scaled. A short account of these diseases are given as:

1. Red rot

   In India the disease was first recorded in the Godawari Delta of Andhra Pradesh by Barber in 1901. Presently this disease is of wide occurrence in varying degree where ever the sugarcane crop is under cultivation in the country & particularly rampant in eastern U.P. & Northern Bihar making these places as ‘hot spots’. This disease because of its most devastating nature has made several promising sugarcane varieties obsolete.

   The disease is caused by a fungus Colletotrichum falcatum Went. The initial symptoms appear as third fourth leaves from the top start drying from margin inwards & ultimately entire leave dry. Mid-rib lesions become conspicuous during monsoon. The lesions usually start as minute red spots on the upper surface of the mid-rib & further develop forming long lesions. During later stage, the canes become shriveled and lighter in weight. When the canes are split open longitudinally, the pith is found reddened accompanied by white transverse patches at right angles. In advance stage of the disease the red colour may be replaced by dirty brown & white bands look hazy or unclear. These dried canes often emit sour odour & juice does not set well on boiling.

   Diseased seed setts are the main source of survival & spread of the pathogen.

2. Smut

   The disease is world-wide in occurrence except Australia, among 121 sugarcane producing countries. During 1942-43, it assumed devastating epidemic form in Bihar affecting 66% of the cane area. The causal organism of this disease is Ustilago scitaminea (syn. Sporosorium scitaminea) which gets transmitted through infected seed setts and can also survive through the spores fallen on the ground.

   Affected plants are characterized by the production of long, whip like structure with black
dusty mass of spores at apex. During early stage this structure is straight & becomes curved, several feet in length. Subsequently, the whip remains covered with a bright whitish membrane. On bursting of membrane the spores come out & healthy plants get infected by air. Such structure can be observed in flushes: first during the months of May-June and secondly during October-November. Infected plants often have slender & thin canes (look likes “Narkul” a wild grass) and become lighter in weight due to drying of canes & sometimes many tillers develop.

3. Wilt

Earlier wilt disease was confined to northern belt of sugarcane particularly Bihar state from where it spread to U.P., Punjab & Haryana. In Tamilnadu, during 1955-56, the disease caused considerable damage with 5-80 percent incidence. Similarly during 1959-60 it assumed severe proportion in Andhra Pradesh where incidence was as high as 100% in cultivar like Co 775. The disease is caused by a fungus *Cephalosporium sachari* and is transmitted mainly through infected seed setts. The fungus can also survive in the soil. This disease commonly occurs with the infection of red rot & poor crop is more prone to wilt infection. Disease intensity largely depends upon faulty drainage & prevailing draught or in sufficient moisture conditions in the field. The most striking symptoms of the disease become apparent late in the season which are yellowing accompanied by drooping of the top when the crop is ready for harvest, the growth of plants is held up & the affected canes dry rapidly. In the initial stage of the disease when the canes are split open, the tissues, particularly of the lowest internodes have a brick-red / dirty red colour in the form of conical shaped spots. This reddening may be confined to a few internodes or extended to the entire length of the cane. Such canes dry up, become hollow & there is considerable reduction in the quality of juice. Disease canes produce characteristic foul odour.

4. Mosaic (Sugarcane mosaic)

In India the disease was first observed in 1927. Subsequently its appearance has been reported from different sugarcane growing areas in the country. The casual virus belongs to the potato virus ‘Y’ group and known as Sugarcane mosaic virus (*Marmar Sacchri*). Infection of this disease occurs through infected seed setts. In India *Rhopalosiphum maidis* is the main vector though *Toxoptera graminum* (*Schizaphis graminum*) has also been demonstrated to be a vector of SCMV. The virus is also sap transmissible. In India disease losses have been estimated between 10-20 percent. The disease symptoms characteristically appear on basal portion of foliage than on the older leaves prominently in the form of yellowish or chlorotic stripes alternate with green space of the leaf- a mosaic pattern. Considerable increase in chloratic area over the normal green & appearance of symptoms on the leaf sheath become common features during advance severe infection yellow stripes also appear on the rind of the internodes & stalks finally dry up forming ‘sunken’ areas called as canker stage of mosaic. The disease affects both in quantity of sugar & Jaggery as well as their quality also.

5. Grassy shoot disease (GSD)

The GSD was first observed in 1919 by Barber and reported by Vasudeva in 1955 from
Belapur, Maharastra. The disease has been recorded in most of the sugarcane growing belt in India. But since then the incidence is being particularly high in Maharastra and is caused by Phytoplasma.

The disease is characterized by proliferation of auxiliary buds from base of the cane giving rise to profuse/ crowded bunch of tillers bearing narrow leaves which exhibit varying degrees of loss of chlorophyll, ranging from total green to white (albinism). Cane formation rarely takes place in affected clumps & if formed they are thin with short internodes giving plant a bushy appearance. According to reports diseased clumps were observed at average. 6%, 16%,24%, 28%, 24% & 2% in June, July, August, September, October & November, respectively.

The primary transmission of disease is through infected cane setts while the secondary transmission is through insect vectors i.e. aphids Rhopalosiphum maidis, Melanaphis sacchari & M indosachari. Transmission through infected knife & dodder (Cuscuta campestris) may also occur from diseased to healthy plants.

6. Ratoon Stunting Disease (RSD)

In India the disease was first reported by Prof. Chilton from Gola Gokarannath of Lakheempur Kheeri distt. of U.P. in 1956 in a cultivar CoS 510. Leifsonia xyli sub sp. xyli a bacteriaum, is responsible for causing this disease in sugarcane which spreads through diseased cane setts.

Yellowish leaves, reduced tillering, short internodes & thin stalks are the characteristic symptoms of RSD. The infected canes when split open longitudinally orange-red vascular bundles in shades of pink, red & reddish brown or yellow-orange at the nodes can be seen. Well defined symptoms appear in the crop deficit in moisture, nutrients etc.

7. Leaf- Scaled

This disease is caused by Xanthomonas albilineans and is favoured by wet seasons, water stress, water logging and low temperature. Symptoms appear in two phases one is “chronic” and other is “acute”.

In chronic phase “white pencil line” extending in entire length of lamina reaching the margin of young leaves and stripes diffuse resulting leaf etiolation. Since drying starts tip onwards therefore a scaled appearance is seen and therefore the name “scaled” has been given, chlorosis varies from total albinism to interveinal chlorosis in young leaves with bussy appearance in standing cane if the stalk is cut, then dark colour vascular strands, & prominent streaks at node may be seen.

In “Acute phase” the symptoms appear suddenly and die without major leaf symptoms. The masking of symptoms are more common during monsoon and symptoms may appear suddenly any time during crop growth.

Disease management in Sugarcane

Depending upon mode of survival of the pathogen, its transmission and source of primary inoculum infection, various diseases occurring in sugarcane, are being managed. For instance.
Diseases like SCMV & GSD which are primarily transmitted through diseased seed setts & subsequently aphid vectors play crucial role in transmission of inoculum from a diseased plant to a healthy plant. The best way to control/ manage the said maladies would be treatment of cane setts through Moist Hot Air method at 54°C for 4 hours coupled with spray of aphicides like Methyl-o-demeton 25 E.C. or Dimethoate 30 E.C. at 0.1 percent concentration for the control of vectors. Similarly, different aspects of management are taken up for the control of various diseases. When more than one disease occur together in a crop season or locality the management of each one of them separately would involve higher cost, more labour & would also consume more time. To over come with such problems comfortably and effectively use of resistance varieties recommended for the particular zone followed by the quality and healthy cane seed coupled with due thermotherapy, chemotherapy and recommended cultural practices are the best way to manage the sett borne diseases because, sugarcane being a vegetatively propagated crop has a low 1:6 to1:8 seed multiplication rate and therefore, non-availability of quality seed material is one of the major draw back faced by the farmers. Further, the bulkey, cane cuttings used for planting as seed harbor many pest & diseases, thereby decreasing cane yield and quality drastically. Infact poor quality seed is a major constraint in sugarcane production and disease management as well.

**Three tier seed production programme in Sugarcane**

As a poor quality seed increases the cost which result in poor germination and consequently less number of malleable cane & poor production and productivity and more incidence of disease and pest it is therefore adesible to go for three tier seed production programme which will not only meet most of the problem but also helpful to minimise the incidence of the seed borne diseases as mentioned above.

**The three tier seed production programme includes the following:**

1. **Nucleus seed/Breeder seed/ Primary seed:** It is genetically 100% pure and free from all kinds of disease and insect pests. This seed is raised by the breeders of originating centers and used for foundation seed productions.

2. **Foundation seed/ Secondary seed:** It is also 100% genetically pure and free from pests and diseases. It is raised from breeder seed in supervision of Scientist/Breeders. Before planting for foundation seed, seed material should be treated with hot water or moist hot air. During crop period five times supervision is required.

3. **Certified seed/ Commercial seed:** This type of seed is raised without hot water/air treatment. This type of seed can be raised in farmers plot of the reserve area of the factory or factory farms in consultation with technician/ technical person. Three inspections or supervisions are required during crop period in which 100% clumps are examined in first visit and 25% in second and third visit.

**Seed cane standards:** There is no certification of seed by any agency so far as sugarcane is concerned. Recently the seed cane standards for sugarcane have been worked out and the approved sugarcane seed cane standards for tropical and subtropical India is as under.
Age of the seed cane at harvest for seed purpose shall be 6-8 months and 8-10 months for sowing in tropics and subtropical respectively. Buds of seed cane material should be undamaged and clean. Each node of seed cane shall bear one bud. The number of nodes without sound bud shall not exceed 5% of total number of buds for seed cane. The number of buds which have swollen up or have projected beyond one centimeter from the rind surface shall not exceed 5% of total number of buds.

I. Application and amplification of general seed cane certification standards.
The certified classes shall be produced from the seed canes/or mericlones where sources and identity be assured and approved by the certification agency.

II. Land requirements
   a. A seed crop of sugarcane shall not eligible for certification if planted on land on which sugarcane was grown in the pervious season.
   b. Land/seed crop shall be kept free from sugarcane residues and drainage from other sugarcane fields.
   c. Foundation stage seed should be raised through hot water/ moist hot air treatment (MHAT).

III. Field inspection:

<table>
<thead>
<tr>
<th>Seed type</th>
<th>Date of inspection after planting (days)</th>
<th>First</th>
<th>Second</th>
<th>Third</th>
<th>Fourth</th>
<th>Fifth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundation</td>
<td></td>
<td>45-60</td>
<td>120-130</td>
<td>150</td>
<td>250</td>
<td>15 days before harvest</td>
</tr>
<tr>
<td>Certified seed or commercial seed</td>
<td></td>
<td>120</td>
<td>200</td>
<td>15 days before harvest</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

IV. Field standards:
   a. General requirement like isolation.
      The sugarcane seed production fields shall be isolated from other fields with a minimum distance of 5 meters to avoid mechanical mixtures of others varieties
   b. At the time of final inspection, tolerance limit of diseases and insect pests should be as under.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Disease and insect- pests</th>
<th>Affected clumps (%)</th>
<th>Breeder seed</th>
<th>Foundation seed</th>
<th>Certified or commercial seed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Red rot, Smut, Wilt, Grassey shoot, Leaf scaled.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Scale insects</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Plassey/Gurdaspur borers</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Other borers</td>
<td>10</td>
<td>20</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

Important points for quality seed production:
   1. All off types and diseased plants shall be rogued out along with roots and destroyed.
2. Maximum permissible limit for detrashing of dry foliage shall be 2.0%
3. The crop should not have more than 10% lodged canes.
4. Seed cane should not have nodal roots. In waterlogged areas, relaxation may be given upto a maximum of 5%
5. Moisture in seed cane should not be less than 65% on wet basis.
6. Germinability of buds should not be less than 85%
7. Physical purity of seed should be 98%
8. Genetic purity of seed should be 100%

REFERENCES

Genetically modified organisms (GMOs) or TRANSGENICS are being developed to transfer of useful genes from GP4 to GP1 species. Transgenics are produced using genetic engineering methods. Transgenics for resistance against plant pathogens such as viruses, fungi, bacteria and nematodes can be developed.

**Methods for development of viral resistant transgenics**

The following methods can be employed in the development of viral resistant transgenic.

1. **Incorporation of viral sequence**
   a. Viral coat protein-effective against all classes of virus in many different plant species such as rice, melon, potato, papaya, sugarbeet. Incorporation of coat protein results in sequestration of the incoming genome of the challenger virus
   b. Replicase gene- shown strong resistance against very close viruses. It has show to provide very strong resistance against only closely related viruses
   c. Dysfunctional movement protein(MP)- It provides resistance to a wide range of strains.

2. **Satellite viruses/RNA**
   a. Satellite RNA(viral parasite)- can not produce capsid coat protein and depends on its replication on supporting strain-reduces the yield of supporting viruses and thereby reduces the severity
   b. Satellite virus- It is a defective virus. It can produce coat protein and it provides resistance against satellite free helper virus

3. **Antisense RNA technology**
   Introduction of antisense RNA blocks gene expression by forming RNA-RNA hybrid with viral sense RNA.

**Methods for developing fungal resistant transgenics**

The following types of genes can be transferred to cultivated varieties to provide resistance against fungal pathogens.

1. Use of gene for cell wall degrading enzymes such as chitinase and beta-1,3 glucanase
2. Ribosome inactivating proteins(RIPs) from different plant species
3. Pathogenesis related proteins(PRPs)
4. Small anti-fungal peptides and anti-fungal peptides or proteins from other organisms
5. Use of a foreign phtoalexin
6. Expression of AOS(active oxygen species)

Chitinase or beta-1,3 glucanase gene can be used either alone or simultaneously. Further, gene for Chitinase can be combined with RIP and this has shown higher level of resistance. Pathogenesis related proteins, PRP-a- induced at high levels of resistance in tobacco during systemic acquired resistance(SAR). Similarly, PRP-5 showed resistance against *Phytophthora infestans*. Small antifungal peptides such as- Defensin, Rs-AF-P2(obtained from radish),
Thionine (from wheat and barley), Lectin (from beetle) and lipid transfer proteins have shown to provide resistance.

**Methods for developing bacterial resistant transgenics**

The following methods can be used for producing bacterial resistant transgenics.

1. Gene from non-plant origin
2. Plant proteins
3. Toxin inactivating enzymes
4. Pathogen derived toxin resistant enzymes
5. Production of antibacterial proteins of non-plant origin
6. Enhancing natural plant defenses
7. Inducing programmed cell death (PCD) at the site of infection

   Alpha-thionine gene obtained from barley and transferred to tobacco produces toxin inactivating enzyme against *P. syringae*

PCD mimics Hypersensitive resistance. It is shown to be associated with the following.

**Expression of PRP**

Generation of oxygen intermediate

Rapid influx of Ca and generation of an oxidative burst

Production of phytoalexin

Cross-linking of components of cell wall

Further, both hydrogen peroxide and superoxide anions are suggested factors in the execution of infected cell death by hypersensitive resistance

Avr9 from *C. fulrum* and transgenic containing resistance gene, cf-9 resulted in massive HR leading to cell death

Finally, transgenic containing avr-9 with a TE (transposable element) inserted in cf-9 would lead to cell death. Upon excision of TE from the cf-9 gene in a particular cell will result in expression of avr-9.

**Breeding for nematode resistant transgenics**

The following strategies have been employed in developing transgenics having resistance against nematode.

1. Anti-invasion and migration
2. Feeding cell attenuation
   - Gene encoding an antinematode effector protein, peptide or interfering RNA
   - Promoters directing a specific pattern of expression for that effector

Effector acts directly at the nematode as well as at the nematode feeding sites (NFS).

Protease inhibitors (PIs) work as antinematode effectors. There are four classes of PIs such as Cysteine, serine, aspartyl and metallo.

Serine PI - Cowpea Trypsin inhibitor (CpTi)

It has expressed in potato against *Globodera pallida*, results in much smaller and less damaging males.

Lectin-pea lectin has shown resistance against t *G. pallida*
Cystatins(Cysteine PI) causes G.pallida to grow slowly than normal, size of females reduced and egg production reduced.

**RNAi(RNA interference)**

There is potential for delivering dsRNA from plant cell to nematode but it requires production of a long RNA for uptake by nematode.

**Use of barnase-barstar system for programmed cell death**

Barnase- a small RNase (a bacterial ribonuclease gene). It's expression leads to emasculation of maize and the gene is regulated by tapetum-specific promoter.

Barstar- an inhibitor protein. The expression of barstar is using promoter, CaMV35S. Expression of barnase predominantly in nematode feeding site(NFS) using a specific promoter is required. The gene, barstar expresses constitutively.

For detail on development of viral, fungal, bacterial and nematode resistant transgenics, the reader is referred to chapter 34(page number 606-612) in Plant Breeding(Roy, 2009).

**Steps involved in the production of transgenics**

The steps involved in the development of transgenics are as follows.

1. Identification of target gene for transfer
2. Creation of plasmid DNA which will contain this target gene and insertion into a vector, say bacteria(*Agrobacterium tumefaciens*)
3. Infection of cell culture with bacteria to transfer gene
4. Growing of cell culture into adult plants and using their seeds to generate GM showing resistance against either herbicide, insect, fungus, bacterium, virus or nematode.

**Problems with transgenics**

1. Recombination between transgene and non-target organism
2. Gene flow of pollen from transgenic to weeds-leading to development of herbicide resistant weeds
3. Transmission of unrelated viruses by transencapsidation or enhanced seed or pollen transmission
4. Synergy with unrelated viruses
5. Exposure to new allergens or toxic proteins
6. Increases susceptibility to other pathogens

Transgenic papaya having resistance to papaya ring spot virus has shown susceptibility to Phytophthora.

Transgenics have been developed in crops such as soybean, maize, cotton, canola and papaya. Out of a total of more than 114 millions ha under transgenics, half area is in U.S.A.

**REFERENCES**

VALEDICTORY ADDRESS

by

Prof. B.S. Bisht

Vice-Chancellor

G.B. Pant University of Agriculture & Technology, Pantnagar- 263 145

on

April 10, 2010

It is a pleasure having to deliver the valedictory address on the successful completion of the 23rd CAFT training on “Recent Advances in Biological Control of Plant Diseases”. I am sure that you all have enjoyed the scientific interaction during your stay at Pantnagar as well as exposure trip to Ranichauri during course of the training.

As you all know, agriculture is a way of life and will continue to remain the mainstay of all strategies for socioeconomic development of the country. In view of increasing world population and escalating overall food requirements rapid growth of agriculture is essential for ensuring food security and alleviating poverty.

It is well known that plant disease epidemics have influenced man’s food, his health, social customs and even his ability to wage wars. Human sufferings and epidemics of plant diseases have gone hand in hand since the earliest history of man. History illustrates that plant diseases can have a significant effect on human society. A most devastating event that vividly illustrates the consequences of a plant disease was the Irish Potato Famine of the 1840's, which explicits the far-reaching effects plant pathogens can have on religion, politics, art, economics, and culture. Approximately, 1.5 million of those victims died as a result of either famine or disease, and the rest were forced to immigrate to North America. Another devastating disease of rice called brown spot led to ‘The Bengal Famine of 1943’ and resulted into the death of an estimated 4 million people in India. Even today, catastrophic plant disease exacerbates the current deficit of food supply in which at least 800 million people are inadequately fed.

India is being acknowledged as growing economic giant but the benefits of this progress are mostly confined to urban or semi-urban areas. More than 65% of the population in the country lives in rural areas and depends on agriculture and related avenues for their sustenance. Hunger and poverty persists because of lack of work opportunities, thus inadequate income for farming community. Indian agriculture, basically characterized as a means of subsistence, is changing fast as per market demands, both domestic and international. Modern high input monocropping based intensive agriculture has resulted in loss of biodiversity (both flora and fauna), out-breaks of pests and diseases,
degradation of soil and water, which has ultimately led to decline in agricultural production and productivity. Climatic changes are becoming a major factor in the present scenario.

Growing population of India thereby putting more pressure on agro-ecosystem for more food is a serous concern. At the time of independence 350 million people lived in the country, which after 60 years have grown to more than a billion with more than 50% below the age of 30 years. As our food production is not meeting the requirements, food is being imported. By 2025, the food requirement is likely to be doubled. Thus, more food will have to be produced in ways that generate income for poor rural populations and that also make food affordable to poor people in urban areas. Growing demand must be met primarily by increasing production on land already under cultivation (productive and marginal lands) and by reducing losses due to diseases and pests.

The crop yield losses, on field and during post harvest period, caused by pests, diseases and weeds are of paramount importance. Diseases are critically important components of agroecosystems globally, for social, economic and biological reasons. Damaging diseases may reduce food production: world wide annual losses due to diseases are 25-30% of attainable production of principle food and cash crops, with developing countries experiencing the greatest losses. In India, the annual crop losses due to diseases and pests have been estimated at Rs 60,000 crores. Avoiding or minimizing these losses could significantly augment the overall food production in the country.

Plant diseases, need not be epidemics, are of paramount importance to human well being. They can make the difference between a comfortable life and life haunted by hunger, misery or even death from starvation. Various types of direct and indirect losses caused by plant diseases include, reduced quality and quantity of crop produce, increased cost of production, threat to animal health and environment, limiting the type of crops / cultivars grown, loss of natural resources and less remunerative alternatives adopted. In order to combat the losses caused by plant diseases, it is necessary to define the problem and seek remedies. At the biological level, the requirements are for the speedy and accurate identification of the causal organism, accurate estimates of the severity of disease and its effect on yield, and identification of its virulence mechanisms. Disease may then be minimized by the reduction of the pathogen's inoculum, inhibition of its virulence mechanisms, and promotion of genetic diversity in the crop.

Success in pest management, as in most walks of life, depends on having the right tools and the confidence to apply them. The key tool for disease control is knowledge and having knowledge gives confidence.

Diagnostic and advisory support systems are facing massive challenges in making relevant and effective knowledge and support available to farmers and market chains and ensuring that upstream researchers are
informed of the real priority problems and issues requiring resolution.

Many countries, including India, have suffered from the entry and spread of an increasing number of plant pathogens. A global Pest Risk Analysis could be done on particular commodities from normal sources to identify the main risks for regions where food aid is anticipated or routinely provided. The global plant pathology knowledge-base should be the basis for facilitating scientifically based decisions relative to quarantine regulations that will ensure the safe and responsible exchange of crop germplasm across international boundaries.

Current sensitivities about environmental pollution are a consequence of improper synthetic pesticide use. Host-plant resistance, natural plant products, biopesticides, natural enemies, and agronomic practices offer a potentially viable option for integrated pest management (IPM). They are relatively safe for the non-target organisms and humans. Biotechnological tools such as marker assisted selection, genetic engineering, and wide hybridization to develop resistant crop cultivars will have a great bearing on future pest management programs. Disease modeling, decision support systems, and remote sensing would contribute to scaling up and dissemination of IPM technologies.

Plant Pathology is challenging and an important science that deals with science of disease development and art of managing diseases. The amount of food loss averted is a direct contribution in the food basket of hungry millions. Society, consumers and growers will only be able to continue to benefit from plant pathology if the discipline can evolve appropriate disease management schemes that can respond to the significant changes in agricultural practices in both industrial and developing countries; the ultimate goal is to produce more and safer food in sustainable agricultural systems that conserve natural resources and the environment. Developing appropriate schemes for large farmers in the industrial countries and for subsistence farmers in the developing countries presents different challenges, but joint action in their development can be of mutual benefit to all parties.

I am delighted to know that all such points were appropriately addressed in this particular training course, which I am sure was very well designed and appropriately conducted.

It is hoped that you would use the knowledge gained through the training in teaching, research and extension activities at your respective institution/university. You are now in a way alumni of this university and I am sure that you will maintain this linkage in a dynamic manner for our mutual benefit in the pursuance of science of Plant Pathology, especially in the area of plant health management.

I wish you a safe and comfortable journey back home and fruitful professional career ahead.

Jai Hind
# ANNEXURE-I

## CENTRE OF ADVANCED FACULTY TRAINING IN PLANT PATHOLOGY
College of Agriculture, Pantnagar-263 145 (Uttarakhand)

Following committees have been constituted for smooth conduct of the training programme on “Plant Pathology in Practice” scheduled on March 22 to April 11, 2010.

<table>
<thead>
<tr>
<th>1. Overall Supervision</th>
<th>2. Course Faculty</th>
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<tbody>
<tr>
<td>Dr. J. Kumar, Director CAFTPP</td>
<td>Dr. J. Kumar – Course Director</td>
</tr>
<tr>
<td>Dr. A.P. Sinha</td>
<td>Dr. H.S. Tripathi, Course Coordinator</td>
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<tr>
<td>Dr. H.S. Tripathi</td>
<td>Dr. R.P. Awasthi</td>
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<td>Dr. R.P. Awasthi</td>
<td>Dr. (Mrs.) K. Vishunavat</td>
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<td>Dr. V.S. Pundhir</td>
<td>Dr. V.S. Pundhir</td>
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<td>Dr. (Mrs.) K. Vishunavat</td>
<td>Dr. A.P. Sinha</td>
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<tbody>
<tr>
<td>Dr. A.K. Tewari– Chairman</td>
<td>Dr. K.P.S. Kushwaha – Chairman</td>
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<tr>
<td>Mr. Narender Singh</td>
<td>Dr. K.K. Mishra</td>
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<td>Mr. S.P. Yadav</td>
<td>Mr. S. P. Yadav</td>
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<td>Mr. Mani Ram</td>
<td>Mr. Jagannath</td>
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<td>Dr. R. P. Awasthi – Chairman</td>
<td>Dr. Pradeep Kumar – Chairman</td>
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<tr>
<td>Dr. Yogendra Singh</td>
<td>Mr. Prakash Joshi</td>
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<tr>
<td>Mr. K. S. Bhatnagar (Account Officer)</td>
<td>Mr. P.C. Khulbe</td>
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<td>Mr. A. B. Joshi</td>
<td>Mr. Bhupesh Kabdwal</td>
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<td>Mr. Praveen Kumar</td>
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<td>Mr. Het Ram</td>
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<th>7. Boarding &amp; Loading Committee</th>
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<tr>
<td>Dr. V.S. Pundhir – Chairman</td>
<td>Dr. (Mrs) K. Vishunavat – Chairperson</td>
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<tr>
<td>Dr. R.K. Bansal</td>
<td>Dr. Pradeep Kumar</td>
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<td>Dr. (Mrs.) Kanak Srivastava</td>
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<th>9. Session Arrangement Committee</th>
<th>10. Field / Excursion Trip Committee</th>
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<tr>
<td>Dr. H.S. Tripathi – Chairman</td>
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<th>12. Committee for typing correspondence work</th>
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<tr>
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# TRAINING ON PLANT PATHOLOGY IN PRACTICE
(December 22 to March 11, 2010)

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</tbody>
</table>
| Faculty | Dr. J. Kumar, Director CAFT Plant Pathology  
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<tr>
<td>Dr. R.P. Awasthi</td>
<td>Professor, Plant Pathology</td>
</tr>
<tr>
<td>Dr. (Mrs.) K. Vishunavat</td>
<td>Professor, Plant Pathology</td>
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<tr>
<td>Dr. V.S. Pundhir</td>
<td>Professor, Plant Pathology</td>
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<tr>
<td>Dr. R.K. Sahu</td>
<td>Professor, Plant Pathology</td>
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<tr>
<td>Dr. Vishwanath</td>
<td>Assoc. Prof., Plant Pathology</td>
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<tr>
<td>Dr. K.P.S. Kushwaha</td>
<td>SRO, Plant Pathology</td>
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<tr>
<td>Dr. Y. Singh</td>
<td>SRO, Plant Pathology</td>
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<tr>
<td>Dr. A.K. Tewari</td>
<td>SRO, Plant Pathology</td>
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<tr>
<td>Dr. N.W. Zaidi</td>
<td>Asstt. Professor, Plant Pathology</td>
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<tr>
<td>Dr. K.K. Mishra</td>
<td>JRO, Plant Pathology</td>
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<tr>
<td>Dr. M.A. Khan</td>
<td>Professor &amp; Head, Entomology</td>
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<tr>
<td>Dr. S.N. Tewari</td>
<td>Professor, Entomology</td>
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<tr>
<td>Dr. H.S. Kushwaha</td>
<td>Professor, Soil Science</td>
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<tr>
<td>Dr. K.P. Raverkar</td>
<td>Professor, Soil Science</td>
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<tr>
<td>Dr. P.C. Srivastava</td>
<td>Professor, Soil Science</td>
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<tr>
<td>Dr. S.K. Saini</td>
<td>Prof. &amp; Head, Agronomy</td>
</tr>
<tr>
<td>Dr. Sunita T. Pandey</td>
<td>Professor, Agronomy</td>
</tr>
<tr>
<td>Dr. H.S. Chawla</td>
<td>Professor, Genetics and Plant Breeding</td>
</tr>
<tr>
<td>Dr. D. Roy</td>
<td>Professor, Genetics and Plant Breeding</td>
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<tr>
<td>Dr. P.K. Shrotia</td>
<td>Professor, Genetics and Plant Breeding</td>
</tr>
<tr>
<td>Dr. B. Kumar</td>
<td>Professor &amp; Head, Agriculture Communication</td>
</tr>
<tr>
<td>Dr. (Mrs.) Surya Rathore</td>
<td>Professor, Agriculture Communication</td>
</tr>
<tr>
<td>Dr. S.K. Tewari</td>
<td>Professor, Agricultural Economics</td>
</tr>
<tr>
<td>Dr. J.P. Singh</td>
<td>Professor, Vegetable Science</td>
</tr>
<tr>
<td>Dr. N.S. Murty</td>
<td>Prof. &amp; Head, Agrometeorology</td>
</tr>
<tr>
<td>Dr. Anil Kumar</td>
<td>Professor and Head, MBGE</td>
</tr>
<tr>
<td>Dr. A.K. Gaur</td>
<td>Professor, MBGE</td>
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<tr>
<td>Dr. Reeta Goel</td>
<td>Professor &amp; Head, Microbiology</td>
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<tr>
<td>Dr. Anita Sharma</td>
<td>Assoc. Prof., Microbiology</td>
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<tr>
<td>Dr. Anil Sharma</td>
<td>Assoc. Prof., Biological Science</td>
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<tr>
<td>Dr. Balwinder Singh</td>
<td>Assoc. Prof., Vet. Anatomy</td>
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<tr>
<td>Dr. K.P. Singh</td>
<td>Assoc. Prof., Plant Pathology, Hill Campus Ranichauri</td>
</tr>
<tr>
<td>Dr. Arundhati Kausik</td>
<td>Assistant Librarian</td>
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</tbody>
</table>
**ANNEXURE-IV**

**CENTRE OF ADVANCED FACULTY TRAINING IN PLANT PATHOLOGY**

G.B. Pant University of Agric. & Tech., Pantnagar-263 145 (UK)

**Course Schedule (March 22 to April 11, 2010)**

“**PLANT PATHOLOGY IN PRACTICE**”

**Venue**: PG Lab- Department of Plant Pathology

<table>
<thead>
<tr>
<th>Day &amp; Date</th>
<th>Time</th>
<th>Topic (Lecture/ Lab)</th>
<th>Speaker/Contact</th>
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</thead>
<tbody>
<tr>
<td><strong>Monday</strong></td>
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</tr>
<tr>
<td>March 22</td>
<td>09:30-10:15 hrs</td>
<td>Registration &amp; Introduction with Plant Pathology Faculty</td>
<td>Registration Committee</td>
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<tr>
<td></td>
<td>10:15-11:30 hrs</td>
<td>Inaugural Function, Venue: Conference Hall, Agriculture College</td>
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<td>11:30-11:45 hrs</td>
<td>Tea Break</td>
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<td></td>
<td>11:45-13:00 hrs</td>
<td>Visit to Plant Pathology Labs</td>
<td>Dr. K. P. S. Kushwaha</td>
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<td></td>
<td>13:00-14:30 hrs</td>
<td>Lunch, Venue: IGH</td>
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<tr>
<td></td>
<td>14:30-15:30 hrs</td>
<td>Plant Disease: A global threat to food production</td>
<td>Dr. H.S. Tripathi</td>
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<td>15:30-15:45 hrs</td>
<td>Tea Break</td>
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<td>15:45-17:00 hrs</td>
<td>T.A. claims &amp; settlement</td>
<td>Dr. R.P. Awasthi</td>
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<tr>
<td><strong>Tuesday</strong></td>
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<tr>
<td>March 23</td>
<td>09:30-10:30 hrs</td>
<td>Department of Plant Pathology and CAFT activities at Pantnagar</td>
<td>Dr. J. Kumar, Director, CAFT</td>
</tr>
<tr>
<td></td>
<td>10:30-11:30 hrs</td>
<td>Seed treatment as innovative crop protection strategies</td>
<td>Dr (Mrs) K. Vishunavat</td>
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<td></td>
<td>11:30-11:45 hrs</td>
<td>Tea Break</td>
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<tr>
<td></td>
<td>11:45-13:00 hrs</td>
<td>Integrated management of foliar diseases of maize</td>
<td>Dr. S.C. Saxena</td>
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<td></td>
<td>13:00-14:30 hrs</td>
<td>Lunch</td>
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<tr>
<td></td>
<td>14:30-15:30 hrs</td>
<td>Breeding strategies for management of Tomato Diseases</td>
<td>Dr. J.P.S. Gautam, Jt. Dir. VRC</td>
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<td></td>
<td>15:30-15:45 hrs</td>
<td>Tea Break</td>
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<tr>
<td></td>
<td>15:45-17:00 hrs</td>
<td>Strategies to mitigate the threat to wheat production from the Ug99 (TTKS) race of stem rust</td>
<td>Dr. K. P. Singh</td>
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<tr>
<td><strong>Wednesday</strong></td>
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<tr>
<td>March 24</td>
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<td>Holiday (Ram Naumi)</td>
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<tr>
<td><strong>Thursday</strong></td>
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<tr>
<td>March 25</td>
<td>09:30-10:30 hrs</td>
<td>College of Agriculture at a glance</td>
<td>Dr. J.P. Tiwari, Dean, Ag. College</td>
</tr>
<tr>
<td></td>
<td>10:30-11:30 hrs</td>
<td>Quality spawn production</td>
<td>Dr. K.K. Mishra</td>
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<td></td>
<td>11:30-11:45 hrs</td>
<td>Tea Break</td>
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<tr>
<td></td>
<td>11:45-13:00 hrs</td>
<td>Visit to different units of MRTC and demonstration of span production</td>
<td>Dr. K.K. Mishra</td>
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<td></td>
<td>13:00-14:30 hrs</td>
<td>Lunch</td>
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<tr>
<td></td>
<td>14:30-15:30 hrs</td>
<td>Cost effective, sustainable and eco-friendly approaches in IPM</td>
<td>Dr. S.N. Tewari</td>
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<td>15:30-15:45 hrs</td>
<td>Tea Break</td>
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<td></td>
<td>15:45-17:00 hrs</td>
<td>Mango Malformation- Doest the threat continues?</td>
<td>Dr. J. Kumar</td>
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<tr>
<td><strong>Friday</strong></td>
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<tr>
<td>March 26</td>
<td>09:30-10:30 hrs</td>
<td>Epidemiological approaches to disease management through seed technology</td>
<td>Dr. (Mrs.) K. Vishunavat</td>
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<tr>
<td>Time</td>
<td>Event</td>
<td>Speaker</td>
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<td>10:30-11:30 hrs</td>
<td>Microbiologically improved compost for reducing biotic &amp; abiotic stresses</td>
<td>Dr. Anil Sharma</td>
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<td>11:30-11:45 hrs</td>
<td>Tea Break</td>
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<tr>
<td>11:45-13:00 hrs</td>
<td>Visit to Mycorrhizae lab</td>
<td>Dr. Anil Sharma</td>
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<tr>
<td>13:00-14:30 hrs</td>
<td>Lunch</td>
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<tr>
<td>14:30-17:00 hrs</td>
<td>Visit-CD-ROM search (University Library)</td>
<td>Dr. Arundhati Kaushik</td>
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<tr>
<td><strong>Saturday March 27</strong></td>
<td>Factors affecting affectivity of bio-agents against sheath blight of rice</td>
<td>Dr. A.P. Sinha</td>
<td></td>
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<tr>
<td>10:30-11:30 hrs</td>
<td>Metagenomics - A tool for identification and characterization of uncultivable microbial diversity</td>
<td>Dr. Reeta Goel</td>
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<tr>
<td>11:30-11:45 hrs</td>
<td>Tea Break</td>
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<tr>
<td>11:45-13:00 hrs</td>
<td>Prospects of Trichoderma spp for Biological Control</td>
<td>Dr. N.W. Zaidi</td>
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<tr>
<td>13:00-14:30 hrs</td>
<td>Lunch</td>
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<tr>
<td>14:30-15:30 hrs</td>
<td>Visit of Microbiology laboratories</td>
<td>Dr. Reeta Goel</td>
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<td>15:30-15:45 hrs</td>
<td>Tea Break</td>
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<tr>
<td>15:45-17:00 hrs</td>
<td>Molecular characterization of <em>F. oxysporum</em> f. sp. ciceri</td>
<td>Dr. S.C. Dubey</td>
<td></td>
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<tr>
<td><strong>Sunday March 28</strong></td>
<td>Departure to Ranichauri</td>
<td>Dr. R.P. Awasthi</td>
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<tr>
<td>09:30-17:00 hrs</td>
<td>Management of Apple scab</td>
<td>Dr. K.P. Singh, Ranichauri</td>
<td></td>
</tr>
<tr>
<td><strong>Monday March 29</strong></td>
<td>Cultural practices in the management of diseases of horticultural crops</td>
<td>Dr. M.C. Nautiyal, Ranichauri</td>
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<tr>
<td>11:30-11:45 hrs</td>
<td>Tea Break</td>
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<tr>
<td>11:45-13:00 hrs</td>
<td>Current Status of Sesame wilt, Etiology &amp; Management</td>
<td>Dr. Y.P. Singh, Dehradun</td>
<td></td>
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<tr>
<td>13:00-14:30 hrs</td>
<td>Lunch</td>
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<tr>
<td>14:30-15:30 hrs</td>
<td>PGPRs in Disease Management</td>
<td>Dr. Yogesh Negi, Dehradun</td>
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<td>15:30-15:45 hrs</td>
<td>Tea Break</td>
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<tr>
<td>15:45-17:00 hrs</td>
<td>Farmers Field Visit</td>
<td>Dr. K.P. Singh</td>
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<tr>
<td><strong>Tuesday March 30</strong></td>
<td>Visit to Farmers field</td>
<td>Dr. K.P. Singh</td>
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<tr>
<td>10:00-11:00 hrs</td>
<td>Return to Pantnagar</td>
<td>Dr. R.P. Awasthi</td>
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<tr>
<td>12:00 noon</td>
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<tr>
<td><strong>Wednesday March 31</strong></td>
<td>Biofungicides: their role in plant disease management</td>
<td>Dr. H.S. Tripathi</td>
<td></td>
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<tr>
<td>10:30-11:30 hrs</td>
<td>Bio-control of insect pests and insect vectors of plant viruses</td>
<td>Dr. M.A. Khan</td>
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<td>11:30-11:45 hrs</td>
<td>Tea Break</td>
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<tr>
<td>11:45-13:00 hrs</td>
<td>IPR and its role in plant protection</td>
<td>Dr. H.S. Chawla</td>
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<tr>
<td>13:00-14:30 hrs</td>
<td>Lunch</td>
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<tr>
<td>14:30-15:30 hrs</td>
<td>Who am I?</td>
<td>Dr. Sunita T. Pandey</td>
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<tr>
<td>15:30-15:45 hrs</td>
<td>Tea Break</td>
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<tr>
<td>15:45-17:00 hrs</td>
<td>Microarray applications for rhizospheric community analysis for introducing bioagents in organic farming</td>
<td>Dr. A.K Gaur</td>
<td></td>
</tr>
<tr>
<td><strong>Thursday April 01</strong></td>
<td><em>Pseudomonas</em>- a promising PGPR and bio-control agent</td>
<td>Dr. Anita Sharma</td>
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<td>09:30-10:30 hrs</td>
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<tr>
<td>10:30-11:30 hrs</td>
<td>Cultural management in plant disease control</td>
<td>Dr. S.K. Saini</td>
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<td>11:30-11:45 hrs</td>
<td>Tea Break</td>
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<td>Time</td>
<td>Session</td>
<td>Speaker</td>
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<tr>
<td>11:45-13:00 hrs</td>
<td>Seed pieces transmissible diseases of sugarcane and three tier seed programme</td>
<td>Dr. R. K. Sahu</td>
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<td>13:00-14:30 hrs</td>
<td>Lunch</td>
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<tr>
<td>14:30-15:30 hrs</td>
<td>Microbial inoculants in Agriculture</td>
<td>Dr. K.P. Raverkar</td>
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<td>15:30-15:45 hrs</td>
<td>Tea Break</td>
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<tr>
<td>15:45-17:30 hrs</td>
<td>Why plant disease matters to food security</td>
<td>Dr. J. Kumar</td>
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<td>Friday</td>
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<tr>
<td>April 02</td>
<td>09:30-10:30 hrs</td>
<td>Visit of Agrometeorology Lab.</td>
<td>Dr. H.S. Kushwaha</td>
</tr>
<tr>
<td>10:30-11:30 hrs</td>
<td>Micro-climate and plant diseases</td>
<td>Dr. H.S. Kushwaha</td>
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<td>11:30-11:45 hrs</td>
<td>Tea Break</td>
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<td>11:45-13:00 hrs</td>
<td>Knowledge transfer through farmer-participatory training and research</td>
<td>Dr. K.P. Singh</td>
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<td>13:00-14:30 hrs</td>
<td>Lunch</td>
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<tr>
<td>14:30-17:30 hrs</td>
<td>Consultation in Library</td>
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<td>Saturday</td>
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<tr>
<td>April 03</td>
<td>09:30-10:30 hrs</td>
<td>Emerging challenges in Indian agriculture</td>
<td>Dr. S.K. Tewari</td>
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<tr>
<td>10:30-11:30 hrs</td>
<td>Past and Future of immunological assays for the detection of plant pathogens</td>
<td>Dr. A. K. Gupta</td>
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<td>11:30-11:45 hrs</td>
<td>Tea Break</td>
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<tr>
<td>11:45-13:00 hrs</td>
<td>Visit to Biotechnology Lab. CBSH</td>
<td>Dr. A. K. Gupta</td>
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<tr>
<td>13:00-14:30 hrs</td>
<td>Lunch</td>
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<tr>
<td>14:30-15:30 hrs</td>
<td>Methods of isolation and quantification of fungi, bacteria and actinomycetes from soil</td>
<td>Dr. A.K. Tewari</td>
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<td>15:30-15:45 hrs</td>
<td>Tea Break</td>
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<tr>
<td>15:45-17:30 hrs</td>
<td>Contd……Methods of isolation and quantification of fungi, bacteria and actinomycetes from soil</td>
<td>Dr. A.K. Tewari</td>
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<td>Sunday</td>
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<tr>
<td>April 04</td>
<td>09:30-10:30 hrs</td>
<td>Host plant resistance in disease management- innovation to impact</td>
<td>Dr. Suresh Pandey</td>
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<tr>
<td>10:30-11:30 hrs</td>
<td>Climate change and plant diseases</td>
<td>Dr. N.S. Murty</td>
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<tr>
<td>11:30-11:45 hrs</td>
<td>Tea Break</td>
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<tr>
<td>11:45-13:00 hrs</td>
<td>Farmers participatory integrated disease management in legumes at ICRISAT</td>
<td>Dr. Suresh Pandey</td>
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<tr>
<td>14:30-17:30 hrs</td>
<td>Molecular Characterization Lab</td>
<td>Dr. M. Pandey</td>
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<td>Monday</td>
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<tr>
<td>April 05</td>
<td>09:30-10:30 hrs</td>
<td>Exploitation of natural compounds in eco-friendly management of plant pests</td>
<td>Dr. N. K. Dubey, BHU</td>
</tr>
<tr>
<td>10:30-11:30 hrs</td>
<td>Ancient Crop Protection Practices: Relevance as on now</td>
<td>Dr. S.L. Chaudhary</td>
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<tr>
<td>11:30-11:45 hrs</td>
<td>Tea Break</td>
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<tr>
<td>11:45-13:00 hrs</td>
<td>Kunapjala for Crop Health</td>
<td>Dr. S.L. Chaudhary</td>
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<tr>
<td>13:00-14:30 hrs</td>
<td>Lunch</td>
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<tr>
<td>14:30-15:30 hrs</td>
<td>Integrated disease management of economically important diseases in oilseed crops</td>
<td>Dr. R.P. Awasthi</td>
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<tr>
<td>15:30-15:45 hrs</td>
<td>Tea Break</td>
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<tr>
<td>15:45-17:00 hrs</td>
<td>Integrated management of soil borne diseases</td>
<td>Dr. S. Gangopadhyay</td>
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<td>Tuesday</td>
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<tr>
<td>April 06</td>
<td>09:30-10:30 hrs</td>
<td>Integrated management of important foliar disease</td>
<td>Dr. S. Gangopadhyay</td>
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<tr>
<td>10:30-11:30 hrs</td>
<td>GM as a new tool in the resistance toolbox</td>
<td>Dr. D. Roy</td>
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<td>11:30-11:45 hrs</td>
<td>Tea Break</td>
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<tr>
<td>11:45-13:00 hrs</td>
<td>Advances in electron microscopy and application in plant pathology</td>
<td>Dr. Balvinder Singh, VM</td>
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<tr>
<td>Time</td>
<td>Activity</td>
<td>Speaker</td>
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<tr>
<td>13:00-14:30 hrs</td>
<td>Lunch</td>
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<tr>
<td>14:30-15:30 hrs</td>
<td>Sclerotinia sclerotiorum: Biology, epidemiology and eco-friendly management of white mold of rajmash</td>
<td>Dr. J.P. Upadhyay, RAU</td>
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<tr>
<td>15:30-15:45 hrs</td>
<td>Tea Break</td>
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<tr>
<td>15:45-17:00 hrs</td>
<td>Integrated management of major diseases of Sorghum</td>
<td>Dr. Y. Singh</td>
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<td><strong>Wednesday</strong></td>
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<tr>
<td><strong>April 07</strong></td>
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<tr>
<td>09:30-10:30 hrs</td>
<td>Integrated disease management modules in Pigeonpea – present status and future prospects</td>
<td>Dr. J.P. Upadhyay</td>
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<tr>
<td>10:30-11:30 hrs</td>
<td>Epidemiology as a tool for disease management</td>
<td>Dr. V.S. Pundhir</td>
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<td>11:30-11:45 hrs</td>
<td>Tea Break</td>
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<td>11:45-13:00 hrs</td>
<td>Presentation by participants</td>
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<td>13:00-14:30 hrs</td>
<td>Lunch</td>
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<tr>
<td>14:30-15:30 hrs</td>
<td>Prospects of Trichoderma spp for Biological Control</td>
<td>Dr. N.W. Zaidi</td>
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<td>15:30-15:45 hrs</td>
<td>Tea Break</td>
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<td>15:45-17:00 hrs</td>
<td>Pathogen population characterization and resistance management</td>
<td>Dr. J. Kumar</td>
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<td><strong>Thursday</strong></td>
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<td><strong>April 08</strong></td>
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<td>09:30-10:30 hrs</td>
<td>Trainers’ training: Scientific approach</td>
<td>Dr. B. Kumar</td>
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<td>10:30-11:00 hrs</td>
<td>Group Photograph</td>
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<td>11:00-11:30 hrs</td>
<td>Presentation by participants</td>
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<td>Tea Break</td>
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<td>11:45-13:00 hrs</td>
<td>Integrated management of wilts of maize</td>
<td>Dr. S. C. Saxena</td>
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<td>13:00-14:30 hrs</td>
<td>Lunch</td>
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<tr>
<td>14:30-15:30 hrs</td>
<td>Cultivar Mixtures in plant disease management</td>
<td>Dr. P.K. Shrtria</td>
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<td>15:30-15:45 hrs</td>
<td>Tea Break</td>
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<td>15:45-17:00 hrs</td>
<td>Visit to Seed Pathology Lab.</td>
<td>Dr. (Mrs.) K. Vishunavat</td>
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<td><strong>Friday</strong></td>
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<td><strong>April 09</strong></td>
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<td>09:30-10:30 hrs</td>
<td>Nutritional deficiencies and their corrections in plants</td>
<td>Dr. P.C. Srivastava</td>
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<td>10:30-11:30 hrs</td>
<td>Role of trainers in personality development</td>
<td>Dr. Surya Rathore</td>
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<td>11:30-11:45 hrs</td>
<td>Tea Break</td>
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<td>11:45-13:00 hrs</td>
<td>Seed Treatment as Innovative Crop Protection strategies</td>
<td>Dr. (Mrs.) K. Vishunavat</td>
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<td>13:00-14:30 hrs</td>
<td>Lunch</td>
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<td>14:30-17:00 hrs</td>
<td>Visit CRC, M&amp; APR &amp; TC, SPC, HRC, Khanna farm and Sugarcane Research Station Kashipur</td>
<td>Dr. R.K. Sahu and Dr. Vishwanath</td>
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<td><strong>Saturday</strong></td>
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<td><strong>April 10</strong></td>
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<td>09:30-10:30 hrs</td>
<td>Perspectives in biological control of nematodes</td>
<td>Dr. Akhtar Haseeb</td>
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<td>10:30-12:00 hrs</td>
<td>Valedictory function, Conference Hall, College of Agriculture</td>
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<td>12:00-13:00 hrs</td>
<td>Discussion with Dr. Akhtar Haseeb</td>
<td>Dr. Akhtar Haseeb</td>
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<td>13:00-14:30 hrs</td>
<td>Lunch</td>
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<td>14:30-17:00 hrs</td>
<td>Visit to Central Computer Facility</td>
<td>Dr. K.P.S. Kushwaha</td>
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<td><strong>Sunday</strong></td>
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<td><strong>April 11</strong></td>
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<td>09:30-10:30 hrs</td>
<td>Plant healthcare for poor farmers</td>
<td>Dr. J. Kumar</td>
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<td>10:30-11:30 hrs</td>
<td>Sitrobubulin fungicides benefits &amp; Risks/ The non target effect of pesticides on plant pathogen</td>
<td>Dr. A.P. Sinha</td>
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<td>11:30-11:45 hrs</td>
<td>Tea Break</td>
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<td>11:30-13:00 hrs</td>
<td>Discussion</td>
<td>Plant Pathology Faculty</td>
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<td>13:00-14:30 hrs</td>
<td>Lunch</td>
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<td>14:30-17:00 hrs</td>
<td>Reimbursement of TA</td>
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